RUBBER RESEARCH INSTITUTE OF SRI LANKA

Annual Review 2021

Cover Story

Rubber Intercropping emerged as a resilient farming system increases the land use efficiency in addition to secure income during the immature period, without any detrimental effect on rubber. Combinations of crops that differ in canopy and root architecture enable more efficient capture and use of growth resources. Inter-crops can be incorporated during the immature or mature phase or throughout the lifespan of rubber.

The revised rubber pineapple inter-cropping system enables to the establishment of three paired rows of pineapple plants hence the productivity increased by 33% more than the previous two pared row system.

Considering the extended immature period and slow canopy distribution of rubber in nontraditional areas, some potential fruit crops, *i.e.* guava, orange, papaya and sour sop have been tested from 2018. Further, the assessments have been continued in terms of growth, yield and physiological parameters of both rubber and inter-crops.

The concept extends to the boundary areas of the plantation with suitable crops. Cinnamon is one of the successful boundary crops yielding 172 kg per one hectare peripheral at five years after planting.

Rubber Research Institute of Sri Lanka

Annual Review - 2021

1st January 2021 to 31st December 2021

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V H L Rodrigo, PhD (Wales)
G P W P P Seneviratne, PhD (Bath)
S Siriwardene, PhD (Malaysia)

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Agalawatta

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Mr V Lokunarangoda, Chairman, Thurusaviya Fund (w.e.f. 15.11.2021)
Mr Prins Gunasekara, Chief Executive Officer, Kegalle/Namunukula Plantations PLC (w.e.f. 15.11.2021)

Ex-Officio Members

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Mr Bhathiya Bulumulla, Chairman, Planters' Association of Ceylon
Mr Madhawa Warnakulasooriya, Director General, Rubber Development Department (w.e.f. 30.06.2021)

In attendance

Dr V H L Rodrigo, Acting Director, Rubber Research Institute (w.e.f. 30.12.2021)
Mr Susantha Dissanayake, Senior Administrative Officer, RRI

STANDING COMMITTEES

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Dr Susantha Siriwardena, Deputy Director - Research (Technology), Rubber Research Institute
Mr Nissanka Seneviratne, Director, Kotalagala Plantations Ltd.

Mr Jagath Hettiarachchi, Senior Manager, Arappolkanda Estate
Mr P A Lukshaman, Senior Manager, Rubber Research Institute
Mr B S S Hewage, Senior Accountant, Rubber Research Institute

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Mr K V D C Wimalasiri, Director (Development), Ministry of Plantation
Mr J M Mangalatissa, Director General, Rubber Development Department (up to 28.04.2021)
Mr Madhawa Warnakulasooriya, Director General, Rubber Development Department (w.e.f. 28.10.2021)
Mrs Sandhya Samarasinghe, Audit Superintendent, Auditor General's Department (w.e.f. 28.04.2021)
Mr K A C Shamantha, Internal Auditor, Ministry of Plantation (w.e.f. 28.10.2021)

In attendance

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Mr B S S Hewage, Senior Accountant, Rubber Research Institute
Ms M S I Senadheera, Internal Auditor, Rubber Research Board
Mr Susantha Dissanayake, Senior Administrative Officer

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Mr Jayantha P Muthutantri, Consultant, No.4/4, Nelum Mw, Sirimal Uyana, Mt. Lavinia

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Mr D M S Dissanayake, Senior Administrative Officer, Secretary
Mr B S S Hewage, Senior Accountant, RRI, Member
Mr T B Dissanayake, Experimental Officer, Elected Committee Member (24th September 2020 - 16th November 2021)
Dr (Mrs) K V V S Kudaligama , Head of Biochemistry & Physiology Department, Elected Committee Member
Mr P K K S Gunarathna, Advisory Officer, Elected Committee Member
Mr J A S Chandrasiri, Rubber Extension Officer, Elected Committee Member

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Telephone Operator	-	Mrs G D D Kalamini

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RUBBER RESEARCH INSTITUTE OF SRI LANKA

STAFF

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	Mrs S G P Bhagayawedha, NDT
	Mrs P K I L Jayawardena, BSc (SL)
	K I D P Perera, BSc (SL) (up to 31st August)
	Miss A H D M N Gunawardena, BSc (SL)
	Mrs E N N Nanayakkara, BSc (SL)
	K N D Tillekeratne, BSc (SL)

Polymer Chemistry Department (*at Telewela Road, Ratmalana***)**

Senior Research Officer	W R N Alles, MSc (SL), MSc (UK), PhD (NZ) (from 16th August)
Research Officers	Mrs I H K Samarasinghe, BSc (SL)
	R Somaratne, BSc (SL), MSc (SL)
Experimental Officer	Mrs N Jayawardane, Dip. Agric. (Bibile)
Technical Officers (Research & Development)	Mrs H M H Dhanukamalee, BSc (SL)
	Mrs S V Rupasinghe, BSc (SL)
	D V D Mallikarachchi, BSc (SL)
	Mrs H L T Tharaka, BSc (SL)
Management Assistant (Clerical)	N W E C Madhuranga

Raw Rubber and Chemical Analysis (*at Telewela Road, Ratmalana***)**

Senior Research Officer	Mrs A P Attanayake, BSc (SL) PhD (SL)
Research Officer	*A M K S P Adikari, BSc (SL), MPhil (SL)
Experimental Officer	Mrs C S Lokuge
Technical Officers (Research & Development)	Mrs M U D S Weerasinghe, BSc (SL)
	H D M S Wijewardena, BSc (SL)
	K A S T Koswatta, BSc (SL)
	Mrs N S Siriwardena, BSc (SL) (up to 26th March)
	Mrs G M Udayangani, BSc (SL) (up to 23rd Sept.)

Raw Rubber Process Development and Chemical Engineering (*at Telewela Road, Ratmalana***)**

Experimental Officers	Mrs U M S Priyanka, BSc (SL), MSc (SL)
	Mrs V C Rohanadeepa
	A K D W Prasad
Technical Officers (Research & Development)	R D Illeperuma, BSc (SL)
	Miss P K N N Sandamali, BSc (SL)
	W A S Bandara, BSc (SL)

Management Assistants (Clerical)	Mrs H A Janani Lakshika, BA (SL) Mrs P D S Dilhani

Sections/Units

Biometry Section	(*at Dartonfield, Agalawatta*)
Principal Research Officer	Mrs B W Wijesuriya, BSc Agric. (SL), MPhil (SL), PhD (SL)
Research Officer	A M R W S D Ratnayake, BSc (SL)
Experimental Officer	O V Abeywardena, Dip. in Agric. (Kundasale)
Management Assistant (Clerical)	Mrs S N Munasinghe
Adaptive Research Unit	**(***at Dartonfield, Agalawatta***)**
Principal Research Officer	Mrs E S Munasinghe, BSc Agric. (SL), PhD (SL)
Technical Officers (Research & Development)	P M M Jayatilleke, NDT (Agric.) Mrs N M Piyasena, Dip. in Agric. (Kundasale)
Management Assistants (Clerical)	Mrs M A Randima Srimalee
Agricultural Economics Unit	**(***at Dartonfield, Agalawatta***)**
Senior Research Officer	J K S Sankalpa, BSc (SL), MSc (SL), MEcon (SL)
Research Officer	Mrs P G N Ishani, BSc Agric.
Library and Publications Unit	**(***at Dartonfield, Agalawatta***)**
Librarian & Publication Officer	Mrs N C D Wijesekera, BSc (SL) MSc (SL)
Library Assistant & Assistant Publication Officer	Mrs R M Amaratunga, Intermediate; Lib. Sci. Doc. & Info. (SLLA)
Experimental Officer	Miss D M S Wijesekera, Dip. Rubber Tech. (PRI)
Library Assistant & Publication Assistant (Ratmalana)	Mrs D N C Amarathunga
Management Assistants (Clerical)	P M P Jayantha

Audio Visual and Information Technology Unit (*at Dartonfield, Agalawatta***)**

Network Administrator	S R D P C Peiris, BSc (SL)

Management Divisions

Administration Department (Agalawatta) (*at Dartonfield, Agalawatta*)

Senior Administrative Officer	D M S Dissanayake, BSc (Mgt.) (SL), MHRM (SL)
Assistant Medical Practitioner	M Subasinghe

Management Assistants (Clerical)	Mrs P W Neelamanie
	Mrs J A D Wijayanthi
	Mrs B D Niranjala
	Mrs O W D Namali Udayanthi
	Mrs P C Athukorala
	Mrs Thamosha Munasinghe
	Mrs O W D Nilusha Udayanthi
	Mrs M N D Perera
	Mrs B Chandralatha, BA (SL)
	Miss M G L Niroshani
Management Assistant (Stenography)	Mrs J A H S Kumarie
Telephone Operator	Mrs J A D C Preethika

Administration Unit (Ratmalana)	(*at Telewela Road, Ratmalana***)**
Administrative Officer	Mrs U K Akila Tharinduni, BSc **(**SL)
Management Assistant (Clerical)	A T Senaratne
	Mrs A R M de Alwis

Internal Audit Unit	(*at Dartonfield, Agalawatta*)
Internal Auditor	Mrs M S I Senadeera, IFA, IPFA, IRCA, EPFA, PGDM
Management Assistants (Clerical)	M A D W K Tilakeratne

Works Section	(*at Dartonfield, Agalawatta*)
Resident Engineer	K A D K Chathuranga, BSc (Eng.). Hons, C. Eng. MIE (SL), AMSSE (SL), GREEN^{SL} AP
Engineering Assistant	Mrs W D D Prasadini, NDES
Technological Officer (Civil)	M A D K Jayasumana, NCT
Transport Officer	U L D R L Gunasinghe
Technological Officer (Mech.)	H J P Fernando, HNDE
Management Assistants (Clerical)	Mrs J A S Dharshanie (Dip. in Management)
	Mrs K K D K P Ranaweera
	Mrs M H W H Kumari, BSc (SL)

Accounts Section	(*at Dartonfield, Agalawatta*)
Senior Accountant	B S S Hewage, CPFA, (UK), CBA, APFA
Accountant	Mrs A M Lasanthi, BSc (SL), MBA (SL), CBA, APFA
Management Assistant (Accounting)	Mrs G P Kukulewithana
Management Assistants (Clerical)	Mrs C Dissanayake
	Mrs S I K Pathirage
	Mrs S A Niluka Harshani

Management Assistants (Clerical)	Mrs K K D Y L Ranaweera
	Miss K K T L Jayasekera
	J A J R Lakmal, Bcom. (SL)
	Mrs R P Thilini
	K A Dilan Sampath
	Mrs Erandi Kanchana Jayasinghe, BA (SL)
	Miss S R Sinhabahu
	Harith Kalutharawithana, BSc (SL)
	(up to 5th April)
	G N K Gunasena
	Miss K D Piyumi Hasara
Cashier	Mrs G A D D Jayawardena

Sub – stations & Estates

Kuruwita Sub-station	(*at Kuruwita*)
Management Assistants (Clerical)	D S Jayasinghe

Polgahawela Sub-station	(*at Narampola Estate, Nungamuwa, Yatigaloluwa*)
Research Officer	Mrs B M D C Balasooriya BSc (SL)
Management Assistant (Clerical)	D P N P Dissanayake

Moneragala Sub-Station	(*at Kumbukkana, Moneragala*)
Field Officers	V G D Nishantha Gunaseela
	N V U S Vijitha Kumara
Management Assistants (Clerical)	Mrs D M P Sandun Kumari
	M M Chamath Kumara

Dartonfield Group	
Senior Manager - Estate	P A Lukshaman, BSc (SL)
Management Assistants	H D D Achinda
	M A N Sachith Pawinda
	T D Harsha
Field Officer	B M Siriwardena

*Study Leave

RUBBER RESEARCH INSTITUTE OF SRI LANKA

DIRECTOR'S REVIEW

V H L Rodrigo

This review aims to provide a synopsis of the rubber industry at Sri Lankan and global scales in 2021 and then, major research and development (R&D) activities of the institute in the same year. Details of research in each division are stated separately. Hindrances for research are given briefly.

Rubber industry of Sri Lanka

Rubber production and consumption

The natural rubber (NR) production of the country in the year 2021 has decreased by about 0.5% from the previous year to 76,884 tonnes. This could be attributed to the reduction of normal tapping days due to adverse weather conditions in the year 2021. When compared to the values in 2019 and 2020, moderate improvement of rubber prices was observed during the year 2021. The NR consumption in the country at the end of the third quarter has been estimated at 98,300 tonnes showing 14% improvement against the same period in the previous year. This increase has mainly been driven by the improvement of the world economic situation after the Covid-19 outbreak and most of the industries has reached their normal capacity with the help of vaccination drives.

Rubber extent

The total extent of rubber lands in the country at the end of 2021 has been recorded as 138.8 thousand hectares with about 75-80% under tapping.

NR average yield

The average annual yield of Sri Lanka has been recorded as 679 kg/ha/year in the year 2021 while it was 642 kg/ha/year in the year 2020.

NR exports and imports

Sri Lanka has exported around 15,490 tonnes of natural raw rubber in the year 2021 against the value of 15,766 tonnes for 2020. A slight reduction in NR exports in the year 2021 has been supported by an increase in NR local consumption in the country and would be a good indicator for the value-added products sector. Earnings through raw rubber exports were Rs.8.3 billion in the year 2021 against Rs.5.6 billion in the year 2020.

Rubber manufacturing sector

Export earnings from finished products were recorded as Rs.208 billion in 2021, showing a remarkable improvement ever recorded during the last decade and an increase of about 43% against the previous year. Export earnings from semi-processed rubber have been reported as Rs.0.62 billion in the year 2021, while it was Rs.0.53 billion in the year 2020. Accordingly, total export earnings from the rubber industry remained at Rs.216.92 billion showing a 43% improvement from the previous year.

Global rubber industry review

Natural rubber supply

Total world NR production was 13,882 thousand tonnes in 2021 against the value of 13,595 thousand tonnes in 2020. World NR production is estimated to increase by 2% according to ANRPC statistics. This is mainly due to the NR price improvements in the major markets in the Asia Pacific region during the year and returning the tapping operations of major rubber growing countries to normally with the overcome of barriers due to the Covid-19 pandemic.

Global NR demand

Total NR demand is estimated to increase to 14,076 thousand tonnes in 2021 showing an 8% increase from the previous year which was amounted to 12,953 thousand tons according to ANRPC. This showed a reduction in the supply-demand gap of rubber which is about 194 tonnes of NR during the reference period.

World NR price movement

Despite the declining trend prevailing in most of the market starting from the year 2011 to 2018, prices experienced a gradual increase for the period of 2019 to 2021. global rubber prices were slightly higher throughout the year 2021. In Sri Lanka, the annual average RSS3 price in 2021 was US$ 2.20 per kg which was remained at US$ 1.86 in the year 2020. The average price of RSS3 was recorded as US$ 2.05 in Bangkok against the previous year's average value of US$ 1.74. Average price of Indian RSS4 has increased to US$ 2.27 from US$ 1.82 per kg against the value of previous year. According to the predictions of ANPRC countries, global natural rubber prices are likely to improve due to the global economic recovery and higher demand from the major consumers in the world.

Research and development focus

Research and development programmes were focused on addressing the urgent issues in the rubber industry, measures on reducing production costs of raw rubber, increase in overall productivity of rubber lands, value addition to raw rubber and monifying environmental benefits of rubber. The new Circular Leaf Spot Disease initially named as ‘Pestalotiopsis’ affected about 20,000 ha of rubber, mostly in the wet regions in the country. Tentative recommendations were issued to control the

disease and field applications were tested together with drone technology. In view of controlling White Root Disease which has been a major yield determinant due to loss of trees, a biopesticide was developed. Whilst promoting once in four day tapping among rubber growers, once a week tapping system was also tested to address the worker shortage in latex harvesting and high cost of production. Whilst continuing the breeding programme for high yields and disease resistance, screening clones for drought resistance was commenced to facilitate the rubber cultivation in drier climates. Also, possibility of using micro irrigation was assessed under this climate. In order to improve the overall land productivity of rubber, growing cinnamon as a boundary crop and planting guava and soursop as intercrops were tested. To assist the medium scale industries on value addition, rubber based compounds suitable to manufacture some automobile components and biomedical items were developed. With 3,000 ha of rubber cultivated in Monaragala and Ampara districts under the STaRR project, a project description document was developed for voluntary carbon market in view of supporting the rubber cultivation in nontraditional areas and the project was listed in an international accredited carbon registry (VERRA). Training workshops and other technology transfer programmes were conducted mainly on demand driven basis. Testing reports on rubber and associated constituents were provided on the request of different stakeholders. Functions of the Finite Element Analyses & Simulation Centre and the establishment of tyre testing center continued.

Obstacles for research

Research outputs were affected with lack of qualified scientists and associated staff. In-country brain drain continued with qualified scientists leaving the institute to join local universities for better remunerative packages. The proposal developed to solve this issue by establishing a university combining all plantation crop research institutes, had virtually no progress. This demands alternative approach. Restrictions on recruitments of scientists and support staff made the situation worse. Poor condition of the vehicle fleet in the institute also affected the field research programmes.

Appreciations

In effective conduct in R&D, the guidance and directions together with financial support and patronages given by the Rubber Research Board and the Ministry are appreciated. Other stakeholder support received in conducting R&D activities is well respected. The contributions made by Deputy Directors, all Heads of scientific and non-scientific divisions and other staff towards the Annual Review are highly acknowledged.

In particular, special appreciations are given to the Economic Unit for providing required data for this review and to the staff in the Library and Publication Unit for compiling the materials and finally building up the Annual Review 2021.

GENETICS AND PLANT BREEDING

S P Withanage

DETAILED REVIEW

Staff

Dr (Mrs) S P Withanage, Head of the Department, Dr K K Liyanage, Principal Research Officer, Mrs T T D Dahanayake, Research Officer, Mr T B Dissanayake, Mr H P Peiris, Mr T M S K Gunasekera, Mrs A K Gamage, Experimental Officers, Mr B W A N Baddewithana, Mrs N S Jayasinghe, Technical Officers (Research and Development) and Mrs S D P K L Peiris, Management Assistant were on duty throughout the year.

Research students

- K M A Gunawardena, a student from the Faculty of Agriculture, University of Ruhuna, carried out her final year research project on "Impact of tree to tree yield variation of *Hevea brasiliensis* (Rubber) clone RRISL 203: A case study in Mapalana (WL2)" under the supervision of Dr (Mrs) S P Withanage.
- P S Kalansooriya, a student from the Faculty of Graduate Studies, University of Ruhuna, carried out her MSc research project on "Characterization of superior genotypes at early stage of rubber (*Hevea brasiliensis*) 2015 HP Progeny" under the supervision of Dr (Mrs) S P Withanage.
- R M C P Ranaweera, a student from the Faculty of Graduate Studies, University of Kelaniya carried out her MSc research project on "A study towards the analysis of genetic basis of Tapping Panel Dryness (TPD) in rubber tree (*Hevea brasiliensis*)" under supervision of Dr (Mrs) S P Withanage.

Meetings/Seminars and Workshops attended

Officer/s	Subject/Theme	Date	Organization
SP Withanage	SOR Meeting	18th Feb.	RRB, Ratmalana
	KPI Settings Meeting	6th April	Dartonfield
	Meeting on establishing NSF-Virtual Institutional Biosafety Committee	10th June	NIPM, Colombo
	KPI Settings Meeting	1st August	RRB, Ratmalana
SP Withanage K Liyanage	Technology Update	12th July	Dartonfield
	Carbon Workshop		
SP Withanage K Liyanage TTD Dahanayake	Scientific Committee Meeting	22nd April	Dartonfield

A study towards the analysis of genetic basis of Tapping Panel Dryness (TPD) in rubber tree (*Hevea brasiliensis*)

Tapping Panel Dryness (TPD) is a complex physiological syndrome found widely in rubber trees that causes severe yield losses. Therefore, a series of studies were started with the objectives of studying the role of antioxidant genes on TPD and the effect of exogenous application of ascorbic acid on TPD clones. Using quantitative real-time PCR (qRT-PCR), the antioxidant gene expressions were analyzed in TPD and healthy rubber trees. The studies carried out previously continued to compare the expression levels of selected antioxidant genes, *HbMnSOD* and *HbCAT* in *Hevea brasiliensis* under the partial TPD incidence and after recovery of the TPD with reference to healthy trees. Trees were selected from twelve years old RRISL 203 field at Eladuwa.

Both *HbMnSOD* and *HbCAT* genes were significantly up-regulated in TPD-affected trees of RRISL 203 where the *HbMnSOD* gene showed a higher level of expression compared to the *HbCAT* gene expression level by suppressing the ROS activity to allow trees to be recovered. The relationship between partially TPD-affected trees and recovered trees were not clearly identified with respect to the level of expression of *HbMnSOD* gene.

Hand pollination programme

The annual hand pollination programme could not be conducted due to Covid -19 pandemic situation.

Developing the *Hevea* Breeding Garden

RRIC 102, RRISL 226, RRISL 223 and PB 28/59 clones were introduced into the breeding garden at Neuchatel Estate. The agronomic practices were continued and selected trees were trained by pruning and bending branches towards the ground for easy and safe access to flower inflorescences for future breeding programmes (S P Withanage, K K Liyanage, T M S K Gunasekara and B W A N Baddewithana).

Multilateral clone exchange programme

A Memorandum of understanding was signed in 2015 by the fifteen member countries of the International Rubber Research and Development Board (IRRDB) to exchange materials under the multilateral clone exchange programme. Objectives are to promote international cooperation and capacity building in the IRRDB member countries for the betterment of the natural rubber industry and to evaluate the performance of all the exchanged clones in different agro-climatic conditions in the member countries.

The second adaptability trial was established at Galewatta Estate, Dartonfield Group with twelve foreign clones, and details are given in Table 1. The average girth after the first year, in the adaptability trial established at Neuchattle Estate, is given in Table 2. The highest girth was recorded in the clones RRIT 3904, RRII 422, and ARCPC 2/4, from Thailand, India, and Myanmar, respectively.

Table 1. *Details of foreign clones established at Galewatta Estate, Dartonfield Group*

Country of origin	Clone	Number of plants established
Thailand	RRIT 251	68
	RRIT 3904	85
	RRIT 3604	77
	RRIT 226	80
	RRIT 408	85
India	RRII 414	106
	RRII 417	79
	RRII 422	70
	RRII 429	81
	RRII 430	51
Myanmar	ARCPC 2/4	86
	ARCPC 6/22	85

Table 2. *Average girth of foreign clones established at Neuchatle Estate*

Country of origin	Clone	Number of plants	Average girth after the first year (cm)
Thailand	RRIT 251	24	10.85
	RRIT 3904	24	13.30
	RRIT 3604	24	6.00
	RRIT 226	24	9.39
	RRIT 408	24	9.71
India	RRII 414	24	11.30
	RRII 417	24	10.56
	RRII 422	23	12.50
	RRII 429	24	10.09
	RRII 430	23	8.09
Myanmar	ARCPC 2/4	20	13.34
	ARCPC 6/22	26	11.19

(S P Withanage, K K Liyanage, T T D Dahanayake, T B Dissanayake T M S K Gunasekara and B W A N Baddewithana)

Evaluation of mother plant nursery

For the early selection of the best performing genotypes, five years old 2015 hand pollinated progeny was subjected to evaluation. The progeny was characterized by yield parameters such as girth, latex yield, and bark thickness. The girth was measured in individual genotypes at the height of 45 cm from the ground level and tapping was done at the same height. Around sixty-three genotypes were subjected to evaluation and high performing twenty-two genotypes were taken for small scale clonal evaluation and details of the top five genotypes were given in Table 3. Rest of seventeen genotypes were not added to the breeding pool.

Table 3. *Girth (cm)at 45 cm, Average bark thickness (mm), and g/t/t of the best performing genotypes from five years old 2015 hand pollinated progeny (seedlings) established in mother plant nursery at Nivitigalakele in 2016*

Genotype number	Girth (cm)	Average bark thickness (mm)	g/t/t
2015 HP-14	32.10	7.00	23.49
2015 HP-26	28.60	5.00	16.31
2015 HP-48	32.50	7.60	15.51
2015 HP-24	29.00	5.30	15.41
2015 HP-15	28.70	5.00	12.67

The gene responsible for Rubber Elongation Factor (*REF*) is mainly associated with the rubber biosynthesis of *Hevea brasiliensis*. Therefore, the studies of the *REF* gene expression with their latex yield will help in the early selection of precise genotypes. Five high yielding and four low-yielding genotypes were selected for quantitative gene expression study of the REF gene and the genotypes, 2015HP-15 which ranked in the middle place in the yield profiles were taken as the control. Litvak method ($2^{-\Delta\Delta CT}$) was used to analyze the quantitative gene expression while cluster analysis and regression analysis in Minitab 17 version were used to analyze the data.

REF gene expression was significantly up-regulated in high-yielding genotypes: 2015 HP-14, 2015 HP-26, 2015 HP-48, and 2015 HP-26 compared to the control genotype of 2015 HP-15. Down-regulation of REF gene expression was observed in low-yielding genotypes; 2015 HP-40, 2015 HP-45, 2015 HP-29, 2015 HP-39. It was clearly identified in two clusters, demarcating high-yielding genotypes and low-yielding genotypes, showing the possibility of using *REF* gene expression for precise early selection in the breeding process (Fig. 1) (S P Withanage, T T D Dahanayake, A K Gamage, B W A N Baddewithana, T M S K Gunasekara and N S Jayasinghe).

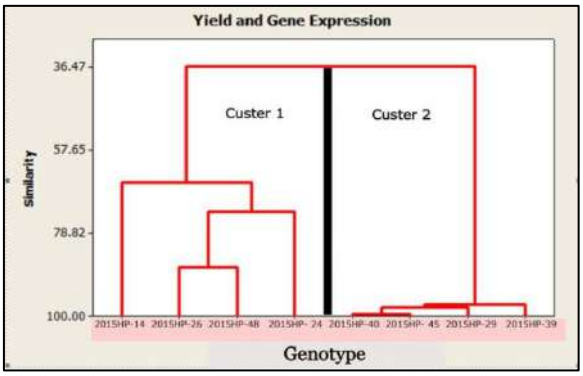


Fig. 1. Yield and *REF* gene expression- based cluster analysis. Cluster 1: High yielding genotypes, 2015 HP-14, 2015 HP-26, 2015HP-48, 2015HP-14. Cluster 2: Low yielding genotypes 2015 HP-40, 2015 HP-29, 2015 HP-39

Tree to tree yield variation of *Hevea brasiliensis* (Rubber) clone RRISL 203 due to the impact of different shade levels: a case study in Mapalana (WL2)

When evaluating the performances of clones under commercial conditions, it has been experienced that the variation of clonal performances occurs due to the differently practiced recommendations over the difference of agro-climatic impact. Accordingly, in the above trial, it has been noticed, that the farm management has not removed the wild trees from boundaries despite continuous requests. As a result, the field was influenced by different shading levels. It has shown the high tree-to-tree variation of the field and negative impact on the overall performance of the clone.

The study was carried out in 11 years old RRISL 203 field, established at the Faculty of Agriculture, University of Ruhuna. Different shade levels were identified within the field as low, medium, and high. A significant growth variation has existed within the field (Table 4), which resulted in a significant variation in yield among different shading levels during February but not during December and January (Table 4). However, it has been taken steps to further evaluate the field separately to avoid the impact of the shade on overall clonal performances and to study the impact of shade on yield. It was arranged to take the metrolac reading along with the volume of latex.

Table 4. *Mean girth and mean volume of rubber latex (ml) and their D'MRT group of three shade levels in three months*

Shade level and light intensity	Mean girth (cm) and D'MRT group	Mean volume (ml) in December and D'MRT group	Mean volume (ml) in January and D'MRT group	Mean volume (ml) in February and D'MRT group
Low (higher than µmol/m²/s)?	70^{a}	45^{ab}	31^{a}	52^{a}
Medium (between µmol/m²/s)?	66^{b}	48^{a}	33^{a}	43^{ab}
High (less than µmol/m²/s)?	67^{b}	41^{b}	32^{a}	35^{b}
CV%	10.24%	9.18 %	18.15 %	16.35 %

(S P Withanage, T T D Dahanayake, B W A N Baddewithana and N S Jayasinghe)

Evaluation of the previous hand pollinated (HP) progenies

Small Scale Clone Trials

The summary of the small-scale clone trials which were maintained and monitored during the year under review are given in Table 5.

Table 5. *Summary of Small Scale Clone Trials*

HP year	Site	Planting season	Current status
2002	Pallegoda I	July 2007	8th year of tapping
2002	Eladuwa II	May 2009	7th year of tapping
2004	Eladuwa Trial I	July 2009	7th year of tapping
2007	Kuruwita Substation (seedlings)	July 2009	6th year of tapping
1995	Yatadola	July 2011	6th year of tapping
2005	Monaragala	Nov 2014	Immature
2008	Eladuwa	Nov 2016	Terminated (due to poor establishment rate)
2010	Eladuwa	Nov 2016	Immature
2011	Eladuwa	Oct 2018	Immature

(S P Withanage, K K Liyanage, T T D Dahanayake, T B Dissanayake, H P Peiris, T M S K Gunasekara, A K Gamage, B W A N Baddewithana and N S Jayasinghe)

Evaluation of 2001 HP clones, Kuruwita Substation (GPB/BST/HPS/2001/02)

The mean yield of clones in the eighth year tapping was grouped using Duncan's multiple range test and the topmost promising HP entries at Kuruwita Substation are given in Table 6 with their girth values. Top-ranked HP entries in Kuruwita Substation had yielded from 47.3 g/t/t to 61 g/t/t. However the control clone RRISL 203 was showed the highest yield

Table 6. *Mean yield and girth of the best performing HP entries of the 2001 HP progeny planted in 2006 in Kuruwita Sub-station*

Clone	Yield (g/t/t)	Mean girth (cm)
RRISL 203	68.79^{a}	61.33
2001 HP-164	61.00^{ab}	59.1
2001 HP- 183	50.00^{ab}	64.94
2001 HP-220	47.33^{ab}	75.48
RRIC 121	46.30^{ab}	72.07

Evaluation of 2002 HP clones
***Pallegoda Estate* (*GPB/BST/HPS/2002/01*)**

Thirteenth-year girth measurements were taken and the mean girth of clones was grouped using Duncan's multiple range tests, and the results are given in Table 7. Genotype 2002 HP-69 has performed better in comparison to control clone RRISL 203. Yield data collection was disturbed due to bad weather.

Table 7. *Mean girth of best performing HP entries selected from the 2002 HP progeny planted in 2007*

Clone	Mean girth (cm)
2002 HP-69	63.66[a]
2002 HP-96	62.31[ab]
2002 HP-17	58.74[abc]
2002 HP-18	57.30[abcd]
RRISL 203	55.70[abcde]
2002 HP-86	51.58[abcdef]
2002 HP-43	50.44[abcdefg]
2002 HP-48	47.97[abcdefg]
2002 HP-67	47.27[bcdefgh]
RRIC 121	46.31[bcdefghi]

(S P Withanage, K K Liyanage, T T D Dahanayake and B W A N Baddewithana)

***Eladuwa - trial II* (*GPB/BST/HPS/2002/02*)**

Thirteen genotypes from 2002 hand pollination progeny were planted with two control clones, RRIC 121 and RRISL 203. Randomized Complete Block Design was used with four replicates per genotype. The replicate size was six. The twelfth-year girth was taken at the height of 150 cm from the bud union and mean girth values are shown in Table 8. Although fifth-year yield data collection was started, only a few test tapings were possible.

Table 8. *Mean girth at twelfth-year of best performing HP entries and control clones selected from the 2002 HP progeny planted in 2009 at Eladuwa*

Clone	Mean girth (cm)	Clone	Mean girth (cm)
HP-138	87.20[a]	RRIC 121	66.80[cd]
HP-93	75.92[b]	HP-19	63.09[de]
HP-66	73.46[bc]	HP-9	62.68[def]
HP-30	72.26[bc]	HP-62	59.29[efg]
HP-139	69.10[bcd]	RRISL 203	55.82[fgh]

(S P Withanage, K K Liyanage, T T D Dahanayake and T B Dissanayake)

Evaluation of 2004 HP clones

Twenty-two genotypes from 2004 hand pollination progeny had been planted at Eladuwa Estate in the year 2009. The clone RRIC 121 was used as the control clone. A Randomized Complete Block Design was used with four replicates per genotype.

Eladuwa Estate trial II (GPB/BST/HPS/2004/02)

The eleventh-year girth was taken. The HP entry 2004-347 showed

significantly higher girth and four entries were ranked above the clone RRIC 121 (Table 9).

Table 9. *Mean girth of 11th year of the best performing HP entries selected from the 2004 HP-progeny planted at Eladuwa Estate. Mean values with the same letter are not significantly different*

Clone	Mean girth (cm)
HP-347	66.61[a]
HP-48	64.11[ab]
HP-107	63.83[ab]
HP-178	63.61[ab]
RRIC 121	63.53[ab]

(S P Withanage, K K Liyanage, T T D Dahanayake and B W A N Baddewitana)

Evaluation of 2007 HP- progeny - Kuruwita Sub Station (GPB/BST/HPS/2007/01)

Thirteenth-year girth data were collected for the seedling progeny and family means are given in Table 10. Family RRIC 130 x GP 21-163 recorded the highest girth. Fifth-year tapping data were collected from the above progeny and family means are given in Table 11. Family RRIC 130 x GP 22-137 recorded the highest yield (g/t/t).

Table 10. *Family mean girth of 2007 HP - progeny at the Kuruwita Substation planted in 2008*

Clone	Mean girth (cm)
RRIC 130 x GP21-163	70.89
RRIC 130 x GP22-137	69.94
PB 260 x IAN 45-710	64.99
IAN 45-710 x PB 260	64.07
RRIC 130 x GP10-154	63.00
45-717 x PB 260	57.33
RRIC 130 x GP44-24	54.17

Table 11. *Family mean yield of 2007 seedling HP progeny planted in 2008*

Clone	Yield (g/t/t)
RRIC 130 x GP22-137	19.29
PB 260 x IAN 45-710	17.02
IAN 45-710 x PB260	16.49
RRIC 130 x GP21-163	12.71
RC 130 x GP10-154	11.36
RRIC 130 x GP44-24	7.28
45-717 x PB 260	3.65

(T T D Dahanayake, S P Withanage, K K Liyanage and H P Peiris)

Evaluation of 2005 HP progeny planted in 2014 at Monaragala GPB/BST/HPS/2005/01 and 2016 at Galewatta GPB/BST/HPS/2005/02

Thirty-five genotypes from 2005 hand pollination progeny which were raised by double selfing of *Corynespora* susceptible clone RRIC 103 and resistant clone RRIC 100, were established at Monaragala substation with parental clones RRIC 100, RRIC 103, grandparents, RRIC 52 and PB 86, and RRISL 201 as a check clone in the year 2014. A Complete Randomized Block Design was used with ten replicates per genotype. The progeny is performing below average and the seventh year average girth was around 25 cm. Trees are to be prepared for the pollination programme with the objectives of developing pseudo hybrids and pure lines concerning clones RRIC 100 and 103.

Evaluation of 2010 HP progeny planted in 2016 at Eladuwa GPB/BST/HPS/2010/01

Sixteen genotypes selected from 2010 HP progeny were planted in Eladuwa Estate in Complete Randomized Block Design with control clones, RRIC 121 and RRISL 2001. All agronomical practices such as weeding, removing offshoots, *etc.* were done according to RRISL recommendations. The fifth-year girth was taken and the mean girth values of only the best performing five genotypes higher to the control clone are given in Table 12 with the control clone RRIC 121.

Table 12. *Mean girth for the fifth year for HP-entries of best performing six genotypes with their control clones of the 2010 HP- progeny planted at Eladuwa Estate*

Clone	Girth (cm)
HP-4	39.50^{a}
HP- 38	38.86^{a}
HP-7	37.58^{ab}
HP-22	37.00^{ab}
HP-9	36.09^{abc}
RRISL 121	34.63^{abcd}

(S P Withanage, T T D Dahanayake, K K Liyanage and A K Gamage)

Evaluation of 2011 HP progeny planted in 2018 at Eladuwa GPB/BST/HPS/2011/01

Sixteen genotypes selected from 2011 HP progeny were planted in Eladuwa Estate in Complete Randomized Block Design with control clones, RRIC 121 and RRISL 2001. All agronomical practices such as weeding, removing offshoots, *etc.* were done according to RRISL recommendations. The third-year girth was taken and the mean girth values of the best performing six genotypes are given in Table 13 with the control clones.

Table 13. *Mean girth for the third year for HP-entries of best performing six genotypes with their control clones of the 2011 HP- progeny planted at Eladuwa Estate*

Clone	Girth (cm)
HP-41	23.33[ab]
HP-297	23.23[ab]
RRIC 121	23.17[ab]
HP-236	23.13[ab]
HP-75	22.90[abc]
HP-42	22.67[abc]

(S P Withanage, T T D Dahanayake, K K Liyanage and A K Gamage)

Estate/RRI collaborative clone trials (ECT's) GPB-01c

Annual girth measurements were taken from all the trials. Table 14a (registered clones) and 14b (unregistered clones) show the planting sites, year of planting, and girth measurements at 150 cm for the year under review and the previous two years. Girth data of trials at Dartonfield were not taken as it is now in uppercut tapping. However, taking girth of trials at long distance also disturbed due to the traveling difficulties faced during to the Covid -19 pandemic.

Table 14a. *Mean annual girth measurements for registered clones of ECTs (Estate/RRISL Collaborative Trials)*

Clone	Site	Year of planting	Mean girth (cm)		
			2019	2020	2021
RRISL 201	Dammeria B	2010	56.2	51.07*	51.89
	Eladuwa	2009	58.9	60.84	61.71
RRISL 203	Monaragala	2009	51.4	53.59	NT
	Eladuwa	2009	59.4	61.80	62.32
	Wewassa	2011	53.0	57.33	61.45
	Lagos	2011	58.3	58.67	59.69
	Muwankanda	2010	51.7	NT	56.45
	Dammeria B	2010	40.7	41.5	41.76
	Kamburupitiya	2011	63.9	68.37	68.55
RRISL 208	Dartonfield	1994	78.7	NT	NT
	Lagos	2013	51.2	53.97	56.50
	Moralioya	2010	58.5	60.56	62.59
	Dammeria B	2010	NT	NT	NT
	Eladuwa	2009	58.7	70.5	58.80
RRISL 210	Payagala	2006	NT	NT	NT
RRISL 211	Dartonfield	1994	NT	NT	NT
RRISL 216	Dartonfield	1994	84.7	NT	NT
RRISL 219	Dartonfield	1994	93.0	NT	NT
	Kuruwita	2008	54.8	55.5	56.40

Clone	Site	Year of planting	Mean girth (cm)		
			2019	2020	2021
RRISL 2000	Kuruwita	2005	73.5	74.56	75.80
RRISL 2001	Dammeria B	2010	56.2	58.76	60.20
	Muwankanda	2010	NT	NT	65.18
	Dammeria B (Hanipe Dev.)	2011	56.2	58.76	NT
	Wewassa	2011	47.2	52.45	56.91
	Lagos	2013	51.5	53.65	56.40
RRISL 2003	Lagos	2013	52.7	55.62	58.40
RRISL 2006	Lagos	2013	45.8	50.66	53.60
	Monaragala	2009	59.4	63.83	NT
	Eladuwa	2009	59.6	62.33	63.50
	Moralioya	2010	61.6	63.0	65.96
RRISL 2100	Monaragala	2009	58.1	61.07	NT
	Edalla	2010	56.0	57.84	61.15
	Kuruwita	2011	52.3	53.55	54.93
RRISL Centennial 3	Kuruwita	2009	60.5	61.76	62.28
	Monaragala	2009	54.6	58.42	NT
	Eladuwa	2009	66.0	68.39	69.00
	We-oya	2010	59.7	62.46	63.60
	Edalla	2010	62.4	64.51	58.92
	Kuruwita	2011	58.4	59.84	61.60
	Siriniwasa	2011	61.8	63.37	63.00
	Lagos	2013	55.3	56.67	58.90
RRISL Centennial 4	Kuruwita	2007	58.3	59.07	60.31
	Eladuwa	2009	56.3	57.13	60.04
	Monaragala	2009	57.1	59.55	NT
	Lagos	2011	60.4	61.73	63.10
RRISL Centennial 5	Eladuwa	2009	59.4	61.61	62.23
	Kuruwita	2007	64.3	65.3	66.39

*****girth is taken at 1.5 m height as commenced the tapping in this year
NT stand for not taken the values

Table 14b. *Mean annual girth measurements of un-registered entries selected to ECTs (Estate/RRISL Collaborative Trials)*

Clone	Site	Year of planting	Girth in cm		
			2019	2020	2021
HP 86-10	Kuruwita	2009	51.9	53.00	53.06
HP 86-87	Kuruwita	2009	55.0	55.75	56.61
HP 87-235	Kuruwita	2008	56.1	57.31	58.66
HP 95-55	Lagos	2013	56.0	57.92	61.13
RRIC 100 seedlings	Kuruwita	2005	72.2	74.98	75.39

(S P Withanage, K K Liyanage, T T D Dahanayake, T B Dissanayake, H P Peiris, T M S K Gunasekara, A K Gamage, B W A N Baddewithana and N S Jayasinghe)

Monthly latex volume data was collected from the following trials. Table 15 represents the planting sites, year of planting and g/t/t values for the year.

Table 15. *Yield (g/t/t) values of clones evaluated*

Clone	Tapping system	Site	Year of planting	Average yield (g/t/t)	Year of tapping
RRISL 201	S2 d2	Eladuwa	2009	27.34	5th
RRISL 203	S2 d2	Dammaria B	2010	21.22	3rd
	S2 d2	Lagos	2011	54.65	4th
	S2 d2	Eladuwa	2009	26.30	5th
RRISL 208	S2 d2	Galewatta	1995	43.34	21st
	S2 d3	Moralioya	2010	NT	4th
	S2 d2	Eladuwa	2009	33.06	5th
RRISL 211	S2 d2	Galewatta	1995	74.03	21st
	S2 d3	Galewatta	1995	50.37	21st
RRISL 216	S2 d2	Galewatta	1995	25.46	21st
RRISL 219	S2 d2	Galewatta	1995	23.48	21st
	S2 d3	Kuruwita	2008	45.77	5th
RRISL 2001	S2 d2	Dammaria B	2010	29.76	3rd
Centennial 4	S2 d2	Kuruwita	2007	24.52	6th
	S2 d2	Lagos	2011	45.10	4th
	S2 d2	Eladuwa	2009	30.58	5th
Centennial 3	S2 d2	We-Oya	2010	33.58	4th
	S2 d3	Siriniwasa	2011	54.46	3rd
	S2 d2	Eladuwa	2009	26.36	5th
RRISL 2006	S2 d3	Moralioya	2010	NT	4th
Centennial 5	S2 d2	Eladuwa	2009	28.7	5th
	S2 d2	Kuruwita	2007	21.44	6th
RRISL 2000		Kuruwita	2005	42.08	9th

(S P Withanage, K K Liyanage, T T D Dahanayake, T B Dissanayake, T M S K Gunasekara, H P Peiris, A K Gamage, B W A N Baddewithana and N S Jayasinghe)

New establishments

Two ECT/RRI collaborative trials were established at We-Oya Estate, Yatiyantota and Notinhill Estate, Mawathagama. The details of clones established are given in the Table 16.

Table 16. *Details of clones, month of plating and number of plants established*

Estate and Agro climatic Zone	Clone	Month of planting	No. of plants established
Yatiyanthota ,We-Oya Estate (WL 2)	MT 11-76 I	August	300
Nottinghill Estate – Mawathagama (IM 3)	MT 11-76 II	June	300
	RRISL 2100		350
	RRISL CEN - 3		300
	RRISL 2100		500

(S P Withanage, K K Liyanage and B W A N Baddewithana)

Conservation and evaluation of the IRRDB germplasm (GPB/GP/85/2)

Multiplication, establishment, and scientific evaluation of the *Hevea* germplasm collection continued to enhance productivity through genetic improvement and management of genetic resources of *Hevea.* Preparation of plants for establishment of new trials were done (Details are given under the new establishment). Trees of two gemplasm selections *i.e*. MT 11-76 I and MT 11-76 II were trained to use as the female parent of next year hand pollination programme (S P Withanage, K K Liyanage, T T D Dahanayake, B W A N Baddewithana and T M S K Gunasekara).

Testing of promising clones for sub-optimal conditions

The objective of the project is the evaluation of the adaptability and performance of new promising clones in non-traditional rubber growing areas (sub-optimal conditions).

Smallholder/RRI collaborative clone trial – Eastern province and control trial established at Kalutara district - 2012 planting

Seven experimental plots were established at Padiyathalawa/Mahaoya areas in the Eastern Province. Their control (reference) plot was established at Bandaragama, which belongs to traditional rubber growing regions. Details of these trials are given in Table 17.

Table 17. *Details of smallholder/RRI collaborative trials at Eastern Province and the ninth year mean girth data*

Trial	Smallholder and location	Agro-climatic Region	75% expectancy value of Annual Rainfall (mm)	Clones planted	Mean girth (cm)
SRT-EP 12/1	SM Wirawardana Marawa Padiyathalawa	IL2	> 1600	RRISL 2001 RRISL 203 RRISL 2005 RRISL 2006	NT

Trial	Smallholder and location	Agro-climatic Region	75% expectancy value of Annual Rainfall (mm)	Clones planted	Mean girth (cm)
SRT-EP 12/2	Indrani Kusumalatha Marawa Padiyathalawa	IL2	>1600	RRISL 203 RRIC 121 RRISL 2001 RRISL 2006	59.91 58.79 58.59 54.43
SRT-EP 12/3	AM Sumanawathi Helakomana Padiyathalawa	IL2	> 1600	RRISL 203 RRIC 100 RRISL 2005 RRISL 208	54.39 54.38 58.60 51.40
SRT- EP12/4	HM Wimalasena Kudaharasgala Mahaoya	IL2	> 1600	RRISL 208 RRISL 2005 RRIC 100 RRISL 203	NT 59.13 56.27 51.34
SRT-WP 12/8	Ranjith Thambawita Bandaragama Panadura (Kalutara district - Control Trial)	WL 1a	>3300	RRISL 208 RRISL CEN 3 RRISL 2001 95HP - 55 RRISL 203 RRIC 100 RRISL 211 RRISL 2005	63.68 65.75 67.00 70.04 62.18 67.00 61.03 65.54

NT stands for not taken

(S P Withanage, K K Liyanage, T T D Dahanayake, T B Dissanayake and T M S K Gunasekara)

Smallholder/RRI collaborative clone trial – Eastern Province (Ampara district) -2013 Planting

Five experimental plots were established in Ampara area in the Eastern Province. However, two trials were terminated due to poor support received from the smallholders (Table 18).

Table 18. *Details of smallholder/RRI collaborative clone trials planted in 2013 in the Eastern Province and the eighth year mean girth data*

Trial	Smallholder & Location	Agro-climatic Region	75% expectancy-value of Annual Rainfall (mm)	Clones planted (No. of trees)	Mean girth (cm)
SRT-EP 13/1	HM Jayarathna 17-1 C, Lathugala Warankatagoda	DL2a	> 1300	RRIC 121 (210)	55.09
SRT-EP 13/4	HM Saman Kumara 17/1 B, Lathugala Warankatagoda	DL2a	> 1300	RRISL 203 (210)	57.00

Trial	Smallholder & Location	Agro-climatic Region	75% expectancy-value of Annual Rainfall (mm)	Clones planted (No. of trees)	Mean girth (cm)
SRT-EP 13/5	M Chandrani Ranasingha 51 B - 2, Lathugala Warankatagoda	DL2a	> 1300	RRISL 203 (210)	53.29

(S P Withanage, T T D Dahanayake, K K Liyanage and T M S K Gunasekara)

Smallholder/RRI collaborative clone trials – Eastern Province established 2014

Details of four experimental plots that were established in Mahaoya area, with three RRISL 2000 series clones and clone RRIC 121 in October 2014 are given in Table 19. However, their seventh year girth was not taken due to the traveling difficulties faced during the Covid-19 pandemic.

Table 19. *Details of smallholder/RRI collaborative clone trials planted in 2014 in the Eastern Province*

Trial	Smallholder & Location	Agro-climatic Region	75% expectancy-value of Annual Rainfall (mm)	Clones planted	Mean girth (cm)
SRT-EP 14/1	G Senevirathne Mahaoya	IL2	>1600	RRIC 121	Not taken
SRT-EP 14/2	M Senevirathne Mahaoya	IL2	> 1600	RRISL 2001	Not taken
SRT-EP 14/3	A M Jayasekara Mahaoya	IL2	>1600	RRISL 2006	Not taken
SRT-EP 14/4	TM Amarasena Mahaoya	IL2	>1600	RRISL 2005	Not taken

(K K Liyanage, S P Withanage, T T D Dahanayake, T M S K Gunasekara and T B Disanayake)

Smallholder/RRI collaborative clone trial planted in 2015 - Uva Province

Four experimental sites were established in Bibile area in collaboration with the World Vision Organization. Sixth year girth data were taken and are given in Table 20. One trial was established in Kataragama and the fourth year girth data were taken and details are given in Table 21.

Table 20. *Details of smallholder/RRI collaborative clone trials planted in 2015 in Uva Province and fourth -year mean girth data*

Trial	Smallholder & Location	Agro-climatic Region	75% expectancy-value of Annual Rainfall (mm)	Clones & the number of plants	Mean girth (cm)
Bibile (Collaborate with World Vision)					
SRT-UP 15/1-WV	HM Punchibanda Ilukpathana	IL1c	>1300	RRISL 2001 (215)	35.55
SRT-UP 15/2-WV	AM Karunawathie Ilukpathana	IL1c	>1300	RRISL 2001 (215)	30.16
SRT-UP 15/3-WV	HMW Wijekumara Kudumirisketiya Ilukpathana	IL1c	>1300	RRISL 2001 (430)	36.98

Table 21. *Details of smallholder/RRI collaborative clone trials planted in 2016 in Uva Province and fifth year mean girth data*

Trial	Smallholder and Location	Agro-climatic Region	75% expectancy-value of Annual Rainfall (mm)	Clones & the number of plants	Mean girth (cm)
Kataragama					
SRT-UP 15/5	GK Chaminda			RRISL2001	28.24
	Diyawaragmmana Junction, Sella Rd Kataragama	DL 5	>650	RRISL 203 (215)	29.31

(S P Withanage, K K Liyanage, T B Dissanayake and T M S K Gunasekara)

Smallholder/RRI collaborative clone trial planted in 2015 - North Central Province

One experimental trial was established in Polonnaruwa district and details are given in Table 22. The seventh year girth was not taken due to the traveling difficulties faced during the Covid-19 pandemic.

Table 22. *Details of smallholder/RRI collaborative clone trials planted in 2015 in North Central Province*

Trial	Smallholder and Location	Agro-climatic Region	75 % expectancy value of Annual Rainfall (mm)	Clones planted	Mean girth (cm)
SRT-NCP 15/1	Army Camp Kandakaduwa Polonnaruwa	DL1c	>900	RRISL 2001 (500) RRISL 2006 (500)	Not taken

(S P Withanage, K K Liyanage and T B Dissanayake)

PLANT SCIENCE

N M C Nayanakantha and T U K Silva

DETAILED REVIEW

Staff

Mr T U K Silva, Senior Research Officer, Mr M N de Alwis, Research Officer, Mr D L N de Zoysa, Mr P D Pathirana and Mr P K W Karunatilaka, Experimental Officers, Mr R Handapangoda, Mrs E U M de Z Dissanayake, Mrs W K S W Watawala, Miss H Subasinghe, Mr D Priyadarshana, Mrs N Udayakumari and Miss W M D Wickramakumari, Technical Officers, Mrs P D A H M A de Almeida, Management Assistants were on duty throughout the year.

Mrs D E Jayawardena, Management Assistant and Mrs R K Samarasekara, Experimental Officer retired from the service on 26.03.2021 and 28.04.2021 respectively. Mr H G H C Arunasiri, Technical Officer who joined the Department on 22.08.2019, resigned from RRISL with effect from 05.08.2021. Dr N M C Nayanakantha, Head of the department, resigned from the institute with effect from 8th August 2021 and Mr T U K Silva was appointed to cover up the duties for the post of Head of the Department with effect from 10th August 2021. Dr (Mrs) D S A Nakandala, Research Officer, resumed duties with effect from 19th April 2021 after resigning from the World Bank Project titled "Climate Adaptation and Resilience Project for South Asia" in Thailand. She was promoted to the post of Senior Research Officer with effect from 01st of April 2021.

Resignations & Retirements:

Mrs D E Jayawardena, Management Assistant, joined to the Plant Science Department on 01.10.1985 and served in the Department for more than 35 years. She assisted the Department activities in numerous ways including compiling Annual Reviews, Advisory Circulars and Handbook more efficiently and reliably. Her valuable contribution towards the betterment of the Department is greatly appreciated.

Mrs R K Samarasekara, Experimental Officer joined to the Plant Science Department on 1984.01.16 and served to the Department for more than 37 years. She had assisted many research activities in the field of latex exploitation and intercropping and also, contributed more in technological improvement of the rubber industry through advisory services and conducting training and workshops. Her boundless support towards the betterment of the Department and industry is greatly appreciated.

Mr H G H C Arunasiri, Technical Officer who joined the Department on 22.08.2019, resigned from RRISL with effect from 05.08.2021.

Dr N M C Nayanakantha, Head of the Department joined Plant Science Department as an Assistant Botanist on 01.07.2001. He obtained his PhD in the field of Molecular Biology and Biotechnology from Indian Agricultural Research Institute (IARI), New Delhi, India in 2014. His contribution to the rubber industry in the capacity of a Head of the Department is remarkable. He had involved in many research relevant to nursery techniques, seed science, exploitation techniques, plant molecular biology and physiological studies with special emphasis on abiotic stress tolerance in rubber plants. He has published more than 50 research papers in international and national journals, bulletins and conference proceedings. He had received fourteen research awards for Best presenter and Best paper made at various national and international conferences and symposia. Apart from research activities, his supports was given towards advisory and conducting training programmes.

Dr Chamil Nayanakantha has resigned from the RRISL with effect from 08.08. 2021, after 20 years of service at the RRISL, to join the Uva Wellassa University as a Senior Lecturer (Grade I). His management of the Plant Science Department as well as dedicative service for organizing Plantation Crop Research Symposium of the Rubber Research Institute and the contribution towards the betterment of the rubber industry in the capacity of a Head of the Department and as a Principal Research Scientist is greatly appreciated.

Research students

- Ms U L R T Gunasinhe, a Research Student of the Department of Plantation Management, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka started her research project titled "Impact of different latex harvesting systems on bark consumption and latex yield of *Hevea brasiliensis*" under the supervision of Mr T U K Silva.

Seminars/Training Programmes/Workshops/Exhibitions conducted

Subject/Theme	Number of programmes	Beneficiary/Client	Officers involved
Rubber nursery management, immature upkeep & tapping	01	Managers of Regional Plantation Companies	NMC Nayanakantha
Tapping	08	Managers, Field staff and tappers of RPC's University students NIPM students Agricultural Diploma students Rubber Development Officers Smallholders	NMC Nayanakantha TUK Silva W Karunathilaka

Subject/Theme	Number of programmes	Beneficiary/Client	Officers involved
Rubber based farming systems	05	Rubber Extension Officers School leavers (Induction course) Diploma students of NIPM	TUK Silva
Nursery management and field establishment	04	NIPM students Agricultural Diploma students Rubber Development Officers Smallholders	DSA Nakandala MN de Alwis
Rain guard	03	Field staff and workers of RPC's and smallholders	W Karunathilaka

Seminars/Conferences/Meetings/Workshops attended

Officer	Subject	Organization
NMC Nayanakantha	NIPM Webinar Workshop on Productivity improvement	National Institute of Plantation Management
	NIPM Research Symposium	National Institute of Plantation Management
TUK Silva	Progress Review Meetings	Ministry of Plantation Industries
	TEC Meetings for Purchase of polybags	Rubber Development Department
	Meeting on Productivity improvement of Elkaduwa Plantation	Ministry of Plantation Industries
D S A Nakandala	TEC Meetings for installation of micro-irrigation systems in RDD nursery	Rubber Development Department
NMC Nayanakantha TUK Silva DSA Nakandala MN de Alwis	Scientific Committee Meeting	Rubber Research Institute of Sri Lanka

Services

Testing the quality of polythene

Polybag samples for government rubber nurseries and polythene samples for rain guards were checked for quality and specifications in order to select bidders (N M C Nayanakantha, P Seneviratne and W Karunatilaka).

Supplying of marking plates

About 176 marking plates (d2 and d3) were issued to stakeholders (N M C Nayanakantha and W Karunatilaka).

Issuing authentic budwood

About 1200 meters of budwood were issued to the Genetics and Plant Breeding Department of RRISL (600 m) and for the Cloden estate (600 m) (N M C Nayanakantha and R Handapangoda).

Nursery inspection

Government, RPC and Private nurseries were inspected and details are given in Tables 11, 12 & 13 (N M C Nayanakantha, M N de Alwis, L N de Zoysa and R Handapangoda).

Visits

Advisory	-	30
Experimental	-	210
Nursery inspection	-	42
Total	-	282

LABORATORY INVESTIGATIONS

Tissue culture

No lab work was done during the 2021. Renovation of the tissue culture laboratory was completed and required equipment and chemicals were purchased under the Special Capital Project No.22-01-17 (N M C Nayanakantha, D S A Nakandala and P Seneviratne).

FIELD EXPERIMENTS

An assessment on the vulnerability of *Hevea* seed production to climate change (CC/2003/1)

Investigation on the effect of height of germination bed on growth and root architecture of rubber seedlings

This experiment was commenced in August 2020 to study the effect of the height of the germination bed on the growth and root attributes of rubber seedlings. Germination beds were prepared with river sand at different heights as shown below.

T1 – Height of germination bed, 5 cm (Control)
T2 – Height of germination bed, 10 cm
T3 – Height of germination bed, 15 cm
T4 – Height of germination bed, 30 cm

Shoot and root attributes of the seedlings were recorded as morphological characters of seedlings at the time of transplanting in the poly bag nursery. Growth of

tap root was varied at different heights of sand beds and results revealed that length of the tap root was elongated only below 10 cm at the time of transplanting (Table 1).

Table 1. *Shoot and root attributes (mean values) of seedlings at the time of transplanting (after one month of germination) SEM values state here*

Treatment	Shoot length (cm)	Stem diameter (mm)	No. of Leaves	Tap root length (cm)
T1	25.3±1.2	3.2±0.1	2.3±0.1	5.8±0.3
T2	28.6±0.9	3.3±0.1	1.9±0.1	7.7±0.3
T3	23.5±1.5	3.2±0.1	2.0±0.1	7.6±0.6
T4	23.2±1.4	3.3±0.1	2.0±0.1	7.7±0.8

Results of morphological attributes of seedling plants are recorded under nursery conditions after two months of transplanting into the poly bag nursery (Table 2).

Table 2. *Effects of the height of germination bed on seedling attributes of rubber after two months of transplanting into poly bag nursery*

	Shoot length (cm)	Diameter (mm)	No. of Leaves	Length of taproot (cm)	Dry weight of shoots(g)	Dry weight of tap root (g)	Dry weight of secondary roots and early secondary roots(g)
T1	36.8±1.3	4.0± 0.2	4.1 ±0.3	29.0 ±2.3	1.6 ±0.2	0.5 ±0.1	0.3 ±0.1
T2	37.6±1.8	4.0± 0.2	4.3 ±0.3	32.4 ±2.3	1.9 ±0.2	0.5 ± 0.1	0.3 ±0.1
T3	33.3±1.8	3.9 ±0.1	3.6 ±0.3	33.6 ±1.7	1.5 ±0.1	0.5 ± 0.1	0.3 ±0.1
T4	40.7±2.6	4.2 ±0.1	4.9 ±0.4	29.9 ±2.9	1.9± 0.3	0.5 ± 0.1	0.4 ±0.1

Growth of tap root of seedlings in polybags were varied according to the treatments applied but no marked effect was seen on other growth parameter *viz;* stem diameter, dry matter and no. of leaves (Table 2). Germination beds causes rapid elongation of the tap root in the germination beds. A repeat trial on the above will be done in 2022 for further evaluation of the growth and physiological parameters and cost effectiveness (N M C Nayanakantha and U N Udayakumari).

Effect of size of the polybag on the growth of rubber nursery plants

Young budding plants established in different sizes of polybags were field planted in 2020 at Dapiligoda of Dartonfield estate. Plants were field planted

according to the RCBD design and study their growth performances under field conditions. Plant growth at the time of transplanting were recorded in Annual Review 2020. The annual girth of plants in different treatments was recorded at 120 cm height (Table 3).

Table 3. *Effect of size of polybags on the growth of plants after one year of field establishment*

Treatment	Girth at 120 cm height (cm)
T1 (5"x13")	7.7 ± 0.49^{b}
T2 (5"x15")	9.0 ± 0.38^{a}
T3 (6"x13")	8.5 ± 0.45^{ab}
T4 (6"x15")	9.1 ± 0.35^{a}

Girth of the treatment plants was significantly ($p\leq 0.05$) increased in size 6”x15” and 5”x15” of polybags. But the growth of all treatment plants was satisfactory after a year irrespective to the treatments except 5”x13” (N M C Nayanakantha, M N de Alwis, R Handapangoda and U N Udayakumari).

Effect of colour of the polybag on the growth of rubber nursery plants

Young budding plants established in different colors of polybags (Black and transparent) in the standard size (6”x15”) were field planted in 2020 at Dapiligoda of Dartonfield estate. Plants were field planted according to the RCBD design and study their growth performances under field conditions. Plant growth at the time of transplanting were recorded in Annual Review 2020. The annual girth of treatment plants was recorded at 120 cm height (Table 4).

Table 4. *Effect of colour of polybags on the growth of plants after one year of field establishment*

Treatments	Girth at 120 cm height (cm)
Black (Control)	9.1 ± 0.38^{a}
Transparent	8.9 ± 0.50^{a}

Results show that the girth of plants is satisfactory for both color and no significant ($p\leq 0.05$) differences were recorded for girth values of plants raised in black and transparent polybags (Table 4) (N M C Nayanakantha, M N de Alwis, R Handapangoda, and E U M De Z Dissanayaka).

Nursery techniques

Effect of different seed quantities on growth and bud grafting performance of rubber nursery plants (NT/SQ/2020/Mon)

An experiment was commenced in 2020 to investigate the effect of seed quantity on germination and the quality of planting material. This study was conducted at Moneragala Substation with different quantities of rubber seeds as treatments *i.e.,* T1: two-folds (control), T2: three-folds, T3: four-folds and T4: five-folds of rootstock plants to be established in a nursery according to the RCBD design. From each treatment, early germinated seeds were transplanted in polybags. The methodology of the above experiment was discussed in the Annual Review 2020. Seedling plants were then bud grafted in 2021 and success rates were recorded. The success percentage of each treatment was given in Table 5. According to the Table 5, plants which were transplanted from the treatment T3 and T4 have shown a higher bud grafting success when compare the T1 and T2 treatment plants.

Table 5. *Bud grafting success*

Treatment	No. of plants grafted	Success plants	Success rate (%)
T1 – two folds	188	128	68
T2 – three folds	176	123	70
T3 – four folds	284	225	79
T4 – five folds	312	256	82

The cost of planting material production from each seed quantity was calculated and recorded in Table 6. The cost of production of nursery plant was reduced in one time harvesting of five folds of seed quantity (T4) even though the initial cost for collecting large amount seeds was high.

Table 6. *Cost of production of treatment plants*

Treatment	Seed quantity used (kg)	Cost of seeds used at a rate of Rs.60 per kg	The total cost of production (Rs.)	Number of successful plants produced	Cost of production per plant (Rs.)
T1 – two folds	3 kg 200 g	Rs.192.00	25,408.00	128	198.50
T2 – three folds	4 kg 600 g	Rs.272.00	25,708.00	123	209.00
T3 – four folds	6 kg 300 g	Rs.378.00	24,890.00	225	110.62
T4 – five folds	8 kg 200 g	Rs.492.00	24,872.00	256	97.15

(M N de Alwis, D S A Nakandala and D L N de Zoysa)

Effect of row arrangements of rootstock nurseries on the growth of rubber in the Intermediate Zone of Sri Lanka (NT/RA/2020/Mon)

The experiment was carried out at Moneragala Substation in 2020. Details were given in Annual Review 2020. Treatments were as follows;

T1 : Single row
T2 : Two rows
T3 : Three rows
T4 : Four rows

Seedling plants from each treatment were bud grafted in 2021 and the grafting success of the plants was recorded. Success rate of each treatment is given in Table 7. More than 80% of higher success rate was recorded by three and four row systems when compared to single and two row systems (Table 7).

Table 7. *Bud grafting success rate of plants under different plant row arrangements*

Treatment	No. of plants grafted	Success plants	Success rate (%)
T1 – Single row	198	105	53
T2 – Two rows	468	365	78
T3 – Three rows	713	599	84
T4 – Four rows	950	779	82

Soil moisture content in polybag plants under each row arrangement was recorded by using Theta-probe equipment. Theta probe was inserted into soils in the polybag up to 10 cm depth and moisture percentage in a volume basis was recorded by using a moisture meter that was connected to the theta probe (Table 8). Results of moisture content have not shown any marked difference on available moisture content under each row arrangement. A repeat trial will be arranged in 2022 for further confirmation.

Table 8. *Average soil moisture content (v/v%) of different treatments after four months of transplanting into polybags*

Treatment	The soil moisture content at different time interval (v/v/%)		
	8.00 am	12.00 noon	4.00 pm
T1	16.9±0.5	13.3±0.5	12.3±0.4
T2	17.5±0.5	14.0±0.6	12.1±0.5
T3	17.9±0.6	14.8±0.5	13.8±0.5
T4	18.4±0.6	15.1±0.5	13.5±0.5

(M N de Alwis, D S A Nakandala and D L N de Zoysa)

Irrigation systems for rubber nurseries and immature plants

Micro-irrigation systems for immature rubber plantings in Intermediate Zone of Sri Lanka (PT/MI/2020/Monaragala)

A porous tube micro-irrigation system was installed at Monaragala in 2020 with an objective of minimizing the drought stress of immature rubber plants under sub-optimum conditions in the Intermediate zone of Sri Lanka. Introducing different techniques of porous irrigation systems to immature rubber plants provides ample amount of irrigation to plants to tolerate the water stress under drought conditions. Three types of porous irrigation systems were installed at the two immature rubber fields in Moneragala. Details of the experimental design and the methodology were given in Annual Review 2020. Different types of porous tube systems as treatments are as follows,

T1 : One porous tube unit at 1foot depth from the surface of the soil
T2 : One porous tube unit at 2 feet depth from the surface of the soil
T3 ; Two porous tube units at 1 foot and 2 feet depths from the surface of the soil
T4 : Manual watering (Control)

Irrigation interval was maintained at three-day intervals and watering done by filling two-liter water bottle at each time and fixing manually to each porous tube unit. In control treatment, watering was done by applying water in the same amount to the base of the plant manually. Plant growth in relation to average annual girth and soil moisture content after irrigation were recorded in Tables 9 and 10. Results show that the girth of one year plants is satisfactory for each irrigation systems and a variation is occurred slightly in plants which were irrigated with different types of porous irrigation systems over manual watering.

Table 9. *The annual girth of irrigated plants with porous irrigation systems*

Treatment	Girth at 120 cm height (cm)
T1	5.8±0.28
T2	5.6±0.24
T3	5.8±0.36
T4	5.5±0.32

Available moisture content of the soil at 30 cm depth was recorded after one hour of subsequent irrigation and recorded in Table 10.

Table 10. *Moisture availability of the soil two hours after irrigation*

Treatment	Moisture content at 30 cm depth (%v/v)
T1	17.4
T2	15.1
T3	23.6
T4	13.2

Water distribution of each irrigation system was varied according to type of irrigation systems and two porous units fixed at 1 foot and 2 feet depths from the surface of the soil (T3) have shown a higher moisture content followed by the girth increment when compare the other types of irrigation systems (D S A Nakandala and P K W Karunatilaka).

Budwood nurseries

BN/2014/Gallewatta, BN/2017/Olikanda and BN/2017DF

Budwood nurseries at Olikanda and Gallewatta were maintained throughout the year. Weeding, manuring, pollarding and application of fungicide were done at regular intervals (N M C Nayanakantha, P Seneviratne and R Handapangoda).

Monitoring and certification of rubber plants

Monitoring and certification of rubber plants in Government, RPCs' and Private nurseries were done during the year and details are given in Tables 11, 12 & 13.

Table 11. *Details of RPC nurseries established in 2021*

Regional Plantation Company	No. of estates having nurseries	No. of nurseries in RPC estates	No. of plants established in 2021	No of plants certified as YB in 2021
Agalawatte	4	4	362,573	142,313
Hapugasthenna	1	1	74,000	11,000
Kegalle	6	10	182,100	87,520
Kelanivally	4	4	695,000	-
Kotagala	8	8	84,000	-
Lalan	1	1	155,000	92,000
Pussellawa	6	6	273,500	51,178
RRISL				5,500
Total	**30**	**34**	**1,826,173**	**389,511**

Table 12. *Details of government nurseries established in August 2020, January 2021 and August 2021*

Name of the Nursery	Season	No. of plants established	No. of plants certified
Egaloya	2020 Aug	290,000	115,000
	2021 Jan	52,700	-
	2021 Aug	400,000	-
Gurugoda	2020 Aug	300,000	170,000
	2021 Jan	56,600	-
	2021 Aug	400,000	-
Karapincha	2020 Aug	120,000	50,000
	2021 Jan	28,500	-
	2021 Aug	160,000	-
Meerigama	2020 Aug	145,000	65,000
	2021 Jan	100,000	-
	2021 Aug	300,000	-
Welikadamulla	2020 Aug	295,000	140,000
	2021 Jan	55,000	-
	2021 Aug	400,000	-
Middeniya	2020 Aug	119,700	23,600
	2021 Jan	100,000	-
	2021 Aug	150,000	-
Moneragala	2020 Aug	450,000	230,000
	2021 Jan	285,000	-
	2021 Aug	380,000	-
Padiyathalawa	2020 Aug	125,000	50,000
	2021 Jan	16,000	8,000
	2021 Aug	200,000	-
Total		**4,928,500**	**851,600**

Table 13. *Details of private nurseries established in 2020 August*

Region	No. of nurseries	No. of plants established	No. of plants certified
Kegalle	20	326,000	131,200
Rathnapura	5	157,000	40,000
Kalurara	1	40,000	25,000
Total	**26**	**523,000**	**196,200**

(N M C Nayanakantha, M N de Alwis, D L N de Zoysa, R Handapangoda,W M D Wickramakumari, U Disanayaka and U N Udaya Kumari)

Inspection of budwood nurseries

All budwood nurseries belonging to Rubber Development Department (RDD) were inspected. Instructions were given to uproot overaged budwood nurseries and establish new nurseries with immediate effect. Clonal composition in budwood nurseries was identified and recorded (N M C Nayanakantha, M N de Alwis, D L N de Zoysa and R Handapangoda).

Discarding weak plants in rubber nurseries (update the text for 2021)

Discarding of weak budded plants and unsuccessful seedling plants in RDD nurseries were done in front of officials of both RRISL and RDD (Table 14).

Table 14. *Details of the plant discarding in 2021*

Nursery	Season	No. of plants discarded
Padiyathalawa	2020 Aug	61,831
	2021 Jan	4,947
Egaloya	2020 Aug	7,901
	2021 Jan	1,371
Welikadamulla	2020 Aug	78,657
	2021 Jan	1,612
Meerigama	2020 Aug	4,869
Karapincha	2021 Jan	1,125
Gurugoda	2020 Aug	9,644
	2021 Jan	1,486
Total		**173,443**

(N M C Nayanakantha, M N de Alwis and D L N de Zoysa)

Planting techniques

Stumped budding experiment (SB/2016/Moneragala)

A stumped budding experiment was established at Moneragala Substation in November 2016. Regular maintenance, including manuring and circle weeding, was done throughout the year. The annual girth and girth increment of the treatment plants (*i.e.* normal stumps and whole plants with root boles) were compared with normal field plants in the same field. Table 15 shows the comparison of each treatment.

Table 15. *Mean annual girth of stumped budded plants, root bole plants and initially established plants*

Treatment	Girth (cm)	Girth increment (cm)
Whole plants with root boles	26.7±1.32	7.6±0.70
Stumped budded plants	24.4±1.43	6.8±0.75
Normal plants	37.4±0.67	9.3±0.45

According to Table 15, the girth of the normal plants which were not replaced by stumps recorded the highest girth increment which was above 9 cm when compared to stumped budded plants. The stumps which were used as root bole whole plants have shown a higher girth increment compared to normal stumped budded plants but the difference was not significant. However the girth of the trees is the most important which is highest with normal plants and it is significantly different (N M C Nayanakantha, D S A Nakandala, M N de Alwis and D L N de Zoysa).

Performances of clones PB 86 and RRIC 100 (2013)

Young budded plants of clones PB 86 and RRIC 100 were established at Gallewatta division of Dartonfield Group in 2013. The objective of this study was to compare the growth and yield performances of two clones under field conditions. Weeding, manuring, and other agronomic practices were done as per recommendations of RRISL. The mean annual girth of two clones was recorded and tabulated in Table 16. Tapping commenced in July 2021 and two tapping systems (d2 and d3) were tested for both clones as per the Table given below (Table 16).

Table 16. *Tapping frequencies practiced for clones RRIC 100 and PB 86*

Clone	Tapping system
RRIC 100	d2
	d3
PB 86	d4
	d3

Figure 1 shows the annual girth of the two clones for seven years. Trees of RRIC 100 clone reached the tappable girth (50 cm stem girth at 120 cm from the bud union) early in the sixth year.

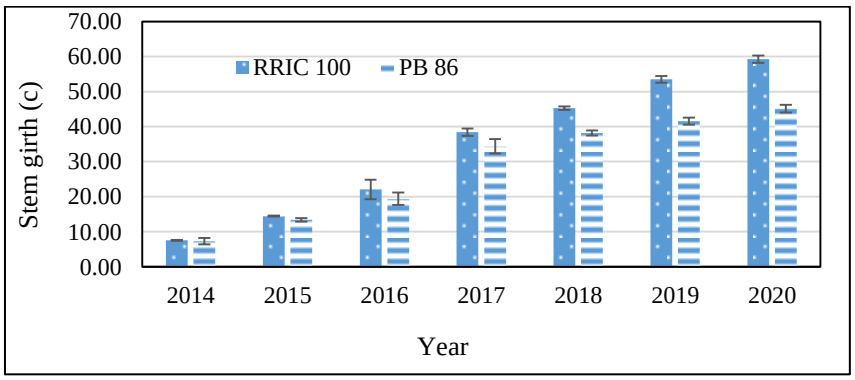


Fig. 1. The annual girth of RRIC 100 and PB from 2014 to 2020

Test tapping commenced in both clones after the trees from PB 86 have reached the tappable girth in 2021. Latex yields obtained from two tapping systems of each clone are shown in Table 17, RRIC 100 recorded the significantly ($p \leq 0.5$) higher yields (both g/t/t and YPH) when compared to PB 86.

Table 17. *Yield comparison between two clones and tapping systems*

Clone	Tapping system	Yield (g/t/t)	Yield (YPH)
RRIC 100	d2	25.4	2,028.3
	d3	28.6	1,531.7
PB 86	d2	11.6	923.5
	d3	16.3	870.4

(P Seneviratne, N M C Nayanakantha and R Handapangoda)

Northern Province planting

Kilinochchi (PT/2015/Kilinochchi)

This experiment was terminated due to inability of undertaking regular visits and maintenance with the travel restrictions imposed by COVID19 pandemic (N M C Nayanakantha, M N de Alwis and D L N de Zoysa).

Different types of planting materials for drier areas (PT/SP/Anuradhapura/2019)

This experiment was commenced at a farmer's field at Kekirawa, in Anuaradhapura District. The objective of the study is to increase field establishment rate of immature rubber under sub-optimal climatic conditions. Different potting media was used to form root bole plants as stated in Table 18. The control treatment was selected as two-whirled young budding plants and plants were arranged in the Randomized Complete Block Design.

Table 18. *Composition of the media used to prepare root bole plants*

	Composition	
Treatment	Coir dust (v/v%)	Top soil (v/v%)
T1	0	100
T2	25	75
T3	50	50
T4	75	25
T5	100	0

General maintenance and fertilizer application were done according to the RRISL recommendations. The annual girth was recorded at the 120 cm height from the grafted union (Table 19).

Table 19 shows that the girth of treatment plants varied significantly ($p \leq 0.5$) according to the added amount of coir pith to root bole plants. The highest girth was

recorded by the root ball plants arranged with 50:50 of coir pith and topsoil mixture (T3). The root ball plants without coir pith (T1) have not shown a significant difference compared to young budding plants (Table 19). Results revealed that root ball plants arranged with coir pith in different quantities would result in vigorous growth of plants during the immature period (M N de Alwis, D S A Nakandala, D L N de Zoysa, R Handapangoda and W M D Wickramakumari).

Table 19. *The annual girth of rubber plants after two years of field establishment*

Treatment	Coir pith% in potting media	Girth at 120 cm height (cm)
Control	Young buddings	8.7^{c}
T1	0	9.1^{c}
T2	25	10.3^{bc}
T3	50	11.9^{a}
T4	75	11.1^{ab}
T5	100	10.3^{bc}

Cultural practices during the immature phase

Planting at high density (PT/1992/1/Kuruwita)

This experiment was established in 1992 and yield data was not recorded from 2020 considering the age of the plantation. Total assessments of timber, fuel and biomass to be conducted in next year after completing its 30 year lifecycle (T U K Silva, V H L Rodrigo and H Subasinghe).

Low-density trial at Galewatta and Nivithigalakele - 2012

Two field experiments on low densities were established at the Galewatta and Nivithigalakele Divisions of Dartonfield Group in 2012. Two different spacing systems (*i.e.* 16'x16' and 14'x15') and two clones (*i.e.* RRISL 203 and RRISL 2001) were used as treatments for both fields (Tables 20 and 21).

Table 20. *Lay out of two different densities of clones RRISL 203 and RRISL 2001 at Gallewatta division*

Clones	No. of plants established	Spacing
RRISL 2001	294	14'×15'
RRISL 203	422	14'×15'
RRISL 2001	314	16'×16'
RRISL 203	391	16'×16'

Table 21. *Lay out of low-density trial of clones RRISL 203 and RRISL 2001 at Nivithigalakele division*

Clones	No. of plants established	Spacing
RRISL 2001	317	16'×16'
RRISL 203	358	16'×16'

General maintenance and fertilizer application were continued according to the RRISL recommendations. The girth of the treatment plants was recorded annually from 2013. Girth and yield data of each trial were recorded continuously in Annual Review 2013 to 2019. Girth data gathered so far were analyzed and interpreted in Tables 22 and 23.

Table 22. *Average annual girth values in different densities of clones RRISL 203 and RRISL 2001 at Gallewatta division*

Clone with spacing	Average annual girth (cm)						
	2013	2014	2015	2016	2017	2018	2019
RRISL 2001 14'×15'	4.5±0.2	13.6±1.1	27.9±0.9	38.4±0.8	41.6±0.9	53.9±0.9	54.2±1.3
RRISL 203 14'×15'	7.6±0.2	16.8±0.5	30.3±0.5	40.9±1.5	47.0±0.7	53.7±0.6	55.1±0.9
RRISL 2001 16'×16'	5.5±0.1	14.1±0.5	28.1±0.6	33.9±1.3	44.4±0.7	53.6±0.7	54.9±0.7
RRISL 203 16'×16'	7.7±0.21	17.3±0.6	32.8±0.8	40.1±1.9	43.9±0.3	51.5±0.5	52.2±0.3

Table 23. *Average annual girth values in low-density trial of clones RRISL 203 and RRISL 2001 at Nivithigalakele division*

Clonal density	Average annual girth (cm)						
	2013	2014	2015	2016	2017	2018	2019
RRISL 2001 16'×16'	5.4±0.1	17.7±0.3	27.4±0.7	39.3±0.9	45.7±0.9	49.3±0.4	49.5±0.9
RRISL 203 16'×16'	7.1±0.3	16.9±0.5	37.1±4.3	41.8±1.3	45.9±0.8	49.0±0.4	50.4±0.9

According to the results, a higher growth rate was recorded by clone RRISL 203 under low density at 16'x16' spacing system compared to 2001 clone at same distance (Table 23). Two tapping systems were adopted as d2 in the Galewatta trail. d3 tapping system was in N'kele after seven years of planting. The highest g/t/t and YPH values were recorded by clone RRISL 203 under the low density of 16'x16' (Table 24). Moreover, the results show that d3 tapping system performed well when compared to the d_2 tapping system (Table 25).

Table 24. *Mean g/t/t and YPH values of rubber clones at different densities at Gallewatta field trial*

Clone	Spacing	Assessment	Values in 2018	Values in 2019
RRISL 2001	14'x15'	g/t/t (g)	33.1	29.8
		YPH (kg)	2318.1	2381.6
RRISL 203	14'x15'	g/t/t (g)	42.8	36.9
		YPH (kg)	2996.1	2914.2
RRISL 2001	16'x16'	g/t/t (g)	37.3	31.2
		YPH (kg)	2612.3	2408.0
RRISL 203	16'x16'	g/t/t	47.7	47.0
		YPH	3337.7	3761.5

Table 25. *Mean g/t/t and YPH values for d_2 and d_3 frequencies at low-density trial at Nivithigalakelle field trial*

Clonal density	Assessment	D/2 in 2018	D/3 in 2018	D/2 in 2019	D/3 in 2019
RRISL 2001	g/t/t (g)	27.7	31.8	31.9	39.4
16'×16'	YPH (kg)	1940.9	1461.1	1752.6	3148.1
RRISL 203	g/t/t (g)	29.2	35.9	36.5	39.7
16'×16'	YPH (kg)	2040.4	1651.4	2009.8	3172.9

(P Seneviratne and R Handapangoda)

Low density trail at Kandakadu, Polonnaruwa – 2013

A low-density experiment with the clone RRIC 121 was established at Kandakadu in Polonnaruwa District in 2013. The spacing system adopted was 16'x16' with banana as an intercrop. A considerable amount of some healthy rubber plants at the experimental site (25%) were destroyed by wild elephants on several occasions. Regular maintenance was not done as well as the annual girth of plants was not recorded due to the travel restrictions imposed by COVID19 pandemic *etc*. Hence almost all plants remaining are under the girth. Thus it was decided to terminate the trial (P Seneviratne, N M C Nayanakantha, M N de Alwis and R Handapangoda).

Morphological, physiological and molecular level variation of different rubber clones grown under wet and dry climates in Sri Lanka (PT/2020/Galewatta)

An experiment was established at the Galewatta Division of the Dartonfield Group in July 2020 with the onset of South-West monsoon rains. The objective of this study was to evaluate the growth, physiological and molecular biological variations of different rubber clones *viz.*, RRISL 201, RRISL 2006, Centennial 4 and RRIC 121 under wet and dry climates. The same trail was planned to be established at Moneragala under a dry climate. But due to the restrictions imposed by COVID19

pandemic, the trial was not established in Moneragala, Intermediate Zone as planned. However, a trial with the same clones will be established in 2022 in order to evaluate the growth performance of plants in two different regions. The growth of the plants in Galewatta Division was recorded after one year of planting in terms of stem girth at a height of 120 cm from the base of the bud union (Table 26).

Table 26. *Variation of stem girth of different clones under wet climatic conditions*

Clone	Stem girth at 120 cm height (cm)
RRISL 201	8.1±0.9
RRISL 2006	8.0±1.2
Centennial 4	7.3±0.9
RRIC 121	7.7±0.9

(N M C Nayanakantha, D S A Nakandala, M N de Alwis and D L N de Zoysa)

Mechanization of planting hole cutting (PT/HE/2020/Moneragala)

An experiment was set up to introduce a new tractor-mounted auger (a digger machine) to the farmer fields in Moneragala District for the first time in Sri Lanka. The main objective of this experiment was to evaluate the growth performance of rubber plants that were planted in planting holes prepared by using a new digger machine. The experiment was established at three fields of Kumarawatta estate in Moneragala District with the onset of North-East monsoon rains in 2020.

The experiment was designed with two methods of holing *i.e.;* using a new digger machine (T1) and manual holing as a control (T2). Details of the experimental design and methodology were discussed in Annual Review 2020. Regular maintenance including the application of fertilizer and circle weeding was done according to RRISL recommendations. An initial basal girth and girth at 120 cm height from the bud union after a year of planting were recorded and shown in Table 27. Accordingly, there was no significant difference in girth observed in plants that were planted in two different types of planting holes. A repeat trial will be conducted next year in order to find the cost effectiveness and the feasibility of applying for different soil conditions.

Table 27. *Initial basal girth (average) and mean annual girth at 120 cm height of plants grown in different types of planting holes*

Treatment	Initial basal girth at (cm)	Girth at 120 cm height (cm)
T1– New digger machine	4.2±0.1[a]	7.3±0.1[a]
T2–Manual holing (control)	4.2±0.1[a]	7.3±0.2[a]

(N M C Nayanakantha, P K W Karunatilaka and H G H C Arunasiri)

Effect of priming of rubber (*Hevea brasiliensis*) plants with some natural or chemical compounds on growth and abiotic stress alleviation under sub-optimal Climatic conditions in Ampara District of Sri Lanka (NRC Project Grant No. 18-088)

The experiment conducted under the research grant was completed successfully and the end report was submitted to the National Research Council (NRC) in December 2021 (N M C Nayanakantha, D S A Nakandala, T U K Silva, P Seneviratne, D Priyadarshana, H Subasinghe and W Karunatilaka).

Intercropping Agarwood with Rubber (IC/AW/2015)

The annual girth of rubber and Agarwood was recorded in Tables 27 and 28. In a single row system, the mean girth of rubber was comparatively higher than the double row system (Table 28). The girth increment appeared to be the same in rubber in both planting systems.

Table 28. *Mean girth and girth increment of rubber after 75 months from planting*

Planting system of rubber	Mean girth at 120 cm height (cm)	Mean girth increment (cm)
Double row	41.4±0.9	2.6±0.2
Single row	43.4±0.9	2.6±0.1

Table 29 shows the girth and girth increment of the different species of Agawood plants under full sunlight and natural shade. Agarwood plants which were grown under full sunlight received sunlight without intercepting by rubber plants. Agarwood plants which were grown under mature trees received nature shade from mature trees (Table 29). In the double row system under full sunlight conditions the highest girth was recorded in *A. crassna* and the highest girth increment was recorded in *A. subintegra.* The lowest girth was recorded in *G. walla* under full light condition. In the single row system under full sunlight condition, the highest girth and girth increment were recorded in *A. crassna*. Under the natural shading system, the highest girth and girth increment were recorded in *A. crassna.*

Table 29. *Mean girth and girth increment of three Agarwood species after 75 months from planting*

Planting system of Rubber	Agarwood species	Girth of plants (cm)	Girth increment (cm)
Double Row	AC	80.6 ± 2.4	9.6 ±0.6
	GW	36.0 ± 1.4	3.7 ± 0.5
	AS	79.3 ± 2.1	10.0 ± 0.4
Single Row	AC	83.7 ± 3.3	11.1 ± 0.7
	GW	33.3 ± 2.7	3.9 ± 0.4
	AS	70.9 ± 2.5	8.4 ± 1.7
Natural shade	AC	60.5 ± 4.3	15.1 ± 1.2
	GW	28.1 ± 6.0	6.3 ± 1.3
	AS	58.9 ± 5.1	11.5 ± 1.8

Gyrinops walla (GW), Aquilaria crassna (AC) and Aquilaria subintegra (AS) were grown as intercrops with rubber under three planting systems

(N M C Nayanakantha, S Watawala and P K W Karunatillake in collaboration with University of Sri Jayawardhanapura and Sadaharitha Plantations Ltd.)

Observing winter pattern – Monaragala, Kumarawatta

Having no site visits due to COVID 19 pandemic situation, no any new observations were made (N M C Nayanakantha, P Seneviratne, R K Samarasekara and W K S W Watawala and H C Arunasiri).

Tapping of RRISL 203 at d2 and d3 frequencies (Padukka estate)

Table 30. *Effect of tapping frequency on g/t/t of RRISL 203*

Treatments	g/t/t
S/2 d3	20.1
S/2 d2	17.3

There is no significant difference among the treatment tested. However, higher yield value was recorded in S/2 d3 without stimulation (N M C Nayanakantha, R K Samarasekera, W K S W Watawala and H C Arunasiri).

Night/Early morning tapping experiment (NT/2016)

Latex was collected from 15 trees for each block. DRC values were estimated and thereby g/t/t was calculated. Weather data such as relative humidity, temperature and wind speed were recorded using a pocket weather meter. The yield was calculated as mean total crop and g/t/t.

Results revealed that there was a significant difference on yield tapped with early hour at 4.00 am and late hour at 7.00 am, time intervals when compared with other hours namely 3.00 am, 5.00 am, 6.00 am and 8.00 am (Fig. 2 & 3).

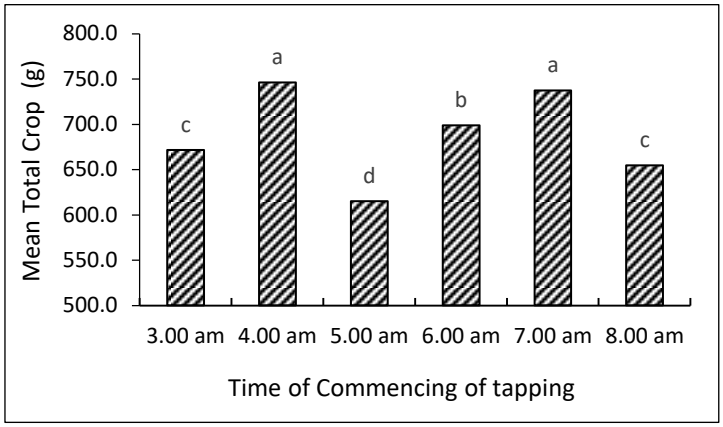


Fig. 2. Mean total crop of 15 trees/tapping at 108 tapping days

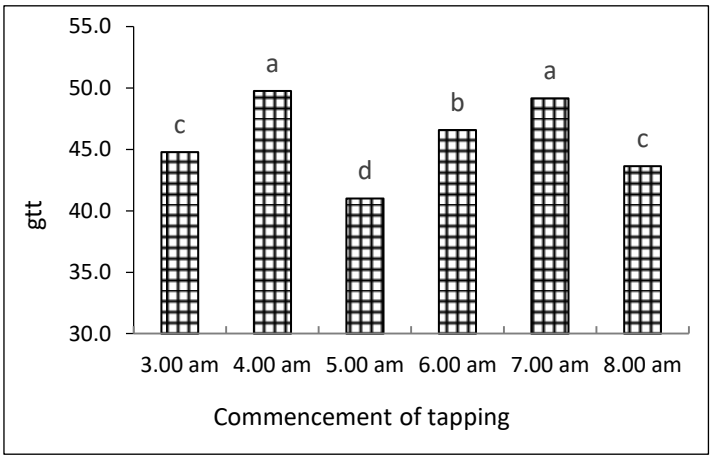


Fig. 3. Mean g/t/t of 15 trees/tapping at 108 tapping days

A novel approach to optimize the bark management of rubber plantations (BCR/2017/Sirikandura)

The objective of this experiment was to investigate the possibilities to increase the productivity of rubber plantations through the management of bark consumption rates. A rubber field established in 2006 with RRIC 121 clone at Sirikandura estate was selected for the study. Six tapping systems were employed as

treatments (Table 31). The experiment was designed according to a Randomized Complete Block Design (RCBD) with three replications of each treatment. Growth and yield data were recorded (Table 32). Out of the six treatments T1, T5 and T6 were recorded with higher g/t/t values than the other treatments due to the lower tapping intensity. The T3 recorded the lowest value due to the effects of both higher frequency and shorter cut length. However, the half spiral daily tapping (T2) recorded a moderate value due to a lesser number of tapping days than T3 due to the absence of rain guards. The treatment which has an additional tapping cut for the holidays, *i.e.* T4 recorded the total value of 60.4 g/t/t in holidays to cover the additional cost to be paid for the tappper for holiday tapping.

Table 31. *Description of tapping systems employed as treatments*

Treatment	Tapping system
T1	S/2 d2 + Recommended number of Recovery Tappings per month (Control)
T2	S/2 d1 + Without Rainguard or Recovery Tapping (Smallholder Practice)
T3	S/4 d1 + With Rainguards (No Recovery Tapping)
T4	S/2 d2 (RG), No RT + Supplementary Holiday Tappings per month (S/4 U d7)
T5	S/4U d3 2.5% ET + S/2D d3 2.5%ET (Panel changing year by year, alternatively)
T6	S/2 d6 5% ET (Monthly)

Table 32. *Mean girth, bark thickness and yield (g) per tree per tapping (g/t/t) under different tapping systems*

Treatment	Mean girth (cm)	Mean bark thickness (mm)	Yield (g/t/t)
T1	72.3	8.4	39.5
T2	75.9	8.6	32.9
T3	73.7	8.2	23.9
T4	71.6	8.3	31.3* 29.1*
T5	70.6	7.7	38.6
T6	72.0	7.5	35.0

* g/t/t recorded from supplementary holiday tapping

(T U K Silva, P Seneviratne, H Subasinghe and D Priyadarshana)

Intercropping

Intercropping demonstration field (IC/DP/2011) - Moneragala

This intercropping field was established as an intercropping demonstration plot at the RRISL substation in Moneragala. The growth of rubber trees in terms of girth under different planting systems is given in Table 33. Tapping was commenced and data recorded.

Table 33. *The girth of rubber trees under different intercropping systems and spacing arrangements*

Intercropping system	Spacing of rubber (m)	Girth of rubber (cm)
Rubber x Pineapple	Single row system	66.3
Rubber x Banana	2.5 m x 7.75 m	61.9
Rubber x pomegranate/Guava	Single row system	58.5
Rubber* x pomegranate*/Guava*	2.5 m x 12 m	48.9
Rubber x Cinnamon	Paired row system	62.9
Rubber x Mango/Rambutan	(3 m x 3 m) – 18 m	59.6

*Planted in the year 2012

(T U K Silva, N M C Nayanakantha, D Priyadarshana and H Subasinghe)

Special Capital Project (22-01-17)

A special capital project was granted in 2018 titled "Intercropping diverse crop plants (medicinal, fruit crops and multipurpose crops) under rubber in non-traditional areas to ensure economically and environmentally sustainable land use practice for rubber cultivation". Funding for this project ended at the end of the year 2021. However, the trials established in farmer fields under this projects will be monitored under the RRI funds.

Rubber x ***Intercropping trials in Moneragala and Ampara districts***

(a) Rubber x ***Fruit crops trial in Moneragala (IC/FC/2018/1)***

Four fruit crops *i.e.* orange, sour soup (Anoda), Guava and Papaya were planted under rubber with 2.5 m x 7.75 m and 2.5 m x 12.0 m spatial arrangements. Planting of both rubber and fruit crops was done as per the recommendations given by RRISL and the Department of Agriculture. The growth of rubber in terms of girth at 4 feet height after four years of planting is shown in Table 34. The growth of intercrops after four years is shown in Table 35.

Table 34. *Mean girth at four feet height (cm) of rubber trees under different treatments and under different spatial arrangements*

Main treatment (spatial arrangement of rubber)	Sub treatment (intercrop)	Girth of rubber (cm)
2.5 m x12.0 m	Sour soup	16.8
	Orange	16.9
	Guava	16.3
	Papaya	16.8
2.5 m x 7.75 m	Sour soup	14.6
	Orange	15.4
	Guava	15.3
	Papaya	13.8

Table 35. *Mean basal girth (cm) of intercrops under different spatial arrangements of rubber*

Main treatment	Sub treatment (intercrop)	Basal girth (cm)
2.5 m x 12.0 m	Sour soup	36.5
	Orange	29.0
	Guava	23.2
2.5 m x 7.75 m	Sour soup	31.3
	Orange	24.1
	Guava	27.8

(T U K Silva, N M C Nayanakantha, H Subasinghe and D Priyadarshana)

***(b) Rubber x Fruit crops trial in Ampara* (IC/FC/2018/2)**

Two hectares of land were selected from a farmer's field at Hingurana in Ampara District in 2018. Four fruit crops *i.e.* orange, sour soup, guava and papaya were planted under rubber with a spacing of 2.5 m x 7.75 m. However, establishment rates of fruit crops and rubber were not satisfactory due to the long dry spells that prevailed at the time of establishing rubber and fruit crops hence discontinued (T U K Silva, N M C Nayanakantha, H Subasinghe and D Priyadarshana).

(c) Rubber x Short-term crops trial in Ampara (IC/ST/2018/3)

Two hectares of land were selected from each farmer's field at Hingurana and Mahaoya in Ampara District to establish intercropping trials with short-term crops. Three short-term crops, *i.e.* thibbatu, thumbakaravila and maize were selected and established under rubber with a 2.5 m x 7.75 m spacing system. Only Mahaoya field has been continued and the girth values are shown in Table 36. However, short-term crops did not established this year (T U K Silva, N M C Nayanakantha, H Subasinghe and D Priyadarshana).

Table 36. *Mean girth (cm) of rubber at 120 cm height in Mahaoya field*

Area	Tree girth (cm)
Replicate 1	15.4
Replicate 2	13.6
Replicate 3	12.6
Control	15.8

PLANT PATHOLOGY AND MICROBIOLOGY

T H P S Fernando

DETAILED REVIEW

Staff

Dr (Mrs) T H P S Fernando, Head, Department of Plant Pathology and Microbiology, Dr (Mrs) M K R Silva, Research Officer, Mrs B I Tennakoon, Mrs E A D D Siriwardene, Mr S C P Wijayaratne and Mr E A D N Nishantha, Experimental Officers, were on duty. Mrs A H M N R Aberathne, and Mr D A N Mallikarachchi, Technical Officers, Mrs K A D Y Madushani Lanka, Management Assistant and Ms K L K Shehani a Temporary Research Assistant under the WRD project, were also on duty throughout the year. Miss W A K S Wijesooriya and Miss B P Kariyawasam, Temporary Research Assistants, Mr G K S Madhusanka and Miss H R G N Peiris, Technical Assistants were on duty with effect from August 2021 under the New Leaf Disease (Pesta) project.

Special research projects in operation

Source and Grant No	**Duration**	**Title of the Project**	**Allocation** (Rs. Mn.)	**Status**
Ministry of Plantation Industries **Development Project – 23/1/15**	2016 - 2021	Identification of the Potential Pest and Disease Problems of Rubber in Non-Traditional Areas to Develop Improved Management Strategies	20.00	Completed
Ministry of Plantation Industries **Development Project – 23/1/17**	2018 - 2022	Improvement of strategies to manage white root disease in rubber plantations	42.99	In progress
Ministry of Plantation Industries **Development Project –** Pesta	2021 - 2025	Studies on the biology and epidemiology of the Pestalotiopsis Leaf fall disease and to develop an effective management strategies	49.46	In progress

Research students

Dr (Mrs) T H P S Fernando supervised the final year research projects of the following undergraduate students and post graduate students.

Name	Study Programme	Duration	University	Project Title
MKR Silva	PhD	2020	University of Colombo	A study of Brown Root Disease of rubber and its causative fungus *Phellinus noxius*
PW Balasooriya	MPhil	2016-2021	University of Colombo	Application of indigenous soil microflora as biological control measures for White root disease of rubber growing lands in Sri Lanka
PLPB Nishantha	MPhil	2018	University of Colombo	Screening of selected *Hevea brasiliensis* clones grown under suboptimal ecological conditions in non-traditional rubber growing areas in Sri Lanka against foliar diseases and for physiological Performance
LTGK Fernando	MPhil	2018	University of Jayawardenapura	Formulation of ethephon based low cost yield stimulant for commercial rubber plantations in Sri Lanka
Helmi Wanthika Gammanpila	MSc	2021	University of Colombo	Molecular characterization of *Rigidoporus* spp. causing White root rot disease of rubber

Committees attended

Officers	Subject	Organization
THPS Fernando MKR Silva	Scientific Committee Meeting	Rubber Research Institute of Sri Lanka
THPS Fernando	Pesticide Technical's Advisory Committee	Department of Agriculture
THPS Fernando	Pesticide Sub-Commette	Department of Agriculture
THPS Fernando	Biopesticides Sub-committee	Department of Agriculture

Training programmes conducted

Dr (Mrs) T H P S Fernando and Dr (Mrs) M K R Silva served as the resource person in training Estate Managers, Assistant Superintendents and Field Officers. Mrs B I Tennakoon, Mrs E A D D Siriwardene, Mr S C P Wijayaratne, Mr E A D N Nishantha, Mrs Nadeeshani Aberathne and Mr Akila Mallikaarachchi covered the practical aspects of the above programmes while all the staff members extended their fullest cooperation in educating students from Universities and Technical Colleges on departmental activities.

Experimental/Advisory visits

Purpose	No of visits
Experimental	490
Advisory	71
Other	19
Total	**580**

LABORATORY AND FIELD INVESTIGATIONS

Chemical Ccntrol of *Hevea* diseases (23/P/01)

White Root Disease Management – Trials undertaken as demonstration plots

Under the white root disease rehabilitation project, demonstration plots to show the efficacy of chemical control and disease management have been established in different rubber growing areas. Most of the trials have been established collaboratively with the ASD or RDD (Tables 1 & 2).

Table 1. *Details of the White root disease demonstration plots established*

	District	Area	Contact	No of affected plants	Chemical application	Sulphur
01	Kegalla	Ruwan-wella	Nalanda estate	42	1st Application 2nd Application	100 kg
02	Kalutara	Maggona	Shantha Visenthi	60	1st Application 2nd Application	100 kg
03	Kalutara	Millewa	Koshan	70	1st Application 2nd Application	50 kg
04	Kalutara	Millewa	Hemachandra	18	1st Application	--
05	Gampaha	Delgoda	KGH Dharmawardena	42	1st Application	50 kg
06	Galle	Badde-gama	Sarath Amarasiri	52	1st Application 2nd Application	50 kg
07	Kalutara	N' Kele	N'Kele	Patch rehabilitation		100 kg
08	Kalutara	Galewatta	D/F	Patch rehabilitation		100 kg
09	Kalutara	Rannagala	Rannagala estate	12	1st Application	--
10	Kalutara	Yatadola	Premasiri	32	1st Application	500 kg
11	Kalutara	Bulath-singhala	NG Jayasena	23	1st Application	--
12	Kalutara	Lihini-yawa	Sarath Fernando	170	1st Application	150 kg

(T H P S Fernando and B I Tennakoon - Funded by the Development Project - Grant 23/1/17)

Table 2. *Details of the white root disease demonstration plots established*

	District	Area	Smallholders	No of affected plants	Chemical application tebuconazole	No. of recovery plants
01	Galle	Pitigala	Upali Galaboda	92	1st Application	90
		Pitigala North	WA Chandrasiri	21	1st Application	21
		Urapola	Sunil	189	1st Application 2nd Application	189
02	Kegalle	Rambukkana	Upali Seneviratne	39	1st Application	39
		Kotiya-kumbura	SD Karunasena	75	1st Application 2nd Application	74
03	Matara	Morawaka	Gunapala	200	1st Application 2nd Application	200

District		Area	Smallholders	No of affected plants	Chemical application tebuconazole	No. of recovery plants
04	Rathna-pura	Kiriella	Hettiarachchi	75	1st Application	75
		Ayagama	Sisira Kumara	75	1st Application 2nd Application	75
		Ayagama	Nimal Kumara	82	1st Application 2nd Application	81
		Pelmadulla	GM Gayan Kumara	75	1st Application	75
05	Kalu-tara	Horana	Samila	100	1st Application	100
		Horana	MD Dharmasena	30	1st Application	30
		Welimanana	KK Siril	20	1st Application	20
		Thebuwana	HD Premarathne	35	1st Application	35
		Thebuwana	Sunil Ranasinghe	16	1st Application	16
		Meegaha-thenna	Duminda	100	1st Application	100

(T H P S Fernando and E A D D Siriwardena - Funded by the Development Project - Grant 23/1/17)

Rehabilitation of White root disease patches- Demonstration plots

White root disease patches were rehabilitated at Galewatta, Nivithigalakele, Dartonfield estate, Kuruwita Substation and Galatura estate. All the infected plants were removed and infected root pieces were burnt *in situ*. Then sulphur sprinkling was carried out to make conditions unfavorable for the growth of the fungus *Rigidoporus microporus.* Later, indicator plants were established (*Gliricidia & Cloterlaria*) to trace out any remaining inocula. Pineapple cultivation was established to ensure an additional income for the grower (Fig. 1). Banana (Fig. 2) and Turmeric (Fig. 3) cultivations have also been established as short term rehabilitation crops to generate some income at the given experimental sites (Table 3) (T H P S Fernando and S C P Wijayaratne: Funded by Development Project 23/1/17).

Table 3. *Details of the demonstration plots established for the rehabilitation of white root diseases patches*

Trial	Rehabilitation crops	Location/Estate
1	Gliricidia/Pineapple	Gallewatta, Dartonfield estate
2	Banana	Nivithigalakale, Dartonfield estate
3	Banana	Kuruwita Substation, RRISL
4	Turmeric	Galathura estate

Fig. 1. White root disease patch rehabilitated using mechanical/chemical and biological measures at Galewatta, Dartonfield Estate, RRISL. - Pineapple as are habilitation crop

Fig. 2. White root disease patch rehabilitated using mechanical/chemical and biological measures at Kuruwita, RRISL - Banana as a rehabilitation crop

Fig. 3. White root disease patch rehabilitated using mechanical/chemical and biological measures at Galathura estate – Turmeric as a rehabilitation crop

Development of new adhesives for chemical repellants, development of new chemical formulations against mammalian pests and introduction of alternative physical methods

In the collaborative trial carried out with the Adaptive Research Unit at Polgahawela Substation, data on the incidence of mammalian pest attacks were collected, after applying the recommended chemical repellent at different time intervals. As per the results of the study, no mammalian pest damage was reported in treated plots during the first six months after applying the repellent. However, trees in non-treated plots have been attacked during the period. However, there was no difference in treated and non-treated plots after six months of application and hence the application of a six-month interval was identified as suitable for the Intermediate Zone (M K R Silva, T H P S Fernando, Dammika Balasooriya collaboratively with the Adaptive Research Unit).

Chemical management of Circular Leaf Spot Disease (CLSD) in rubber plantations

Screening of potential fungicides against the Circular Leaf Spot Disease was carried out under three levels: *in vitro,* polybag-level and field level.

a) *In vitro* screening of the potential fungicides against CLSD

Seven potential fungicides and other formulations were tested *in vitro* for their efficacy against four *Colletotrichum* isolates from the pathogen collection. These isolates were selected representing the clusters that appeared in the clustogram developed based on the pathogenicity values of the *Colletotrichum* isolate collection. Below fungicides were tested under laboratory conditions. Carbendazim 50% w/w, tebuconazole 250 EW, hexaconazole 50g/l EC, thiophanate methyl 70% a.i., mancozeb 80% a.i., sulphur 80% a.i., and copper hydroxide 57.6 % a.i.

The poisoned food technique (PFT) was used for the study. A completely randomized design with four replicates was adopted. The analysis of variance of the diameter reduction values over the control at different concentrations of the fungicides and the pathogen isolates was carried out using the statistical software SAS and subsequently, mean separation was done with Duncan's Multiple Range Test (DMRT). The variation in the diameter reduction of the fungus values (DR) at different concentrations of the systemic fungicides is shown in Figs 4 a, b, c, & d. According to the results, all the pathogen isolates, fungicides and concentrations showed significant variations in DR value and significant interactions were present among fungicides and concentrations (M K R Silva, T H P S Fernando, B I Tennakoon, E A D D Siriwardena, S C P Wijayaratne, A H M N R Aberathne, G K S Madusanka - Development Project on Pestalotiopsis Leaf fall disease).

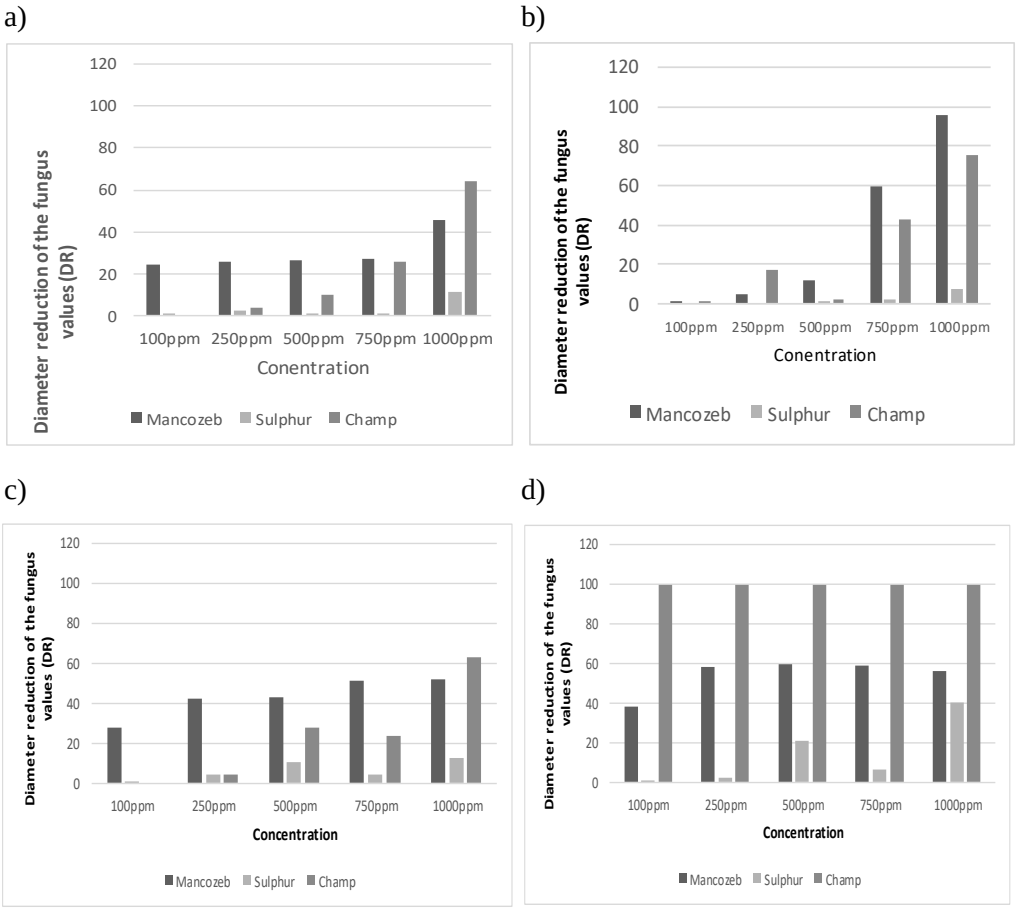


Fig. 4. *In vitro* effect of contact fungicides and their concentrations on the growth of *Colletotrichum* isolates **a.** Isolate C 1: **b.** Isolate C7: **c.** Isolate C15: **d.** Isolate C24. *Values in the same column followed by the same letters are not significantly different at DMRT at P=0.0001

b) Screening of the potential fungicides against Circular Leaf Spot Disease under polybag nursery conditions

Budded rubber plants of the clone RRISL 203 planted in polybags were used to determine the effect of prospective fungicides on disease management. Forty seedlings were used for each treatment. The treatments are summarized in Table 4.

Table 4. *Details of the different fungicide treatments used in the polybag experiment*

Treatment No	Fungicide	Concentration
T1	carbendazim	3g/l
T2	carbendazim	4g/l
T3	carbendazim	5g/l
T4	hexaconazole	3ml/l
T5	hexaconazole	4ml/l
T6	hexaconazole	5ml/l
T7	carbendazim & hexaconazole alternatively	3g/l and 3ml/l
T8	carbendazim & hexaconazole alternatively	4g/l and 4ml/l
T9	mancozeb & carbendazim alternatively	3g/l and 3g/l
T10 (Control)		No fungicide application

The plants were kept under a diseased rubber clearing at Dartonfield and the natural inoculation was assumed. The fungicides were sprayed using a hand sprayer at two-week intervals. The symptom development was regularly observed and at six weeks of fungicide application, (after twelve fungicide applications), the lesion percentage was calculated in twenty plants as follows,

$$\text{Lesion percentage} = \frac{\text{Number of leaflets with CFLD lesions}}{\text{Total number of leaflets}} \times 100$$

Thereafter, fungicide application was ceased and the Lesion Percentage was calculated for another disease reading 10 weeks after first fungicide application. At two readings, the Lesion Percentages of each treatment were subjected to ANOVA, and the mean separation was done with Duncan Multiple Range Test (DMRT).

According to the mean lesion percentages, a significant variation was observed among the treatments. At six weeks of fungicide application, treatment numbers 2, 3, 7, 8 and 9 showed a significantly lower mean disease rank over the other treatments at the probability level of 0.001. Similarly, after 10 weeks of first fungicide application, treatment numbers 2, 3, 8 and 9 showed a significantly lower mean disease rank over the other treatments. However, treatment number 5 also showed a significantly lower mean disease rank over all the other treatments whereas treatment number 7 did not show a significantly lower mean disease rank over all the other treatments (Figs. 5 a & b) (M K R Silva, T H P S Fernando, A H M N R Aberathne and D A N Mallikarachchi)

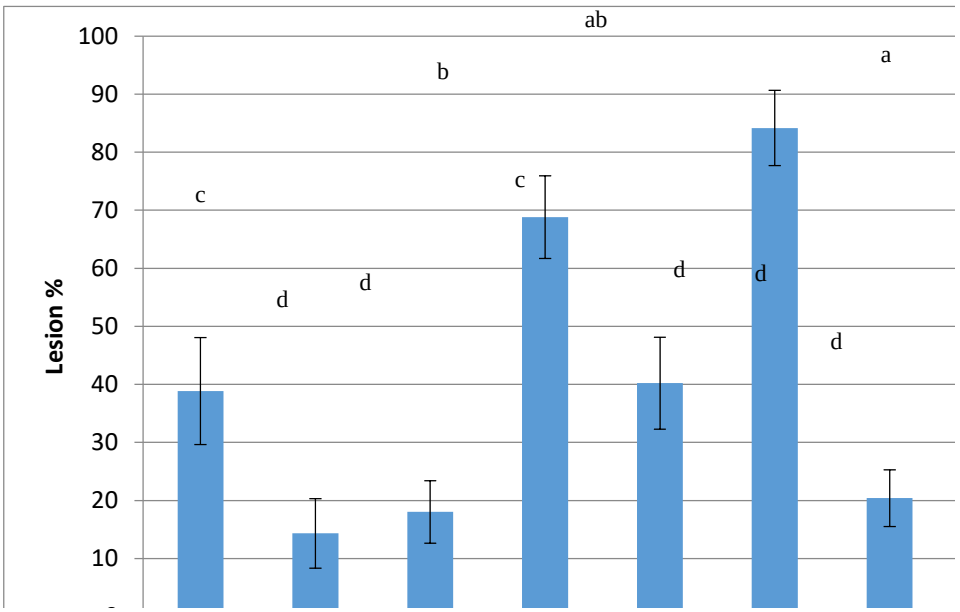


Fig. 5a. Effect of fungicide treatments on lesion development under polybag conditions - at six weeks of fungicide application

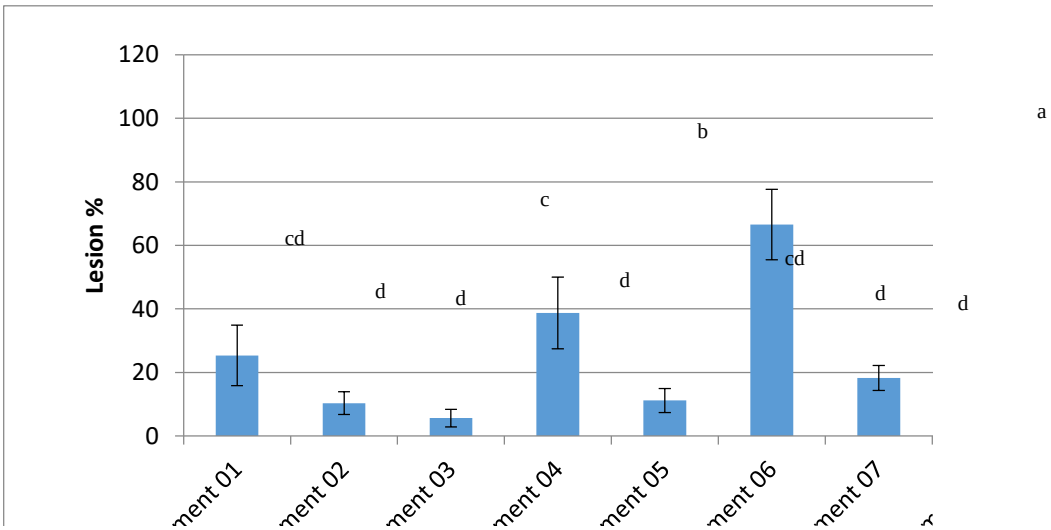


Fig. 5b. Effect of fungicide treatments on lesion development of Circular leaf spot disease under polybag conditions- after ten weeks of the first fungicide application

c) Screening of the potential fungicides against the CLSD under field conditions

The field experiments on the chemical management of CLSD were carried out during the refoliation stage of 2021. Details of the treatments are given in Table 5 and each treatment had approx. 6 replicate sites Each replicate consisted of mature rubber in a land area of 1ha. The experiments were carried out at the stakeholders' rubber fields given in Table 6. In two weeks intervals, the CLSD severity of each plot (Average Disease Severity Index-ADSI) was evaluated based on the leaf fall status of a random set of trees as follows:

ADSI of the treatment plot = $\frac{[(0 * n1) + (1 * n2) + (2 * n3) + (3 * n4) + (4 * n5)]}{N}$

n1 = No. of plants representing score index 0
n2 = No. of plants representing score index 1
n3 = No. of plants representing score index 2
n4 = No. of plants representing score index 3
n5 = No. of plants representing score index 4
N = Total number of trees

Moreover, the leaf fall data was taken weekly as a measure of disease severity. The data collection procedure was disturbed due to the lockdown condition prevailed due to Covid 19 pandemic. The disease severity data of the fungicide spraying at the refoliation phase showed that the spraying had resulted in a delay in disease incidence & severity. However, it has not imposed a significant effect on the disease development throughout the time. The fungicide spraying progamme which was planned to be implemented with the onset of rainfall to evaluate the effect of late application of fungicides on the canopy could not be implemented due to the Covid 19 lockdown condition (M K R Silva, T H P S Fernando, B I Tennakoon, E A D D Siriwardena, S C P Wijayaratne, E A D N Nishantha and D A N Mallikarachchi).

Table 5. *Treatments adopted in the field experiments on the chemical management of CLSD*

Treatment	Fungicide/Fungicide combination	Quantity	No of applications
T1	Carbendazim 4 (during refoliation)	5g/l	4 (during refoliation)
T2	carbendazim	10g/l	-do-
T3	hexaconazole	5ml/l	-do-
T4	hexaconazole	10ml/l	-do-
T5	carbendazim x hexaconazole Alternatively	5g/l x 5ml/l	-do-

Treatment	Fungicide/ Fungicide combination	Quantity	No of applications
T6	carbendazim x hexaconazole Alternatively	10g/l x 10ml/l	-do-
T7	carbendazim x mancozeb	10g/l x 10g/l	-do-
T8	carbendazim x copper	10g/l x 10g/l	-do-
T9	carbendazim	10g/l	-do-
	Ground application (hexaconazole)	3ml/l	3
T10	Intensive application	carbendazim 10g/l	Up to 10
	Control	-	-

Table 6. *Details of the field experiments on the chemical management of CLSD*

Location	No. of treatments	Officer responsible
Neuchattle estate Horana Plantations Limited	10 Treatments	BI Tennakoon
Mohomadi estate Agalawatta Plantations Limited	5 Treatments	
Sirikandura estate	5 Treatments	
Warakagoda – smallholder farmer	Intensive	
Payagala estate Kotagala Plantations Limited	10 Treatments	EADD Siriwardena
Eladuwa estate Namunukula Plantations Limited	5 Treatments	
Baddegama estate Namunukula Plantations Limited	5 Treatments	
Clyde estate Agalawatta Plantations Limited	Intensive	
Citrus estate Namunukula Plantations Limited		
Palm Garden estate Balangoda Plantations Limited	10 Treatments	SCP Wijayaratne
Thalgaswala estate Elpitiya Plantations Limited	5 Treatments	
Peenkanda estate Agalawatta Plantations Limited	5 Treatments	
Penrith estate Pussallawa Plantations Limited	5 Treatments	
Kuruwita estate Dartonfield Group	1 Treatment	
Salawa estate Pussallawa Plantations Limited	1 Treatment	EADN Nishantha
Dartonfield estate Dartonfield Group	1 Treatment	DAN Mallikarachchi

d) Chemical management of Circular Leaf Spot Disease using drone technology

In the management of Circular Leaf Spot Disease, experiments to find out the prospects of using drone technology in spraying fungicides were initiated. With the outsourcing of the drone service, the fungicide application was initiated in rubber plantations: Haldummulla, Halpe Estate and Diurumpitiya Estate. Treatments were designed to optimize the fungicide and the concentration, spray volume to cover a unit land area and timing of fungicide applications. However, the planned progamme was disturbed due to the rain interferances experienced up to the end of the year (T H P S Fernando, M K R Silva, S C P Wijayaratne and D A N Mallikarachchi).

e) Evaluation of different oils to be used as a base of fungicide spraying against CLSD

In order to seek the feasibility of introducing as a base of fungicide application (oil-based fungicide application), eight oils with organic origin namely: Castor oil, Cinnamon oil, Citronella oil, Coconut oil, Margosa oil, Palm oil, Sesame oil and Mustard oil and four oils with petroleum base: Paraffin oil, Lubricating oil, Petrol and Diesel were evaluated for the phytotoxicity.

Among the oils used, Castor oil, Mustard oil, Lubricating oil and White oil showed no phytotoxicity at foliar application onto rubber. Thereafter, then they were evaluated for the ability of desolving the effective fungicides (Table 7).

Table 7. *Solubility levels of fungicides in oils*

Oil	**Solubility (approximate percentage)**				
	carbendazim	**hexaconazole**	**copper hydroxide**	**mancozeb**	**carbendazim + mancozeb**
Castor oil	100%	100%	0	100%	100%
White oil	0%	0%	0	100%	100%
Machine oil	0%	2%	0	100%	100%
Mustard Oil	95%	100%	0	100%	100%

(M K R Silva, T H P S Fernando and D A N Mallikarachchi)

Biology of Pests (23/P/02)

Studies on the diversity of the symptomatology in the Circular Leaf Spot Disease of rubber

Diseased leaf samples were collected from all the rubber growing regions of the country (Fig. 6). Different symptoms were observed and photographed. In addition to the typical brown circular lesions, other lesion types were noted. Yellow large irregular lesions/slightly green circular patches/small irregular brown patches/ brown irregular lesions/brown pinpoint lesions/brown pin head lesions with blighting conditions (Fig. 7) (T H P S Fernando, M K R Silva, E A D N Nishantha, A H M N R Aberathne and S Madusanka).

Fig. 6. Disease symptoms of Circular Leaf Spot disease on rubber trees. **(a)**. Leaf defoliation **(b)**, Application of fungicides to the canopies **(c)**, blighting of the leaves **(d)** and leaf spot on rubber leaves

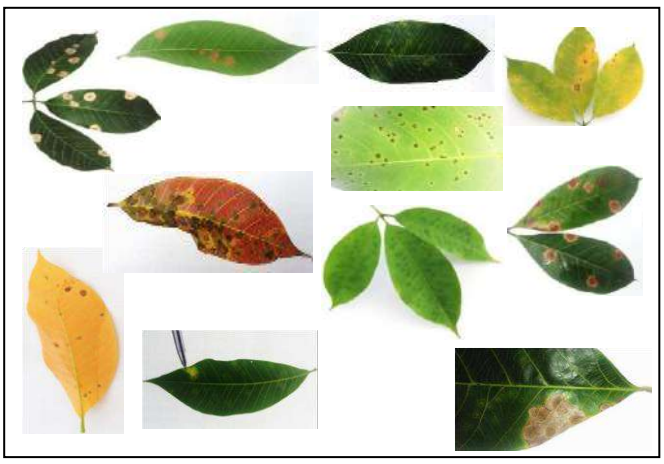


Fig. 7. Diversity of symptoms reported for the newly spreading circular spot disease

Identification of causative organisms associated with the Circular Leaf Spot Disease

The causative pathogens were isolated using the disease samples collected from different rubber growing areas. Morphologically different cultures were selected. They were observed under a light microscope. According to the microscopic characters and cultural characters *Colletotrichum* spp. Pestalotioides cultures and other fungal colonies were also identified.

- *Pestalotioides* spp. ≥ 70%
- *Colletotrichum* spp. ≈20%
- Other species ≈ 10%

(T H P S Fernando, M K R Silva, E A D N Nishantha, A H M N R Aberathne and G Peiris)

Cultural characteristics and reproductive characteristics

Single spore isolations were performed to obtain pure cultures. Mycelial plugs (5 mm) from a 7-day-old culture were transferred onto the middle of PDA plates. The cultural characters were recorded after 10 days of incubation period under normal light and dark conditions at 27 ^{0}C (Table 8). Slide cultures were prepared for each isolate using a modified method by Londhe *et al*., (2019) and they were observed under 40x magnification of OPTIKA light microscope. Reproductive characteristics; conidial shape, conidial size, colour, reproductive structures, presence of appressoria and spore concentration were recorded for each isolate. Conidia were aseptate with one cell, green colour, smooth-walled, cylindrical, rounded at both ends, guttulate and granular. A clear area could be seen without granules in the middle of the conidia. The conidia size varied between (13-16 x 3-6) µm. Mycelium of the isolates was septate and branched with a size between (2-4) µm in width (T H P S Fernando, M K R Silva, A H M N R Aberathne, E A D N Nishantha and G Peiris).

Table 8. *Cultural characteristics of the Colletotrichum population under investigation*

Isolate No.	Color		Form	Margin	Elevation	Growth Rate cm/day	Opacity
	Upper	Lower					
1	White	Whitish yellow	Irregular	undulate	raised	1.18	Opaque
4	Pale yellow	Pale brown	filamentous	filiform	flat	1.5	Opaque
5	White	Black	Irregular	filiform	raised	2.07	Opaque

Isolate No.	Color		Form	Margin	Elevation	Growth Rate cm/day	Opacity
	Upper	Lower					
7	White	Pale yellow	filamentous	undulate	raised	1.31	Opaque
9	Yellow	Yellowish brown	Irregular	Undulate	flat	1.56	Opaque
10	Yellow	Yellow	Irregular	Filiform	flat	1.75	Opaque
11	White	Yellowish white	Irregular	Undulate	raised	1.17	Opaque
12	White	Pale yellow	Irregular	Entire	flat	1.05	Opaque
13	White	White	Irregular	Undulate	flat	1.33	Opaque
14	Yellowish white	Yellow	Irregular	Entire	flat	1.18	Opaque
16	White	Pale orange	Irregular	Entire	flat	1.18	Opaque
17	White	Yellow	Irregular	Undulate	flat	1.28	Opaque
18	White	White	filamentous	Filiform	flat	1.13	Opaque
20	White	Brown	Irregular	Entire	flat	1.34	Opaque
21	Pure white	White	Irregular	Entire	Raised	2	Opaque
22	Pure white	Whitish to yellow	filamentous	Filiform	Raised	1.21	Opaque
23	White	White	Irregular	Entire	flat	1.54	Opaque
24			filamentous	Filiform	flat	1.19	Opaque
25	White	Yellowish brown	Irregular	Filiform	flat	1.10	Opaque
26	White	Yellow	Irregular	undulate	flat	1.25	Opaque
27	Pure white	Yellow to pale brown	filamentous	Filiform	Raised	1.33	Opaque
28	Whitish to yellow	Yellow	filamentous	Filiform	flat	1.04	Opaque
29	Whitish to yellow	Brown	Irregular	Undulate	Raised	1.43	Opaque
30	White	Pale yellow	Irregular	Undulate	Flat	1.32	Opaque
31	White	Yellowish brown	Irregular	Entire	Raised	1.22	Opaque
32	White	Ash	Irregular	Entire	Flat	1.25	Opaque
33	White	Whitish to yellow	Irregular	Undulate	Flat	1.34	Opaque
34	Pure white	Yellowish brown	Irregular	Entire	Raised	1.41	Opaque
35	white	Yellowish white	Irregular	undulate	flat	1.65	Opaque

Isolate No.	Color		Form	Margin	Elevation	Growth Rate cm/day	Opacity
	Upper	Lower					
37	Pure white	Pale brown	Irregular	Undulate	raised	1.21	Opaque
40	Pure white	Yellowish brown	Irregular	Undulate	raised	0.73	Opaque
41	Pure white	White	filamentous	Filiform	Flat	1.02	Opaque
42	Pure white	white	Irregular	Undulate	raised	0.36	Opaque
43	White	White to pale yellow	Irregular	Undulate	Flat	1.12	Opaque
44	White	Yellow	Irregular	Entire	raised	1.23	Opaque
45	white	Yellowish white	Irregular/ circular	Entire	Flat		Opaque
48	White	White	Irregular	Undulate	Flat	0.54	Opaque
49	Pure white	Pale yellow	Irregular	Filiform	raised	1.14	Opaque
50	White	Pale yellow	Irregular/ circular	Entire	Flat	0.79	Opaque
51	White	Yellow	filamentous	Filiform	raised	1.28	Opaque
52	White	Pale pink	Irregular	Undulate	raised	1.37	Opaque
53	White	Pale pink	Irregular	Undulate	raised	1.33	Opaque
54	white	Yellow	Irregular/ circular	entire	flat	1.42	Opaque
55	white	Yellow	Irregular	Undulate	Flat	1.13	Opaque
56	Pure white	White	Irregular	Undulate	Flat	1.50	Opaque

Molecular identification of the pathogen isolates

DNA extraction

Pathogen isolates were grown on PDA plates and the fresh mycelial mats were scraped using a sterilized glass slide after 07 days of incubation under normal light and dark conditions. They were ground in a chilled pestle and mortar and DNA was extracted from each culture following the protocol described in NORGEN Plant/ fungi DNA extraction kit (Product # E5038; Made in Canada).

Gel electrophoresis for extracted DNA

Extracted DNA samples were run in 1.2% Agarose gel, 1x TBE buffer was used as the loading buffer. Extracted DNA samples were loaded to wells by mixing 5 µL of each extracted DNA sample with 2 µL of loading dye. It was run under 70V voltage with 100mA for 30 minutes. The gel was stained using Diamond Dye staining

solution. After staining the gel, it was observed under UV transilluminator and the gel pictures were taken using 'Quantum' software.

Polymerase Chain Reaction (PCR)

Amplification of ITS gene regions was carried out using ITS1 and ITS4 forward and reverse primers respectively.

PCR for ITS region

The total volume of the 25 µL reaction mixture was used for PCR with adjustments of components, volumes and concentration when needed. PCR was carried out in a thermal cycler. The gel electrophoresis was carried out at 70V, 300mA, and 60 W for 60 minutes in a horizontal gel electrophoresis system.

Volumes of each ingredient/chemical used in PCR mixture for ITS region

Ingredient	**Volume**
5x PCR buffer	5 µL
$MgCl_2$ 25 mM	2 µL
dNTPs 10 mM	0.75 µL
Forward primer 10µM	1 µL
Reverse primer 10µM	1 µL
Taq DNA polymerase 5U/ µL	0.5 µL
DNA template	2 µL
Nuclease free water	12.75 µL
Total volume	25 µL

PCR conditions used for ITS

	Step	**Temperature (^{0}C)**	**Time**
35 cycles	Initial denaturation	95 °C	2 min
	Denaturation	95 °C	30 s
	Annealing	47 °C	30 s
	Extension	72 °C	2 min
	Final extension	72 °C	5 min
	Hold	4 °C	∞

Gel electrophoresis for PCR products

Amplified PCR products were separated by gel electrophoresis by mixing 5µL of the PCR product with 2µL of loading dye. Then those mixtures were loaded to wells in 1.2% Agarose gel which was prepared with 1M Tris-Boric EDTA solution and 100bp and1kb ladder (Promega, USA) was also added to another well. It was run under 70V, 300mA, 60 W for 60 minutes in a horizontal gel electrophoresis system

(Labnet; Model- E0500; Made in Taiwan). After electrophoresis, the gel was stained using a Diamond Dye staining solution. After staining the gel, it was observed under UV transilluminator and the gel pictures were taken using 'Quantum' software (ST4).

Sequencing of PCR products

After observing the PCR bands, samples were sent to Macrogen-Korea through Genetech-Sri Lanka for bi-directional sequencing.

Identification of isolates

Raw sequences were assembled using Contig Express software. Sequence homologies for the assembled consensus sequences were analyzed using the BLASTn of the NCBI for the primary identification of fresh isolates used in the analysis. Thirteen isolates of *Colletotrichum* species were identified (T H P S Fernando, M K R Silva, A H M N R Aberathne and S Liyanage).

Pathogenicity of the *Colletotrichum* spp.

Conidial suspensions (conidia concentration - $5x10^4$conidia/ml) were prepared using ten-day-old isolates by re-suspending the conidia with 10 ml of sterilized distilled water per culture and conidial concentration was adjusted using a haemocytometer. Six rubber leaves of the same clone (RRIC 121) and the maturity stage between copper brown and apple green were inoculated by placing 06 drops of the conidial suspension per leaf (20 µl per drop) using each culture. The inoculation was done on the upper surface of the rubber leaves. Another six leaves were maintained as the control by placing the drops of sterilized distilled water. The inoculated leaves were incubated in a moist chamber at 28 °C and the symptoms were observed after 03 days from the inoculation (Fig. 8). They were ranked using a scale of 0-4 as follows:

0 - No visible infection
1 - Light lesion around inoculation point lacking spores
2 - Large dark lesion without sporulation
3 - Large lesion and weak sporulation
4 - Very strong sporulation on the upper and lower surfaces of the leaf

The results were expressed as disease severity index (ADSI). The disease index (DI) for each leaf was calculated using the following formula (Ma and Michialides, 2002).

$$DI = \left(\sum_{i=0}^{4} N \, x \, i \right) / \sum_{i=0}^{4} N$$

Where,
i - severity (0–4)
N - the number of leaves with the severity of i.

The isolate, C14 didn't produce conidia within the considered time duration. The results were subjected to cluster analysis (Fig. 8) (T H P S Fernando, M K R Silva, A H M N R Aberathne, E A D N Nishantha and S Madushanka).

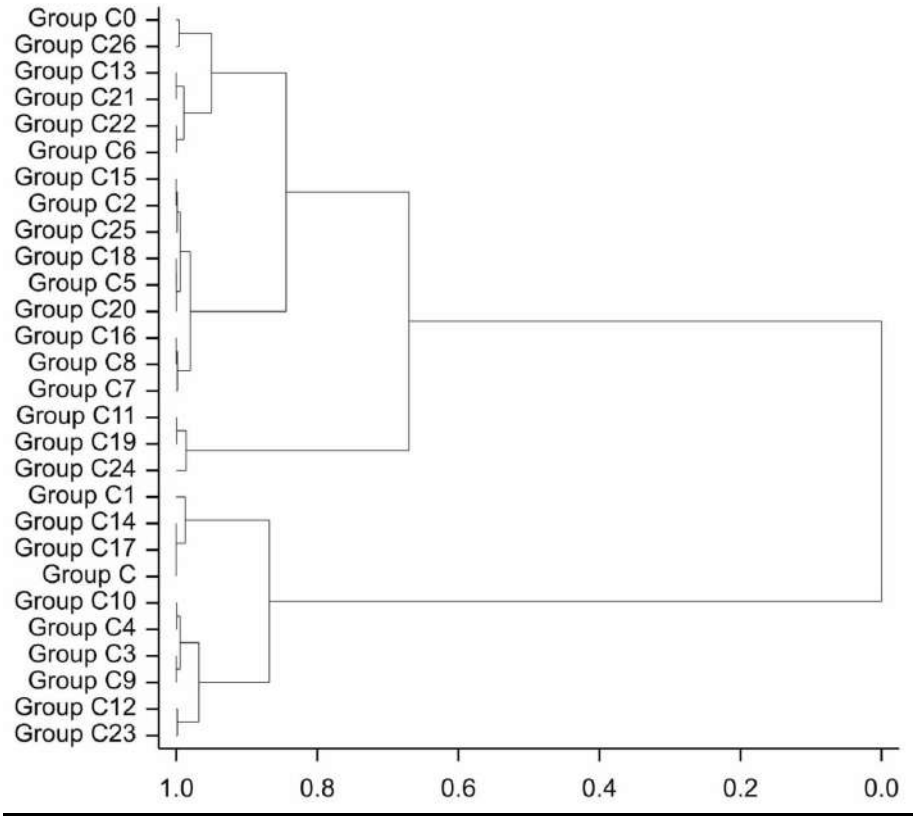


Fig. 8. Clustogram for the pathogenicity levels among the *Colletotrichum* isolates assayed by the detached leaf method

Studies on the factors affecting spore production, germination and viability of *Pestalotioides* sp. causing the circular spot disease of *Hevea brasiliensis*

Isolation of the fungus

Leaf tissues were collected from the lesion margin after leaf samples were surface sterilized in 75% ethanol, rinsed with sterile water two times and air dried. The leaf tissues were placed on PDA and incubated at room temperature. Pure colonies were obtained after three to five purifications and stored on PDA slants.

Morphological analysis

To observe the cultural characteristics, 5.0 mm mycelial plugs were taken from the advancing margin of a seven-day-old culture of the test isolate and were placed at the center of Petri dishes containing PDA. The plates were incubated at RT under normal light and dark regimes. Colony colour, texture and growth rates were recorded. The growth rate has been determined by measuring colony diameter along two perpendicular lines. Three replicates were used in all experiments. By preparing slide cultures, the microscopic characters; spore production, mycelium arrangement and reproductive structures of the selected antagonistic species were observed.

Identified isolates with more pathogenicity (P 7, P 20 and P 44) were selected for further study. The cultural characteristics of three isolates that belong to the genus with more pathogenicity are provided in Table 02. Colonies of P7 are white on PDA, with an average growth of 1.31cm/day at RT and conidiomata with black slimy conidial masses that superficially develop on mycelia (Figure 9). Conidia of P7 are fusoid to ellipsoid and comprise five cells with a length of 21.89 µm and a width of 5.88 µm. The middle three cells are brown colour. The apical cell is conical, hyaline and has two appendages. The basal cell is conical, hyaline and has one appendage. Colonies of P20 are pale brown on PDA, with an average growth of 1.34 cm/day at RT, and black conidial masses embedded or semi-immersed in mycelia. Conidia of P20 are fusoid to ellipsoid and comprise five cells with a length of 24.55 µm and a width of 7.78 µm. P20 has darker-coloured concolorous median cells. Colonies of P44 are white to pale yellow on PDA, with an average growth of 1.23 cm/day at RT and conidiomata with black slimy conidial masses that superficially develop on mycelia. Conidia of P44 are fusoid to ellipsoid and comprise five cells with a length of 21.37 µm and widths of 6.15 µm. The middle three cells are versicolor. The two upper median cells are darker than the lower cell. The apical cell is conical, hyaline and has two to three appendages. The basal cell is conical, hyaline and has one appendage (Fig. 9) (T H P S Fernando, M K R Silva, S Liyanage, E A D N Nishantha and A H M N R Aberathne).

Molecular identification of Circular Leaf Spot Disease causative pathogens

To confirm the species of antagonistic fungi, the fungal isolates were cultured on PDA for 48 hr. Subsequently, DNA was isolated from the fungal mycelia using the protocol described in NORGEN Plant/fungi DNA extraction kit (Product #

E5038; Canada). DNA quality was assessed by agarose gel electrophoresis. The internal transcribed spacer (ITS) region was amplified with the primer pairs ITS1/ITS4 according to the protocol described by McKay *et al*., 2009 with optimized PCR conditions. PCR products were visualized and separated by gel electrophoresis. Successful PCR products were sent for sequencing at Macrogen-Korea through Genetech-Sri Lanka. The BLAST search results for the isolates showed that they belong to the genus of *Neopestalotiopsis*, *Pseudopestalotiopsis* and *Pestalotiopsis* (Table 9).

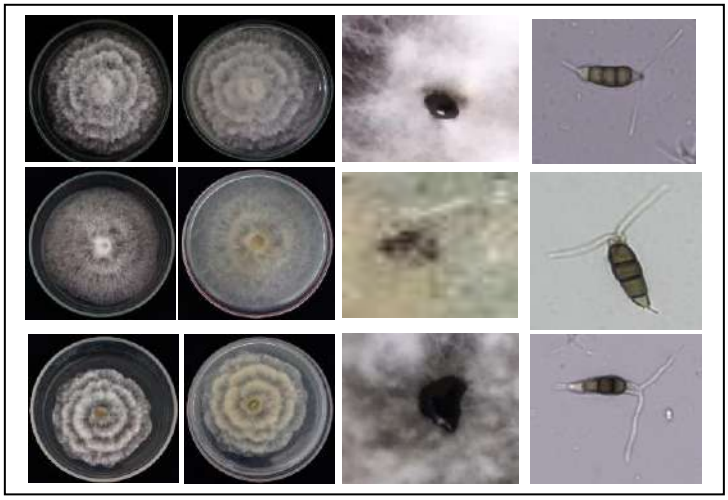


Fig. 9. Morphological characteristics of the *Pestalotiopsis* species isolates P7, P20 and P44. **(a)** Top view and **(b)** bottom view of a colony on PDA, conidiomata with **(c)**, black slimy exudate and **(d)** conidia

Table 9. *Details of Pestalotioides isolates of Circular Leaf Spot Disease under the study*

Genus	Isolate
Neopestalotiopsis	P1, P 5, P10, P 44, P54
Pseudopestalotiopsis	P 12, P13, P 20
Pestalotiopsis	P7, P43

Pathogenicity test

Conidial suspensions (10^5 conidia/ml) were prepared from ten day old cultures of each isolate by re-suspending the conidia with 10 ml of sterilized distilled water per culture. Conidial concentration was adjusted using a haemocytometer. Then, six rubber leaves belonging to the same clone (RRISL 121) and the maturity stage between copper brown and apple green colour were inoculated with 06 drops of

the conidial suspension per leaf (20 µl per drop). They were applied to the upper surface of the detached rubber leaves with wounding. Another six leaves were maintained as the control by placing the drops of sterilized distilled water. The inoculated leaves were incubated in a moist chamber at RT and the symptoms were observed after 02 days from the spore inoculation (Lin *et al*., 2017). They were ranked using a scale of 0–4 as follows:

0 - No visible infection
1 - Light lesion around inoculation point lacking spores
2 - Large dark lesion without sporulation
3 - Large lesion and weak sporulation
4 - Very strong sporulation on the upper and lower surfaces of the leaf

The results were expressed as disease severity index (ADSI). The disease index (ADSI) for each leaf was calculated using the following formula (Ma and Michialides, 2002).

$$\mathrm{DI} = \left(\sum_{i=0}^{4} N\ x\ i\right) / \sum_{i=0}^{4} N$$

Where,
i - severity (0–4)
N - the number of leaves with the severity of i.

Fifty fungal isolates were obtained from the infected leaf samples. The pathogenicity tests using detached leaves demonstrated that only 10 isolates caused leaf spot on wounded leaves, whereas no symptoms were observed in the control group or on non-wounded leaves. Germinating conidia were present in each drop of conidia suspension when observed using the microscope. The isolate No. 44 caused small lesions on wounded leaves while no symptoms were observed on non-wounded leaves at the apple green stage (T H P S Fernando, M K R Silva, S Liyanage, E A D N Nishantha and A H M N R Aberathne).

Table 10. *Cultural characteristics of the isolates on PDA medium after 10 days of incubation at RT*

Isolate	Form	Elevation	Growth rate (cm/day)	Surface	Margin	Opacity	Colony colour	
							Upper surface	Lower surface
P 7	filamentous	raised	1.31	Smooth, cloudy	undulate	Opaque	White	White
P 20	Irregular	flat	1.34	Smooth	Entire	Opaque	White	Pale brown
P 44	Irregular	raised	1.23	Smooth, fluffy	Entire	Opaque	White	Pale yellow

Cell wall degrading enzyme production by *Colletotrichum* spp. and *Pestalotioides* associated with the circular leaf spot disease

Detection of cell wall degrading enzyme production by pathogen isolates

For the experiments, four isolates of *Colletotrichum spp. (C.tropicale, C.accutatum, C.siamense, and C.fructicola)* and three isolates of *Pestalotiopsis* (Isolate P7, P20, P44) were used. The isolates were grown in Ammonium Tartrate Medium with either citrus pectin, or carboxymethyl cellulose (Sigma) as the main source of carbon (for the assays on pectinolytic enzymes, and cellulolytic enzymes respectively). Portions of 40 ml of the liquid medium were dispensed into 250 ml Erlenmeyer flasks, and for each experiment, three replicates were used. Each flask was inoculated with 1/2 cm diameter discs cut from 4-day-old cultures of the fungal isolates grown on MEA. Incubation was carried out at room temperature (RT) under dark conditions without shaking.

Assessment of growth in liquid medium

The fungus was grown in citrus pectin as the sole carbon source. Growth of the four *Collectotrichum* isolates in the ammonium tartrate liquid medium with citrus pectin as the main sources of carbon. *C. fructicola* showed a significant growth rate after 4 days. Other inoculates showed comparatively slower growth rates than the *C. fructicola* isolate.

Determination of the enzyme activity

The cultures incubated with citrus pectin, and carboxy methyl cellulose as the carbon source were subjected to the assays on pectinolytic enzymes, and cellulolytic enzymes respectively. Three replicate cultures were used to harvest the target incubation interval of each experiment. So, the fungal mats were harvested by filtering through Whatman no. 1 filter papers and the resulting culture filtrates were

subjected to the enzyme assays. Time-course studies were carried out to detect the course of enzyme production by the above mentioned four isolates of *Collectotrichum* and three isolates from *Pestalotiopsis*. Furthermore, the variation of the pH of the culture filtrate was recorded throughout the incubation period.

Pectinolytic enzyme

Polygalacturonase (PG)

To determine the Polygalacturonase activity, two methods: namely the cup plate method and the viscosity reduction method (Fig. 10a), were used. When assayed by the cup plate method (Fig. 10b), PG production of the four isolates showed peaks after 2 days of incubation. *C. tropicale* showed the highest PG activity than the other three isolates *(C. acutatum, C. siamense, and C. fructicola).* At the viscosity reduction method *C. tropicale* and *C. fructicola* showed higher PG production after 2 days of incubation.

All the three isolates of Pestalotioides gave higher PG activity after 2 days of incubation assayed by viscosity reduction method (Fig. 11a) and cup plate method (Fig. 11b). However, isolate P7 and P44 showed a significantly higher PG level than P20. In addition, all the isolates produced PG.

The *Colletotrichum* isolates showed a pH level varying from 4.3 to 8.6 throughout the incubation period when citrus pectin was the primary carbon source. The production of pectic enzymes showed a similar trend to the variation of the pH level of the medium. The three *Pestalotioides* isolates showed a pH varying from 4.4 to 7.6 throughout the incubation period when citrus pectin was the primary carbon source (T H P S Fernando, W A K S Wijesooriya and E A D N Nishantha).

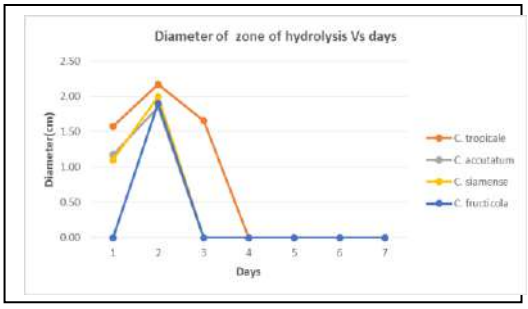


Fig. 10a. Production of polygalacturonase by four isolates of *Collectotrichum spp.* grown in liquid cultures assayed by the viscosity reduction method

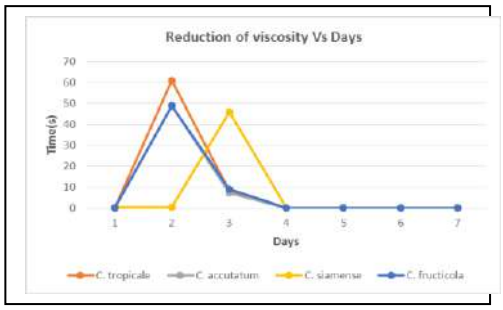


Fig. 10b. Production of polygalacturonase by four isolates of *Collectotrichum spp.* grown in liquid cultures assayed by the viscosity reduction method

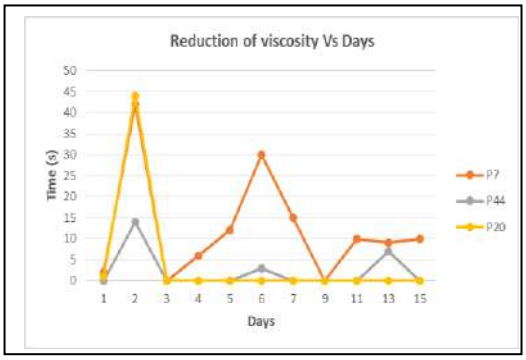


Fig. 11a. Production of polygalacturonase by isolates of *Pestalotiopsis* detected by viscosity reduction method

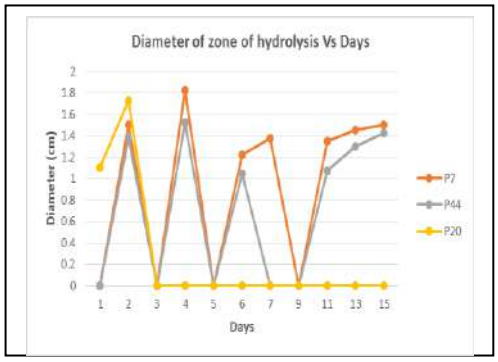


Fig. 11b. Production of polygalacturonase by isolates of *Pestalotiopsis* detected by cup plate method

Toxic metabolite production by *Colletotrichum* spp. and *Pestalotioides* associated with the circular leaf spot disease

Detection of toxic metabolite production by pathogen isolates

Pathogen isolates of *Colletotrichum; C. acutatum, C. siamense, C. tropicale, and C. fructicola* produced phytotoxins in culture media under laboratory conditions. The cultures were maintained on PDA. Erlenmeyer flasks (250 ml) each containing 25 ml of Czapek Dox liquid media were inoculated with three mycelial plugs, 8 mm in diameter, taken from 7-day old colonies of *Colletotrichum* spp. grown on potato dextrose agar (PDA) at room temperature (28 ± 2 ˚C). The cultures were incubated at RT under normal light and dark regimes as stationary cultures. The cultures were harvested 9 d after incubation by filtering Through Whatman No. 1 paper and then through 0.22 µm millipore filters. The resulting culture filtrate was stored at 4 ˚C in small aliquots of 10 ml and used as the source of toxins.

Detached apple green staged leaves from *Hevea brasiliensis* (clone RRIC 121) were used to detect the toxic activity of the culture filtrates. Three needle point injuries were made on either side of the mid-rib of each leaf and 0.02 ml droplets of the culture filtrate were placed on these pin-point wounds. Subsequently, these inoculated *Hevea* leaves were incubated for 72 h at RT under 100% RH in trays lined with moist blotting papers. At the end of the incubation period, the inoculated drops were removed by using a blotting paper and the lesions were ranked from class I–V based on their size of the lesions. Filtrates from uninoculated media served as controls. Figure 1: necrotic lesions produced by *C. acutatum.* Results of all four isolates of *Colletotrichum* spp. secreted toxic metabolites in the Czapek dox liquid medium and produce necrotic lesions on Rubber leaves. According to the *C. acutatum* was the lowest producer. In this study, *C. tropicale* produced more toxic substances (T H P S Fernando, D P Kariyawasam and E A D N Nishantha).

Effect of soil nutrition on the development of the CLSD

a) Polybag nursery study

The effect of soil nutrition on the development of the CLSD was tested under polybag nursery conditions at Dartonfield. Polybag plants established under a mature rubber clearing at Galewatta, Dartonfield were applied with different fertilizer treatments (Table 11) at biweekly intervals and the natural inoculation of the disease was assumed. Starting from the establishment, the lesion percentage of 20 plants in each treatment was calculated as follows:

$$\text{Lesion percentage} = \frac{\text{Number of leaflets with CLSD lesions}}{\text{Total number of leaflets}} \times 100$$

The Lesion Percentages of each treatment were subjected to ANOVA, and the mean separation was done with Duncan Multiple Range Test (DMRT). The Lesion percentage of each fertilizer treatment at five readings is given in Figure 12. At all five readings, the Lesion Percentage in the treatment with additional silicon dose was the lowest while it was significantly lower than the negative and positive controls at the second and fifth readings. The experiment is being repeated at Dartonfield for the confirmation of the results (M K R Silva, T H P S Fernando and A H M N R Aberathne – collaboratively with the Department of S & PN).

Table 11. *Treatments of the fertilizer experiment on the Circular Leaf Spot Disease under polybag condition*

Treatment No	Fertilizer component	Method of application
1	Recommended fertilizer amount	Drenching
2	No fertilizer	-
3	Recommended fertilizer amount with an additional potassium dose	Drenching
4	Recommended fertilizer amount with an additional Silicon dose	Drenching
5	Recommended fertilizer amount with additional micronutrients	Foliar spray

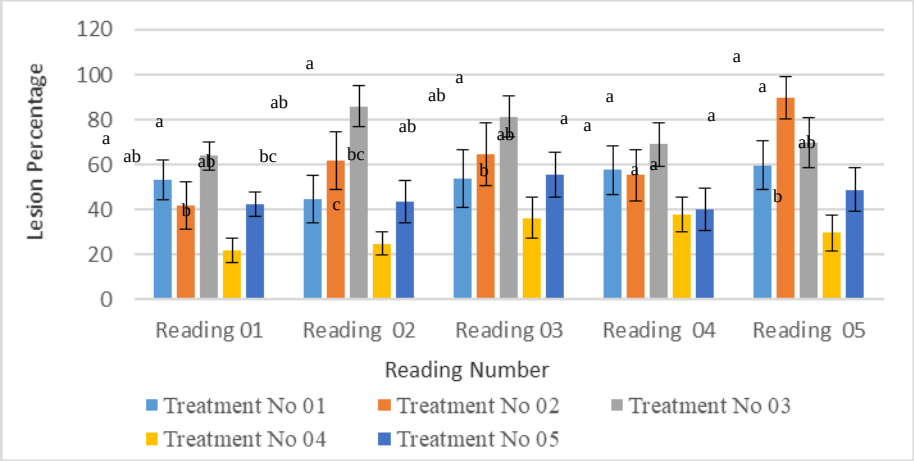


Fig. 12. Lesion percentage of each fertilizer treatment at five readings
*Lesion Percentage values in each reading followed by the same letters are not significantly different at DMRT at P=0.05

b) Case study carried out at a location with low CLSD incidence

During the survey on the incidence of CLSD, a location with low disease incidence was reported in a 22 year old rubber clearing in the Welgama area of Kalutara district, while the adjoining area of the same plantation was showing drastic devastation due to the disease. With the subsequent basic inquiry, on the rubber plantation we came to know that the specific location of the rubber plantation had been used as a threshing ground (‘kamatha’) of the neighboring paddy field for a long time. An investigation was undertaken to find out whether any relationship exists between the development of the CLSD and the soil nutrient status of the respective field (M K R Silva, T H P S Fernando and D A N Mallikarachchi – collaboratively with the Department of S & PN).

Applications of different chemicals for increasing vigor against CLSD

A pot experiment was initiated at Dartonfield to evaluate the effect of prophylactic foliar application of different chemicals on the development of CLSD. Seedlings established in pots were sprayed with a concentration series of potential chemicals: $ZnSO_4$, sodium nitroprusside, SiO_2, salicylic acid, NaCl and stress-nil (a commercial preparation containing salicylic acid and seaweed extract) and the evaluation of the disease development was carried out. The experiment is in progress (M K R Silva, T H P S Fernando and D P Kariyawasam- Partially funded by the Development Project on Pestalotiopsis Leaf fall disease).

White Root Disease Survey to establish the spread of the disease on the cover crop

Mucuna bractiata

The incidence of White Root Disease on the cover crop, *Mucuna bractiata* was revealed (Table 12). The gaps of knowledge in view of improving the management strategies of white root disease were also reported.

Table 12. *WRD survey with reference to Mucuna bractiata, cover crop*

Estate	Presence/Absence of disease on the cover crop, *Mucuna bractiata*	Estate	Presence/Absence of disease on the cover crop, *Mucuna bractiata*
Udabage Estate	√	Padukka Estate	√
Udapola Estate	X	Payagala Estate	X
Eladuwa Estate	X	Dartonfield Estate	√
Delkith Estate	√	Arappolakanda Estate	√
Raigam Estate	√	Vogan Estate	√
Rathnapura, Elapatha (SH)	√	Kalvariya Estate Maggona	√

SH – smallholding

Screening of clones for Leaf and Panel Diseases (23/P/03)

Screening of* Hevea *clones against Corynespora leaf fall disease (CLFD)

The incidence of Corynespora leaf fall disease was mild during the year 2021 (Table 13). The pathogen isolates were obtained from non-traditional rubber growing areas *viz*, Padiyathalawa and Moneragala (T H P S Fernando, E A D D Siriwardena, E A D N Nishantha and Buddika Nishantha - Funded by Development Project 23/1/15).

Table 13. *Results of the Survey on Corynespora leaf fall disease conducted in 2021*

Clone	ADSI *	Clone	ADSI *
RRIC 121	0	RRISL221	0
RRIC 102	0	RRISL222	0
RRIC 130	0	RRISL 202	2.0
RRISL 203	0	RRISL 200	3.2
PB 260	0	RRISL2000	0
RRIC 133	0.8	RRISL2002	0
RRISL 201	1.0	RRISL2004	0
RRISL 205	0	RRISL2005	0
RRISL206	0	RRISL2006	0
RRISL210	0	GPS 1	0
RRISL211	0	PB 255	1.0

Clone	ADSI *	Clone	ADSI *
RRISL215	0	PR 255	0
RRISL216	0	PR 305	0
RRISL217	0.6	RRII 105	1.0
RRISL219	0	PB235	0
RRISL2001	0	BPM 24	0
RRISL2003	0	RRISL 200	3.0
RRISL 218	1.2	Centennial 2	0
RRISL 204	0	Centennial 3	1.0
RRISL 220	0	Centennial 4	0
RRISL 208	1.2	Centennial 5	0

*ADSI- Average Disease Severity Index
ADSI; 0-free from the disease; 0.01-1.0, slight infections; 1.01-2.0, moderate infections; 2.01-3.0, severe infections

Maintenance of nurseries for screening purposes – Ratnapura District

Ten plants from fifty *Hevea* clones have been established at the Kuruwita substation Ratnapura for clonal evaluation against Corynespora leaf fall disease and the other foliar diseases. Corynespora leaf disease was reported from RRIC 121 plants. The cultures are being studied for their variability (T H P S Fernando, M K R Silva and E A D N Nishantha: Funded by Development Project 23/1/15).

Establishment of a nursery for screening purposes - Moneragala

Ten plants from fifty *Hevea* clones have been established at the Moneragala Substation, Moneragala for clonal evaluation against Corynespora leaf fall disease and the other foliar diseases (T H P S Fernando, M K R Silva and S C P Wijayaratne: Funded by Development Project 23/1/15).

Establishment of a nursery for screening purposes – Padiyathalawa

Ten plants from fifty *Hevea* clones have been established at the Padiyathalawa Rubber Development Department premises for clonal evaluation against Corynespora leaf fall disease (T H P S Fernando, M K R Silva, E A D D Siriwardena: Funded by Development Project 23/1/15).

Establishment of a nursery for screening purposes – Sapumalkanda Estate

Ten plants from forty eight *Hevea* clones have been established at Sapumalkanda estate for clonal evaluation against Corynespora leaf fall disease and other potential diseases (T H P S Fernando, M K R Silva and B I Tennakoon: Funded by Development Project 23/1/15).

Establishment of a nursery for screening purposes - Dartonfield

Ten plants from fifty *Hevea* clones have been established at the Dartonfield Estate, RRISL for clonal evaluation against Corynespora leaf fall disease and other potential diseases (T H P S Fernando, M K R Silva and E A D D Siriwardena: Funded by Development Project 23/1/15).

Surveillance of potential pests and disease outbreaks (23/P/04)

Isolation of pathogens from cover crops Mucuna and Peuraria leaves

The symptomatic leaves were subjected to isolation of the pathogens after surface sterilization. They were placed on Potato Dextrose Agar medium and incubated for three days under normal dark and light conditions at RT. Morphologically different cultures were selected. They were observed under a light microscope and categorized as *Pestalotiopsis* sp. and *Colletotrichum* sp. Proving the Kock's Postulates is in progress (T H P S Fernando, A H M N R Aberathne and S Madushanka).

Identification of potential pests and disease problems of rubber lands in non-traditional areas to develop improved management strategies (Development Project Funded by the Ministry of Plantation Industries P 23/1/15)

Selected sites

Site	Ownership
Kandakaduwa Farm, Polonnaruwa	Army Camp
Padiyathalawa	Rubber Development Department premises
Baduraliya	Smallholder
Vavuniya	Smallholder
Moneragala	Smallholder
Dartonfield Estate	Reference cultivation
Anuradhapura	Smallholder

(T H P S Fernando, P Senevirathne, M K R Silva, B I Tennakoon, E A D D Siriwardena, S C P Wijayaratne and E A D N Nishantha collaboratively with Biochemistry and Physiology Department)

Biological control of Hevea diseases (23/P/05)

Two *Trichoderma*-based biopesticides against white root disease have been submitted to the Registrar of Pesticides for registration. The products were prepared in two media such as compost and talc (T H P S Fernando, P Senevirathne, M K R Silva, E A D D Siriwardena, S C P Wijayaratne, A H M N R Aberathne and S Madushanka collaboratively with Biochemistry and Physiology Department).

Study and formulation of Plant Growth Promoting Rhizobacteria (PGPR) as biofertilizer

PGPR were isolated from the rubber growing soils. Nitrogen fixing bacteria were isolated from the root nodules of *Pueraria phaseoloides.*

Isolation methods

Direct nodule placement

Surface sterilized nodules were placed on Petri plates containing PDA.

Placement of nodules of slices

Another few surface sterilized root nodules were taken and thin slices were placed on PDA containing Petri plates.

Maceration of root nodules

Root nodules were cut using a sterile mortar and pestle with mixing a few drops of sterilized distilled water. PDA containing Petri plates were streaked with macerated liquid. They were incubated overnight.

Isolation from soil samples

Bacteria were isolated by serial dilution method and spread plate method. Pure cultures were obtained using the streaking method and 25 isolates were obtained.

Screening the bacteria for nitrogen fixation

Nitrogen-fixing bacteria both symbiotic and free-living were isolated. Rhizosphere bacteria fix atmospheric nitrogen in nitrogen free medium. Hence, nitrogen free Jenson's medium was used for bacterial screening. The growth of bacteria observed in nitrogen free media was assumed as nitrogen-fixing bacteria. They were selected for further studies (T H P S Fernando, A H M N R Aberathne and Devmi).

Isolation and study of wood-decaying fungi

A saprophytic fungus was isolated from the root of rubber seedlings and pure cultures were prepared. Another 02 isolates which were identified previously as good wood decaying fungi were taken from department culture collection and pure cultures were prepared. They were inoculated to sterilized rubber root pieces and allowed to

grow. They are expected to be inoculated into rubber seedlings to test their pathogenicity to rubber plants. If not phyto-pathogenic, to be introduced as decomposers (T H P S Fernando and A H M N R Aberathne).

Developing a national level Fungal culture collection

A collection of fungal cultures is maintained at the Plant Pathology & Microbiology Department in view of using them for research and development purposes. These pure cultures of beneficial and pathogenic nature are provided for nationally and internationally important research and development purposes.

The collection mainly consists of *Colletotrichum acutatum/Colletotrichum gloeosporioides/Corynespora cassiicola/Phytophthora spp./Rigidoporus microporus/ Phellinus noxius/Xylaria thwatsii/Fusarium solani/Nattrassia mangiferae/ Thanetephorus cucumeris/Rhizoctonia solani/Pestalotiopsis spp./Phomopsis spp./ Botrodiploidea theobromae*/*Trichoderma* spp./*Aspergillus* spp./*Penicillium* spp./ *Trichoderma harzianum*/*Trichoderma hamatum*) (T H P S Fernando, M K R Silva, A H M N R Aberathne, Gayani Peiris and the staff of Plant Pathology & Microbiology Dept.).

Advisory visits and training programmes (PP - 08)

The staff of the department made 71 advisory visits mainly to handle complicated disease problems. Majority of these visits were for the estate sector while the others were directed to the department by the Extension staff (T H P S Fernando and the staff of Plant Pathology & Microbiology Dept.)

SOILS AND PLANT NUTRITION

R P Hettiarachchi

DETAILED REVIEW

Staff

Dr (Mrs) R P Hettiarachchi, Head of the Department, Mrs H A R K Jayawardana, and Mr L A T S Liyanaarachchi Research Officers were on duty throughout the year. Experimental Officers Miss V Edirimanna, Miss A Thevarapperuma and Mr T Gunathileke, Technical Officers, Mrs K E de Silva, Mr G C Malawaraarachchi, Mr M W H Gayan, Mrs K M M E K Kulatunga, Mrs R M Baddevidana, Mrs P D S D O Rathnasooriya and Mr B N K Rangana were also on duty throughout the year. English Stenographer, Mrs L Rupasinghe served the department until her retirement on 10th June.

Research students

- W A S N Sarathchandra, a student from the Faculty of Science, University of Colombo Sri Lanka conducted a part of her final year research project on "Influence of herbaceous ground cover on soil fertility in immature rubber land in Kalutara district, Sri Lanka" under the supervision of Dr (Mrs) R P Hettiarachchi.

Seminars/Trainings/Workshops/Conferences/Meeting conducted

Officer	Subject	Organization
RP Hettiarachchi	Nature Safe Fertilizers for Rubber Plantations	Rubber Research Board
	Nature Safe Fertilizers for Rubber Plantations	Chief Executive Officers, Plantation Sector
	Presentation on "A feasibility study on the potential for utilization of natural rubber processing wastewater for enhancement of soil fertility"	Ministry of Environment
	Enhancing soil fertility and plant growth of immature rubber (*Hevea brasiliensis*) by the application of biofilmed biofertilizer	Symposium of National Institute of Plantation Management
	Challenges and opportunities in converting to organic cultivation; Rubber	Webinar, National Institute of Plantation Management

Officer	Subject	Organization
	රබර් වගාව සඳහා කාබනික පොහොර භාවිතය	සුභ උදෑසනක් Rupawahini Programme
	රබර් වගාව සඳහා පොස්ෆේට් පොහොර භාවිතය	Lanka Phosphate limited
	රබර් වගාව සඳහා කාබනික පොහොර භාවිතය සහ හඳුන්වාදෙන නව නිර්දේශ/පැකේජ	Rubber Development Dept. Rubber Research Institute (Technology update)
	රබර් වගාව සඳහා කාබනික පොහොර භාවිතය සහ හඳුන්වාදෙන නව නිර්දේශ/පැකේජ	Advisory Service Department Smallholder Sector

Seminars/Training Programmes/Workshops/Exhibition attended

Officer	Subject	Organization
RP Hettiarachchi	Scientific Committee Meeting	Rubber Research Institute
	Fertilizer Advisory Committee Meeting	Ministry of Agriculture
	Technical Evaluation Committee Meeting, Importation of Organic Speciality Fertilizer for Paddy and other Crops	Ministry of Agriculture
	Introduction Session to Documentation of Sustainable Land Management (SLM) Technologies and Approaches in Sri Lanka and National Level Award Ceremony	Ministry of Environment
	Preparing National Fertilizer Policy based on the Interim Fertilizer Policy	Ministry of Agriculture and the State Ministry of Production and Supply of Fertilizer *etc.*
HARK Jayawardana	Scientific Committee Meeting	Rubber Research Institute
TS Liyanaarachchi	Scientific Committee Meeting	Rubber Research Institute

Visits

Advisory	6
Experimental	78
Others	16

LABORATORY AND FIELD INVESTIGATIONS

Soil fertility management

Isolation of effective microbes for soil fertility enhancement

Determination of growth medium colour change

Bacterial isolates mentioned in the Annual Review 2020, were tested for their growth medium colour change in nitrogen-free bromothymol combine carbon medium (CCM). Bacterial isolates having the ability to fix atmospheric nitrogen should grow successfully on CCM. After 24 hours of incubation, the CCM medium showed a colour change from green to yellow with a reduction in growth medium acidity by acids secreted by well-grown bacterial isolates. Different isolates that grew in CCM medium changed their color at different time periods of 2, 3 and more than 6 days after their inoculation (Table 1). This knowledge is important to identify effective nitrogen-fixing bacteria in different isolates (R P Hettiarachchi and K E de Silva).

Table 1. *Colour change of different bacterial isolates in CCM growth medium*

Isolate No.	Incubation period						
	1 day	2 days	3 days	4 days	5 days	6 days	7 days
B3	PY	**Y**					
B4	G	PY	PY	PY	PY	**Y**	
B5	G	G	G	G	G	Y	
B6	G	G	G	PY	PY	Y	
B8	PY	**Y**					
B10	G	PY	**Y**				

Y- yellow PY - pale yellow G - green

Rehabilitation of degraded lands

Identify degraded lands and promote their fertility levels by using organic, inorganic and biofertilizer

Activities of the above project funded by NRC began in six estates; Parambe, Udabage, Elston, Penrith, Halpe and Pussella in 2020 and they consisted of different fertility levels (50% recommended fertilizer only, 100% recommended fertilizer only, 50% recommended fertilizer with Good Agricultural Practices (GAP) and 75% recommended fertilizer with GAP). Plant diameter was measured at 15 cm above the ground level after eight months of their field establishment and showed significant differences among treatments. Plants treated with 50% recommended fertilizer and 75% recommended fertilizer with GAP gave significantly higher plant diameter compared to inorganic fertilizer alone two treatments which included 100% and 50% of the recommended fertilizer only (Table 2). Also, soil fertility parameters were measured at the end of the first year which showed no significant differences among

treatments for soil pH, organic carbon (OC), available phosphorus (P), exchangeable potassium (K), and calcium (Ca). However total nitrogen (N) content in combined use treatment, 50% of recommended fertilizer with GAP (T3) gave significantly higher value compared to the recommended fertilizer only treatment (T2) and no significant difference between 100% recommended fertilizer (T2) and 75% recommended fertilizer with GAP treatment (T4) (Table 3). Further, data showed that there were no significant differences between 100% and 50% of the recommended fertilizer treatments, *i.e.*T1 and T2 for soil nutrients; N, P, K, Ca and plant growth. It means the application of recommended fertilizers (100% recommended) and half of that amount (50% of the recommended level) were not able to make differences in many soil fertility levels and finally plant growth because of mainly the low holding capacity of nutrients in most of the rubber growing soils. Such soil fails to hold more nutrients with 100% recommended fertilizer treatment (T2) compared to 50% recommended fertilizer treatment (T1). Moreover, no significant differences between combined use treatments T3 and T4 mean that it takes some time to show a difference. Overall results showed that the release of extra nutrients with GAP-related activities and their support to hold more nutrients in the soils gave more benefits to the treatments with GAP (R P Hettiarachchi, V Edirimannne, T Gunathilake and K E de Silva).

Table 2. *Effect of different treatments on plant diameter of immature rubber plants*

Treatments	**Plant diameter, 8 months after planting (mm)**
T1-50% Recommended fertilizer	23.1[b]
T2-100% Recommended fertilizer	23.0[b]
T3-50% Recommended fertilizer + GAP	26.2[a]
T4-75% Recommended fertilizer + GAP	26.0[a]

Values in the same column followed by the same letter are not significantly different at p = 0.05

Table 3. *Different soil fertility parameters in the top 0-15 cm soil layer in respect of different treatments at the end of 12 months*

Treatments	**pH**	**O.C %**	**N %**	**P (ppm)**	**K (ppm)**	**Mg (ppm)**	**Ca (ppm)**
T1-50% Recommended fertilizer	5.7[a]	0.96[a]	0.09[c]	28.1[a]	82.23[a]	26.1[b]	72.2[a]
T2-100% Recommended fertilizer	5.6[a]	1.04[a]	0.10[bc]	30.75[a]	78.9[a]	32.8[a]	71.7[a]
T3-50% Recommended fertilizer + GAP	5.6[a]	1.07[a]	0.11[a]	29.0[a]	92.0[a]	29.6[ab]	76.0[a]
T4-75% Recommended fertilizer + GAP	5.6[a]	1.05[a]	0.11[ab]	27.9[a]	85.4[a]	31.5[a]	73.7[a]

Values in the same column followed by the same letter are not significantly different at p = 0.05

Combined use of partially burned paddy husk and inorganic fertilizer for immature rubber

The study was started in 2019 at a small holder's rubber field to investigate the effect of applying partially burned paddy husk (PBPH) on plant growth of immature rubber plants and the effect of different levels of the inorganic fertilizer applied (100%, 75% or 50% of the recommended fertilizer by the Rubber Research Institute of Sri Lanka) for plants in a split-plot design. Two applications of treatments were done during the year under review. Soil samples were collected 12 months after treatment application and analyzed. Plant girth was recorded at three stages during the period. It was revealed that there is a significant effect of PBPH incorporation on plant growth (Table 4). Significantly greater plant girth values were observed in plants treated with PBPH amendment compared to those not treated with PBPH at all stages of measurements after treatment (Table 4).

Table 4. *Effect of PBPH amendment on plant girth (cm) (Mean separation of main plot factor)*

Main plot treatment	Mean girth (cm) at different stages (months after treatment)		
	at 12 months	at 15 months	at 18 months
T0 (no PBPH)	7.3[b]	9.0[b]	11.4[b]
T1 (with PBPH)	8.2[a]	10.5[a]	13.7[a]

Means followed by the same letters in each column are not significantly different at $P \leq 0.05$ as determined by Duncan's Multiple Range Test.

Further, there was no significant difference in the mean plant girth of the different levels of fertilizer *i.e.* 100%, 75% or 50% as recorded by the mean separation of the sub-plot factor (Table 5).

Table 5. *Effect of different levels of fertilizer on plant girth (cm) (Mean separation of sub plot factor*

Different fertilizer levels	Mean girth (cm) at different stages (months after treatment)		
	at 12 months	at 15 months	at 18 months
F1 – 100%	7.8[a]	9.7[a]	12.8[a]
F2 – 75%	7.6[a]	9.7[a]	12.5[a]
F3 – 50%	7.9[a]	9.8[a]	12.3[a]

Means followed by the same letters in each column are not significantly different at $P \leq 0.05$ as determined by Duncan's Multiple Range Test.

It is a well-known fact that most of the inorganic fertilizer gets wasted mainly due to leaching and only a limited percentage of the applied fertilizer would be available to the plants and be utilized for their growth. This might have resulted in more or less similar girth under different fertilizer levels in the current study, suggesting that fertilizer waste has caused the 100% fertilizer treatment to supply the same amount of nutrients to the plants as that was available from the 50% fertilizer treatment. However, the plant girth values recorded are comparatively low when compared to the accepted crop growth of the rubber. Therefore, the long-term effect of fertilizer cut down without supportive organic amendment, mulch or any other efficient practice (GAP) would negatively effect on plant growth and consequently. The ways of reducing fertilizer wastage or improving fertilizer use efficiency should be investigated. Leaf samples were collected for analyzing the nutrient status. There were significant effects of PBPH and fertilizer treatments on some soil parameters at 12 months after treatment application (Tables 6 and 7). The pH was significantly increased with PBPH application compared to PBPH not applied treatments (Table 6). Exchangeable K was also high in the soils treated with PBPH compared to non-treated plants. It could be suggested that PBPH has supplied a significant amount of K into the soil.

Table 6. *Effect of PBPH amendment on soil parameters at 12 months after treatment*

Soil parameter	T0 (no PBPH)	T1 (with PBPH)
pH	5.32^{b}	5.49^{a}
Total N (%)	0.12^{a}	0.09^{a}
Available P (ppm)	34.32^{a}	39.59^{a}
Exchangeable K (ppm)	34.62^{b}	45.73^{a}
Exchangeable Mg (ppm)	36.19^{a}	45.59^{a}
Sand (%)	77.4^{a}	80.6^{a}
Silt (%)	6.15^{a}	5.71^{a}
Clay (%)	16.5^{a}	13.7^{a}
CEC (cmol/kg)	5.48^{a}	4.46^{a}
Bulk Density	1.15^{a}	1.23^{a}

Mean values followed by the same letter in each row are not significantly different at $P \leq 0.05$ as determined by the mean separation of main plot treatments by Duncan's Multiple Range Test.

Also, there was a significant effect in different levels of fertilizer applied to the soil K content where, 100% fertilizer application showed significantly greater soil exchangeable K value than that of both 75% and 50% fertilizer treatments irrelevance to PBPH application (Table 7). Similar observations were noted in Exchangeable Mg (Table 7) (H A R K Jayawardana, A Thewarapperuma and T Gunathilake).

Table 7. *Effect of different levels of fertilizer application on soil parameters at 12 months after treatment*

	Different fertilizer applications		
Soil parameter	**F1– 100%**	**F2– 75%**	**F3– 50%**
pH	5.60[a]	5.31[b]	5.31[b]
Total N (%)	0.11[a]	0.09[a]	0.11[a]
Available P (ppm)	40.66[a]	30.86[a]	39.34[a]
Exchangeable K (ppm)	57.66[a]	33.76[b]	29.11[b]
Exchangeable Mg (ppm)	65.02[a]	30.53[b]	27.14[b]
Sand (%)	79.5[a]	77.4[a]	80.1[a]
Silt (%)	5.9[a]	6.0[a]	5.9[a]
Clay (%)	14.6[a]	16.6[a]	14[a]
CEC (cmol/kg)	4.81[a]	5.13[a]	4.95[a]
Bulk Density	1.20[a]	1.18[a]	1.19[a]

Mean values followed by the same letter in each row are not significantly different at $P \leq 0.05$ as determined by mean separation of sub plot treatments by Duncan's Multiple Range Test.

A preliminary study to evaluate the effect of rubber processing effluent as a nutrient source for plants

Nine crepe rubber-producing factories were selected for sample collection. Samples were collected from different stages of the production from the coagulation tank to smooth milling from those factories. The average levels of nutrients in the fresh serum were greater than the effluent produced at the latter steps. The fresh serum was acidic (4.7 - 6.6) and other properties of the fresh serum were recorded. The observation made in the effluent collected from the DF factory is given in Table 8.

Table 8. *Average nutrient content of effluent water collected from different processing stages at Dartonfield factory*

Processing steps	**Total N (ppm)**	**Total P (ppm)**	**Total K (ppm)**	**Total Mg (ppm)**	**pH**
Coagulation tank	560	Not in a	468	118	5.45
Step 1	292	detectable range	250	59	5.06
Step 2	327		127	56	6.48
Step 3	222		117	92	6.82
Step 4	187		91	52	6.04
Step 5	163		69	32	6.76
Step 6	140		75	26	6.09

An experiment was conducted to investigate the effect of rubber factory fresh serum as a nutrient source for the cultivation of Salad cucumber plants grown in soil-

less media (coir media) under a protected environment. The fresh serum collected from the coagulation tank was stored in a trap tank so that the non-rubber particles were trapped. Then the serum was filtered and the pH was tested and adjusted to 6.3 using NaOH and used for the study. Daily application of Albert solution and effluent water was done according to the treatments. Five Treatments (Treatment application was started when plants were at the age of one month) were designed to find the effect of cutting down on Albert fertilizer while combining with the application of effluent water (Table 9a and 9b). The average total N content in the fresh serum (500 mg/liter) was considered when designing the treatments. It was assumed that about 50% of total N in the serum will be readily available for the plants, and the volume of serum to be applied for compensating the reduced Albert fertilizer was calculated accordingly. Twenty plants per treatment were arranged in a completely randomized design (CRD). Growth parameters of the plants were recorded at regular intervals.

Table 9a. *Treatments (from 0 - 2 weeks of treatment application)*

	Percentage of Albert Solution	**Volume of fresh serum**
T1- control	100% (600 ml)	0 ml
T2	75% (450 ml)	150 ml
T3	50% (300 ml)	300 ml
T4	25% (150 ml)	450 ml
T5	0% (0 ml)	600 ml

During this period normal recommendation of Albert solution is 1.5 g per plant dissolved in the ratio 1 kg of Albert mixture : 400 liters of water.

Table 9b. *Treatment (from 2-4 weeks of treatment application)*

	Percentage of Albert Solution	**Volume of fresh serum**
T1-control	100% (800 ml)	0 ml
T2	75% (600 ml)	200 ml
T3	50% (400 ml)	400 ml
T4	25% (200 ml)	600 ml
T5	0% (0 ml)	800 ml

During this period normal recommendation of Albert solution is 2.0 g per plant dissolved in the ratio of 1kg Albert mixture: 400 liters of water.

Plant height and the number of leaves recorded at pre-treatment and after-treatment stages are presented in Tables 10 and 11 respectively.

Table 10. *Effect of treatments on plant height*

Treatment	The average plant height Before treatment (cm)	The average plant height After treatment (cm)	Rate of increment (cm/day)
T1 control	19.7	318.5	9.9
T2	23.1	338.7	10.5
T3	19.0	317.9	9.9
T4	20.5	353.4	11.1
T5	28.9	322.1	9.8

Data are not statistically analyzed.

Table 11. *Effect of treatments on the number of leaves*

Treatment	The average number of leaves before treatment	The average number of leaves after treatment	Rate of increment/month
T1 control	3.19	26.69	23.5
T2	3.44	31.75	28.31
T3	3.0	28.19	25.19
T4	3.19	32.94	29.75
T5	3.69	30.5	26.81

Data are not statistically analyzed.

When considered the yield recorded during the experiment period (Table 12), it was observed that the yield of the control treatment was the significantly less than that of the rest and further investigations will be conducted regarding that. There was no significant difference in the yield observed in fresh serum alone treatment (T5) compared to T2, T3 and T4 (R P Hettiarachchi, H A R K Jayawardana, L A T S Liyanaarachchi, M W H Gayan and B N K Rangana).

Table 12. *Effect of treatments on crop yield*

Treatment	The yield during one month of the experiment period (g/Plant)
T1	186.2^{b}
T2	599.1^{a}
T3	590.1^{a}
T4	640.9^{a}
T5	497.8^{a}

Mean values followed by the same are not significantly different at $P \leq 0.05$ as determined by Duncan's Multiple Range Test.

A preliminary study on the effect of micro-nutrients and silicon as supplements on rubber nursery plants

An experiment was started in November 2020 to investigate the effect of the application of micronutrients and silicon in addition to the recommended fertilizers on the growth of polybagged nursery plants. There were three treatments as below (Table 13).

Table 13. *The treatment combination of the experiment*

T1	Recommended fertilizer and micronutrient supplements
T2	Recommended fertilizer only - control
T3	Recommended fertilizer and silicon nutrient supplement

A commercially available micronutrient supplement was used as a foliar application according to the recommended dosage by the manufacturer. Commercially available silicic acid fertilizer was dissolved in water according to the recommended dosage by the manufacturer and applied to the poly bags. Treatments were arranged in a Completely Randomized Design with 80 plants per treatment. Treatments were applied once in 2 weeks and growth measurements were taken at regular intervals. During the Covid pandemic period, fertilizer application was disturbed but managed with recommended fertilizer though supplements were not applied during that period. The seedlings were bud grafted after 5 months of treatment application. The plant diameter and height recorded are presented in Tables 14a and b. Control treatment recorded the lowest values of girth after 2 and 3 months of treatment. However, consistency of the significant treatment effect was not observed in plant height and there was no similarity in observations of plant diameter and height. The experiment will be repeated (H A R K Jayawardana, R M Baddevidana, M W H Gayan and B N K Rangana).

Table 14a. *Effect of different treatments on plant diameter with time*

	Mean diameter (mm) at different stages (months after treatment)		
Treatments	**1 month**	**2 months**	**3 months**
T1	4.20^{a}	6.34^{a}	7.55^{a}
T2	4.05^{a}	5.12^{c}	6.88^{b}
T3	3.96^{a}	5.74^{b}	7.75^{a}

Mean values followed by the same letter in each column are not significantly different at $P \leq 0.05$ as determined by Duncan's Multiple Range Test.

Table 14b. *Effect of different treatments on plant height (cm) with time*

Treatments	Mean plant height (cm) at different stages (months after treatment)		
	2 months	3 months	5 months
T1	50.55[ab]	68.08[a]	109.04[a]
T2	51.44[a]	65.29[a]	110.83[a]
T3	47.73[b]	65.98[a]	84.75[b]

Mean values followed by the same letter in each column are not significantly different at $P \leq 0.05$ as determined by Duncan's Multiple Range Test.

Effect of soil nutrient status on the severity of *Pestalotiopsis* disease in rubber - A case study

This study was initiated with the collaboration of the Plant Pathology and Microbiology Department for investigating the correlation between soil nutrient status and applied fertilizer on the *Pestalotiopsis* disease in rubber plantations. The site under the study (Kamatha estate) had visible demarcated two areas with comparatively low and high disease severity. Analysis of major soil nutrients was conducted to identify the correlation between the disease and soil nutrient status. Accordingly, there was no significant difference in the nutrient levels of N, P, K, Mg, and Ca between the areas with low and high disease severity. Since the site had the possible source of silicon nutrition in the soil, samples were analysed for Si content using the gravimetric method. However, it was revealed that there was no significant difference in soil Si content (SiO2 % by mass) between the soils collected from areas with high disease severity (46.73%) and low severity (49.38%). To clarify further, spatial variability of the nutrient contents was mapped using GIS. According to the maps, there were scattered distributions of nutrient high and nutrient low areas in both disease- low and disease-high areas without any prominent relationship (Figs. 1-5) and it was revealed that there was no effect of spatial nutrient distribution on the occurrence of the disease.

Plant nutrition and fertilizer use

***Nutrient requirement of Hevea grown in the low country Intermediate* Zone**

This experiment was started in 2016 and the experimental design was explained in the annual review of 2016. There were two sites of 4-5 -year upkeep in Moneragala, one site was in the fourth year and the other site was in the fifth year upkeep after its establishment in Padiyathalawa and Mahaoya areas. Due to Covid 19, pandemic situation in the country disturbed the proper assessment of experimental sites (R P Hettiarachchi, V Edirimannne, T Gunathilake and G C Malawaraarachchi).

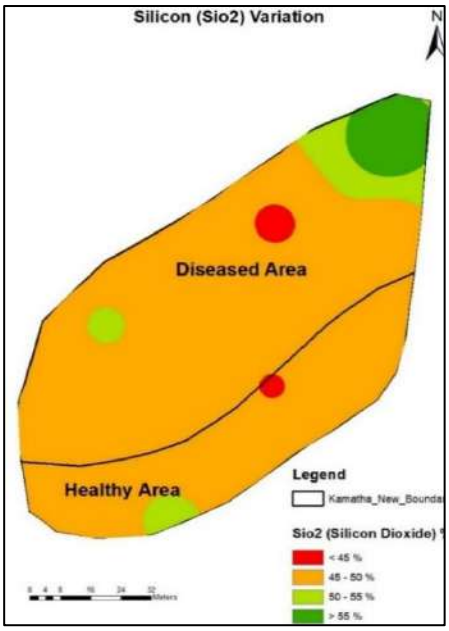


Fig. 1. Spatial variability of soil SiO_2

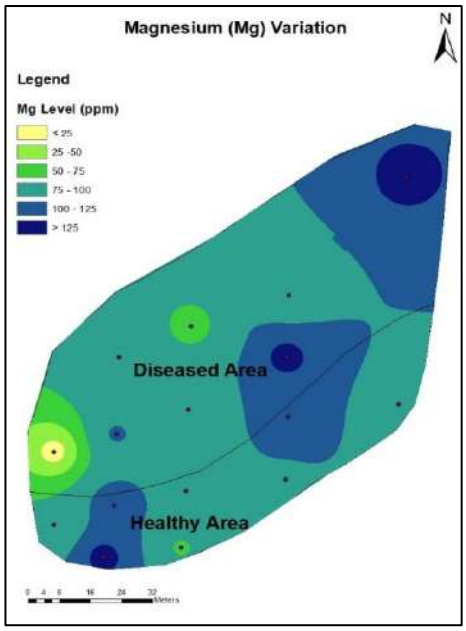


Fig. 2. Spatial variability of soil Mg

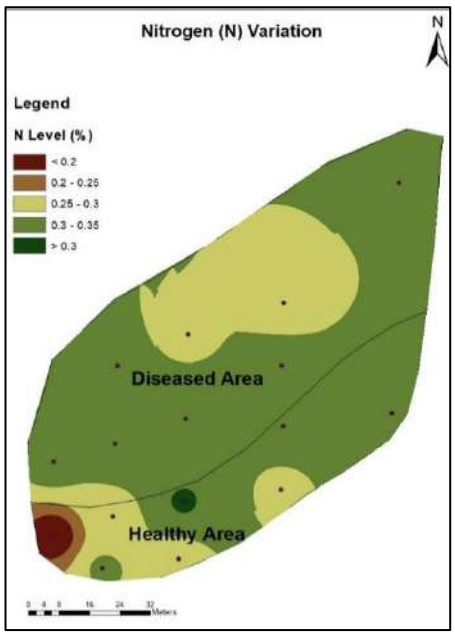


Fig. 3. Spatial variability of soil N

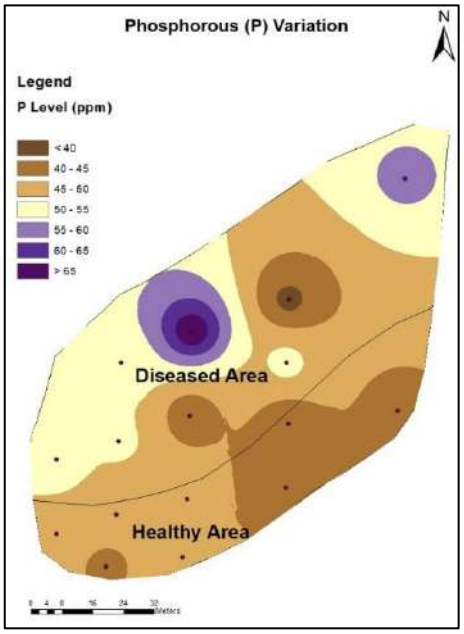


Fig. 4. Spatial variability of soil P

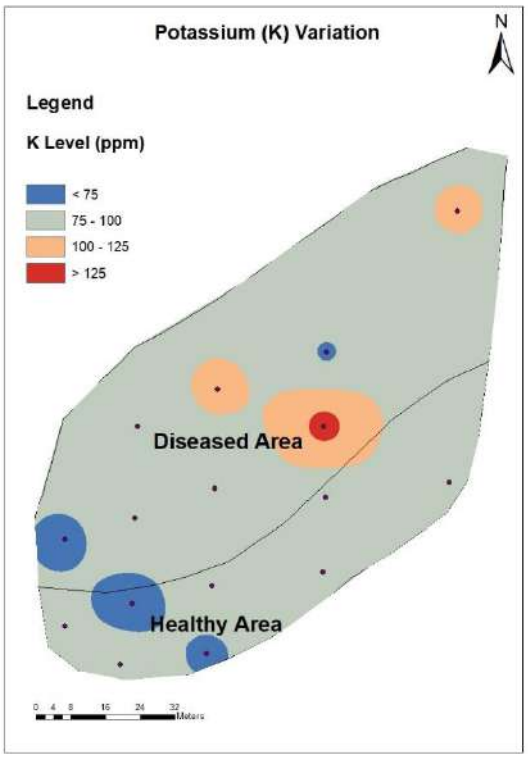


Fig. 5. Spatial variability of Soil K

Slow-release fertilizer application

Application of slow release fertilizer technique, reusable porous tube (RPT) for immature rubber plants

An experiment was laid down at Ganepalla estate, Yatiyanthota to study the effectiveness of RPT on the growth of rubber plants. The experimental design was mentioned in the 2019 annual review. Plant girth was taken at 4 feet above the ground level of the plant at 36 months after the planting of young budding plants. The assessment of plant girth showed significantly higher plant girth with the treatment of RPT type 2 compared to the other two treatments; control and RPT type 1 (Table 15) The filling medium was the difference between RPT type 1 and RPT type 2 and they were included only the 50% of the recommended fertilizers.

Table 15. *Effect of different fertilizer application methods on plant girth at 36 months after planting*

Treatments	Girth (cm)
T1 (Control)	22.18[b]
T2 (RPT type 1, NPK mixture R/U 12:14:14 and Kieserite mixed with filling medium No.1)	23.49[b]
T3 (RPT type 2, NPK mixture R/U 12:14:14 and Kieserite mixed with filling medium No.2)	25.96[a]

Values in the same column followed by the same letter are not significantly different at p=0.05

Above mentioned treatment combinations were also established at Elston estate to study the effectiveness of treatment combinations under the Homagama soil series. Compared to other soil series low soil fertility parameters were observed in the Homagama soil series including the soil textural class of sandy loam. Plant girth was taken at 4 feet above the ground level of the plant at 30 months after the planting of young budding plants. The assessment of plant girth showed significant differences between treatments. The RPT treatments (T2 & T3) gave significantly higher girth compared to the control treatment (T1) and RPT type 2 gave significantly the highest girth compared to other treatments (Table 16).

The slow-release experiments conducted in both sites showed that 50% of recommended fertilizers included RPT treatments gave significantly higher or similar girth values compared to conventional fertilizer application, *i.e.* control treatment (T1) (R P Hettiarachchi, V Edirimannne, T Gunathilake and K E de Silva).

Table. 16. *Effect of different fertilizer applications on plant girth at 30 months after planting*

Treatments	Girth (cm)
T1 (Control)	15.0[c]
T2 (RPT type 1)	17.29[b]
T3 (RPT type 2)	17.88[a]

Values in the same column followed by the same letter are not significantly different at p=0.05

Land degradation and land suitability

Geo-statistical approaches to assess the spatial variability of soil chemical properties in mature rubber growing lands

The variability of crop behaviors and soils causes yield barriers that cannot be overcome via conventional nutrient management approaches. Therefore, identifying the spatial variability of a crop field helps identify nutrient demands with respect to the spatial variability of soil nutrients. Geo-Statistical approaches are famous tools to identify soil spatial variability in crop fields. Geographic Information Systems (GIS) and Remote Sensing (RS) are key platforms for the Geostatistical analysis of such

crop and soil variability. The identification of nutrient demand variables helps to establish management zones with respect to the spatial variability of soil nutrients. Application of fertilizer based on such management zones ensures the Nutrient Use Efficiency (NUE) and cost-effective fertilizer application. This project was conducted with the focus on establishing a Variable Rate Fertilizer application (VRF) based on the spatial variability of soil nutrients for the mature rubber instead of traditional fertilizer recommendation.

A mature rubber stand with a 12 ha area at the Kuruwita substation of the Rubber Research Institute of Sri Lanka (RRISL) was selected as the study area. A total number of 16 composite soil samples were taken throughout the land randomly from both the top and subsoils (Tables 17 & 18). The sampling points were demarcated with a GPS receiver to map the sampling locations. Soil Nitrogen (N), Phosphorous (P), Potassium (K), Magnesium (Mg), Soil pH and Soil Organic Carbon (SOC) were determined at the Soils and Plant Nutrition Laboratory for both top and subsoil samples. The spatial variability of the above soil chemical properties was assessed with Inverse Distance Weighted (IDW) method in the GIS environment and values were determined for un-sampled locations in the soil. IDW is a famous geostatistical tool that is commonly used for spatial prediction of soil properties in GIS environments. However, different geostatistical tools to be used in the future to identify the most suitable one to assess the spatial variability of rubber-growing soils.

Table 17. *Descriptive statistics of top soil chemical properties*

Property	Mean	Median	Standard deviation	Minimum	Maximum	n
TN	0.12	0.12	0.04	0.04	0.17	16
pH	5.13	5.12	0.34	4.67	6.12	16
Av. P	31.66	30.41	12.60	11.37	54.48	16
K	113.71	114.85	16.80	92.12	147.27	16
Mg	36.38	36.76	12.82	14.71	59.95	16
SOC	1.75	1.78	0.23	1.26	2.13	16

TN – Total Nitrogen, Av. P – Available Phosphorous, K – Potassium, Mg – Magnesium, SOC – Soil Organic Carbon

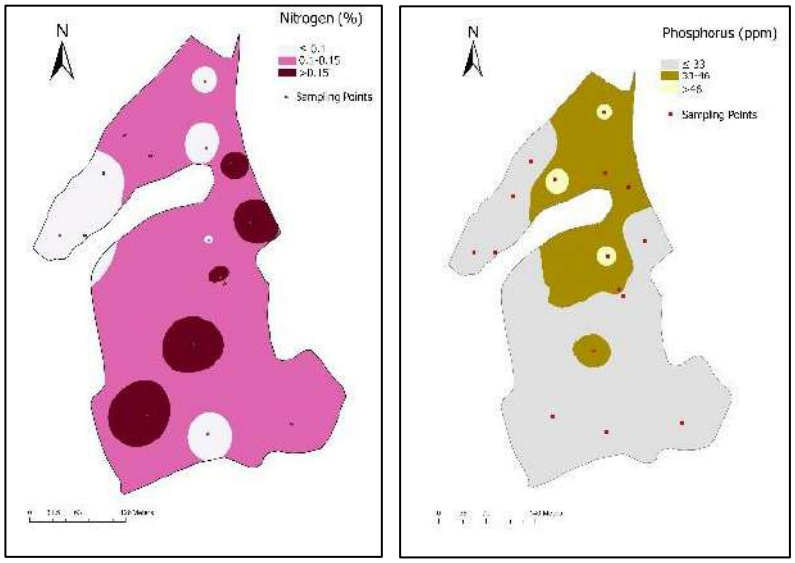
Table 18. *Descriptive statistics of sub soil chemical properties*

Property	Mean	Median	Standard deviation	Minimum	Maximum	n
TN	0.135	0.14	0.06	0.02	0.28	16
pH	5.06	5.01	0.23	4.76	5.61	16
Av. P	25.93	25.55	10.34	13.34	44.15	16
K	74.15	73.77	10.49	58.14	91.45	16
Mg	25.79	24.63	10.62	8.86	43.19	16
SOC	1.23	1.25	0.27	0.80	1.70	16

TN – Total Nitrogen, Av. P – Available Phosphorous, K – Potassium, Mg – Magnesium, SOC – Soil Organic Carbon

Spatial variability of top soil chemical properties in sampling locations at experimental site of Kuruwita Substation

As descriptive statistics revealed there are ranges of different chemical properties with IDW geostatistical tool in the study area of the topsoils. According to the analyzed samples and the predicted spatial values are in the appropriate range as the study area consists of the Homagama soil series (Fig. 6).



(a) **(b)**

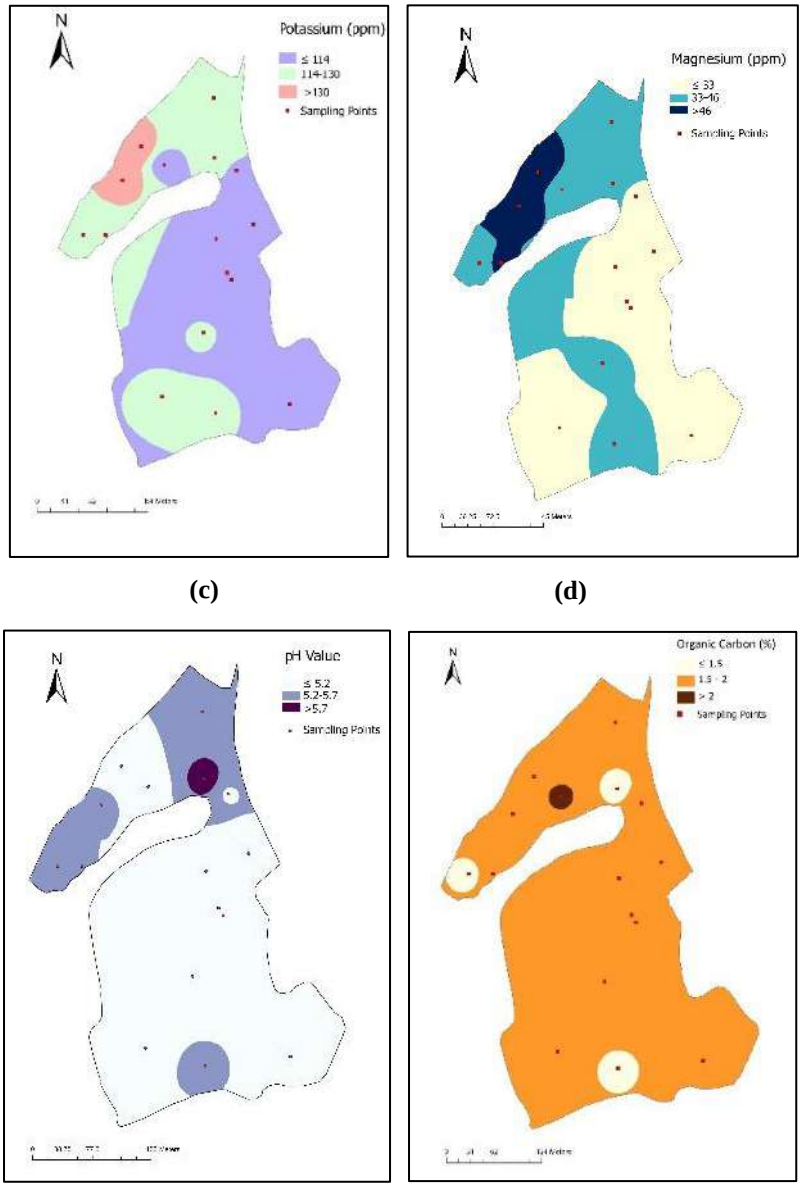
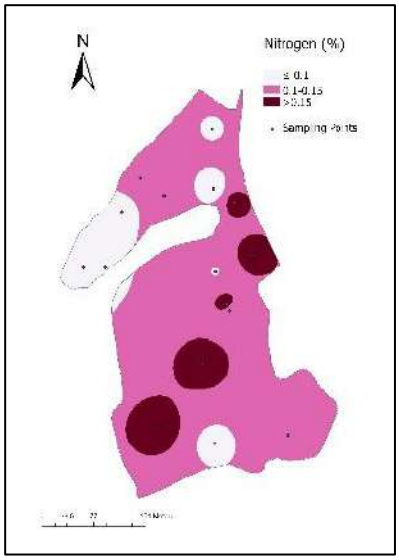


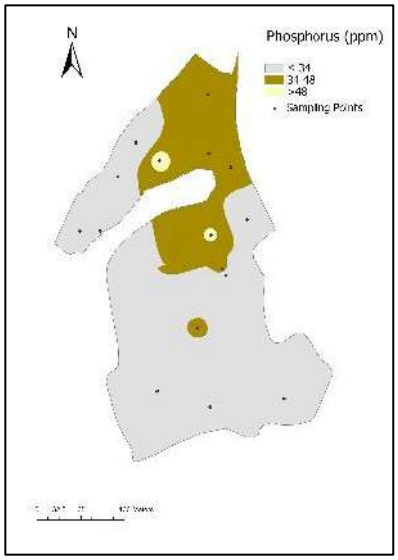
Fig. 6. Spatial variability of top soil chemical properties **(a)** Nitrogen, **(b)** Phosphorous, **(c)** Potassium, **(d)** Magnesium, **(e)** pH, **(f)** Soil Organic Carbon, in Kuruwita Substation of RRISL

Spatial variability of subsoil chemical properties in sampling locations at experimental site of Kuruwita Substation

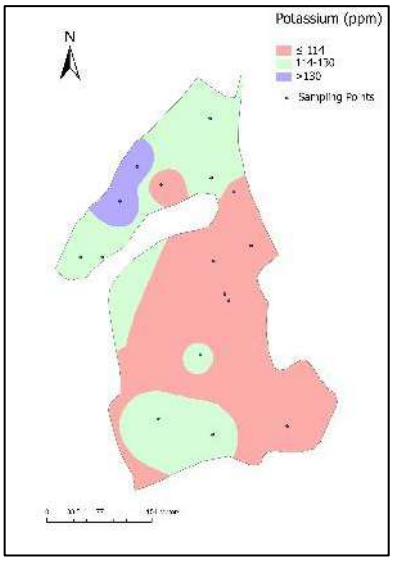
There are range of different chemical properties that were identified with IDW geostatistical tool inside the study area at subsoils. As usual, these values were comparatively lower than the values identified in topsoil (Fig. 7).



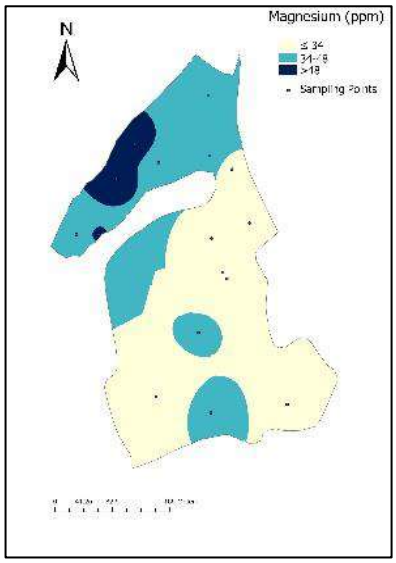
(a)



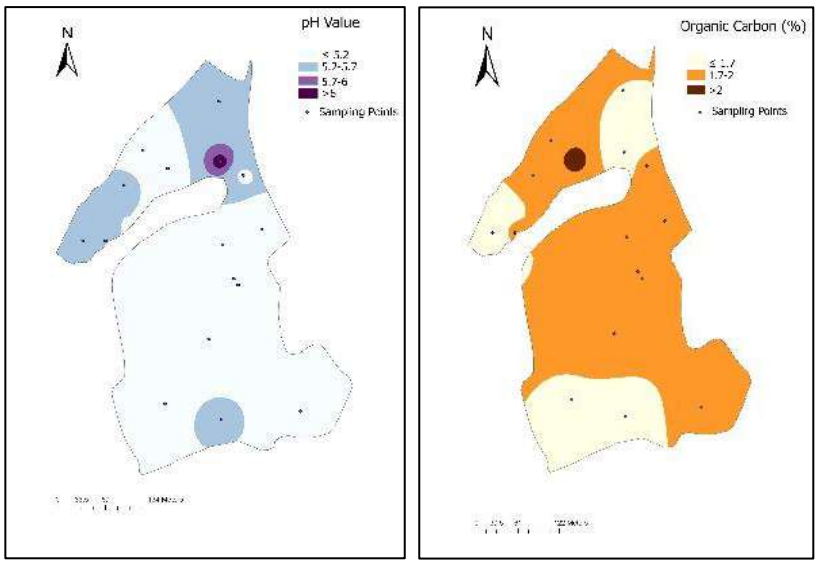
(b)



(c)



(d)



(e) **(f)**

Fig. 7. Spatial variability of sub soil chemical properties **(a)** Nitrogen, **(b)** Phosphorous, **(c)** Potassium, **(d)** Magnesium, **(e)** pH, **(f)** Organic Carbon, in Kuruwita substation of RRISL

The identified variability of both top and sub-soil chemical properties will be re-analyzed with different geostatistical tools to identify the best tool for the spatial prediction and re-soil sampling will be done in 2022 to compare the changes (L A T S Liyanaarachchi, M W H Gayan and Kasun Rangana).

Modification of fertilizer recommendations of Hevea with reference to plant, soil and field parameters (a special capital project) - 0363K)

This project activity focused on four provinces; Western, Southern, Sabaragamuwa and Wayamba and under which seven districts; Kalutara, Colombo, Galle, Matara, Ratnapura, Kegalle and Kurunugala. This area included 13 different soil associations and five soil series of Agalawatta, Boralu, Homagama, Parambe, and Ratnapura which have been identified by the Rubber Research Institute. The soil and leaf samples were collected and field parameters were recorded on the sampling unit (estate) and which were representing different soil associations and soil series. Assessments of soil parameters; Total N, Organic Carbon, Bulk density, pH, total phosphorus, available phosphorus, cation exchange capacity, texture, exchangeable cations of potassium, calcium, magnesium and total leaf nutrient contents of nitrogen, phosphorus, potassium and magnesium were done. Considering the differences in the

soil parameters, it was divided into three main categories; Parambe, Homagama and other rubber-growing soils (Fig. 8), and their major nutrient levels are presented in Table 19.

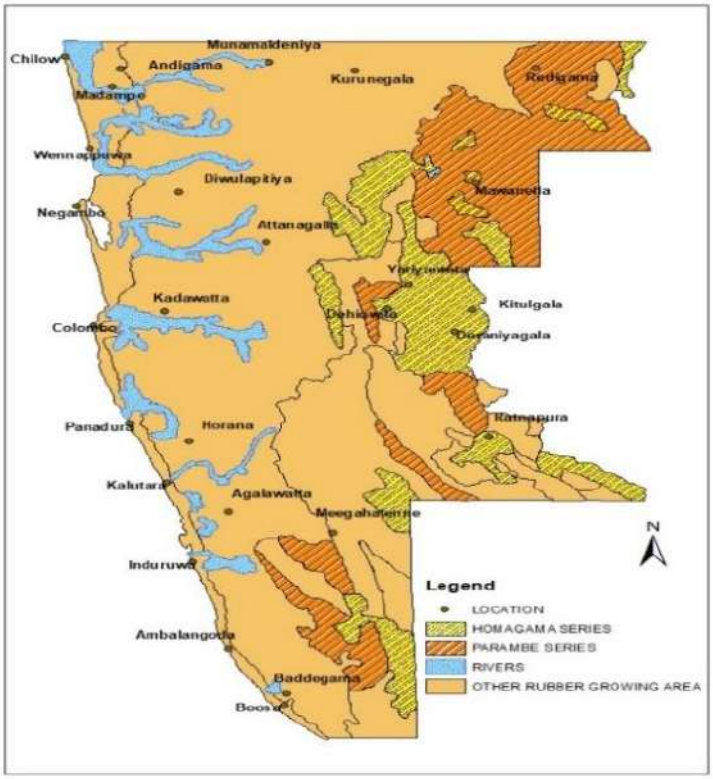


Fig. 8. Based on soil parameters, soils in Wet Zone were categorized into three main groups; Parambe, Homagama and other rubber-growing soils

Table 19. *Approximate major nutrient contents in different soil categories*

Soil Series	Available N%	Available P (ppm)	Available K (ppm)	Available Mg (ppm)
Parambe	0.12-0.18	22-40	90-150	45-65
Homagama	0.08-0.11	20-30	35-50	15-20
Other rubber-growing soils	0.09-0.13	22-37	48-65	22-32

Services

Land selection and suitability for rubber cultivation

Under the routine land selection programme, 369.70 Hectares of land were surveyed in non-traditional areas while 10 hectares of land were surveyed in the

estate sector in traditional rubber growing areas. A total number of 8 reports were issued for the above-mentioned survey programmes. Details of the survey are given in Table 20 (R P Hettiarachchi, L A T S Liyanaarachchi and all the staff of the department).

Table 20. *Details of the land selection programme*

Place	Extent surveyed (ha)
Medirigiriya, Mahaweli D	86
Hingura, Embilipitiya	2.43
Kotabova, Medagama, Moneragala	144
Kataragama, Thanamalwila	1.21
Keviliyamauwa, Ampara	6.07
Ipalogama and Kebithigollewa	5.06
Ruwanpura and Buddhangala, Padaviya	125
Giragama Estate, Peradeniya	10
Total	379.70

Site-specific fertilizer recommendation by soil and foliar survey programme

Site-specific fertilizer recommendation programme was not attended due to covid 19 pandemic situation in the country (R P Hettiarachchi, H A R K Jayawardana, A Thewarapperuma and all the staff of the department).

Analytical service

Under this programme, various samples received from estates, smallholders, universities and other private organizations were analyzed according to the SLSI methods. 304 samples (1,244 parameters) including 87 fertilizer samples from rubber growers were analyzed to assure the application of good quality fertilizers to their rubber lands. Analytical service issued 68 analytical reports and details of the service are given in Table 21 (R P Hettiarachchi, H A R K Jayawardana, V Edirimanna, K E de Silva, R M Baddevidana and all the staff of the department).

Table 21. *Details of the analytical services*

	Name of the Company/estate	Analytical services		Income
		No of reports	No of samples	Outside analytical service (Rs.)
1	Pallegoda	1	1	675.00
2	Weniwella	3	6	4,050.00
3	Mahaoya	1	4	2,700.00
4	Atale	1	3	2,025.00
5	Lalan Rubber Pvt.. Ltd	1	4	12,000.00

	Name of the Company/estate	Analytical services		Income
		No of reports	No of samples	Outside analytical service (Rs.)
6	Pelawatta	1	9	6,075.00
7	Rambukkanda	1	2	1,350.00
8	Hathbewa	1	5	4,525.00
9	Baddegama	3	10	6,750.00
10	Mirishena	1	6	4,050.00
11	Etana	1	5	3,375.00
12	Miriswatta	1	1	675.00
13	Millakanda	2	36	3,820.00
14	Parambe	2	9	7,575.00
15	Edella	1	1	675.00
16	Bibile	1	26	19,500.00
17	Niriella	1	38	47,500.00
18	Madeniya	1	5	3,375.00
19	NR Agri	2	3	3,500.00
20	Neuchattel	1	6	4,050.00
21	Mr Yasoda Somarathna, RRI, Rathmalana	2	3	4,850.00
22	Mr R Ganemulla, Ratmalana	2	4	3,050.00
23	Mr Devapriya, Neboda	1	2	150.00
24	Mr Nishkantha, Agalawatta	1	5	375.00
25	Mr NJM. Senanayake, Ragina Estate	1	1	1,525.00
26	Prof. Saman Darmakeerthi, University of Peradeniya	1	45	30,375.00
27	Mrs DD Weerakoon, Provincial Department of Agriculture (Western)	1	20	13,500.00
28	PLC, Kottawa	1	4	1,800.00
29	Dip Product Services, Department of Plant Science, University of Colombo	1	4	3,600.00
30	Prof. HLDWeerahewa Open University of Sri Lanka	1	36	104,400.00
	Total	39	304	**301,870.00**

BIOCHEMISTRY AND PHYSIOLOGY

K V V S Kudaligama

DETAILED REVIEW

Staff

Dr (Mrs) K V V S Kudaligama, assumed duties as the Head of the Biochemistry and Physiology department with effect from 11th of February, 2021. Mrs N P S N Karunarathne, Research Officer was on maternity leave from 23rd of April, 2021 to 2nd of September, 2021. Mr M K P Perera, Experimental Officer, Mrs P D T L Madushani, Mr L T B K Fernando and Miss N N Abewardhana Technical Officers and Mrs H A M E Hettiarachchi, Management Assistant were on duty throughout the year.

Research students

Student name	University	Research Topic
GK Supun Madhusanka	University of Wayamba	Final year research project in BTec

Seminars/Conferences/Workshops/Exhibitions attended

Officer/s	Subject/Theme	Organization
KVVS Kudaligama NPSN Karunarathne	Scientific Committee Meeting	RRISL
NPSN Karunarathne	Workshop on introduction to qualitative and quantitative data collection and analysis	University of Colombo
	The art of writing a research policy brief	SLCARP
KVVS Kudaligama NPSN Karunarathne MKP Perera PDTL Madushani NN Abewardhene LTBK Fernando HAME Hettiarachchi	Workshop on skill development of use of advance Excel techniques	NIPM
NPSN Karunarathne LTBK Fernando	Application of GIS in plantation sector	NIPM

Training programmes conducted

Officer/s	Subject/Theme	Remarks
KVVS Kudaligama	Theoretical and practical training programmes on the S/2 d4 system	31 programmes were conducted for rubber smallholders
	Use of stimulants in low-intensity harvesting	Induction Course for Planter Trainees, NIPM
	Use of stimulants in low-intensity harvesting	Refresh training programme for RDOs of Rubber Development Department
	Effective introduction of new LIH systems to address current issues in the rubber plantation industry (capital project)	Rubber Development Department (Uwa Province and Southern Province) Palmadulla Estate Haupe Estate Payagala Estate

Field visits

Advisory - 06 visits
Experimental - 367 visits
Miscellaneous - 11 visits

Sample testing

Commercial Ethephon mixtures - 09 samples

LABORATORY AND FIELD INVESTIGATIONS

Low-intensity harvesting to improve the sustainability of rubber farming (BCP/01)

Research, development and commercial introduction of low-intensity harvesting strategies

Commercial scale testing of S/2 d4, low-intensity harvesting system was continued in 04 tapping blocks replanted in 2010 (Field No: 2010/5.58) with RRIC 121/RRISL 203/RRISL 217 mixed genotypes in Gallewatte division, Dartonfield. Tress were stimulated with 2.5% oil-based ethephon on monthly basis except during wintering. Daily yields were monitored as dry rubber content and volume of latex together with scrap weight. The average actual tapping days under the S/2 d4 system was 74. In all four blocks, the average DRC% of latex was 40%. Variation of the yield of blocks was mainly due to the degree of mixing clones in particular tapping blocks (Table 1).

Table 1. *Yield parameters of four tapping blocks harvested with S/2 d4 system at Gallewatta division of Dartonfield Estate*

Tapping system	No. of trees	Actual tapping days	DRC (%)	GTT (g)	YPT (kg)	Estimated YPH* (kg)
Block 1	172	73	40	73	3.43	1372
Block 2	195	75	40	75	2.92	1168
Block 3	171	70	40	70	3.02	1210
Block 4	206	77	40	77	3.34	1337
Average	**186**	**74**	**40**	**74**	**3.18**	**1271**

(*Stand per ha has taken as 400 trees for calculating YPH)

Commercial level testing of S/2 d4 has been also continued in eight tapping blocks replanted with RRIC 121 and RRISL 203 clones in 2010 at Nivithigalakele division of Dartonfield Estate (No:2010/5.17). The total number of tapping days under d4 frequency was 81 and the average productivity of the field was 1,165 kg. Variation of the yield of blocks was mainly due to the degree of mixing clones (Table 2).

Table 2. *Yield parameters of eight tapping blocks harvested with S/2 d4 system at Nivithigalakele division of Dartonfield Estate*

Tapping system	No. of trees	Actual tapping days	DRC (%)	GTT (g)	YPT (kg)	Estimated YPH* (kg)
Block 1	192	82	40	41.02	3.33	1332
Block 2	217	82	39	35.95	2.93	1173
Block 3	252	81	40	34.72	2.83	1132
Block 4	254	83	39	32.46	2.67	1070
Block 5	223	81	39	37.18	2.99	1196
Block 6	168	77	40	38.69	2.90	1159
Block 7	132	80	39	37.00	2.95	1181
Block 8	199	80	39	34.08	2.70	1078
Average	**204**	**81**	**39**	**36.39**	**2.91**	**1165**

(*Stand per ha has taken as 400 trees for calculating YPH)

(K V V S Kudaligama, V H L Rodrigo, N P S N Karunarathne, M K P Perera, P D T L Madushani, L T B K Fernando and N N Abewardhana)

Effective introduction of newly developed low-intensity harvesting (LIH) systems to address the current issues in the rubber plantation industry (Special capital project 36.1.17)

Rs.109.564 Mn worth of funds were received through a special capital project to popularize recommended low-intensity harvesting systems to rubber growers in Sri Lanka. The overall objective of the project is to provide an evidence-based approach

through demonstrations, to popularize new low-intensity harvesting systems in both smallholder and plantation sectors to address current issues and thereby to obtain associated benefits.

Two knowledge dissemination programmes were conducted to the extension personals attached to the Advisory Department of RRISL and Rubber Development Department during the year. To improve the knowledge on adaptation, 31 awareness programmes were conducted to rubber smallholders and sixteen S/2 d4 demonstration fields have been established. Three training programmes had been conducted to Managers, Field Officers, Supervisors and harvesters of Palmadulla Estate, Haupe Estate and Payagala Estate to improve their knowledge on stimulation based low intensity harvesting systems (K V V S Kudaligama, N P S N Karunarathne, M K P Perera, L T B K Fernando, P D T L Madushani and N N Abewardhana).

Research and development on biochemical and physiological aspects to improve the sustainability of rubber farming (BCP/02)

Growth and physiological performance of different clones planted under different agro-ecologies

Padiyathalawa (Intermediate Zone)

Nine clones developed by RRISL were established in the experimental field at Padiyathalawa in 2017. The growth and physiological performance of clones was evaluated. Out of nine clones RRISL 2001, Centennial 3 and RRIC 121 showed better performances in plant height. Centennial 3, RRISL 201 and RRISL 2001 had the highest plant girth. Overall RRISL 2001 and Centennial 3 performed better in both plant height and girth wise whilst RRIC 102 and RRISL 2100 clones showed poor performance when compared to the other clones planted in the Padiyathalawa field (Table 5).

Table 5. *Average plant growth performances of different clones planted in the Padiyathalawa experimental field*

Clone	Height (cm)	Girth at 4 ft (cm)
RRIC 100	632.98	23.21
RRIC 102	576.62	20.38
RRIC 121	694.73	22.44
RRISL 201	683.61	27.16
RRISL 203	675.61	24.49
RRISL 2001	823.80	25.84
RRISL 2100	550.87	18.06
Centennial 3	708.40	27.22
Centennial 4	629.52	23.89

Chlorophyll content, epicuticular wax content, relative water content, leaf area, stomatal conductance and soil moisture level in the morning were assessed as physiological parameters of the above clones planted at Padiyathalawa in March (Fig. 1). Wind speed, air temperature and relative humidity were recorded as environmental parameters at the time of measuring (Table 6).

Table 6. *Average environmental condition in Padiyathalawa field at the time of taken plant physiological data*

Clone	Wind speed (km/hr)	Air temperature (^{o}C)	Relative humidity (%)
RRIC 100	2.0	29.1	92.0
RRIC 102	1.5	29.3	85.3
RRIC 121	2.8	29.0	88.0
RRISL 201	2.4	29.3	86.3
RRISL 203	1.4	29.0	91.0
RRISL 2001	2.0	29.0	87.5
RRISL 2100	1.5	29.1	85.1
Centennial 3	1.9	29.9	86.1
Centennial 4	1.8	28.1	91.6

Highest chlorophyll content was found in Centennial 3 (60.78 SPAD units) and RRISL 201 (60.10 SPAD units) clones whilst the lowest was in RRIC 102 (49.40 SPAD units) (Fig. 1a). The highest and lowest epicuticular wax contents resulted in Centennial 3 (0.0039 g/cm^2) and RRISL 203 (0.0016 g/cm^2) respectively (Fig. 1b). Relative water content was changed from a maximum value of 91.65% in RRISL 2100 to a minimum value of 86.36% in RRIC 102 (Fig. 1c). RRIC 100 (117.66 cm^2) and RRIC 102 (72.84 cm^2) clones reported the highest and lowest leaf area values in the Padiyathalawa field (Fig. 1d). Stomatal conductance was maximum in RRIC 102 (0.86 mmolm^{-2}s^{-1}) whilst RRIC 121 (0.56 mmolm^{-2}s^{-1}) reported the minimum value (Fig. 1e). Soil moisture content during the morning time of the field was varied from 5.94 - 14.37% (Fig. 1f).

Hambegamuwa (Intermediate Zone)

Performances of eight clones developed by RRISL established in the experimental field at Hambegamuwa were evaluated with plant physiological data during 2021. Chlorophyll content, epicuticular wax content, relative water content, leaf area, stomatal conductance and soil moisture level in the morning were assessed as physiological parameters of the clones planted at Hambegamuwa in October. Wind speed, air temperature and relative humidity were recorded as environmental parameters at the time of measuring (Table 7).

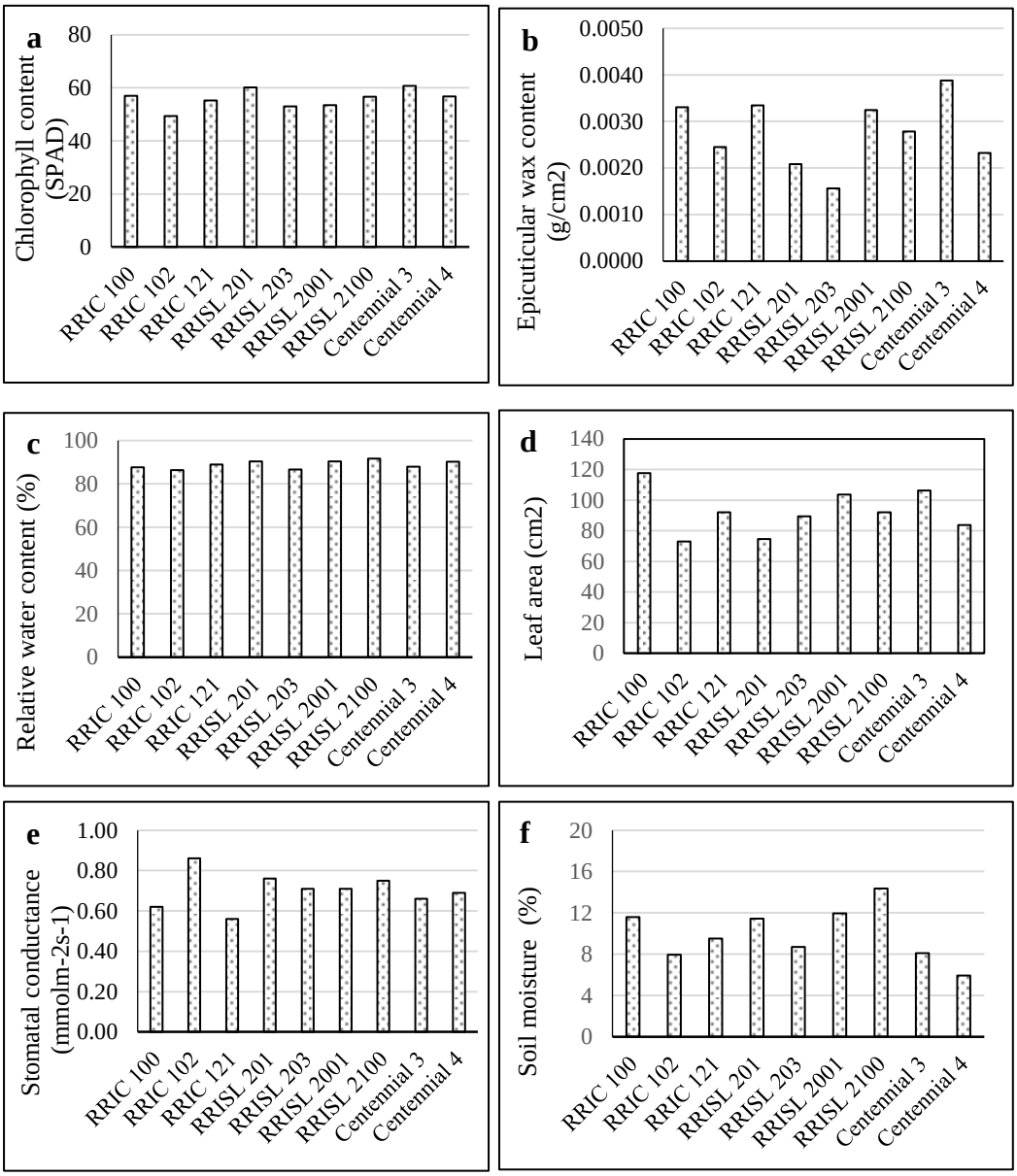


Fig. 1 a). Chlorophyll content, **b)**. epicuticular wax content, **c)**. relative water content, **d).** leaf area, **e).** stomatal conductance and **f).** soil moisture level of different *Hevea* genotypes planted at the Padiyathalawa experimental site

Table 7. *Average environmental condition in Hambegamuwa field at the time of taken plant physiological data*

Clone	wind speed (km/hr)	Air temperature (^{o}C)	Relative humidity (%)
RRIC 100	4.8	31.4	75.3
RRIC 102	5.1	32.9	75.2
RRISL 201	4.8	33.0	72.5
RRISL 203	3.9	32.1	77.7
RRISL 2001	3.5	32.6	78.5
RRISL 2100	3.6	33.0	74.2
Centennial 3	4.4	32.6	73.7
Centennial 4	1.2	31.9	77.3

As shown in Figure 2, chlorophyll content of the leaves was varied in clones with the highest value observed in Centennial 4 (52.20 SPAD units) and the lowest value in RRIC 102 (42.69 SPAD units) clones (Fig. 2a). Among the genotypes tested, RRIC 100 (0.0045g/cm^2) and RRISL 201 (0.0044 g/cm^2) showed a considerably higher epicutucular wax content in leaves whilst RRIC 102 (0.0018 g/cm^2), RRISL 203 (0.0019 g/cm^2) and RRISL 2100(0.0020 g/cm^2) had the minimum amounts (Fig. 2b). RRIC 100 (92.85%), RRIC 102 (92.73%), RRISL 2001 (92.47%) and RRISL 2100 (92.80%) clones reported a higher relative water content whilst RRISL 203 (87.14%) and Centennial 3 (84.68%) reported a comparatively lower relative water content in leaves (Fig. 2c). The highest leaf area was observed in Centennial 3 (90.87 cm^2) followed by RRIC 100 and RRISL 203 clones. However, other five clones showed a considerable lower leaf area at the Hambegamuwa site (Fig. 2d). In Hambegamuwa field, stomatal conductance of Centennial 3 (0.60 mmolm^{-2}s^{-1}) and Centennial 4 (0.74 mmolm^{-2}s^{-1}) showed a relatively higher value whilst all other clones attributed lower values (<0.48 mmolm^{-2}s^{-1}) of the same (Fig. 2e). Soil moisture content during the morning time of the experimental field varied from 13.84 - 21.64% (Fig. 2f).

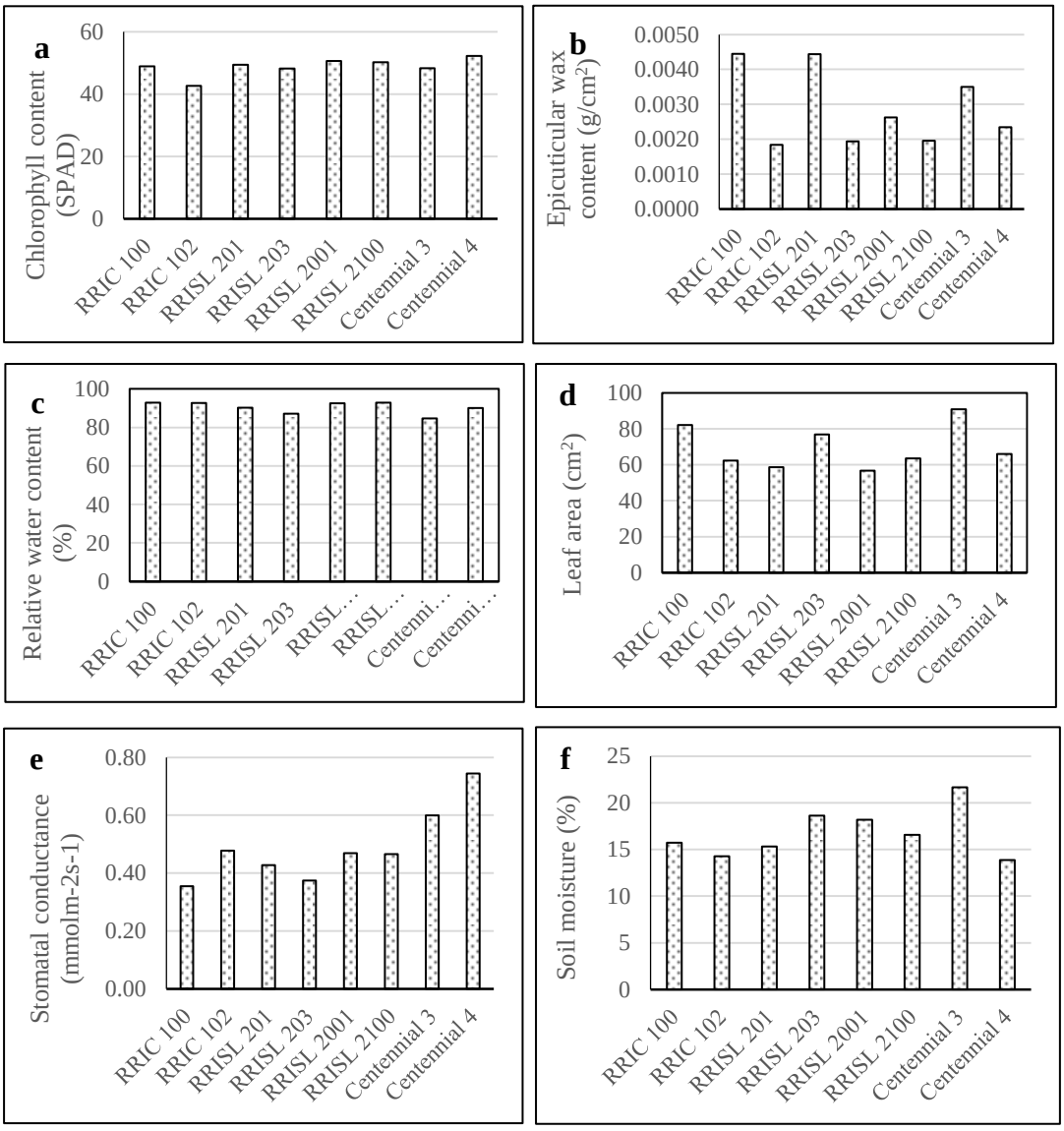


Fig. 2. a). Chlorophyll content, **b).** epicuticular wax content, **c).** relative water content, **d).** leaf area, **e).** stomatal conductance and **f).** soil moisture level of different *Hevea* genotypes planted at the Hambegamuwa experimental site

(K V V S Kudaligama, N P S N Karunarathne, M K P Perera, P D T L Madushani, L T B K Fernando and N N Abewardhana)

Research and development on rubber latex to identify best genotypes that produce quality raw rubber during screening process

Effect of biochemical components of latex on quality of raw rubber

Latex physiology parameters and raw rubber properties were assessed in rubber trees stimulated with water-based ethephon, oil-based ethephon and locally produced water-based ethephon at Elston Estate, Awissawella with the aim of identifying the effects of biochemical components of latex on quality of raw rubber. Raw rubber properties were tested with collaboration of Department of Raw Rubber and Chemical Analysis, Ratmalana (Table 8).

Among the ethephon mixtures tested a significant difference in latex physiological parameters, has been observed only in inorganic phosphorus contents. Locally produced water-based ethephon stimulated rubber trees showed a higher inorganic phosphorus content (15.76 mM ± 1.70) in latex than other treatments show a better metabolic activity in laticifers.

Out of raw rubber properties, volatile matter content and Plasticity Retention Index (PRI) varied significantly amongst three treatments. Latex taken from water-based ethephon stimulated rubber trees had the highest volatile matter content (0.55 %) and the PRI value (91.37). The lowest value of PRI (79.84) has been observed in rubber from locally produced water-based ethephon stimulated trees. Further assessments will be carried out in order to identify long term effects.

Table 8. *Comparison of latex physiological parameters and raw rubber properties of water-based ethephon, oil- based ethephon and locally produced water- based ethephon stimulated rubber trees*

	Water-based ethephon	**Oil-based ethephon**	**Locally produced water-based ethephon**
Latex physiology parameters			
Sucrose content (mM)	5.21±1.28	4.81±1.43	4.85 ±0.64
Thiol content (mM)	0.37±0.043	0.29±0.03	0.30 ±0.02
Inorganic phosphorus content (mM)	8.51±0.72	11.05±1.55	15.76 ±1.70
Polyphenol content (mM)	1.55±0.18	1.47±0.09	1.66±0.08
Raw Rubber Properties			
Plasticity Retention Index	91.37	85.24	79.84
Mooney viscosity ML (1+4)@100^{0}C	85.21	88.45	84.35
Volatile Matter Content %	0.55	0.34	0.33
Nitrogen Content %	0.45	0.40	0.38
Ash content %	0.14	0.16	0.16
Colour (Lovibond)	2.00	2.00	2.00

(N P S N Karunarathne, K V V S Kudaligama, P D T L Madushani, N N Abewardhana and L T B K Fernando)

Biochemical and physiological screening of HP progenies

Biochemical and physiological assessment of latex of twenty *Hevea* HP genotypes of the progeny developed in 2014 was carried out at the field established in Nivithigalakele Sub-station on request of Department of Genetics & Plant Breeding. The contents of sucrose, inorganic phosphorus, thiol polyphenols, dry rubber content, total solids content and g/t/t were determined during the year 2021 (Table 9).

According to the results, *Hevea* genotypes no. 2, 5, 33, 58, 62, 106, 164 and 167 had very low sucrose level with a lower g/t/t. These genotypes do not show any possibility to increase the yield due to being with a lower level of sucrose. Genotypes 11 and 78 showed a comparatively higher g/t/t level with a lower dry rubber content (DRC). Lower sucrose content of them confirms a deficiency of raw material for any further regeneration of rubber in laticifers. Genotypes 39 and 65 were with an appropriately higher sucrose level and a better DRC% showed a reasonable yielding capacity. However, with lower inorganic phosphorous and higher sucrose level of genotype, 39 confirms a better performance in stimulation based low intensity harvesting (LIH) systems. A similar possibility is also with genotype 13 and 114. Genotypes 79 and 83 with a DRC level below 25% were with a reasonably higher sucrose level. Comparatively lower g/t/t level reveals a deficient latex regeneration capacity in both genotypes. Though the latex sucrose content of 21, 35, 42 and 102 is lower, considerably higher g/t/t and DRC levels would confirm their medium yielding capacity with unstimulated tapping systems (Table 9).

Table 9. Comparison of yield and latex physiological parameters of *Hevea* HP progenies

Genotype No:	Sucrose (mM)	Inorganic phosphorus (mM)	DRC %	TSC %	Non rubber content %	Total volume (ml)	g/t/t (g)
2	1.48	22.12	23.49	26.66	3.18	43.50	10.45
11	2.15	21.43	25.59	27.46	1.87	100.00	25.59
13	5.81	6.51	37.95	40.70	2.75	10.50	4.31
15	1.38	11.94	26.94	30.38	3.43	59.50	15.68
21	1.93	13.67	31.65	33.49	1.85	72.50	22.92
33	3.01	7.66	35.16	38.79	3.64	16.00	5.63
35	3.43	13.21	28.14	31.75	3.61	70.00	19.72
39	6.11	7.51	40.17	43.29	3.12	40.00	15.54
42	1.89	20.82	30.49	33.04	2.49	100.00	22.87
58	2.57	12.05	27.45	30.73	3.28	57.00	15.59
62	2.58	23.85	21.68	25.02	3.34	22.00	4.59
65	7.70	20.68	36.16	39.64	3.48	65.00	23.50
78	2.67	10.07	24.44	29.76	5.32	93.50	24.14
79	7.53	11.91	25.05	28.46	3.41	15.50	6.26

Genotype No:	Sucrose (mM)	Inorganic phosphorus (mM)	DRC %	TSC %	Non rubber content %	Total volume (ml)	g/t/t (g)
83	4.80	13.22	24.41	27.71	3.30	41.00	10.01
102	3.61	15.01	29.97	32.97	3.00	65.00	19.48
106	3.75	10.49	28.67	31.93	3.26	37.00	10.66
114	6.02	12.80	28.90	31.78	2.88	42.50	12.33
164	1.40	16.35	22.09	25.39	3.30	74.00	16.35
167	4.15	18.80	26.71	30.26	3.55	36.00	9.61

(N P S N Karunarathne, K V V S Kudaligama and N N Abewardhana)

Effect of circular leaf spot disease on yield and biochemical components of latex

An experiment has been conducted in collaboration with the Plant Pathology and Microbiology Department of RRISL in order to investigate the effects of new leaf fall disease on latex yield and physiological parameters. Tapping blocks have been selected from 2010 replanted field in the Gallewatte division of Dartonfield Estate. The majority of the trees are of RRIC 121 genotype and tapped with S/2 d4 latex harvesting system. This field was severely attacked by the new leaf disease in 2020. The yield data was monitored throughout the year 2021. Though 10 ethephone applications were planned with S/2 d4 harvesting system for the year avoiding wintering period, another two applications had to be suspended during November and December due to heavy defoliation observed. This has shown a combined effect on the overall yield of the tree with the disease. Dry rubber content of latex of the trees did not show much variation throughout the year and values varied between 39-40% (Fig. 3). However, latex volume of a tree has been reduced resulting a lower per day yield from a tree. Due to suspending ethephon application on November and December, a yield increase has not been observed as usual during these months (Fig. 3). Average volume and daily dry rubber yield per tree was 102.51 ml and 40.93 g, respectively.

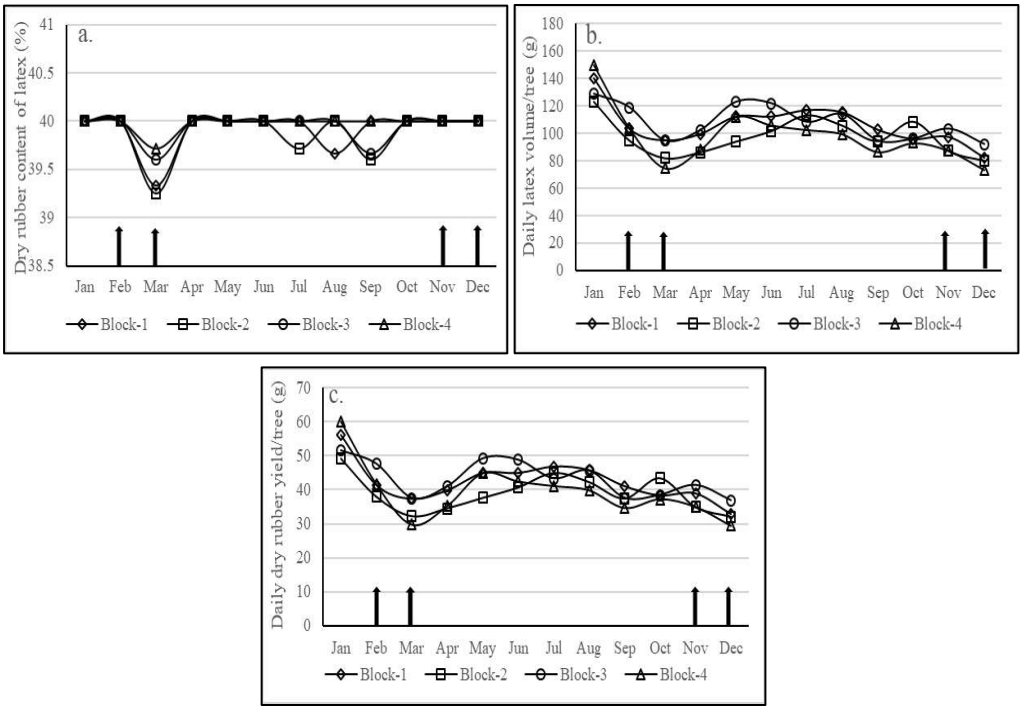


Fig. 3. variation of **a).** Dry rubber content, **b).** Daily latex yield and **c).** Dry rubber yield per tree in trees affected with circular leaf spot disease (arrows indicate the months which suspended ethephon application)

(N P S N Karunarathne, K V V S Kudaligama, M K P Perera, L T B K Fernando, P D T L Madushani and N N Abewardhana in collaboration with Plant Pathology and Microbiology department, RRISL)

Commercial scale testing of in-country ethephon formulation developed by RRISL

Experiment established at Elston Estate, Puwakpitiya has been continued to investigate the effectiveness of new water based (NWB) formulation together with two commercial ethephon mixtures available in the local market, *i.e.* existing water based (EWB) and existing oil based (EOB). Tapping system used was S/2 d4 system with application of 0.6 g of 2.5% ethephon per tree at a rate on monthly basis avoiding the wintering period. This field has been replanted in 2010/2011 season with RRIC 121 clone and opened for tapping in 2018. Tapping task size is 300-317 trees/tapper and for each formulation three tapping blocks were allocated.

Over the year, average dry rubber content of latex in tapping blocks applied three formulations varied from 34-39% and the average value was about 37% in all three treatments. Due to the higher rainfall received during the year 2021, the number

of tapping days was lower than the expected level (80 days/yr) under S/2 d4 condition. The average intake per harvester in blocks applied with NWB, EWB and EOB during the year 2021 was 16.79, 14.39 and 16.35 kg, respectively. The observed yield per hectare (assuming 400 trees/ha) was 1500, 1304 and 1569 kg, respectively. Productivity under New water based ethephon formulation was comparable with the existing oil based formulation. However, the new water based formulation showed comparatively higher productivity than that of the existing water based formulation (Table 10).

Table 10. *Average yield of tapping blocks (300 trees) harvested with S/2 d4 system using different types of ethephon formulations in Elston Estate*

Tapping system	Actual tapping days	DRC (%)	GTT (g)	IPH (kg)	YPT (kg)	YPH (kg)
New water based	67	37	55.97	16.79	3.75	1500
Existing water based	68	37	47.95	14.39	3.26	1304
Existing oil based	72	37	54.49	16.35	3.92	1569

(K V V S Kudaligama, T H P S Fernando, V H L Rodrigo, P Seneviratne, A P Attanayaka, N P S N Karunarathne, M K P Perera, L T B K Fernando P D T L Madushani and N N Abeywardhena)

ADVISORY SERVICES

P K K S Gunarathne

DETAILED REVIEW

Staff

Mr P K K S Gunarathne (Advisory Officer) has been appointed to cover up the duties of the Head of the Department since 01st of March 2021. Mr Susith Rathnayake (Rubber Extension Officer) and Mr S G G Wijesinghe (Rubber Extension Officer) have been appointed to cover up the duties of Advisory Officers since 05th of April 2021. Mrs Priyasha Manahari, Assistant Training Officer and fifteen Rubber Extension Officers (REOs) were on duty throughout the year. Mr S G G Wijesinghe, Rubber Extension Officer who covered up duties of the Advisory Officer (*Kalutara* region) retired from the service with effect from the 05th of September 2021. Mr I P L Kithsiri (Rubber Extension Officer) retired from the service with effect from the 21st of April 2021. Mr A R Kulathunga (Rubber Extension Officer) resigned from the service with effect from the 05th of April 2021. Mrs J A N R Jayasinghe (Management Assistant) retired from the service with effect from the 07th of July 2021.

Conferences/Meetings/Seminars/Workshops attended

The following meetings were attended by Mr P K K S Gunaratne.

Subject/s	Organization/s
Technology Update Programmes	RRISL
Meetings of staff, review, research, Scientific Commetee and budget	RRISL
Provident Fund Meeting	RRISL
Workshop on "Organic fertilizer production and application"	Sustainable Agriculture Research and Development Centre, Makadura
Workshop on "Presenting 'Science' online" and "Upon Journal Submission to the Publication: The Process and the Journey"	Post Graduate Institute of Agriculture, University of Peradeniya
Workshop on "Structural Equation Modeling (with AMOS) for Quantitative Research"	National Centre for Advanced Studies
Workshop on "Introduction to Qualitative and Quantitative Data Collection and Analysis"	National Centre for Advanced Studies
Workshop on "Application for GIS in Plantation Sector"	National Institute of Plantation Management

Subject/s	Organization/s
Project on "Road map for organic agriculture"	Ministry of Plantation of Sri Lanka
Project on "Joint action plan on organic fertilizer for rubber"	Rubber Development Department
Project on "Divisional rubber auction"	Rubber Secretariat, Ministry of Plantation Industries of Sri Lanka
Project on "Development of rural economy"	Estate Ministry of company Estate Reforms
Project on "Organic Plantation"	Estate Ministry of company Estate Reforms
Project on "National programme of the improvement of the rural economy"	Ministry of Plantation Industries of Sri Lanka
The Eighth International Conference of Sabaragamuwa University of Sri Lanka	Sabaragamuwa University of Sri Lanka
The Eighth International Conference on Multidisciplinary Approaches	Faculty of Graduate Studies, University of Sri Jayewardenepura
The Eighteenth International Conference on Business Management 2021	Faculty of Management Studies and Commerce, University of Sri Jayewardenepura
The PGIA Annual Congress	Postgraduate Institute of Agriculture, University of Peradeniya
The International Conference Geography and Global Sustainability	Faculty of Arts, University of Colombo
The Multidisciplinary International Research Symposium of Rajarata University of Sri Lanka	Rajarata University of Sri Lanka
International Conference on Environmental Governance	Central Environmental Authority, Sri Lanka
The Seventh International Conference on Humanities and Social Sciences	Faculty of Arts, University of Colombo
The National Geography Conference	Department of Geography, University of Peradeniya
The Symposium on International Forestry and Environment	University of Sri Jayawardenepura
Symposium The Faculty Annual Research Session 2021	Faculty of Applied Science, Vavuniya Campus of the University of Jaffna
The Second National symposium on Sustainable Plantation Management	National Institute of Plantation Management

PROGRESS OF PROJECTS AND SERVICES

Extension and advisory programmes were carried out under four thrust areas, to improve the productivity of the rubber smallholder and estate sectors, by enhancing the adoption rate of recommended technologies developed by RRISL.

Thrust area 01: Transfer of technologies to improve the productivity of the smallholder rubber sector and estate sector

Project 1(ASD/01/A) Participatory development of selected rubber smallholdings as models

To demonstrate the value of adopting RRISL recommendations to increase the land-use-efficiency of rubber smallholdings, the extension strategy focused on farmer participatory development of selected rubber holdings as "Model rubber holdings" was continued successfully (Table 1). As models, 52 immature and 61 mature holdings were fully developed (Fig. 1, 2).

Fig. 1. Mature model rubber holding – Mr. J.R.A. Chamil Sarandana (Hakmana REO range)

Fig. 2. Immature model rubber holding – Mr. Jayathissa Hadapangoda (Kosgama REO range)

Table 1. *Details of participatory development done for selected smallholder rubber holdings*

Region	No. of developed holdings	
	Mature	**Immature**
Colombo/Gampaha	4	2
Kegalle	24	17
Kalutara	12	13
Ratnapura	8	8
Galle/Matara	13	12
Total	**61**	**52**
		113

Project 2 (ASD/01/B) Participatory development of rubber processing centers as models

Advisory and extension support services were provided to maintain 29 "Model rubber processing centers" to demonstrate the importance of the adoption of recommended practices to improve the quality of RSS to obtain maximum economic returns (Table 2).

Fig. 3. Inside of a model rubber processing center – Mr N H Kandambi (Hakmana REO range)

Table 2. *Participatory development of rubber processing centers for selected smallholder rubber holdings*

Region	No. of model centres developed
Colombo/Gampaha	2
Kegalle	12
Kalutara	6
Ratnapura	6
Galle/Matara	3
Total	**29**

Project 3 (ASD/01/C) Promotion of usage of rainguards

To popularize the rainguard technology as a short-term strategy to increase the productivity of rubber smallholdings, 31 demonstration plots were established under the supervision of REOs (Table 3).

Fig. 4. Rainguard model rubber holding – Mr K L Kumara (Kandy/Matale REO range)

Table 3. *Details of rainguard demonstration holdings*

Region	**No. of demonstration holdings established**
Colombo/Gampaha	2
Kegalle	12
Kalutara	6
Ratnapura	4
Galle/Matara	7
Total	**31**

Project 4 (ASD/01/D) Promotion of area specific intercropping and mixed cropping systems

To popularize area specific intercropping systems to increase the income during the immature period of rubber smallholdings, 06 intercropping demonstration plots were established (Table 4).

Fig. 5. Intercrop model with pineapple – Mr Iresh Galabada (Baduraliya REO range)

Table 4. *Area-specific intercropping and mixed cropping demonstration holdings*

Region	No. of demonstration
Colombo/Gampaha	1
Kalutara	3
Kegalle	2
Total	**6**

Project 5 (ASD/01/E) Construction, rehabilitation and modification of new and substandard rubber processing centers

Advisory and extension services were provided for the construction of 30 new RSS production centers and rehabilitation of 09 substandard processing centers, to maintain them as cost-effective units as per the requests of owners (Table 5) (Fig. 6).

Fig. 6. New rubber processing center – Mr Nalaka Atapattu (Akuressa REO range)

Table 5. *Construction, rehabilitation and modification of new and sub-standard rubber processing centers*

Region	No. of RSS production centers	
	New centers	Rehabilitated centers
Colombo/Gampaha	1	0
Kegalle	16	4
Kalutara	3	2
Ratnapura	0	0
Galle/Matara	10	3
Total	**30**	**09**

Project 6 (ASD/01/F) Projects related to advisory visits in traditional rubber growing areas

Nine hundred seventy pre-planned advisory visits were conducted by Rubber Extension Officers to solve technology adoption problems in the participatory development models (Table 6).

Table 6. *Details of projects-related advisory visits*

Region	Nature of advisory visit						
	Model farm development	Introduction of Intercropping Systems	Introduction of rainguard technology	Maintenance of model RSS centers	Construction of new RSS centers	Rehabilitation of substandard RSS centers	Total
Colombo/Gampaha	15	2	5	4	1	0	**27**
Kalutara	195	11	32	20	15	0	**273**
Kegalle	145	4	59	32	41	11	**292**
Rathnapura	65	0	11	19	0	0	**95**
Galle/Matara	184	0	28	13	42	16	**283**
Total	**604**	**17**	**135**	**88**	**99**	**27**	**970**

Project 7 (ASD/01/G) Application of organic fertilizer (Compost)

Thirty nine rubber smallholdings were established with compost application covering a total of 82 acres in Kalutara, Kurunegala, Kandy/Matale, Kegalle, Matara, Galle, Colombo and Ratnapura Districts (Fig. 7) (Table 7). Eleven farmers were produced compost themselves for the field application while 28 farmers were purchased from the market.

Table 7. *Details of smallholdings on compost application*

District	No. of immature holdings	No. of immature extent (Ac)	No. of mature holdings	No. of mature extent (Ac)
Kalutara	6	7.5	2	2.5
Kegalle	11	18.94	9	20.75
Galle/Matara	3	6.5	6	21.0
Ratnapura	1	0.75	1	4.0
Total	**21**	**33.69**	**18**	**48.25**

Fig. 7. Demonstration on organic manure application – Mr M Jayasinghe, (Kalutara REO Range)

Thrust area 02: Advisory programmes to solve technology adoption problems of all stakeholders of the rubber sector

Project 8 (ASD/02/A) Individual advisory visits and demonstrations on requests of rubber smallholders

Three hundred and eighty two advisory visits and 177 demonstrations were made by REOo to solve technology adoption problems of rubber smallholders in relation to all agronomic and processing aspects. A separate report was prepared by REOo on each visit and follow-up actions were attended where necessary (Tables 8 and 9).

Table 8. *Demonstrations conducted on requests of rubber smallholders*

Type of demonstration	No. of demonstrations
Immature	
Planting holes	5
Planting	7
Soil conservation	7
Branch induction	3

Type of demonstration	No. of demonstrations
Removal of branches	16
Fertilizer application	9
Weed control	1
Intercropping	3
Diseases	2
Cover crops	2
Animal damages	1
Other	1
Mature	
New panel marking	12
Tapping correction	30
Fertilizer application	8
Rainguard	10
New tapping knife	10
Disease	16
TPD	6
Other	9
Processing	
Ceiling	1
Oven	1
Sheet making	4
One day smoke house	7
New Smokehouses	1
Chimneys	1
Other	4
Total	**177**

Table 9. *Details of Individual advisory visits conducted on requests of smallholders*

Region	No. of advisory visits made by REOo			
	Immature	**Mature**	**Processing**	**Total**
Colombo/Gampaha	2	9	0	11
Kegalle	21	65	6	92
Kalutara	53	79	20	152
Ratnapura	22	29	4	55
Galle/Matara	13	50	9	72
Total	**111**	**232**	**39**	**382**

The above advisory visits were categorized as follows (Figs. 8, 9 and 10).

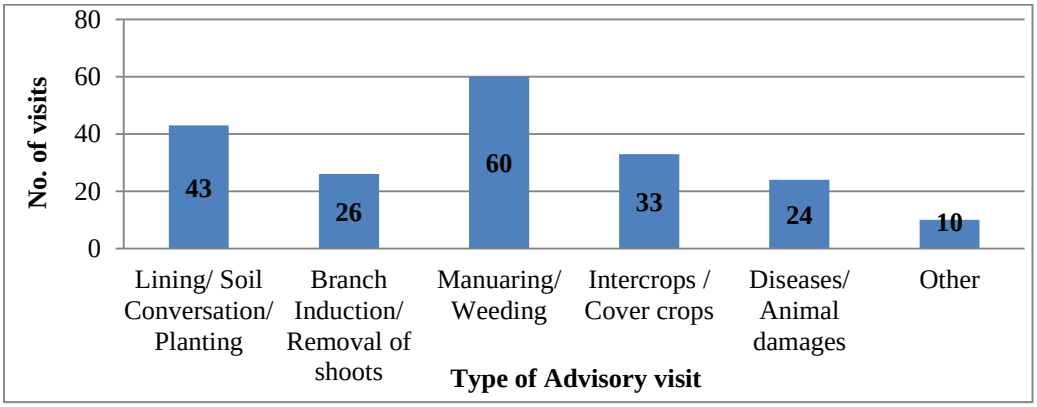


Fig. 8. Types of advisory visits conducted in immature holdings

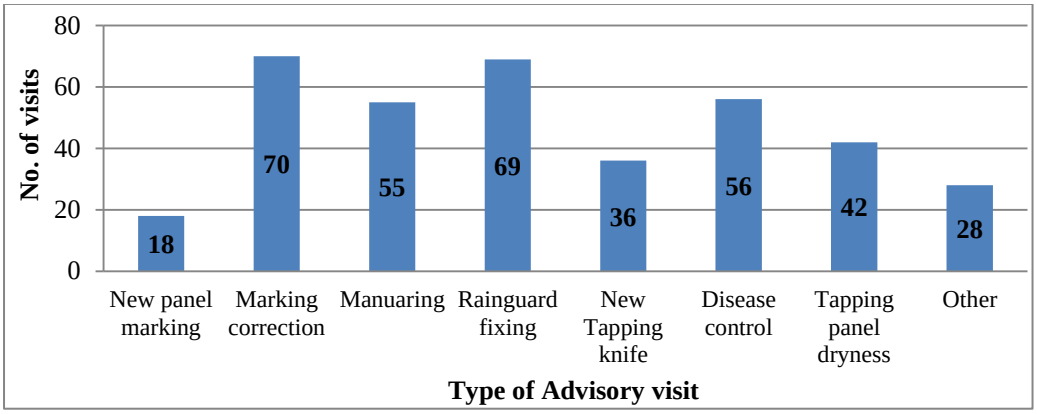


Fig. 9. Types of advisory visits conducted in mature holdings

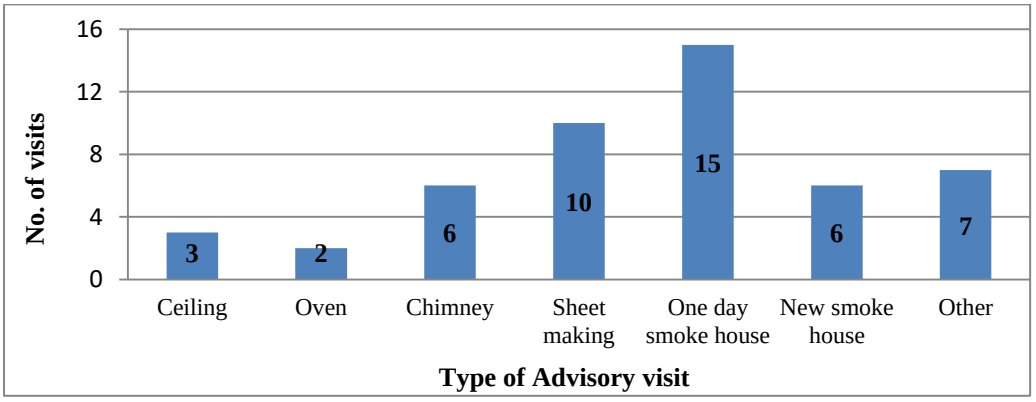


Fig. 10. Types of advisory visits conducted in RSS production centers

Project 9 (ASD/02/B) "Vihidum Sathkara": centrally planned special group advisory and extension programmes for smallholders in rubber growing areas

To meet the growing demand for advisory services, a group extension programme called "*Vihidum Sathkara"* was effectively conducted for 137 smallholdings in traditional rubber growing areas for necessary improvement (Table 10). A schematic representation of this activity is given in Figure 11.

Table 10. *Number of smallholdings that conducted Vihidum Sathkara programmes for rubber smallholders*

Region	**No. of lands (Vihidum Sathkara)**	
	Immature	**Mature**
Colombo/Gampaha	11	12
Kegalle	3	14
Kalutara	10	21
Ratnapura	18	24
Galle/Matara	14	10
Total	**56**	**81**

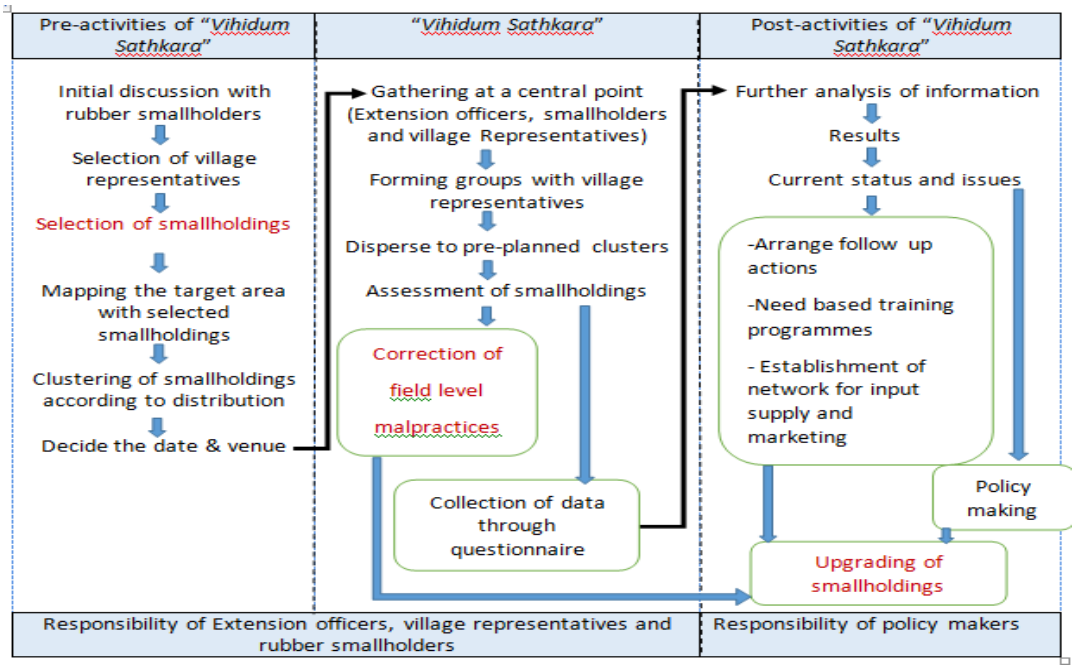


Fig. 11. Schematic representation of "Vihidum Sathkara" group advisory programme

Thrust area 03: Human resource development of all stakeholders in the rubber smallholder sector and estate sector

Project 10 (ASD/03/A) Awareness raising programmes

Fifteen awareness training programmes on general cultivation aspects of rubber were conducted to educate 203 rubber smallholders and 51 field staff of estates. Eighteen awareness training programmes on rainguards were conducted to educate 371 rubber smallholders and 40 estate staff (Figs. 12, 13 and 14). Participation from each estate for awareness programmes on general cultivation aspects of rubber and rainguard application are summarized in Tables 11,12 and 13.

Table 11. *Details of estate staff participation in Awareness programmes on general cultivation and processing aspects of rubber in the estate sector*

Name	No. of participants
Pelmadulla estate - Kahawatta Plantation (Field Officers)	24
Pelmadulla estate - Kahawatta Plantation (Field Officers)	11
Dumbara estate (Field Officers)	16
Total	**51**

Table 12. *Details of estate staff participation for Awareness programmes on rainguard in the estate sector*

Name	No. of participants
Pelmadulla estate	12
Dumbara estate	16
Ayre estate	12
Total	**40**

Table 13. *Details of farmer participation in Awareness programmes on general cultivation and processing aspects of rubber and rainguards in the smallholder sector*

Region	No. of programmes	No. of farmers trained	No. of programmes	No. of farmers trained
Kalutara	4	44	0	0
Galle	1	2	0	0
Kegalle	1	30	5	120
Rathnapura	6	127	10	251
Total	12	203	15	371

Fig. 12. Awareness and Training programme conducted for Field Officers at Palmadulla Estate Kahawatta Plantation

Fig. 13. Awareness and Training programme conducted for Field Officers on Low-Frequency Tapping at Palmadulla Estate, Kahawatta Plantation

Fig. 14. Conducting Rainguard awareness programme at Ampagala (Bulathkohupitiya REO range)

Project 11 (ASD/03/B) Mobile tapper training schools

As a solution to the tapper shortage in rubber growing areas, 02 Mobile Tapper Training programmes were conducted in Galle and Ratnapura Districts covering both practical and theoretical aspects and 23 and 37 new tappers from each distrct participated, respectively (Table 14).

Table 14. *Details of Tapper Training Programmes conducted for rubber tapper (smallholder sector)*

Region	No. of programmes	No. of new tappers trained
Galle	1	23
Ratnapura	1	37
Total	**2**	**60**

Project 12 (ASD/3/C) Skills development of rubber tappers

To upgrade the knowledge and skill levels of semi-skilled rubber tappers, skill development training programmes were conducted to improve the quality of tapping of 210 selected rubber tappers for the estate sector (Table 15) (Fig. 15 and 16).

Table 15. *Details of skill development programmes conducted for semi-skilled rubber tappers (Estate sector)*

Estate	No. of programmes	No. of semi-skilled tappers trained
Diddenipotha	1	35
Pelmadulla	1	48
Madolwitiya	1	07
Ayre	1	62
Sanquar	1	15
Parambe	1	43
Total	**06**	**210**

Fig. 15. Tapping skill development programme conducted at Parambe Estate – Kegalle Plantation

Fig. 16. Tapping skill development programme conducted at Palmadulla Estate – Kahawatta Plantation

Project 13 (ASD/3/D) Quality improvements of RSS

To improve the product quality of RSS produced by rubber smallholders, 04 training programmes were conducted for the benefit of 74 selected RSS producers in Kegalle, Ratnapura and Galle Districts (Table 16).

Table 16. *Details of Quality improvements of RSS programmes conducted for rubber smallholders*

Region	No. of programmes	No. of rubber smallholders trained
Kegalle	1	30
Ratnapura	2	42
Galle	1	2
Total	4	74

Project 14 (ASD/03/F) Involvement of REOs as resource personnel for other organizations

The following programmes were attended by REOs as resource personnel on requests made by different organizations (Table 17).

Table 17. *Details of the services provided by REOs*

Name of the programme	Organization	Number of programmes
Quality improvement of RSS (one day)	Thurusaviya Fund	04
Rainguard Awareness Programme (one day)	Thurusaviya Fund	07
Tapper Training School (seven days)	Thurusaviya Fund	05
Disease Control Programme (one day)	Thurusaviya Fund	02
Organic Fertilizer Awareness Programme (one day)	Thurusaviya Fund	05
Rainguard Awareness Programme (one day)	NIPM	07
Disease Control Programme (one day)	NIPM	02
Organic Fertilizer Awareness Programme (one day)	NIPM	02

Project 15 (ASD/03/G) Training Centre

The training center of the ASD is located in Nivitigalakale premises with accommodation facilities for 50 individuals and at present, capacity-building programmes are being conducted. Planned programmes couldn't be achieved due to the Covid 19 pandemic situation. However, three webinar programmes were organized *via* zoom technology on organic fertilizer application and new leaf disease (Fig. 16 and 17) for rubber smallholders and three inservice training programmes for REOs. Accomadation facilities were provided for NIPM diploma students. Three training programmes were conducted physically, successfully as follows;

1) Introduction and establishment of pasture in selected land of rubber smallholders in Kalutara District
2) In-serviceice training for REOs
3) Awareness programme on introducing rainguard for rubber smallholders in Kalutara District

Fig. 17. Webinar Flyer on Farmer Training on Organic Fertilizer

Fig. 18. Webinar Flyer on New Leaf Disease of Rubber Cultivation

Thrust area 03: Development of an effective extension network in the smallholder rubber sector

Project 16 (ASD/04/A) GIS based mapping for effective planning of extension programmes

GIS based mapping was in progress in relation to all field training and advisory programmes.

Project 17 (ASD/04/B) Rubber Techno Park at Monaragala Substation

Road constructions, establishment of technical banners and preparation of exhibition area in Techno Park at Monaragala substation were completed. Gliricidia cultivation unit was established at Technopark aiming cultivation, maintenance, processing and marketing aspects of Gliricidia. It consisted of following parts.

1) Establishment of Gliricidia demonstration plots

The land was prepared according to the recommended planting distances and agronomic practices. The proposed site was a "Deniya" land. So proper drainage system and several culverts were installed to facilitate the drainage.

2) Establishment of exhibition area on *Gliricidia* cultivation and related aspects

The main aim was to transfer the knowledge to farmers, school students, University students and the community about *Gliricidia* industry. Main areas focused:

- History of *Gliricidia* cultivation
- Present and future potentials
- Economic and environmental significance

Awareness through printed media (Rubber Puwath, leaflets *etc.)* and electronic media (DVD, Internet) will be conducted in this unit.

3) Preparation of *Gliricidia* for the market

This unit is in progress. Demonstrations will be conducted on stem cutting, chopping, drying and packaging to reflect on how *Gliricidia* is to be prepared for the market.

Project 18 (ASD/04/C) Introduction and establishment of pasture in selected land of rubber smallholders in Kalutara District

This project was started in 2021 with the collaboration of Milco Pvt Ltd. (Fig. 19). The objective of this study was to improve the livelihood of the rubber smallholder sector by introducing an extra income. Fourteen rubber smallholders participated for the project covering 12 acres.

Fig. 10. Harvesting of pasture grass in Kalutara District

Project 19 (ASD/04/D) Initiation of construction of the Technology Transfer Centre, Regional Office in Kegalle

The construction of the Technology Transfer Centre, Regional Office in Kegalle with indoor training facilities for 75 trainees was initiated. The objective of the establishment of this centre is to initiate capacity building programmes for rubber stakeholders in Kegalle, Kurunegala, Kandy and Matale Districts (Fig. 20).

Fig. 20. Initiation of construction of Technology Transfer Center, Kegalle – Regional Office

Project 20 (ASD/04/E) Certificates and tool awarding ceremony at Regional Office, Kegalle

After completion of the mobile tapper training school programme (10 days) conducted at Kegalle Regional Office of the ASD, trainee tappers were awarded certificates and tools for tapping with collaboration with Thurusaviya Fund (Fig. 21).

Fig. 21. Certificates and tools awarding ceremony at Regional Office, Kegalle

Project 21 (ASD/04/F) Distribution of mini scale effluent treatment plants and equipment among rubber smallholders

The collaboration research project named "usage of rubber effluent as source of fertilizer for short term crops" with raw rubber processing and soil and plant nutrition departments was initiated. The mini scale effluent treatment plants which are used to collect effluent under this project were distributed among the 15 rubber smallholders among Kegalle, Kalutara and Galle Districts (Fig. 22).

Fig. 22. Mini scale effluent treatment plants distributed among rubber smallholders

Project 22 (ASD/04/G) Reserch students

Two university students of the University of Colombo were assistant to carry out their undergraduate research.

Project 23 (ASD/04/H) Introduction and establishment of new fuelwood growing models in selected Lands of smallholder rubber farmers

This project is funded by the Food and Agriculture Organization under its strategic area "Promoting sustainable Biomass energy production and modern bio-energy technologies". The main objective of this project is to introduce a synergistic and strategic approach to establishing fuelwood species in smallholder rubber lands which assures a sustainable biomass energy production system while improving the livelihoods of smallholder rubber farmers. The Biometry section is involved in this project in designing and carrying out socio-economic surveys and constructing indices for the combined benefit and monetary advantage. The details of activities conducted during this year are presented in the review of the Advisory Services Department. This is a collaborative project between Advisory Services Department, Agricultural Economics Unit and the Biometry Section. The progress of this project is adversely affected by the Covid-19 endemic situation in 2021 as well.

RUBBER TECHNOLOGY AND DEVELOPMENT

Dilhara Edirisinghe

DETAILED REVIEW

Staff

Dr (Mrs) Dilhara G Edirisinghe, Head of the Department and Mrs U Aloka Weerasinghe, Research Officer were on duty throughout the year. Mr W D M Sampath, Senior Research Officer reading for PhD degree was on full-time study leave throughout the year.

Mrs Priyanthi Perera, Experimental Officer and Mr Mahesh Abhayawardena, Miss Ishani Jayaratne, Mr Nadun Tillekeratne, Miss Madushani Gunawardena and Mrs Nushara Nanayakkara Technical Officers were on duty throughout the year. Miss Gayathri Bhagyawedha, Technical Officer was on maternity leave from 15th September. Mr Indika Perera, Technical Officer resigned from the institute on 31st August.

Research students

Postgraduate students

- Mrs Hasara Samarasinghe (Research Officer, Polymer Chemistry Dept.), PhD student, University of Moratuwa continued her research project on "Development of property correlations for nitrosamine safe binary accelerator systems in sulfur vulcanized natural rubber" under the supervision of Dr (Mrs) D G Edirisinghe.
- W D M Sampath (Senior Research Officer, Rubber Technology & Development Dept.), PhD student, Wayamba University of Sri Lanka continued his research project on "Synthesis of nanographene and characterization of its composites based on natural rubber" under the supervision of Dr (Mrs) D G Edirisinghe.
- Ms Amali Weerakoon, PhD student, University of Sri Jayewardenepura continued her research project on "Synthesis of phenol formaldehyde resins and their adducts by utilizing the polyphenols from banana (*Musa paradaisica* L.) pseudostem for production of solid tyres" under the supervision of Dr (Mrs) D G Edirisinghe.
- Indika Perera, MPhil student, University of Sri Jayewardenepura continued his research project on "Modification of rigid polyurethane foam waste to develop blends with nitrile rubber for special applications" under the supervision of Dr (Mrs) D G Edirisinghe.
- Danushka Wijewardena, MPhil student, Uva Wellassa University of Sri Lanka continued his research project on "Rheological and mechanical properties of

ternary composites of thermoplastics and skim natural rubber" under the supervision of Dr Susantha Siriwardena and Dr (Mrs) D G Edirisinghe.

- A J M Vithanachchi, MPhil student, University of Sri Jayewardenepura, Sri Lanka initiated his research project on "Improvement of electrical insulation of rubber mats produced with NR/SBR blends using inorganic fillers" under the supervision of Dr (Mrs) D G Edirisinghe.
- Lakshman Samarakoon, MSc (Polymer Science and Technology), University of Sri Jayewardenepura completed his research project on "Evaluation of physico-mechanical properties of natural rubber and polystyrene-butadiene blended latex foam in continuous sheet manufacturing process" under the supervision of Dr (Mrs) D G Edirisinghe.

Undergraduate students

- T G K H Madushika, BSc (Palm and Latex Technology and Value Addition) undergraduate student, Uva Wellassa University of Sri Lanka conducted her research on "Development of oil palm fiber waste filled natural rubber composites" under the supervision of Dr (Mrs) D G Edirisinghe and Mrs U A Weerasinghe.

Webinars/Training/Conferences/Workshops/Meetings attended

Officer/s	Subject/Theme	Organization
DG Edirisinghe	A series of Zoom Meetings - Development of national competency standards for latex based product manufacturing technician	Manufacturing & Engineering Services Industry Skills Council in collaboration with National Apprentice and Industrial Training Authority (NAITA)
	Zoom Meeting - Rubber industry development	Ministry of Plantation Industries (MPI)
	Meetings - Editorial, Seminars, Workshops and Image Building Committee	Plastics & Rubber Institute of Sri Lanka (PRISL)
	Two Advisory Committee Meetings on Rubber, Rubber Products and Plastics	Export Development Board (EDB)
	Virtual discussion - Institutional IP Policy Support - Sri Lanka	World Intellectual Property Office (WIPO) in collaboration with Coordinating Secretariat for Science, Technology & Innovation (COSTI)
	2nd National Symposium on Sustainable Plantation Management	National Institute of Plantation Management (NIPM)
	Workshop on Action Plan 2021	MPI

Officer/s	Subject/Theme	Organization
DG Edirisinghe	Meeting - Development of Rubber Cultivation and related Industries in Sri Lanka	MPI
DG Edirisinghe & UA Weerasinghe	Webinar- Rubber compound processability and curing characteristics determination	TechnoBiz Lanka
	Webinar - Testing material possibilities for the tyre industry	ZwickRoell Pvt. Ltd., India
	Two Webinars - Customer Discovery and Industry Engagement, Creative Business Development: Value Propositions for Customer Segments that Open Doors and Opportunities	WIPO
	Three Day Virtual Workshop on "Technological Advancements for Latex Rubber Product Manufacturing"	EDB, PRISL & Sri Lanka Association of Manufacturers and Exporters of Rubber Products (SLAMERP)
	Webinar - Mechanical Testing	Hemsons International (Pvt.) Ltd.
	Scientific Committee Meeting	Rubber Research Institute of Sri Lanka (RRISL)
	Webinar - Basics of Intellectual property rights	Council for Agricultural Research Policy (CARP)
	Webinar - The Art of Writing a Research Policy Brief	CARP
DG Edirisinghe, WDM Sampath, UA Weerasinghe & KIDP Perera	Commencement Webinar & three Zoom Meetings - EIE Remote Mentorship Program for IP and Technology Support (Mentor - Dr. Cheryl McCaffery, WIPO)	WIPO in collaboration with COSTI
DG Edirisinghe, UA Weerasinghe WDM Sampath & Mahesh Abhayawardena	Sri Lanka Polymer Research Forum 2021 *via*. Zoom	TechnoBiz, Lanka in collaboration with TechnoBiz, Thailand
UA Weerasinghe	Webinar - Oscillatory Rheometry: How to Measure Curing Samples at the Kinexus Rotational Rheometer	NETZSCH
	Awareness of Good Laboratory Practice (GLP)	Sri Lanka Accreditation Board (SLAB)
	Webinar - Accreditation Awareness Programme	SLAB

Officer/s	Subject/Theme	Organization
UA Weerasinghe	Webinar - Polymer Testing: Going Advanced with Extra Flexibility	PerkinElmer
UA Weerasinghe & Madushani Gunawardena	Training Program on "Material Selection, Characterization and Significance on Rubber Compounds"	TechnoBiz Thailand in collaboration with TechnoBiz Lanka
DG Edirisinghe, WDM Sampath & UA Weerasinghe	The first awareness Workshop on Patenting for Scientists, Researchers & Innovators	National Science Foundation (NSF) in collaboration with National Intellectual Property Office (NIPO)
UA Weerasinghe, Mahesh Abhayawardena & Madushani Gunawardena	Skill Development of Use of Advanced Excel Techniques	NIPM
WDM Sampath UA Weerasinghe	Workshop on "Electron Microscopy - Part I" *via*. Zoom	Dept. of Chemistry University of Colombo

Lectures/Webinars/Conferences/Training/Workshops conducted

Officer/s	Subject/Theme	Beneficiary/Client
DG Edirisinghe	Sri Lanka Polymer Research Forum-Presentation on "Rubber Research Developments at Rubber Research Institute of Sri Lanka"	TechnoBiz, Lanka in collaboration with TechnoBiz, Thailand
WDM Sampath	Compounding ingredients used in dry rubber	Students of the Certificate Course in Rubber Technology - PRISL
	Raw materials for monomers and polymers	Students of the Certificate Course in Rubber Technology - PRISL
	Structure and property relationship of polymers	Students of the Certificate Course in Rubber Technology - PRISL
	Synthetic rubbers and their properties (dry rubber and latex)	Students of the Certificate Course in Rubber Technology - PRISL
	Rubber coated textiles	Students of the Certificate Course in Rubber Technology - PRISL
KIDP Perera	Compound formulations and processing techniques	Students of the Certificate Course in Plastics Technology - PRISL
UA Weerasinghe	Microbial activities on latex and their effects	Students of the National Diploma in Plantation Crop Technology – Rubber Processing – NIPM
	Miscellaneous Latex Products	Students of the Certificate Course in Rubber Technology - PRISL
	Latex technology -vulcanization	Students of the Diploma Course in Rubber Technology – PRISL

Officer/s	Subject/Theme	Beneficiary/Client
UA Weerasinghe	Vulcanizing systems of different latex films	Students of the Diploma Course in Rubber Technology - PRISL
	Natural rubber latices - Manufacturing processes	Students of the Certificate Course in Rubber Technology - PRISL
	Compounding Ingredients used in Latex Industry	Students of the Certificate Course in Rubber Technology - PRISL
	Vulcanization and Vulcanization Properties (Dry Rubber)	Students of the Certificate Course in Rubber Technology – PRISL
	Rubberized-coir Products	Students of the Certificate & Higher National Diploma Courses in Rubber Technology - PRISL
Staff of the department	Practical demonstration on "Latex based and dry rubber based products manufacture" at RRISL, Ratmalana	BSc (Agri. Sp.) undergraduates of the Department of Plantation Management, Wayamba University of Sri Lanka
	Field training on "Rubber Technology"	Undergraduate students of Palm & Latex Technology and Value Addition - Uva Wellassa University
	Field training on "Rubber Technology"	Undergraduate students of Dept. of Agricultural Technology, Faculty of Technology, University of Colombo

LABORATORY INVESTIGATIONS

Dry rubber technology

Development of natural rubber composites with nano materials

(a) Synthesis of micro size oil palm fibers and development of natural rubber composites with the synthesized micro-fibers

Natural fiber based rubber composites attract greater attention due to the concern of the global community in the path towards green technology. Different types of natural fiber based rubber composites such as coconut husk, banana stem, areca nut husk, pineapple crown, *etc*. have been studied in order to replace the existing hazardous filler materials which can cause human as well as environmental issues in the long run. In this study, mesocarp part of the oil palm fruit fiber (OPF) which is generated as a waste material in palm oil processing industry was used as the green filler in the natural rubber (NR) composites. Chemical and mechanical treatments were conducted on the OPF for removal of excess oil and particle size reduction. Thereafter, five NR composites C1, C2, C3, C4 and C5 were prepared with 2 phr loading of OPF from each size range as given in Table 1 and the effect of the size of OPF on physico-mechanical and ageing properties was evaluated. A control

NR composite (C0) was prepared by incorporating carbon black similar to the amount of OPF in the five NR composites and properties of the C0 composite were compared with those of the NR composites prepared with OPF.

Table 1. *OPF size ranges of the NR composites*

NR composite	Range of OPF size (μm)
C1	250-350
C2	125-175
C3	75-125
C4	25-75
C5	below 50

Tensile strength of the composites prepared with OPF is higher than that of C0 and the highest tensile strength is shown by the composite C2 (24.36 MPa) (Fig. 1). This could be due to orientation of the OPF in the NR matrix when a tensile force is applied. However, elongation at break of the composites prepared with OPF is lower than that of C0 (Fig. 2) as fibers impose resistance to stretching. As expected, tensile strength of all six NR composites has increased after ageing probably due to formation of more crosslinks at extended periods of heating.

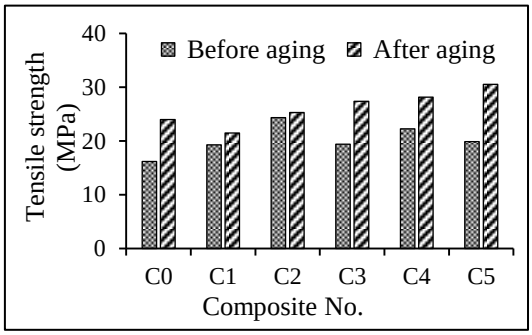


Fig. 1. Tensile strength of NR vulcanizates

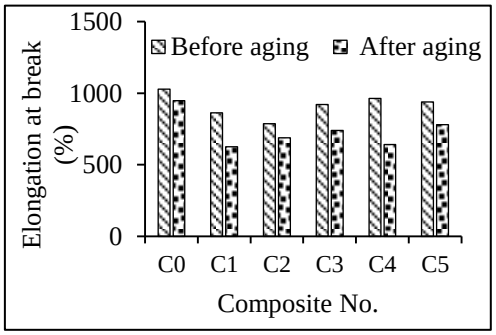


Fig. 2. Elongation at break of NR vulcanizates

Hardness (Fig. 3) and water absorption (Fig. 4) of the composites prepared with OPF are also greater than those of C0. Increase in hardness can be attributed to strong and stiff nature of fibers. Higher water absorption due to hydrophilic nature of OPF indicates a greater cooling effect for the NR composites prepared with the same. A research paper was presented at the International Conference, IRCUWU 2021 organized by the Uva Wellassa University of Sri Lanka.

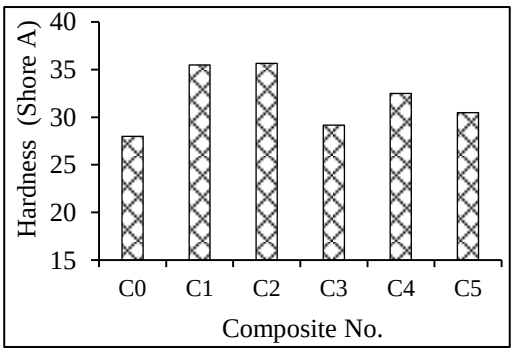


Fig. 3. Hardness of NR vulcanizates

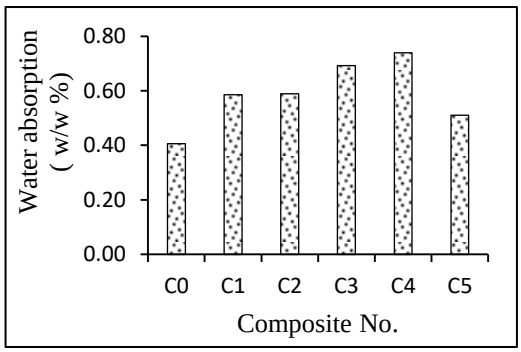


Fig. 4. Water absorption of NR vulcanizates

(U A Weerasinghe, D G Edirisinghe and T G K H Madushika – BSc (Palm & Latex Technology and Value Addition) undergraduate student, Uva Wellassa University of Sri Lanka.

(b) Synthesis of polyethylene glycol-grafted graphite and its effect on properties of natural rubber composites

Modified graphite has attracted considerable interest over recent years due to its surface functionality and better dispersibility with polymeric materials. Incorporation of a small quantity of modified graphite filler into polymer can create novel composites with improved properties. In this study, polyethylene glycol (PEG) was grafted onto the graphite surface in the presence of maleic anhydride (MAH). The PEG-grafted graphite (PEG-g-Graphite) was characterized *via*. fourier transform infrared spectroscopy (FTIR), X-ray diffraction spectroscopy (XRD), thermogravimetric analysis (TGA), and scanning electron microscopy (SEM), and the analysis proved that PEG was successfully grafted onto the graphite surface. Subsequently, natural rubber (NR) composites were prepared by varying PEG-g-Graphite loading from 2 phr to 10 phr at 2 phr intervals and properties were evaluated according to ISO and ASTM standards.

Figure 5 shows the comparison of FTIR spectra between graphite and PEG-g-Graphite. Graphite powder indicates a peak at 1766 cm^{-1}, which is the stretching vibration of aromatic C=C bond. Further, asymmetrical and symmetrical stretching vibrations of C-H bonds which belong to the PEG molecular chain are observed at 2935 and 2915 cm^{-1}. In addition, the peak at 1028 cm^{-1} is attributed to the stretching vibration of C-O-C bond in the ester groups of PEG-g-Graphite owing to the reaction of hydroxyl group with MAH. Hence, FTIR results suggest that PEG molecules are chemically grafted to the graphite through esterification reaction with the MAH coupling agent. XRD patterns of graphite and PEG-g-Graphite are shown in Figure 6.

Graphite powder shows a characteristic peak at $2\theta = 26.6^{o}$. When PEG is grafted to graphite, the graphitic peak shifts to $2\theta = 26.73^{o}$. In addition, two extra narrow peaks have appeared at $2\theta = 23.65^{o}$ and $2\theta = 31.36^{o}$ due to grafting PEG via the MAH. In addition, graphite shows two other very low peaks at $2\theta = 44.65^{o}$ and $2\theta = 54.67^{o}$. However, these peaks are shifted to $2\theta = 44.08^{o}$ and $2\theta = 54.54^{o}$, respectively due to incorporation of PEG. The surface morphologies of the graphite and PEG-g-Graphite were studied using SEM images shown in Figure 7. As seen in this figure 7(a), graphite looks like a thin "petal" flake with a typical lamella structure in which graphene layers are not distinguishable. Further, graphite surface has not shown improved adhesion among the graphite particles. However, in PEG-g-Graphite (Fig. 7(b), graphite surface dispersibility and homogeneity have been improved. The PEG-g-Graphite sample was assessed *via*. TGA (Fig. 8) for confirmation of the success of grafting. On the basis of the results, graphite exhibited no significant weight loss up to 600 ˚C. However, two weight loss stages are observed in PEG-g-Graphite after its modification. The primary mass loss of the grafted samples is indicated in the temperature range of 120-205 ˚C, which is assigned to the degradation of grafted MAH molecules. The major weight loss of grafted sample has occurred at the temperature range approximately between 205-400 ˚C, which originates from the grafted PEG chain.

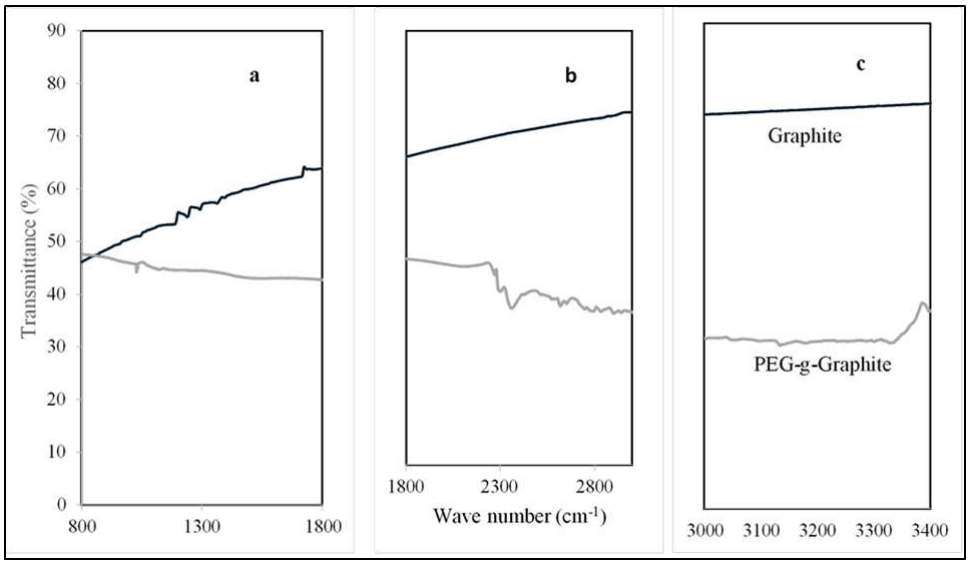


Fig. 5. FTIR spectra of Graphite and PEG-g-Graphite for different regions **a)** 800 to 1800 cm^{-1} **b)** 2000 to 3000 cm^{-1} **c)** 3000 – 3400 cm^{-1}

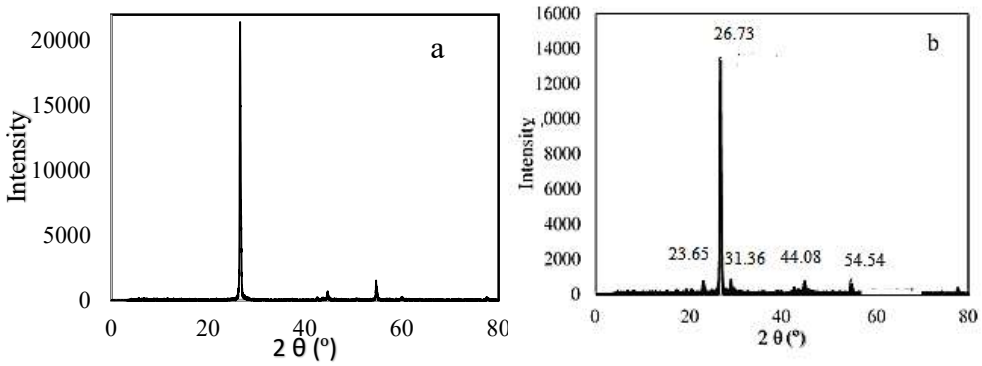


Fig. 6. XRD diffractogram of **a)** Graphite **b)** PEG- g-Graphite

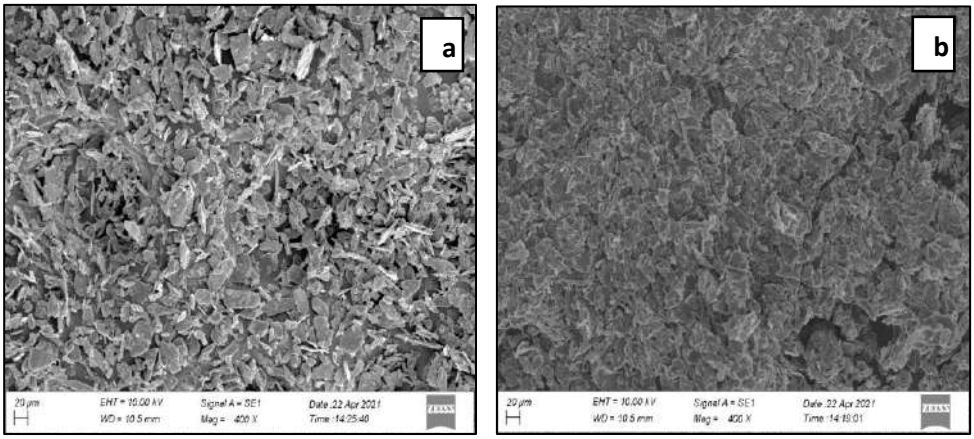


Fig. 7. SEM images of surface of (a) graphite and (b) PEG-g-graphite

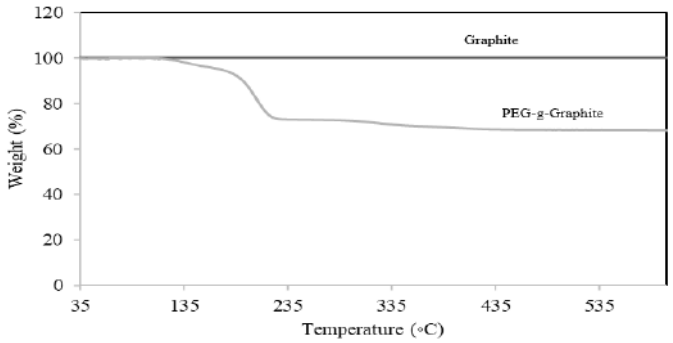


Fig. 8. TGA curves of graphite and PEG-g-graphite

Figure 9 shows the stress-strain behaviour of NR composites prepared with and without PEG-g-Graphite. Most of the composites prepared with PEG-g-Graphite show higher stress-strain properties compared to the control. Hardness of NR composites at different PEG-g-Graphite loadings is shown in Table 2. Hardness of all the composites varies within the range 40-45 IRHD. Hardness of all composites prepared with PEG-g-Graphite is slightly higher than that of the control. The composite prepared with 10 phr loading of PEG-g-Graphite showed the highest hardness and it could be due to the high crosslink density. According to Table 2, 10 phr PEG-g-Graphite loaded composite displays the highest tensile strength as PEG has generated better interactions with the polymeric material. In addition, PEG has been used as a dispersant and toughening agent to enhance the compatibility between the filler and polymeric material. Moreover, elongation at break of the composites has also increased with the addition of PEG-g-Graphite (Table 2). The reason for this increment could be better dispersibility of PEG-g-Graphite material in the NR matrix. Tear strength of the composites is in the range 36 - 39.7 N/mm (Table 2) and, tear strength at 8 phr loading of PEG-g-Graphite composite is the lowest possibly due to the weak interface, which exists between NR and PEG-g-Graphite. Furthermore, the control composite has indicated the highest resilience (Table 2) due to absence of PEG-g-Graphite as the filler material. However, there is no significant difference in resilience between the PEG-g-Graphite composites and the control.

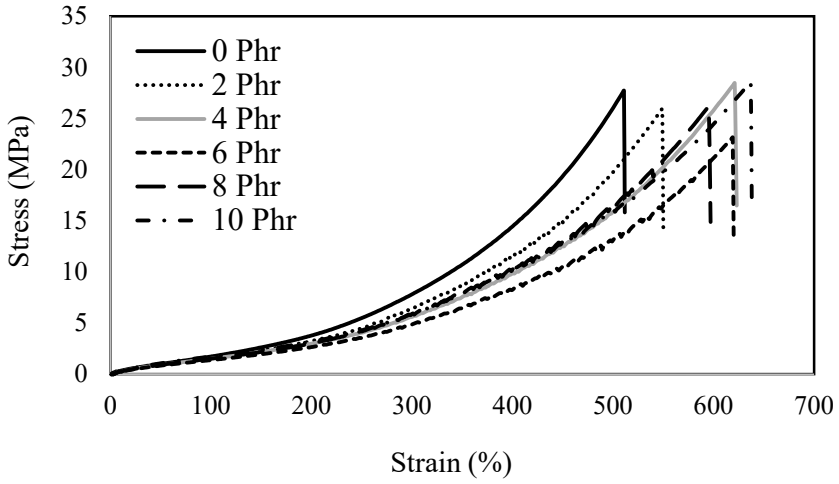


Fig. 9. Stress-strain properties of PEG-g-Graphite/NR composites

Sheet resistance of PEG-g-Graphite filled NR composites varies from 3879.58 x 10^5 to 2 x 10^5 ohms/square as shown in Table 3. Sheet resistance of a material is directly proportional to its resistivity. The composites prepared with PEG-

g-Graphite have shown lower sheet resistance than the control. Hence, PEG-g-Graphite composites express better electrical conductivity.

Table 2. *Physico-mechanical properties of PEG-g-Graphite/NR composites*

Property	**PEG-g-Graphite loading (Phr)**					
	0	**2**	**4**	**6**	**8**	**10**
Hardness (IRHD)	40	42	43	43	44	45
Tensile strength (MPa)	27.5	25.5	27.9	23	24.7	28.6
Modulus at 100% elongation (MPa)	0.9	1	0.9	0.9	1	1.1
Modulus at 300% elongation (MPa)	2.1	2.8	2.3	2	2.4	2.3
Elongation at break (%)	509	546	631	618	602	637
Tear strength (N/mm)	37.8	39.7	38.8	39.6	37.0	38.8
Resilience (%)	76	75	74	73	73	73

Table 3. Sheet resistance of PEG-g-Graphite/NR composites

Property	**PEG-g-Graphite loading (Phr)**					
	0	**2**	**4**	**6**	**8**	**10**
Sheet resistance ($x10^5$) (ohms/square)	3879.58	2.10	2.08	2.03	2.00	2.00

In overall, the composite prepared with 10 phr loading of PEG-g-Graphite exhibits better physico-mechanical properties in terms of hardness, tensile strength and elongation at break. Uniform dispersion of the 10 phr loading of PEG-g-Graphite in the NR matrix is indicated by the enhancement in the above properties. PEG-g-Graphite composites show a remarkable improvement in electrical conductivity compared to the insulated NR composite (control). It is concluded that the composite prepared with 10 phr loading of PEG-g-Graphite is suitable as an electrical conductive polymer composite in electronic applications (W D M Sampath, D G Edirisinghe and C A N Fernando - Professor, Head/Dept. of Nano Science Technology, Wayamba University of Sri Lanka).

Latex technology

Development of natural rubber latex films with natural colouring materials

Synthetic colouring materials are generally used in latex based products manufacture. Food grade synthetic colouring materials are used in rubber products such as toys, infant/baby items, rubber products in contact with food, *etc*., which require the use of non-toxic materials, however these are expensive. At the request of a small scale latex based product manufacturer, possibility of replacing these synthetic colouring materials with extracts of readily available plant-based natural materials was assessed. A series of natural rubber latex based cast films was

produced with extracts of twelve plant-based natural materials. Storage properties of the cast films were evaluated. Five of these natural materials gave promising results in terms of colour as shown in Figure 10.

Fig. 10. Natural rubber latex based cast films of different colours produced using five natural materials

(D G Edirisinghe, U A Weerasinghe, Ishani Jayaratne and Nushara Nanayakkara)

Industrial extension

The following properties of materials were tested and test reports were issued to the respective companies/government organizations at their request.

Sole Crepe Hardness	**Rubber Compound** Physico-mechanical properties	**Rubber Product** Physico-mechanical properties	**Polythene** Tensile and ageing properties
• Atale estate, Kegalle Plantations	• John Keels Research	• Torintain of Engineering	• Rubber Development Department
• Elston estate, Pussellawa Plantations Ltd.	• University of Ruhuna	• Busan Dipping Ko- Lanka (Pvt.) Ltd.	• Lalan Rubbers (Pvt.) Ltd.
• Panawatte estate, Kelani Valley Plantations Plc	• Microcells (Pvt.) Ltd.	• Ferentino Tyre Corporation	

Sole Crepe Hardness	**Rubber Compound** Physico-mechanical properties	**Rubber Product** Physico-mechanical properties	**Polythene** Tensile and ageing properties
• Dewalakanda Estate, Kelani Valley Plantations Plc.	• University of Peradeniya	• Quality Latex Products (Pvt.) Ltd.	
	• Unison Enterprises		
	• Acna Industries		
	• Morex Lanka (Pvt.) Ltd.		
• Almar International (Pvt.) Ltd.	• Dulanka International (Pvt.) Ltd.		
	• Shamini Rubber Industries (Pvt.) Ltd.		
	• Lal Tyre Retreaders (Pvt.) Ltd.		
	• Samson Compounds (Pvt.) Ltd.		
	• Udaya Industries		
	• David Peiris Motor Co.(Lanka) Ltd.		
	• Shiran Rubber Industries (Pvt.) Ltd.		
	• Champion Recycle (Pvt.) Ltd.		
	• D. Samson Industries (Pvt.) Ltd.		
	• Richard Peiris Rubber Products Ltd.		
	• Bombuwala Rubber Mills (Pvt.) Ltd.		
	• Nethchem Colour Works Lanka (Pvt.) Ltd.		

Development of rubber compounds/products

The following rubber compound/product developments were conducted on requests made by the respective clients.

Development	Client
Rubber compound for cable guide of motor cycles	Shamini Rubber Industries/David Pieris Motor Company
Rubber compound for a bio-medical item	R.A.P. Engineering (Pvt.) Ltd.
Rubber compound for brake pads of bicycles	Acna Industries (Pvt.) Ltd.
NR based micro-cellular sheet	Entrepreneur
Rubber compound for brake washers	Lucky Trading (Pvt.) Ltd.
Natural rubber latex based fishing bait	National Aquatic Resources Research & Development Agency (NARA)
Natural rubber latex based compound to bind rubber waste	Samson International Plc.

POLYMER CHEMISTRY

Y R Somarathna

DETAILED REVIEW

Staff

Mr Y R Somarathna, Research Officer covered up the duties of the Head of Department of Polymer Chemistry Department throughout the year. Mrs I H K Samarasinghe, Research Officer resumed duties on 2nd July 2021 after completing three years of study leave period which was granted to conduct her post graduate studies at University of Moratuwa. Dr Ravindra Alles assumed duties as Senior Research Officer at the department with effect from June, 2021. Mrs Nirmala Jayawardena, Experimental Officer was on duty throughout the year. Mrs H M H Dhanukamalee, Mrs P S V Rupasinghe, Mr D V D Mallikaarachchi and Ms H L T Tharaka; Technical Officers were on duty throughout the year. Mr N W E Chanu Maduranga, Management Assistant was on duty throughout the year.

Research students

- Ms E D S Edirisinghe, undergraduate student from Uva Wellassa University of Sri Lanka conducted her final year industrial project entitled 'the effect of silane coupling agents on physical, mechanical and thermal properties of natural rubber mica (NR/Mica) composites' under the supervision of Mr Y R Somarathna.
- Ms I S Jayasooriya, undergraduate student from Wayamba University of Sri Lanka conducted her final year industrial project entitled 'Study of nano and micro particle loading of waste mica on NR composites' under the supervision of Mr Y R Somarathna.
- Ms J M M I Hemachandra, undergraduate student from Uva Wellassa University of Sri Lanka conducted her final year industrial project entitled 'surfactant-assisted synthesis and characterization of mica nanosheets for latex applications' under the supervision of Mr Y R Somarathna.

Lectures/Seminars/Webinars/Training/Workshops/Conferences conducted

Officer/s	Subject/Theme	Beneficiary/Client
YR Somarathna	Value added natural rubber grades	Students of Advance Certificate Course in Plantation Management, National Institute of Plantation Management
	Manufacturing of concentrated latex	Students of Advance Certificate Course in Plantation Management, National Institute of Plantation Management

Officer/s	Subject/Theme	Beneficiary/Client
YR Somarathna	Introduction to rubber compounding ingredients and their applications	Students of Diploma course in Dry Rubber Technology, Plastic Rubber Institute, Sri Lanka
YR Somarathna Nirmala Jayawardena	Adhesive manufacturing Workshop	Small and medium scale entrepreneurs

Lectures/Seminars/Webinars/Training/Workshops/Conferences/Meetings attended

Officer/s	Subject/Theme	Organization
YR Somarathna	Scientific Committee Meeting	Rubber Research Institute of Sri Lanka
	Steering Committee Meetings	Finite Elemental Analysis and Simulation Centre, and Plastic Rubber Institute
	Workshop on Value-added products from Sri Lanka carbonate deposit	Postgraduate Institute of Science, University of Peradeniya
	The First Awareness Workshop on Patenting for Scientists, Researchers, and Innovators	National Science Foundation and National Intellectual Property Office
	Webinar on research idea generation	SLCARP
	Webinar on the art of writing a research policy brief	SLCARP
	Webinar on how to make your career a success story	SLCARP
IHK Samarasinghe	Moratuwa Engineering Research Conference (MERCon 2021)	University of Moratuwa
	Workshop on Advanced Instrumental Techniques and Future Advanced Materials	University of Moratuwa
	Workshop on Skill Development of Use of Advance Excel Techniques	NIPM
	Webinar on The Art of Writing a Research Policy Brief	SLCARP
	Webinar on Testing Material Possibilities for the Tyre Industry	Plastic Rubber Institute

Officer/s	Subject/Theme	Organization
IHK Samarasinghe	Short online awareness Program on "obtaining accreditation to the Laboratories"	Sri Lanka Accreditation Board (SLAB)
	Sri Lanka Polymer Research Forum	TechnoBiz Lanka
	The First Awareness Workshop on Patenting for Scientists, Researchers, and Innovators	National Science Foundation and National Intellectual Property Office

LABORATORY INVESTIGATIONS

Development of property correlations for nitrosamine safe binary accelerator systems in sulfur vulcanized natural rubber

The use of nitrosamine free diisopropyl xanthogen polysulfide (DIXP) and nitrosamine safe tetrabenzyl thiuramdisulfide (TBzTD), zinc dibenzyl dithiocarbamate (ZBeC) and N-tert-butyl-2-benzothiazole sulfenamide (TBBS) as single accelerators in efficient sulfur vulcanization of NR was compared in terms of cure properties, crosslink density and physico-mechanical properties.

Cure characteristics

The results reveal that the accelerator type noticeably influences the cure behavior of the compounds (Fig. 1. and Table 1). Minimum torque (S′ min) generally relates to the viscosity of uncured compound whereas maximum torque (S′ max) corresponds to the stiffness and shear modulus of vulcanized rubber and indicates the state of crosslinking. Nitrosamine free DIXP and the nitrosamine safe ZBeC show lower S′ max values compared to nitrosamine safe TBzTD and TBBS accelerators indicating an unsatisfactory state of crosslinking of the compounds. Delta cure [S′ max - S′ min] is an indication of the crosslink density of the vulcanizates and observed values for compounds prepared with TBBS and TBzTD accelerators are higher than those of the compounds prepared with ZBeC and DIXP accelerators. This indicates a higher crosslink density for the compounds accelerated with sulphenamide and thiuram based nitrosamine safe accelerators compared to xanthogen and dithiocarbamate accelerators.

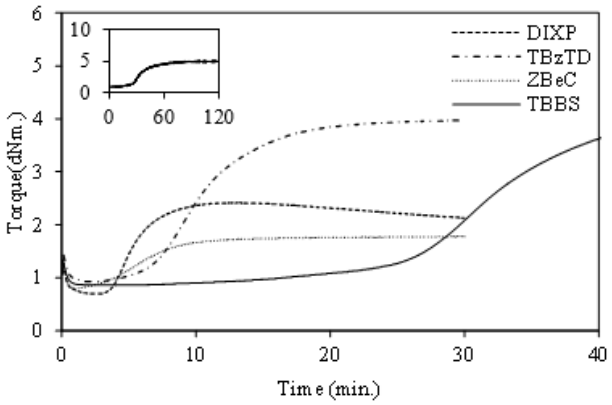


Fig. 1. Rheographs of NR compounds prepared with different types of accelerators (complete rheograph for TBBS accelerator is given separately in the Figure)

Table 1. *Effect of accelerator type on cure characteristics of the NR compounds*

Accelerator type	Cure characteristics				
	ts_2 *(min)*	t_{90} *(min)*	*S'min (dNm)*	*S' max (dNm)*	*Delta cure (dNm)*
DIXP	-	10.0±0.7	0.7±0.0	2.2±0.1	1.5±0.1
TBzTD	11.7±0.6	16.1±0.5	1.1±0.1	4.1±0.1	3.0±0.1
ZBeC	-	11.6±0.5	0.9±0.0	1.9±0.1	1.1±0.1
TBBS	33.4±0.4	58.0±1.4	0.7±0.0	5.3±0.1	4.6±0.1

Scorch time (ts_2), also known as premature vulcanization time is an important characteristic feature of the vulcanization process. In this study, commonly used TBBS indicates the longest scorch time while TBzTD exhibits significantly a shorter ts_2 value compared to TBBS. However, ts_2 for DIXP and ZBeC accelerated compounds was not observed as maximum torques of those compounds do not increase above two units of the minimum toque. This observation may be attributed to the use of lower levels of sulfur in this experiment. Optimum cure time (t_{C90}) is a measurement of time that required to achieve 90% cure and among four accelerators studied, DIXP exhibits the lowest t_{C90} which would be extremely beneficial for industrial applications such as jar rings, oil seals and O-rings.

Crosslink density and physico-mechanical properties

Crosslink densities ($\times 10^5$, $molcm^{-3}$) for the four different types of vulcanizates are as follows; DIXP (1.78±0.07), TBzTD (5.14±0.10), ZBeC (2.83±0.64) and TBBS (8.09±0.23). A significant variation was detected even though similar loadings of the accelerator and sulfur were used in the formulation. This is

probably due to the contribution of different mole amounts and the chemical reactivities of the accelerators, to the crosslinking reaction rather than that of the mass. Molecular weight of each accelerator is 335 $gmol^{-1}$ for DIXP (as tetrasulfide), 554 $gmol^{-1}$ for TBzTD, 610 $gmol^{-1}$ for ZBeC and 238 $gmol^{-1}$ for TBBS. Therefore, the corresponding mole amounts of the above accelerator used in this study are 5.97×10^{-3}, 3.61×10^{-3}, 3.27×10^{-3} and 8.40×10^{-3} respectively. In the present study, commonly used TBBS shows the highest crosslink density followed by TBzTD, ZBeC and DIXP. This could be due to its ability of providing sufficiently higher moles of accelerators to produce active sulfurating agents (Fig. 3. (c)) and the subsequent formation of crosslinks. Although DIXP provides comparatively higher number of moles of accelerators than TBzTD and ZBeC, it shows the lowest crosslink density indicating its lower activity compared to the other accelerators. According to literature, TMTD, a thiuram disulfide has shown superior degree of crosslinking compared to TBBS which may be due to its sulfur donor ability and efficient utilization of sulfur during vulcanization. However, from the results of this study, it appears that although TBzTD is a thiuram type accelerator, crosslink density provided by TBzTD, is lower than that of TBBS accelerator. The observation could be related to its lower contribution of mole amount and as well to the steric hindrance created by the two bulky benzyl groups attached to the thiuram nitrogen. Though ZBeC and TBzTD provide almost similar number of moles, ZBeC accelerated vulcanizate shows comparatively lower value for crosslink density compared to TBzTD and it is probably be due to the contribution of sulfur donor activity of the thiuram disulfide accelerator.

Table 2 shows the average values of physico-mechanical properties observed for the vulcanizates prepared with different types of accelerators. TBBS accelerator yields the highest tensile strength and tear strength to the vulcanizate followed by TBzTD, ZBeC and DIXP, and the observed variation is in accordance with the crosslink density variation as determined by the equilibrium swelling data.

As expected, vulcanizate formulated with TBBS possesses the lowest elongation at break which also agrees with its crosslink density, *i.e.*, when crosslink density increases, the network structure consists of greater number of short inter crosslink chains, resulting in an increase of the restriction on the mobility of inter crosslink chains. Vulcanizates prepared with TBBS and TBzTD possess higher modulus and tear strength in comparison to vulcanizates prepared with DIXP and ZBeC (Table 2). This could be attributed to both TBBS and TBzTD providing greater crosslink density to the vulcanizate.

Table 2. *Effect of accelerator type on physico-mechanical properties and crosslink density of NR vulcanizates*

Accelerator type	Tensile strength (MPa)	Modulus at 300% elongation (MPa)	Elongation at break (%)	Tear strength (N/mm)	Hardness (Shore A)	Crosslink density $\times 10^5$ (molcm^3)
DIXP	5.5±0.4	0.64±0.01	888±4	7.2±0.3	15	1.78±0.07
TBzTD	9.2±0.5	1.12±0.03	733±8	13.0±0.6	30	5.14±0.10
ZBeC	8.4±0.8	0.87±0.06	665±28	9.1±0.4	28	2.83±0.64
TBBS	18.0±1.0	1.41±0.09	641±12	16.1±0.3	28	8.09±0.23

It is apparent from Table 2 that hardness of the vulcanizate also depends on the accelerator type. DIXP accelerator imparts the lowest hardness to the NR vulcanizate due to insufficient crosslinks in the three-dimensional network structure. Generally, hardness of NR vulcanizate follow a linear increasing trend with the increment of crosslink density. However, the observed values for hardness of vulcanizates prepared with TBzTD and ZBeC does not in agreement with that of the variation of crosslink density of the vulcanizates. Further, it was observed, vulcanizate containing ZBeC possesses comparable hardness to that of the TBBS accelerated vulcanizate, although the former vulcanizates possess lower crosslink density compared to the latter. In addition, it is noted that TBzTD provides the highest hardness among the four different types of accelerators studied in this experiment (I H K Samarasinghe, D G Edirisinghe, S Walpalage and S M Egodage-Senior Lecturers, Dept. of Chemical and Process Engineering, University of Moratuwa).

Effect of bis-(3-triethoxyslylpropyl)-tetrasulfide and polyethylene glycol on the properties of natural rubber/mica composite

The bis[3-(triethoxysilyl)propyl]tetrasulfide, commonly known as Si-69 is a widely employed coupling agent to enhance the compatibility between silica fillers and rubbers. This study aims to assess the effect of different combinations of bis[3-(triethoxysilyl)propyl]tetrasulfide and polyethylene glycol (PEG) on cure characteristics, physical and mechanical properties of natural rubber filled mica composites. The mica loading was kept constant at 30 phr. Three types of composites were made by varying the Si-69 to PEG ratio as 1:0 (SP10), 0:1 (SP01), and 1:1 (SP11) maintaining the Si69/PEG content at 2 phr. A composite free from Si-69/PEG was used as the control (SP00).NR/mica composites were prepared according to a standard rubber compounding formula.

According to curing characteristics shown in Table 3, the highest optimum cure time (t_{C90}) and the scorch time (t_{s2}) are observed in SP10. Usually, in the absence of surface treatment of silica fillers, there is a high possibility of adsorption of curatives on silica surfaces through silanol groups leading to the optimum t_{Cs90} and the best scorch safety (t_{s2}). However, it is interesting to note that the application of PEG in SP01 and SP11 has reduced t_{C90} and t_{s2}.

Addition of either Si-69 or PEG or combination of both does not affect both maximum torque (M_H) and minimum torque (M_L) values. Therefore, it infers that use of these ingredients do not affect in formation of crosslinks.

Table 3. *Curing characteristics of NR/mica compounds*

Sample name	**T_{90} (min)**	**T_{S2} (min)**	**M_H (dNm)**	**M_L (dNm)**	**ΔM (M_H - M_L)(dNm)**
SP00	6.91	3.76	10.25	1.81	8.44
SP01	4.17	1.99	10.38	1.91	8.47
SP10	13.03	6.54	10.92	1.52	9.40
SP11	5.63	3.07	10.90	1.90	9.00

According to Figure 2a, SP10 recorded the highest tensile strength and elongation at break (EB) values, which could be attributed to enhanced rubber-filler interactions with the application of a silane coupling agent. The lowest tensile strength is recorded in SP00, which reflects the poor interactions between NR and mica. SP10 records the highest tensile strength, which may be attributed by the formation of more crosslinks in the presence of Si-69. The reduction of tensile strength of SP11 with the introduction of PEG may be caused the lubricating action of PEG. Figure 1b reveals the variation of modulus in NR/mica composites. Accordingly, the highest modulus values at all three elongations of SP11 composite reflect superior rubber-filler interactions when compared to all the other composites.

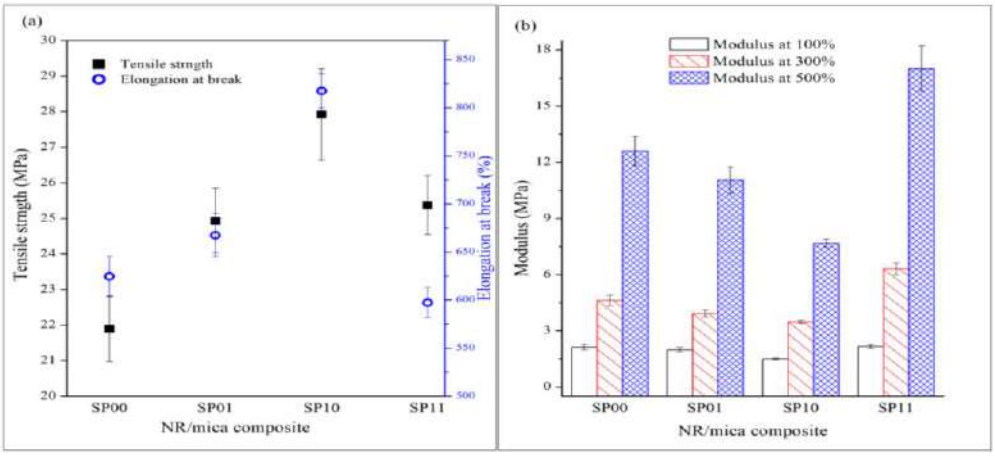


Fig. 2. (a) Variation of tensile and elongation at break, and **(b)** Variation of modulus at 100%, 300%, and 500% elongation of NR/mica vulcanizates

As shown in Figure 3, the highest hardness and resilience values are recorded for the SP11 composite. Both composites with PEG (SP01 and SP11) possess better resilience owing to the plasticizing ability of PEG in rubber. Moreover, abrasion volume loss is slightly higher in the composites prepared using Si69 (SP10 and SP11). The abrasion volume loss is slightly higher in SP10 and SP11 samples.

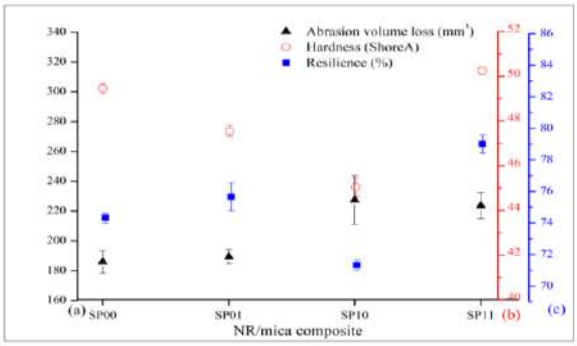


Fig. 3. **(a)** Abrasion volume loss, **(b)** hardness, and **(c)** resilience of NR/mica composites

Thermo-gravimetric results shown in Figure 4 discloses that the onset and maximum degradation temperatures of mica incorporated samples are almost comparable. Therefore, it can be concluded that the application of both Si-69 and PEG does not alter the thermal stability of NR/mica composites (Y R Somarathna, Nirmala Jayawardena, H M H Dhanukamalee, D V D Mallikarachchi, P S V

Rupasinghe, H L T Tharaka and E D S Edirisinghe (Undergraduate Student of Uva Wellassa University of Sri Lanka).

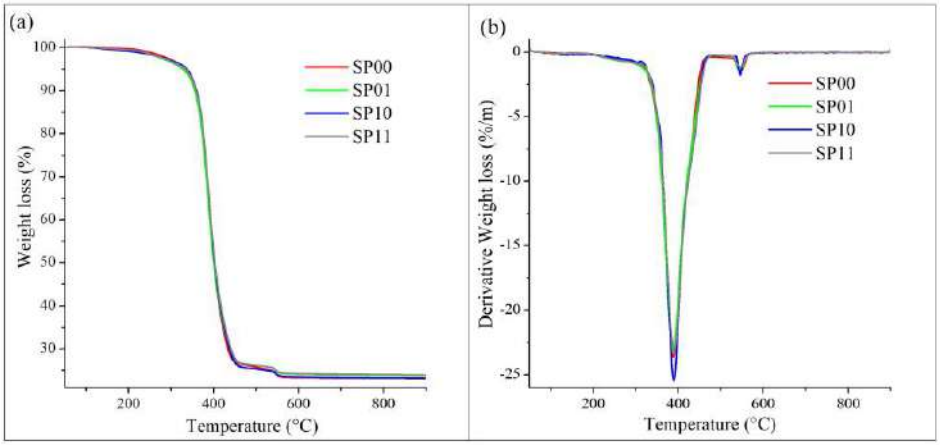


Fig. 4. Thermograms of NR/mica composites

Industrial extensions

Following clients obtained both technical and consultancy services from the Department throughout the year.

- National Water Supply & Drainage Board
- Sri Lanka Railway Department
- Export Development Board
- Associated Motorways (Pvt.) Ltd
- Elastomeric Technologies (Pvt.) Ltd
- Dipped Products PLC
- Samson Rubber Industries (Pvt.)Ltd
- Textrip (Pvt.) Ltd
- Polymer Products Impex (Pvt.) Limited
- Samson International PLC
- Samson Rubber Products (Pvt.) Ltd
- Associated Specialty Rubbers (Pvt.) Ltd
- Samson Compounds (Pvt.) Ltd
- Jefferjee Brothers Export (Pvt.) Ltd
- Sewwandi Rubber Industrial
- University of Ruhuna
- University of Sri Jayewardenepura
- University of Colombo
- University of Peradeniya

RAW RUBBER AND CHEMICAL ANALYSIS

Anusha Attanayake

DETAILED REVIEW

Staff

Dr (Mrs) A P Attanayake, Senior Research Officer was the officer in-charge of the overall activities of the department throughout the year. Mr A M K S P Adhikari, Research Officer was on study leave continuing his post-graduate studies at University Putra Malaysia, Malaysia.

Mrs C Lokuge, Experimental Officer was on duty throughout the year. Ms M U D S Weerasinghe, Mr H D M S Wijewardana, Mr K A S T Koswatta Technical Officers were on duty throughout the year. Ms N C Y Kithmini was on maternity leave from 22nd August 2021. Ms N S Siriwardena and Ms Mauri Udayangi resigned from RRISL with effect from 26th March and 30th September 2021, respectively after 5 years of service. Management Assistant Miss W D D Samanmali was on duty throughout the year.

Seminars/Training Programmes/Workshops/Exhibitions conducted

Officer/s	Subject	Beneficiary/Client
AP Attanayake	Raw rubber properties of natural rubber	Students from National Diploma in Plantation Crop Technology
The staff of the department	Determination of dry rubber content	Students from National Diploma in Plantation Crop Technology

Lectures/Seminars/Workshops/Meetings attended

Officer/s	Subject	Organization
AP Attanayake	Heads of department meeting	Dartonfield, Agalawatta
	NASTEC Progress Review Meeting	Dartonfield, Agalawatta
	Scientific Committee Meeting	Dartonfield, Agalawatta
	Audit of Tyre Testing Laboratory	Camso Loadstar, Ekala

LABORATORY INVESTIGATIONS

Effect of residual Diammonium Hydrogen Phosphate (DAHP) content on natural rubber centrifuged latex properties and latex film properties

The amount of DAHP added to latex in order to reduce Mg2+ content to a minimum level prior to latex centrifugation is decided after an estimation of initial

Mg^{2+} concentration in latex. But in practice some of the Centrifuged Latex (CL) manufacturers add a constant amount of DAHP over the years without estimating the Mg^{2+} present in field latex, in most cases, leading to addition of excess amounts of DAHP. It leaves excess PO_4^{3-} in latex which leads to quality issues in CL latex and products. The objectives of the present study are to determine how natural phosphate ion content in centrifuged latex vary with storage time, to compare the remaining phosphate ion contents, viscosity and stability of centrifuged latex samples treated with different amounts of DAHP and their variations with latex storage time.

CL used in this study was centrifuged latex (CL) commercially prepared without adding DAHP. The CL sample was divided into 6 portions to contain 8 liters per in each. Calculated amounts of 15% DAHP were added into each portion of latex as given in the Table 1.

Table 1. *CL sample series used in the study*

Latex sample number	Sample label	Amount of 15% DAHP added (g)
01	0D (control)	-
02	3D	3
03	6D	6
04	9D	9
05	12D	12
06	15D	15

Table 2. *Initial properties of the centrifuged latex (CL)*

Test	Value
Alkalinity (%)	0.7
Total solid content (w/w %)	61.42
Dry rubber content (w/w %)	60.57
Volatile fatty acid number (w/w %)	0.012
Mechanical stability time (seconds)	75
Viscosity (cPs)	86.2
Magnesium ion content (ppm)	Not detectable
Phosphate ion content (ppm)	359.00
Chemical stability time (seconds)	52

Figure 1 shows that during the first week, phosphate content of the 0D sample (339.66 ppm) is less than the initial amount, 359.02 ppm. It is evident that there is a remaining amount of Mg^{2+}present in the aqueous phase. The minimum detection limit of the Mg^{2+} detection test method used above is around 12 ppm. Although the result shows not in detectable level, there may be residual Mg^{2+} ions remaining in the latex. During the second week and third week phosphate content of the 0D sample has increased than that in the first week. Phosphate content of the 0D

sample has decreased during the fourth week. It may be due to the adsorption of phosphate into the rubber particle surface. And also may be due to the precipitation of phosphate ions with other divalent metal ions such as Calcium. Phosphate content of treated samples (3D, 6D, 9D, 12D and 15D) are higher than the 0D sample due to the addition of excess phosphate ions. 3D, 6D, 9D, 12D and 15D samples show rapid decrease in phosphate content during the second week and there is a fluctuation of phosphate content after the second week. This might be due to different chemical reactions taking place in latex with excessive phosphate contents.

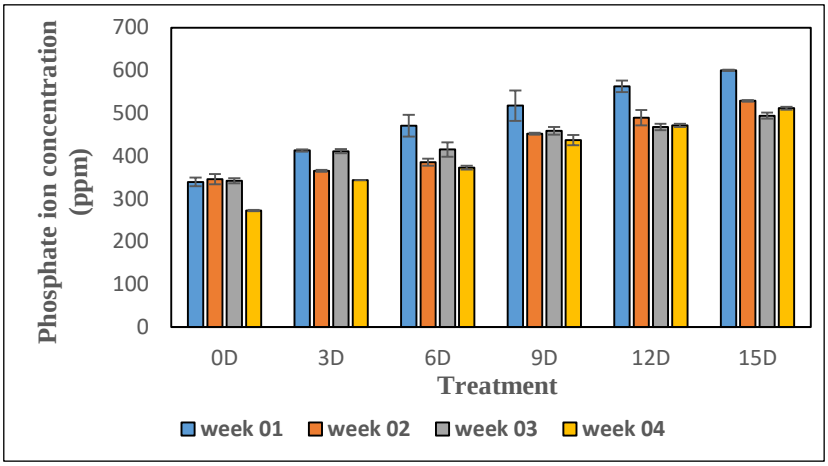


Fig. 1. Variation of Phosphate content of different treatment samples with time

According to the Figure 2, variation of viscosity of the latex samples showed a similar pattern in every week. Viscosity increases from 0D to 9D treatment samples and has reached to a maximum value and gradually decreased in 12D and 15D samples in every week. Excess phosphate content in the aqueous phase cause increase in ionic strength which leads to thickening of latex. However, higher phosphate ion content (12D and 15D) has ultimately resulted in reduction of viscosity due to colloidal destabilization of latex.

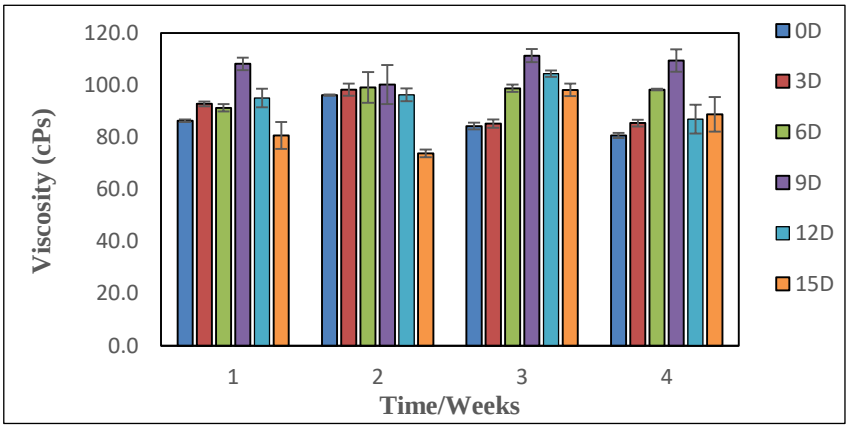


Fig. 2. Variation of viscosity of different treatment samples with time

It has been reported that in previous studies reported that too high phosphate contents in latex causes low adhesiveness on the mold in dipping process. Gradual decrease of viscosity in latex samples treated with too high phosphate content (12D and 15D samples) support the above observation.

It has been reported that Mechanical Stability Time (MST) value of centrifuged latex tends to increase with storage time due to the favorable conditions for the maximum hydrolysis of phospholipids in the presence of ammonia. Figure 3 clearly shows the increase of MST of latex samples with maturation of the centrifuged latex.

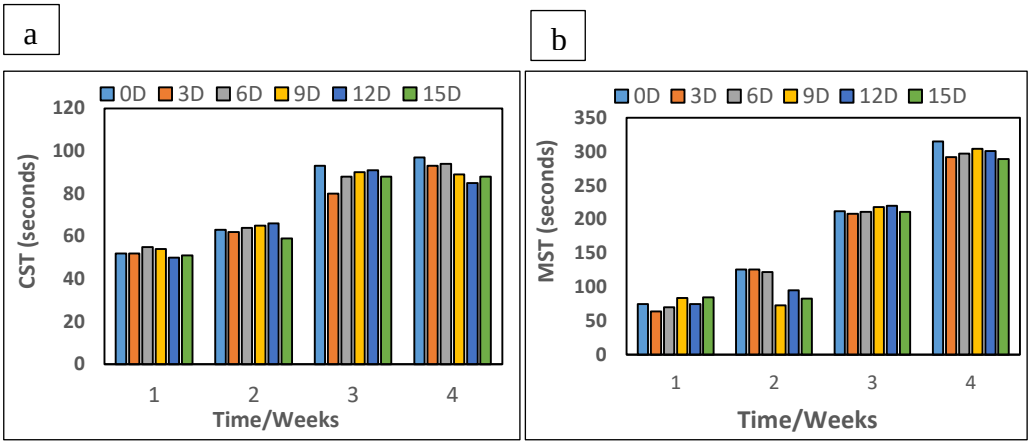


Fig. 3. Variation of MST and CST of latex samples treated with different amount of DAHP

According to the Figure 3a, after 28 days of latex maturity OD sample showed a significant increase of MST value. This might be due to the significantly low phosphate ions present in latex (Fig. 1).

When zinc oxide is added to ammonia preserved latex, it begins solubilization and results in formation of positively charged complex ions which decrease the colloidal stability of latex. According to the Figure 3b, highest chemical stability was reported with the 0D sample after four weeks. With the addition of excess DAHP, ammonium ions will promote solubilization of Znic ions. Formation of positively charge complex ions will decrease the colloidal stability of latex and chemical stability. Therefore, after 4 weeks 15D sample showed lowest MST & CST value.

Figure 4 shows that tensile strength has increased with time as well as with the increase of phosphate ion concentration. The minimum acceptable range of ASTM standards for tensile strength of latex gloves is 14 M Pa- 24 M Pa. The Figure 4 clearly shows that tensile strength of 0D treatment has increased from 14 M Pa- 25 M Pa with storage time. But tensile values of the other treatments (3D, 6D, 9D, 12D, 15D) have increased around 11 M Pa- 23 M Pa over the storage time of the study. According to the literature, mainly proteins and mono ordi-phosphates participate in the crosslinking process and lead to increase crosslinking density and tensile strength of vulcanized latex films. Therefore, increase of tensile strength with the increase of DAHP concentration might be due to the formation of crosslinking between polyisoprene chains with the PO_4^{3-} groups during the film formation.

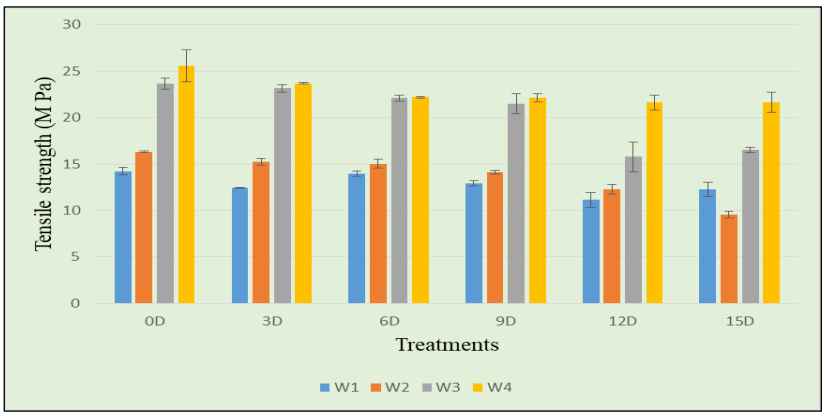


Fig. 4. Variation of tensile strength of treatments with DAHP concentration

Tensile strength of latex films of each and every batch has increased over time, with the highest value shown in the last week (Fig. 5).

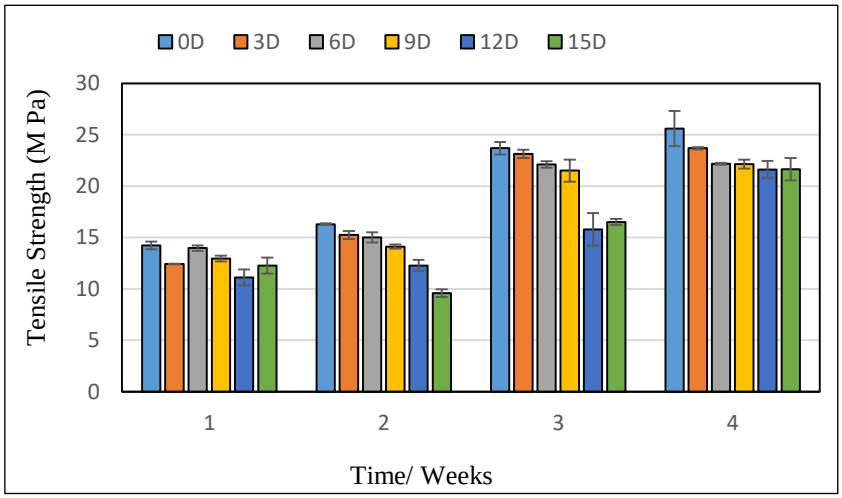


Fig. 5. Variation of tensile strength of latex films prepared by different treatment samples with time

According to Figure 6, Elongation at break (EB) of all the samples are greater than 750%. The acceptable range of EB for latex gloves is 400-750% according to the ASTM standards. Accordingly EB of all the latex samples are above the minimum range stipulated in ASTM standards. This might be a result of an increase of crosslinking density due to the presence of excess phosphates in the latex samples during film formation.

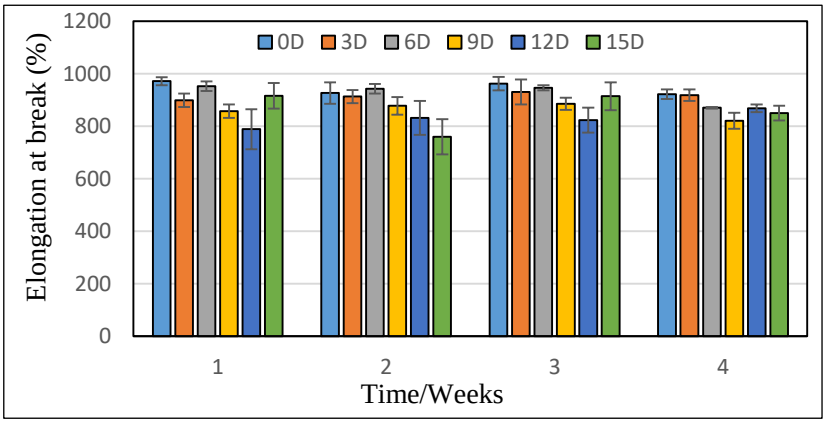


Fig. 6. Variation of Elongation at break of latex films differently treated samples

Comparison of plasticity (P_o) aged plasticity (P_{30}) and Plasticity retention index (PRI) of fractionated and bleached crepe rubber with varied concentrations of bleaching agent

In the manufacturing process of crepe rubber, bleaching agent (35-40% aqueous solution of Sodium salt of tolyl mercaptan or sodium para-toluene thiophenate) is added to latex to bleach the carotenoid pigments, a naturally occurring non-rubber substance in rubber latex. According to the RRI Rubber Technology Handbook, the recommended dosage is 100g -150g from 35% solution for 100kg of dry rubber to obtain the desired bleaching effect. However, samples received for analysis reflects that inferior dry rubber properties probably due to the use of high concentration of bleaching agent (BA). Therefore, this study was initiated to study the properties of raw rubber properties namely plasticity number, aged plasticity and plasticity retention index of crepe rubber (Fig. 7).

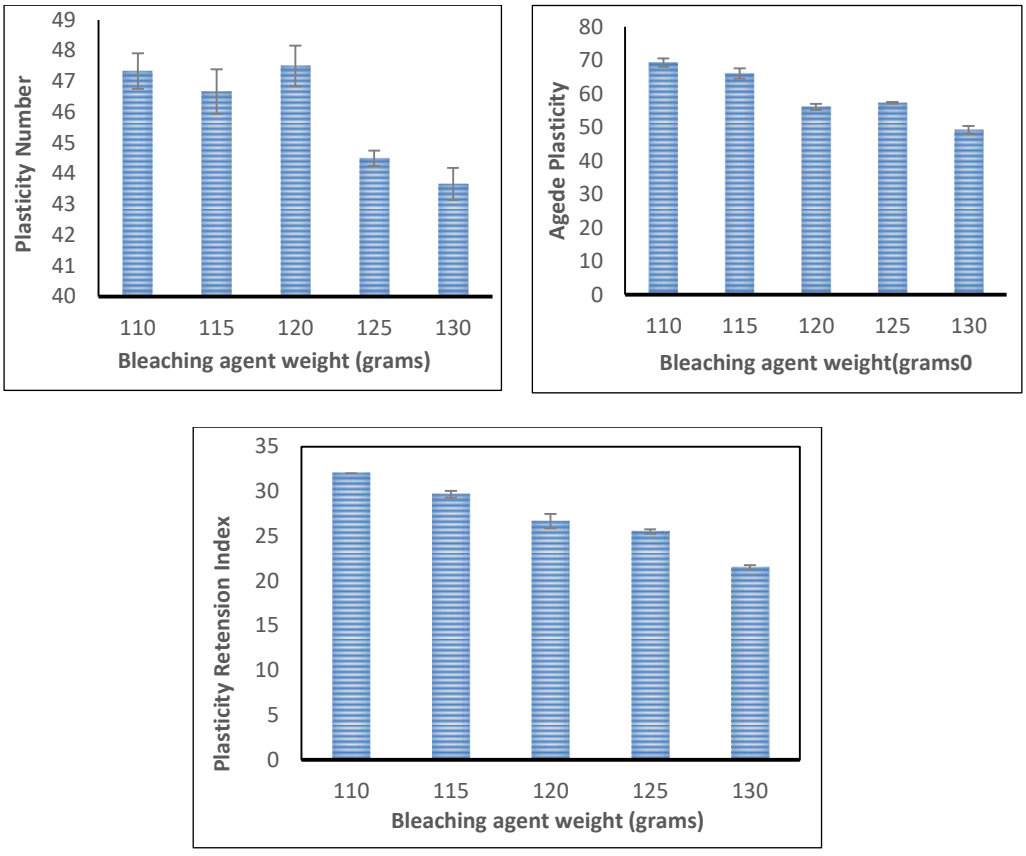


Fig. 7. Variation of plasticity number, aged plasticity and plasticity retention index with the dose of bleaching agent

It was evident form the results that with the increase of the bleaching agent concentration, plasticity number, aged plasticity and plasticity retention index values were significantly reduced. This study will be continued next year to evaluate the effect of bleaching agent for some other physical properties of rubber compounds.

Quality analysis of latex, raw rubber and rubber processing chemicals

Testing and certification services were provided to all the sectors in the rubber industry as given below:

Service	No. of samples
Miscellaneous analysis	
Dry rubber	1301
Latex samples	889
Chemical samples	28
Polythene samples	19
Testing certificates	363

RAW RUBBER PROCESS DEVELOPMENT AND CHEMICAL ENGINEERING

Susantha Siriwardena

DETAILED REVIEW

Staff

Mrs U M S Priyanka, Experimental Officer supervised most of the departmental activities under the guidance of Dr Susantha Siriwardena, Deputy Director-Research (Technology) throughout the year. Ms V C Rohanadeepa and Mr A K D Warnajith, Experimental Officers Ms P K N N Sandamali, Messrs R D Illeperuma and A S Bandara, Technical Officers, Mr D S Wijewardna, Graduate Trainee and Janani Lakshika Management Assistant were on duty throughout the year. Mrs H A Chathimini joined the department as a graduate trainee on 13th December, 2021.

Research students

Postgraduate students

- Danushka Wijewardena, Postgraduate student, Uva Wellassa University continued his research project on "Rheological and Mechanical Properties of Ternary Composites of Thermoplastics (TPs) and Skim Natural Rubber (SNR)" under the supervision of Dr Susantha Siriwardena.

Undergraduate students

- Ms W G P D Manukularathne, BSc undergraduate student from Uva Wellassa University of Sri Lanka, completed her research project titled "A Comparative Study on Degradability of NBR and NR Latex Gloves under the supervision" of Dr Susantha Siriwardena.

- Ms K C N Weerasinghe, BSc undergraduate student from Wayamba University of Sri Lanka, completed her research project titled "Cure characteristics and physico - mechanical properties of processed drinking water purification tank sludge filled SBR/NR based tyre tread composites" under the supervision of Dr Susantha Siriwardena.

- Ms W M D S Lakshani, BSc (Special) undergraduate Student from Uva Wellassa University of Sri Lanka, completed her research project titled "Preparation and characterization of pre-vulcanized natural rubber latex made out of creamed latex

under different types of accelerator" under the supervision of Dr Susantha Siriwardena.

- Ms W K A Nilmini BSc undergraduate student from University of Sri Jayewardenapura completed her research project titled "The effect of hand sanitizing chemical on physicomechanical properties of glove" under the supervision of Dr Susantha Siriwardena.

- Mrs Mihiri P Karunanayaka, BSc in Technology student of Faculty of Technology from University of Sri Jayawardenapura, Sri Lanka commenced her final year research project titled "Effect of selected grades of carbon black on physical and curing characteristics of natural rubber composites" under the supervision of Dr Susantha Siriwardena.

Seminars/Training Programs/Workshops/Conferences/Meetings attended

Officer/s	Subject	Organization
UMS Priyanka	Internal auditing of laboratory quality management system as per ISO/IEC 17025:2017	Sri Lanka Accreditation Board

Seminars/training programs/workshops/Exhibitions conducted

Officer/s	Subject	Organization
AKD Warnajith	Certificate Course in Rubber and Plastic Technology	Plastic and Rubber Institute
	Training program on RSS Manufacturing for Rubber Development Officers	Rubber Development Department
	Training program on Raw Rubber processing for Diploma holders	Agunakolapelessa Agriculture School and Karapincha Agriculture School
	Training program on Crepe Rubber Manufacturing for Staff of Pussallawa Plantation Ltd (Two Programs)	Pussallawa Plantation Ltd
	Training program on RSS Manufacturing for smallholders	Global Rubber Industries
	Training program on RSS Manufacturing for smallholders (Six Programs)	Small Tea and Rubber Revitalization Project

Officer/s	Subject	Organization
	Training program on Latex Preservation and safe chemical handling for smallholders (Six programs)	Dipped Products Ltd,
	Field Training Program on Raw Rubber Processing	National institute of Plantation Management

Advisory visits

Services provided	No. of factories/visits
Process and quality improvements	31
Waste water treatment	11
Waste water sample collection for testing	27/23
Plans issued for construction of new SS drying systems with capacity less than 100 kg	06
Miscellaneous advisory and troubleshooting	02
Tank calibration	02

Waste water analysis

Collection of waste water samples from raw rubber processing and allied industries and analysis of waste water for water quality parameters were carried out throughout the year.

Samples tested and certificates issued

Type of samples tested	Samples/Certificates
Waste water: rubber related	60 / 42
Waste water: non-rubber related	15/14
Processing water	06/02
Miscellaneous samples (metal ions, ZnO *etc.)*	13/05
Analysis of extractable proteins	12/06
Number of certificates of epidemic prevention issued for sole crepe	62

Contract research

A contract research carried out for University of Aukland, New Zealand on Techno-economic study on the feasibility of application of commercial (Geo 40) Colloidal Silica (CS) provided from Geo40 Pvt. Ltd., New Zealand in rubber product manufacturing application was completed. A wrap-up meeting was held and the final report submitted to the University of Aukland was accepted. Major findings and recommendations made are summarized below.

(i). Tyre industry

Technically, Nano silica has a high potential to replace the commercial silica as silica is a sustainable green natural product offering better physical and mechanical properties to the carbon black free (white) tyre compounds. Environmentally, silica is considered a green material as it is obtained from a natural source using minimal power consumption and will have a higher demand, particularly in the face of growing global pressure on utilization of sustainable and green materials. However, the use of silica in colloidal form from Geo40 is not economically feasible, due to the excessive consumption of acid to lower the pH of CS incorporated latex, partial loss of silica during processing and other operational issues. It is strongly recommended to convert Nano-scale CS into a dry Nano scale amorphous silica in powder form. Geo Silica may be functionalizing with a suitable silane coupling agent to add extra value to the product and offer as a premium grade functional grade especially for rubber compounding. It is recommended to do a formal feasibility study on the potential of replacement of carbon black grades, when CS in dry form is available from Geo40.

(ii). Latex based industry

Use of Colloidal Silica (CS) from Geo40 in latex dipped products industry is technically and economically feasible, provided that it could be supplied at a competitive price as an alternative to the widely used fillers such as $CaCO_3$ and silica-based Clay in latex dipped product industry as pre-preparation of dispersions is not required. It is recommended to carry out specific product oriented comprehensive research on the use of CS in latex-based product industries. It is also recommended to focus attention on increasing the total solid content of the dispersion while reducing P^H level to reduce the transport cost and latex coagulation cost.

The Department carried out the project collaboratively with faculty of Technology, University of Jayewardenepura, Dipped Products PLC and Global Rubber Industries (GRI) Tyres. Total contract was worth of $6,646.50 (Total).

LABORATORY INVESTIGATIONS

Quantification and characterization of effluent water generated in the sheet rubber and crepe rubber processing industry in Sri Lanka

A study on quantification and characterization of effluent water generated in Ribbed Smoked Sheets (RSS) and Crepe rubber manufacturing industry in Sri Lanka funded by Small Grant Research Program–2021, Ministry of Environment was carried out. Data were collected from ten fractionated and bleached crepe rubber manufacturing factories and fifteen small scale RSS manufacturing units scattered in different areas of the country. A summary of volumes of water discharged at different processing points are summarized in Tables 1 and 2.

Table 1. *Statistical analysis of volume of waste water in liters discharged at different points of processing steps for 1,000 kg of crepe rubber*

Parameter	Average	Median	Standard Deviation	Lower and upper limits of average values	Range of amounts
Serum generated in the coagulant tank	4,422.2	4,698	908.0	3,724 **;** 5,120	3,266-6,292
Total serum quantity trapped in coagulum	3,788.3	3,749	736.5	3,222 ; 4354	2,763 -4,888
Total mill water consumption for first 03 passes	5,816.1	3,920	4,526.5	2,337 ; 9295	1,597-14,583
Total mill water consumption for other passes	6,346.8	6,888	3,335.8	3,783 ;8,911	2,129- 11,685
Total mill water consumption (3+4)	12,162.9	11,543	7,283.3	6,564 ; 17,761	3,726-24,350
Total effluent generation (1+2+3+4)	20,373.4	19,441	7,272.2	14,783 ; 25,963	11,240-32,248

Table 2. *Statistical analysis of volume of waste water in liters discharged at different points of processing steps for 1,000 kg of RSS*

Parameter	Average	Median	Standard Deviation	Lower and upper limit of average values	Range of amounts
Fresh serum generated in coagulation pans	2033.2	2078	480.5	1,756 ; 2,311	1,375-2,930
Serum generated in smooth milling (liters)	1583.6	1553	269.2	1,428 ; 1,739	1,230-2,120
Serum generated in diamond milling(liters)	382.1	367	73.1	340 ; 424	230-510
Total serum generated (liters)	3998.9	4020	790.8	3, 542;4, 456	2835-5320

Figure 1 shows the total volume of water discharged and the percentage of quality of crepe rubber produced at different crepe rubber factories under this study.

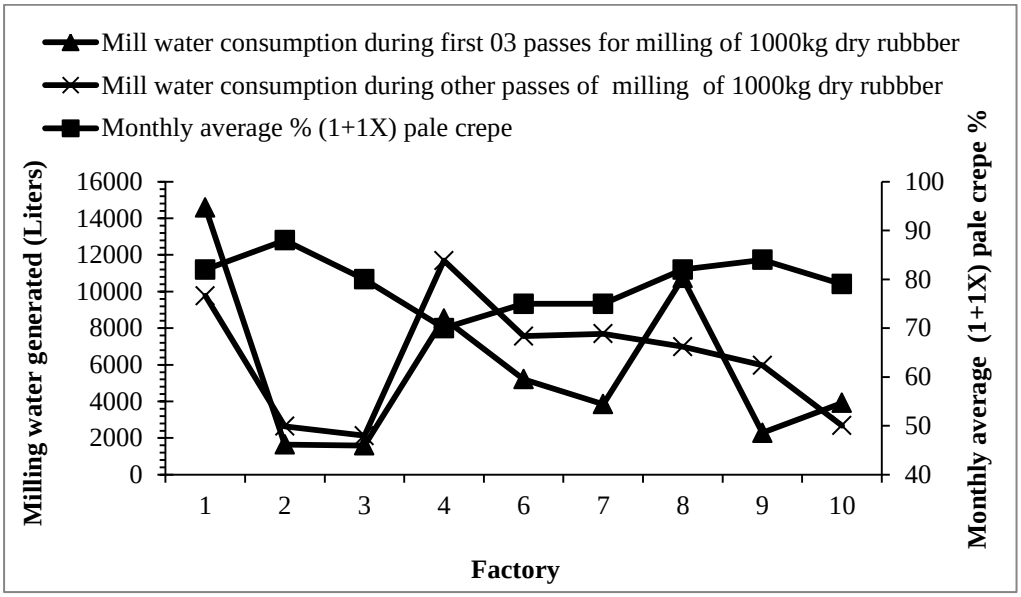


Fig. 1. Variation of total effluent generation with monthly average percentage of (1+1X) of pale crepe rubber

Average effluent water quality parameters of the effluent discharged at different points of the manufacturing process of crepe rubber and sheet rubber are given in Tables 3 to 6.

Table 3. *Average waste water quality parameters at different processing stages in crepe rubber manufacturing process*

Quality parameter	Fresh effluent	Milling water at first 03 passes	Milling water at other passes
COD (ppm)	6,915.6	1,600.7	139.3
BOD (ppm)	4,149.0	780.0	35.0
P^H	4.4	4.8	5.3
TSS (ppm)	551.1	173.2	34.7
TS (ppm)	13,376.0	1,977.3	208.0

Table 4. *Average and ranges of metal ions of fresh effluent and waste water generated at different processing stages in crepe rubber manufacturing in µgml^{-1}*

Metal ion	Type	Average	Range
Zinc ions	Fresh effluent	0.413	0.063-0.666
	Macerator mixed	0.333	0.064-1.209
	Diamond mixed	0.096	0.053-0.228
Total ferrous ions	Fresh effluent	0.624	0.100-1.076
	Macerator mixed	0.681	0.001-1.411
	Diamond mixed	0.351	0.000-0.990
Manganese ions	Fresh effluent	0.057	0.000-0.196
	Macerator mixed	0.041	0.000-0.099
	Diamond mixed	0.010	0.000-0.027
Magnesium ions	Fresh effluent	1.040	1.04-High
	Macerator mixed	10.309	5.022-High
	Diamond mixed	3.972	0.584-12.158
Copper ions	Fresh effluent	0.549	0.398-0.664
	Macerator mixed	0.149	0.17-0.410
	Diamond mixed	0.001	0-0.002
Lead ions	Fresh effluent	0.646	0.628-0.663
	Macerator mixed	0.626	0.547-0.668
	Diamond mixed	0.2915	0-0.583

Table 5. *Average waste water quality parameters at different processing stages in RSS rubber manufacturing process*

Quality parameter	Fresh effluent	Milling water
COD (ppm)	13,733	10,911
BOD (ppm)	7,542	5,548
P^{H}	4.31	4.24
TSS (ppm)	1,142	1,057
TS (ppm)	13,547	13,821

Table 6. *Average concentrations of metal ions of fresh effluent and waste water generated at different processing stages in RSS manufacturing in µgml^{-1}*

Metal ion	Type	Average
Zinc ions	Fresh effluent	0.7282
	Milling	0.7367
Total ferrous ions	Fresh effluent	1.1196
	Milling	1.8860
Manganese ions	Fresh effluent	0.2490
	Milling	0.1012

Metal ion	Type	Average
Magnesium ions	Fresh effluent	66.9918
	Milling	64.0657
Copper ions	Fresh effluent	0.6334
	Milling	0.7627
Lead ions	Fresh effluent	0.6318

**Average metal ion concentrations were determined based on samples which were taken from five*

RSS manufacturing facilities

For both RSS and Crepe rubber manufacturing processes, a high concentration of magnesium ions are registered. Other ion concentrations generally show higher concentrations in waste water generated at RSS manufacturing industry than that in crepe rubber manufacturing industry, probably due to the use of low volumes of water in standardization and milling processes.

Suitability of waste water generated at different processing points for disposal on lands

Suitability of direct land disposal of the waste water collected at different manufacturing steps was studied at all crepe rubber processing factories for irrigation purposes while considering the tolerance limits stipulated by the Central Environment Authority (Tolerance limits for industrial waste discharged on land for irrigation purposes). A summary of the observations is given in Table 7 for waste water discharged from crepe rubber manufacturing industry.

Table 7. *Suitability of waste water discharged on land for the irrigation purposes*

Quality parameter	Fresh serum	First three milling passes	Other milling passes up to smooth milling
COD	×	×	√
BOD	×	×	√
pH	×	×	×
TSS	×	×	√
TS	×	×	√

A summary of the observations made from this study is listed below.

Crepe rubber industry

1. There is a high potential to lower the milling water consumption without affecting the quality of rubber produced as excessive amounts of water are apparently used during milling in the present practice of crepe rubber processing.

2. Generation of effluent water at the coagulation tank and trapped water in the coagulum varies from 1.6 to 14.6 and 2.8 to 4.9 l/kg respectively. Waste water generated during milling processes however, varies in a comparatively wider range. They vary from 1.6 to 14.6 and 2.1 to 11.68 for first three milling passes and onwards. These wide variations may be due to the inherited individual approaches and uncontrolled washing practices during milling processes
3. Waste water treatment could be restricted only for the effluent generated at the latex coagulation tanks and the waste water generated at the first three mill passes thereby reducing the total effluent treatment capacity by 18% to 42%
4. Treatment of waste water generated after the third mill passes is required as the waste water quality parameters are already below the CEA standards and a new water reuse protocol could be recommended to reuse the waste water generated after third milling for washing of mats during first three milling passes.

RSS manufacturing industry

1. The volume of waste water generated at RSS processing units are very smaller compared to crepe rubber manufacturing and requires treatment prior to discharge to the environment
2. There is no significant difference in the waste water generated from coagulation and milling stages of the RSS manufacturing process as far as the quantity is concerned and there is no necessity for segregation

Based on the above observations, following recommendations could be made for implementation at pilot scale trials:

(i) It is recommended to introduce a protocol for optimum utilization of milling water to the crepe rubber industry to prevent the use of excessive volumes of processing water during milling. A suggested protocol is given in Figure 2
(ii) It is recommended to segregate the effluent water generated at the crepe rubber processing factories after third milling to separate waste water generated at different milling stages enabling waste water generated at intermediate milling is qualified for discharge onto land after a pre-treatment
(iii) It is recommended to introduce a cost-effective treatment system for waste water generated at RSS processing units as presently no such treatment system has been suggested for small scale RSS manufacturers.

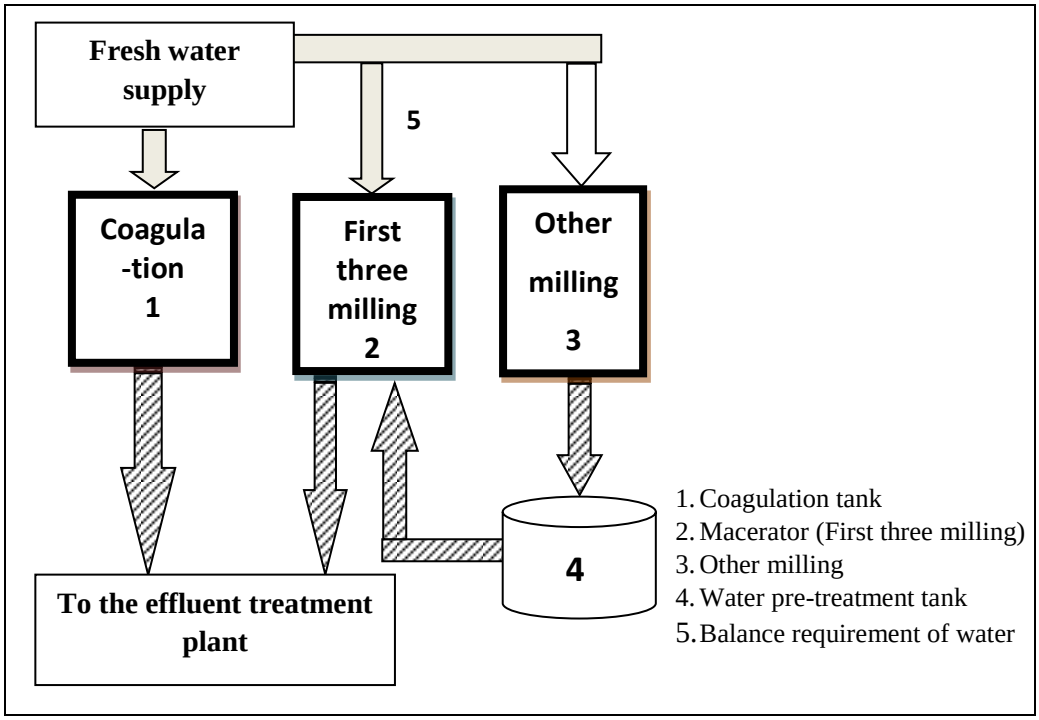


Fig. 2. Proposed processing water reuse protocol for crepe rubber manufacture

Based on the observations made at the above study and the experience of the advisory officers of the Advisory Service Department, a collaborative project was initiated to evaluate the possibility of use of pre-neutralized rubber free effluent water generated at the RSS manufacturing facilities as a nutrient source for different agricultural applications. The proposed effluent pre-treatment unit is shown in Figure 3.

The same study was extended to study the fertilizer value and possibility of land application of pre-treated water generated at the crepe rubber industry in collaboration with the Soils and Nutrient department. Preliminary studies have shown that application of pre-treated water has no adverse effect on the plant growth. A detailed study is continued as a joint project of above two departments, Biometry Department and Raw Rubber Process Development and Chemical engineering department to study the potential utilization of rubber effluent as a nutrient source and at the same time introducing a simple and cost effective alternative instead of complex and costly effluent treatment systems presently practiced by the industry.

Fig. 3. Pre-treatment system suggested for waste water generated at RSS manufacturing facilities

A comparative study on degradability of NBR and NR latex gloves

Natural rubber (NR) and Nitrile rubber (NBR) gloves are two main types of latex gloves used in the personal protective equipment market. In the face of an abrupt increase in the demand and usage of these gloves due to the present Covid-19 pandemic, disposal of these gloves after usage may create an environmental threat. Therefore, a study was conducted to compare the degradable behavior of these two products. Both glove types were treated under thermal, hydrothermal, and UV radiation environments. Untreated samples were used as the control. Under thermal, hydrothermal and photo-oxidative treatments, an increase of the swelling index of untreated NR gloves (65.2%) increased by 38.23%, 14.69% and 7.17%, respectively while NBR gloves showed a percentage swelling index increment of 14.52%, 15.56% and 12.12% when compared with the percentage of the swelling index of the untreated sample (28.77%) in the same order of treatments. The average tensile strength of NR gloves was decreased from 16.89 to 15.67, 11.19, and 15.63 MPa while for NBR gloves it was decreased from 28.06 to 24.35, 23.93 and 20.56 MPa after the thermal, hydrothermal and UV exposure, respectively. Spectra of thermally and hydrothermally treated NBR showed identical loss of the peak responsible for the cyanide group. TGA analysis showed that the initial decomposition temperature of NR gloves has reduced from 365.42 ˚C to 364.95 ˚C, 360.63 ˚C and 365.27 ˚C, respectively after thermal, hydrothermal and UV treatments. NBR gloves also showed the same trend except for hydrothermal treatment where an increase in initial decomposition temperature was recorded. Overall, hydrothermal treatment was the best degradation method for NR gloves among candidates while exposure to UV radiation exhibited the highest degradation potential for NBR gloves. It was also found that cyanide group is cleaved when NBR gloves were subjected to hydrothermal degradation (S Siriwardena, P K N N Sandamali, E A L Lochana, A M

W K Senevirathna and W G P D Manukularathne: Uva Wellassa University of Sri Lanka).

Effect of selected grades of carbon black on physico-mechanical and curing properties of natural rubber composites

Carbon black (CB) has been the most multifaceted and cost-effective reinforcing filler used in the rubber industry until today, as it provides excellent reinforcement to the rubber matrix. Overall filler characteristics including particle size, aggregate shape, specific surface area, and CB surface chemistry affect the reinforcement and processability properties of filled rubber vulcanizates. A study was carried out to determine the effect of common industrially utilized grades of CB on the curing and mechanical properties of natural rubber compounds. Five different CB grades with different particle size ranges namely, N134 (20-25 nm), N220 (24-33 nm), N330 (28-36 nm), N550 (39-55 nm), and N990 (250-350 nm) were used to prepare compounds using a two roll mill, and curing was done using both conventional vulcanization (CV) and efficient vulcanization (EV) systems. Formulations used in this study are given in Table 8 and the mixing sequence is given in Table 9.

Table 8. *Formulae used to prepare compounds*

Ingredients	**Amount(phr)**									
	Conventional vulcanization system					**Efficient vulcanization system**				
	CV N134	**CV N220**	**CV N330**	**CV N550**	**CV N990**	**EV N134**	**EV N220**	**EV N330**	**EV N550**	**EV N990**
NR (RSS1)	100	100	100	100	100	100	100	100	100	100
Zinc Oxide	5	5	5	5	5	5	5	5	5	5
CB (N134)	50	-	-	-	-	50	-	-	-	-
CB(N220)	-	50	-	-	-	-	50	-	-	-
CB(N330)	-	-	50	-	-	-	-	50	-	-
CB(N550)	-	-	-	50	-	-	-	-	50	-
CB(N990)	-	-	-	-	50	-	-	-	-	50
Processing Oil	10	10	10	10	10	10	10	10	10	10
TMQ	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
TBBS	0.6	0.6	0.6	0.6	0.6	3	3	3	3	3
Sulphur	2.5	2.5	2.5	2.5	2.5	0.5	0.5	0.5	0.5	0.5
Total			**172.6**					**173**		

Table 9. *Mixing cycle used for the compounding process*

Additive	Added time (minutes)
NR (RSS 1)	0^{th}
Zinc Oxide + Stearic Acid + TMQ	2^{nd}
½ Carbon Black	4^{th}
½ Carbon Black	6^{th}
Processing Oil	7^{th}
TBBS	8^{th}
Sulphur	9^{th}
Dispatch	12^{th}

NR composites were characterized to obtain their curing properties according to the ISO standards at 150ºC under a pressure of 20 MPa. Mechanical properties of the cured composites such as hardness, tensile strength, modulus at 300% elongation, and elongation at break were measured according to the ISO standards. Curing characteristics and the physico-mechanical properties of the compounds are presented in Tables 10 and 11 respectively.

Table 10. *Cure characteristics and filler dispersion of the compounds*

Compound	M_H (dNm)	M_L (dNm)	$\Delta M = M_H - M_L$ (minutes)	t_{90} (minutes)	ts_2 (minutes)	Filler dispersion (%)
CV system						
CV N134	14.01	2.68	11.33	20.68	3.49	89.08
CV N220	12.9	2.1	10.80	21.07	3.92	85.88
CV N330	12.51	2.08	10.43	20.74	3.78	91.43
CV N550	12.84	2.00	10.84	21.37	3.97	94.29
CV N990	5.97	1.05	4.92	23.37	9.08	83.18
EV system						
EV N134	9.59	1.9	7.69	14.00	4.09	73.72
EV N220	11.02	2.40	8.62	13.29	4.2	64.69
EV N330	10.03	2.21	7.82	14.05	3.72	97.61
EV N550	10.46	1.71	8.75	15.75	4.49	88.18
EV N990	5.29	1.06	4.23	20.28	9.15	89.08

Table 11. *Physico-mechanical properties of the composites*

Composite	Hardness (IRHD)	Modulus at 300% elongation (%)	Tensile strength (MPa)	Elongation at break (%)
CV system				
CV N134	71.31	6.14	22.36	991.33
CV N220	70.70	5.38	20.38	933.57
CV N330	70.63	5.18	19.73	723.35

Composite	Hardness (IRHD)	Modulus at 300% elongation (%)	Tensile strength (MPa)	Elongation at break (%)
CV N550	67.41	5.90	20.64	868.47
CV N990	41.63	1.33	19.17	1,824.98
EV system				
EV N134	66.17	3.71	19.29	1,168.66
EV N220	69.52	4.10	25.53	863.38
EV N330	69.28	4.03	22.31	853.75
EV N550	65.98	4.19	16.47	1,015.76
EV N990	40.11	0.86	17.93	2,139.32

Interestingly, only CB N990 showed a significant influence on curing characteristics and mechanical properties in both CV and EV systems compared to the other CB grades. For instance, the CB N990 incorporated NR vulcanizates showed a significant reduction in M_L, $M_{H,}$ hardness, and modulus at 300% elongation and a considerable increment of ts_2 and t_{90} and elongation at break values in both CV and EV systems. Therefore, except CB N990, all the other grades have the potential to use as reinforcing fillers without affecting much on curing characteristics as well as the mechanical properties. Hence, the CB filler grades N134, N220, N330, and N550 may be used for the products with a reasonable wide range of mechanical properties (S Siriwardena, R D Illeperuma, Mihiri P Karunanayaka (undergraduate student from University of Sri Jayewardenepura).

The effect of hydrogen peroxide based hand sanitizing chemicals on the physico-mechanical properties of NR and NBR gloves

With the spread of Covid-19 pandemic, all industrial and examination gloves are subjected to disinfection during service using hand sanitizers globally. Natural Rubber and Nitrile gloves are widely used in many sectors including health sector at large scale. However, effect of exposure of these gloves to the disinfection chemicals have not been widely reported. Therefore, NR and NBR gloves were exposed to sanitizing chemicals with different application frequencies for eight hours and the properties were evaluated after 48 hours. Glove samples were selected randomly as control and testing samples. The chemicals required to make sanitizer formulation were prepared according to Table 12, following the recommendation issued by the World Health Organization.

Table 12. *Hand sanitizer (HS) formulation used*

Reagents for sanitizer formulation	The final concentration for the formulation
Isopropyl alcohol 99.8%	Isopropyl alcohol 75% (v/v)
Hydrogen peroxide 3%	Hydrogen peroxide 0.125% (v/v)
Glycerol 98%	Glycerol 1.45% (v/v)
Sterile water or boiled cold water	Sterile water or boiled cold water

The thickness of gloves was measured using a Digital Thickness Gauge (thickness range from 0-0.5 mm). The color of control and test glove samples was tested by visual inspection and photos were taken from a 13-megapixel primary rear camera. Glove samples were prepared by keeping them dipped in the sanitizer for around 3 minutes according to the following test conditions at room temperature; Test sample 1- once in every 15 minutes, Test sample 2-once in every 30 minutes, Test sample 3-once in every 1 hour, Test sample 4-once in every 2 hours, Test sample 5-once in every 3 hours for 8 hours. The test samples were matured for 48 hours at room temperature and the test specimens were then characterized for their chemical and physico-mechanical properties.

Discoloration

Colour variation of untreated and treated samples was visually assessed. There was no any significant color change between controls (unexposed) and the samples exposed to sanitizers for three hours.

Effect of the hand sanitizer treatment on the mechanical properties of the gloves

Table 13 presents the mechanical properties such as tensile strength, elongation at break, and tear resistance of the control and HS treated glove samples. Two main factors that influence the mechanical properties of latex films are the nature of crosslinks and the crosslink density in addition to the strength of the macromolecules. Mechanical properties of both types of gloves dipped at different frequencies show insignificant difference between the properties. Therefore, it can be deduced that the exposure of gloves to the sanitizer does not make any change either in crosslink structure or the main chain. This explains the non-detectable effect of application of sanitizers on mechanical properties of both types of gloves during the period of testing.

It may also be due to the lack of adequate time for the sanitizer chemicals to be penetrated the depth of the glove material. Therefore, the observations made by assessing the discolouration and mechanical properties will provide an interesting conclusion that if the glove material being exposed for a shorter period (less than eight hours) to these sanitizing chemicals, there may not be a tendency for the material to get deteriorated. Nevertheless, the examination gloves have a very short usage time. Therefore, it can be concluded that the effect of hydrogen peroxide-based hand sanitizer formulations on NBR examination gloves is negligible (Susantha Siriwardene, U M S Priyanka, W K N Aradhana, Renuka Nilmini and Gayan Priyadarshana, Faculty of Technology, University of Sri Jayewardenepura).

Table 13. *Mechanical properties of untreated and treated glove samples dipped in sensitizers at different frequencies*

Treatment Frequency of dipping	NR gloves				NBR gloves			
	Tensile Strength (MPa)	Elongation @ break (%)	M(100) (MPa)	Tear strength (N/M)	Tensile Strength (MPa)	Elongation @ break (%)	M(100) (MPa)	Tear strength (N/M)
Control sample	13.7	583.3	1.6	92	33.2	400.0	3.5	1.9
Once in 15 min	14.0	583.3	1.6	110	30.9	433.3	2.7	3.1
Once in 30 min	14.2	600.0	1.5	84	29.9	433.3	2.8	2.3
Once in 1 hour	14.2	566.7	1.5	101	33.8	450.0	2.6	3.1
Once in 2 hours	13.5	550.0	1.6	91	33.5	416.7	2.8	2.9
Once in 3 hours	13.7	583.3	1.5	100	30.0	416.7	2.8	2.9

Effects of disinfectants used for Covid-19 on the tyre tread performance

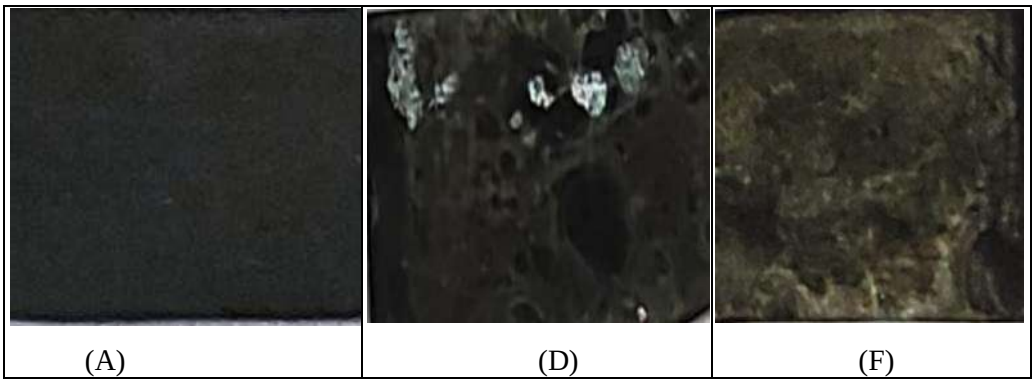
During the COVID-19 pandemic situation, contact of indoor-outdoor surfaces which may readily be in contact with humans who are infected by the virus causes to spread of virus by contamination. It has been established that the virus is capable of surviving on different surfaces with different life spans. Therefore, frequent disinfection of such surfaces become a common and essential health safety measure all over the world. Sodium hypochlorite is one of the widely used as the chemical disinfectant due to its low cost and frequent availability. Under these circumstances, disinfection of tyres of the vehicles particularly food and health care transportation industry became a fairly new but essential practice, however, there was no much information available on the effect of exposure of Sodium hypochlorite on surfaces of tyers (tyre trades). Therefore, a study was carried out to study the effect of exposure of disinfectants on the performance of tyre tread vulcanizates, sodium hypochlorite solution of 0.5% concentration was exposed to pneumatic tyre tread vulcanizate samples during a week at different frequencies. Mechanical properties such as Tensile strength, tear strength, modulus at 300% elongation and hardness tests were measured to evaluate the mechanical properties of the exposed tyre treads. Different treatments studied are presented in Table 14.

The effect on surface appearance

Photographs of the surface of the control (free from exposure) and treated samples taken from a 13-megapixel primary rear camera are shown in Figure 4. It could be seen that control retains smooth and black in colour without any visual difference. However, exposed samples showed a distorted surface with a colour variation of the samples exposed to sodium hypochlorite at higher frequencies.

Table 14. *Disinfection frequency used in the study*

Condition	Sample	Exposure time period (during 7 days of period, dipping time 3 min)	Number of exposures or frequency for 7days
0.5% concentrated Sodium Hypochlorite at room temperature	A	No exposure control	0
	B	After 7 days	1
	C	Every 24 hours	7
	D	Every 12 hours	14
	E	Every 8 hours	21
	F	Every 4hour	42



(A) (D) (F)

Fig. 4. Photographs of differently treated tyre tread samples

Sodium hypochlorite is a well-known bleaching agent and a salt of moderately strong base known as hypochlorite ion (OCl^-) and the weak HOCl acid. This ability of bleaching may be responsible for this discoluration. In addition, oxidation of the macromolecular chain may occur due to the oxidizing ability of hypochlorite ions. Therefore, this observation clearly indicates easily visuable surface discoloration and roughness of the tyre treads effected by the application of sodiumhypocholorite solution.

Physico-mechanical properties

Physico-mechanical properties of differently treated tyre treads are tabulated in Table 15. It is clear from the results presented in the Table that frequency of the

application of sodium hypochlorite on tyre tread has a clear effect on the tensile and tear properties. It has shown a decreasing trend with the increase of the frequency of the disinfection application. In contrast hardness shows a slightly increasing trend. Therefore, it could be concluded that long-term exposure of sodium hypochlorite has greater possibility to adversely affect the performance of tyre treads and justifies the need of in-depth research on the same subject.

Table 15. *Physico-mechanical properties of differently treated samples*

Mechanical property testing	A	B	C	D	E	F
Tensile strength (MPa)	27.18	27.60	27.63	26.59	25.8	25.73
Modulus@100% (MPa)	2.13	2.55	2.03	2.02	2.02	2.02
Modulus@300% (MPa)	11.81	12.90	10.92	10.97	10.72	10.63
Modulus@500% (MPa)	23.76	24.61	23.03	22.62	22.09	22.34
Elongation at break (%)	563.46	507.07	594.83	565.55	605.89	563.14
Tear strength (N/mm)	80.63	86.22	72.62	93.09	74.55	76.47
Hardness	63.64	64.57	63.75	65.11	65.10	65.74

(Susantha Siriwardene, U M S Priyanka, N Renuka Nilminia, G D D K Karunathilaka and Gayan Priyadarshana: Faculty of Technology, University of Sri Jayewardenepura)

Characterization of P50 SNR DV (at 10 phr EPDM) composites with different filler loadings

As a part of the MPhil research project carried out on "Rheological and Mechanical Properties of Ternary Composites of Thermoplastics (TPs) and Skim Natural Rubber (SNR)", characterization of dynamically vulcanized PP/SNR(50/50) blends compatibilized with 10 phr EPDM) and filled with different $CaCO_3$ composites loadings was carried out. Formulations used and the sequence of mixing of mixing of ingredients are shown in Tables 16 and 17 respectively. Blends and composites were prepared using the Hakke internal mixer at 70 rpm and at mixing temperature of 180 ^{0}C. The mechanical properties of the composites were evaluated.

Table 16. *Mixing formula used for preparation of compatibilized PP/SNR (50/50) DV blend and its composites*

Compound	Quantity /phr	Weight/g						
		F 0	F 5	F 10	F 15	F 20	F 25	F 30
PP	100	86.9	83.1	79.6	76.4	73.5	70.8	68.3
SNR	100	96.4	92.2	88.4	84.8	81.6	78.6	75.8
EPDM	10	16.4	15.7	15.1	14.4	13.9	13.4	12.9
Filler ($CaCO_3$)	*	0.0	24.7	47.4	68.3	87.6	105.4	122.0
IPPD	0.75	0.7	0.7	0.7	0.6	0.6	0.6	0.6
ZnO	2.5	2.4	2.3	2.2	2.1	2.0	2.0	1.9
Stearic Acid	1	1.0	0.9	0.9	0.8	0.8	0.8	0.8

Compound	Quantity /phr	Weight/g						
		F 0	F 5	F 10	F 15	F 20	F 25	F 30
TMTD	1.25	1.2	1.2	1.1	1.1	1.0	1.0	0.9
TBBS	1	1.0	0.9	0.9	0.8	0.8	0.8	0.8
Sulphur	0.25	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Table 17. *Mixing schedule used for preparation of compatibilized PP/SNR (50/50) DV blend and its composites*

Activity	Initiation time/min
PP was added & Rotor was started in 10 rpm	0
Rotor speed was adjusted to intended rpm for mixing	5
NR was added with IPPD	8
EPDM was added	10
Half from the total weight of $CaCO_3$ was added	12
Another half from the total weight of $CaCO_3$ was added	13
Stearic acid and ZnO were added	14
TBBS and TMTD were added	15
Sulphur was added	17
Mixing was stopped and dumped (two minutes after a stabilization torque is achieved)	22

Tensile properties (Un-aged and aged)

Stress-strain curves of EPDM compatibilized P50 SNR DV blend and its composites with different filler loadings are presented in Figure 5. All curves have shown the behavior of typical thermoplastic elastomers (TPEs) with relatively high initial modulus and less defined yield stress. Figure 6 shows the effect of filler loading on tensile strength and aging properties of EPDM compatibilized P50 SNR DV blend and its composites. It was found that the tensile strength of the composites showed a maximum value at 15 phr loading and further increase of the filler loading has decreased the tensile strength. This may be due to the possible filler agglomeration as the loading increased.

Figure 7 shows the elongation at break (EB) results of EPDM compatibilized P50 SNR DV blend and its composites. It could be seen that a similar trend of EB values for both aged and non-aged counterparts. However, higher EB values could be seen when increasing the filler loading up to 10 phr but there is no significant difference in EB value between aged and non-aged P50 SNR composites while increasing the filler loading from 15 phr to 30 phr. This can be attributed to the presence of $CaCO_3$ which suppresses the ability of the PP matrix to undergo a plastic-deformation process.

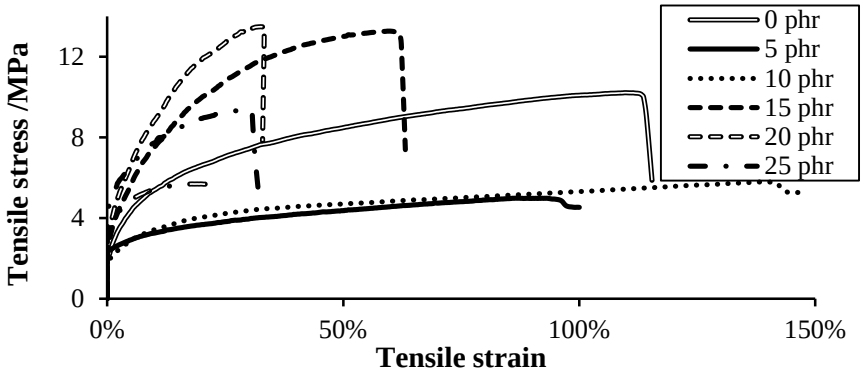


Fig. 5. Stress-strain curves of EPDM compatibilized P50 SNR DV blend and its composites

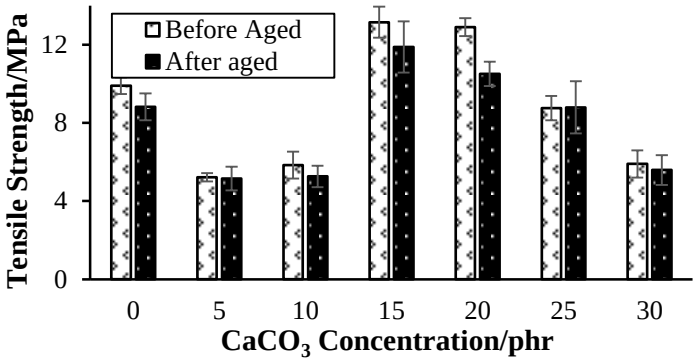


Fig. 6. Effects of filler loading on tensile strength and ageing properties of EPDM compatibilized P50 SNR DV blend and its composites

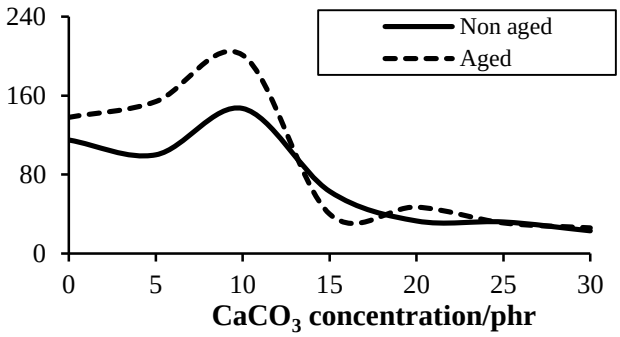


Fig. 7. Elongation at break results of aged and non-aged EPDM compatibilized P50 SNR DV blend and its composites

Hardness

The effect of filler loading on hardness of EPDM compatibilized P50 SNR DV blend and its composites is shown in Figure 8. Hardness of the composites varies in a narrow range for all the composites. However, maximal value of hardness could be seen in the compatibilized P50 SNR DV composites filled with 15 to 20 phr of $CaCO_3$ loading. It is reported that in this type of composites, vulcanized rubber particles and fillers are dispersed in the continuous plastic phase and hardness of the composites is mainly governed by the properties of the continuous phase.

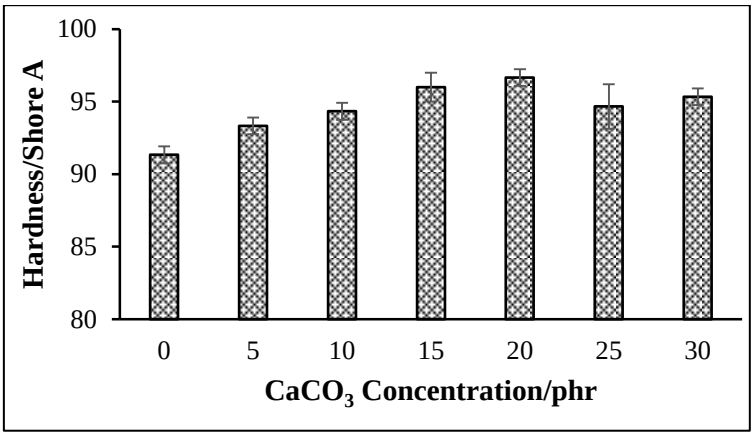


Fig. 8. Effect of filler loading on hardness properties of EPDM compatibilized P50 SNR DV blend and its composites

ADAPTIVE RESEARCH

E S Munasinghe

DETAILED REVIEW

Staff

Dr (Mrs) E S Munasinghe, Principal Research Officer, Mrs B M D C Balasooriya, Research Officer (Polgahawela Substation), Mr P M M Jayathilake and Mrs N M Piyasena Technical Officers and Mrs M A R Srimali, Management Assistant were on duty throughout the year.

Seminars/Training/Workshops/Exhibitions conducted

Officer/s	Subject/Theme	Beneficiary/Client
ES Munasinghe	Awareness Programme on Dry Zone Rubber Cultivation	Rubber smallholders in Nachchaduwa & Nochchiyagama
	Awareness Programme on Climate Change, Carbon Footprint & Carbon Trading	High officials of rubber-related Government Organizations

Seminars/Training/Workshops/Meetings/Conferences attended

Officer/s	Subject/Theme	Organization
ES Munasinghe	Progress Review Meeting	IFAD
ES Munasinghe & BMDC Balasooriya	Research Meetings	RRISL
	NASTEC Review Meeting	RRISL
BMDC Balasooriya	Wayamba University Research Congress	Wayamba University of Sri Lanka
	International Symposium on Agriculture and Environment	University of Ruhuna

Field visits

Experimental - 68
Advisory - 04
Other - 05

FIELD INVESTIGATIONS

Expansion of rubber cultivation to non-traditional areas (ARU/01)

Factors influence the adoption of smallholder rubber cultivation in non-traditional areas

The study was conducted to identify the factors that influence the adoption of cultivating rubber among the smallholders in non-traditional areas. Ampara district, which is recently used for new planting programme of rubber, was considered in the study. The databases available in the Rubber Development Department and Smallholder Tea and Rubber Revitalization Project were used to obtain the required secondary information. A field survey was conducted to collect the primary data on factors related to the adoption of rubber cultivation in all rubber-growing divisions of Ampara district. A stratified random sampling technique was employed to select each 40 new rubber planters and non-planters from rubber growing divisions. A questionnaire survey was instrumented to gather data on socio-economic, environmental, technological and institutional aspects affecting the adoption of new rubber planting in the non-traditional rubber smallholding sector. A logistic regression model was developed to determine the influence of the above characteristics on smallholders' decisions on the new planting of rubber.

The logistic analyses revealed that participation in seasonal training programmes (by 67%), age, education level and monthly income of the farmers had a significant positive correlation on the adoption of farmers to new planting of rubber in the Ampara district. Nevertheless, problems in accessing initial capital for cultivation (by 37%) and distance to the permit received land from the farmer's home (by 19%) showed a significant negative association (Table 1).

Table 1. *Parameters of the logistic regression model explaining the factors influencing the adoption of rubber planting in the Ampara district*

Factors	Coeff.	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
Seasonal training	3.6077	0.8923	4.04	0.000	1.8586	5.3567
Age	0.0540	0.0369	1.46	0.100	-0.0182	0.1264
Education	0.1734	0.0932	1.86	0.063	-0.0092	0.3562
Monthly income	0.0001	0.0001	2.19	0.028	6.05e-6	0.0001
Lack of initial capital	-1.5340	0.7028	-2.18	0.029	0-2.911	-0.1565
Distance	-0.7949	0.4353	-1.83	0.068	-1.6482	0.0584
Constant	-3.2620	2.3985	-1.36	0.174	-7.9631	1.4390

Although not strong enough to represent the logistic model, the awareness of farmers on the government subsidy scheme, the current situation of rubber cultivation in Ampara district, seen of a rubber cultivations at latex harvesting stage in Ampara district and income status of an existing rubber plantation in Ampara district had significantly contributed to the increase in adoption of the new planting programme. Further, fear of incompatibility with other familiar crops, non-establishment of clear

impression, misconceptions on rubber cultivation among farmers and non-receive of rubber planting materials to farmers at the onset of the rainy season showed significant negative correlation with the adoption of new planting (A M U K Attanayaka, E S Munasinghe, W Wijesuriya and S P Nissanka).

Improving the protocols available to cultivate rubber in the Dry Zone

With the aim of improving suitable protocols available to cultivate rubber in the Dry Zone, farmer participatory adaptive research trials were maintained in the Northern and North Central provinces of the country.

Growth performance (in terms of girth and height) of immature rubber plants of sites in Kilinochchi, Mullaithivu and Anuradhapura was assessed (Table 2).

Table 2. *Details of rubber planting sites in the Dry zone*

Sites	Year of planting	Site code	Land extent (Ac)	Clone	% Tree density	Mean girth at 120 cm (cm)
Kilinochchi	2017	2017/K1	½	RRISL 203	45	17.1 ± 0.49
	2017	2017/K2	½	RRISL 203	68	21.0 ± 0.48
	2017	2017/K3	½	RRIC 121	50	17.3 ± 0.48
Mullativu	2013	2013/M1	½	RRIC 121	98	51.4±1.10
	2017	2017/M2	½	RRIC 121	75	22.5±0.59
Anuradhapura	2017	2017/A1	2	RRISL 203	93	33.4 ± 0.25
			2	RRIC 121	98	32.9 ± 0.22
	2019	2019/A2	½	RRIC 121	99	10.5±0.20
			½	RRISL 203	96	7.1±0.20
			½	RRISL2001	98	9.4±0.20
	2019	2019/A3	¾	RRISL 203	88	9.9±0.18
	2019	2019/A4	1	RRISL 203	93	10.1±0.18
	2019	2019/A5	1	RRIC 121	92	10.6±0.17
			½	RRISL 203	85	9.3±0.21
			½	RRISL2001	85	9.3±0.21

Farmers were rather inresponsive to the instructions given by RRISL in K1 and K3 sites resulting in poor maintenance and low level of plant growth. Therefore, it was decided to withdraw the involvement of RRISL from these sites. Although, plant growth in sites K2 and M2 are also not upto the expected level, growers showed sufficient level of interest to cultivate rubber. The plant growth of these sites would have been affected by climatic conditions in the area.

Awareness programmes were conducted to educate rubber growers on dry zone rubber cultivation in Nochchiyagama and Nachchaduwa of Anuradhapura district in collaboration with the Rubber Development Department and Mahaweli Authority.

Feasibility studies were conducted for suitability assessments and farmer participatory adaptive research trials were established in Nachchaduwa of

Anuradhapura district and Katharagama of Moneragala district (E S Munasinghe, V H L Rodrigo, P M M Jayathilake and N M Piyasena).

Water requirement of young rubber plants in the Dry zone

This study was conducted to assess the water requirement of young rubber plants in the Dry Zone of the country. The experiment was laid out as a farmer participatory adaptive research trial established in 2017 at Thalawa, Anuradhapura. The experiment consists of two factors, watering interval (5, 6 and 7- day intervals) and amount of water applied (4, 8 and 12 litres per plant). Randomized Complete Block Design was applied with four blocks (replicates) with each block having all nine combinations of watering intervals and amounts. The overall system was repeated twice in the same site with two different clones, *i.e.* RRIC 121 and RRISL 203. Each treatment plot contained 8 trees.

During the dry period prevailed from March to September (no rains above 0.03 mm/day), the following watering schedule was followed;

T1 - 4 l in 5 day interval
T2 - 4 l in 6 day interval
T3 - 4 l in 7 day interval
T4 - 8 l in 5 day interval
T5 - 8 l in 6 day interval
T6 - 8 l in 7 day interval
T7 - 12 l in 5 day interval
T8 - 12 l in 6 day interval
T9 - 12 l in 7 day interval

The growth of rubber plants was monitored in terms of girth at 120 cm height. Within the period, no significant difference in mean girth increment rates among treatments was observed. However, the clone RRISL 203 reported higher rates than those of the clone RRIC 121 in all treatments (Table 3).

Table 3. *Mean girth increment rates of rubber plants under different watering systems*

Watering system	Mean girth increment (cm per month)	
	RRIC 121	RRISL 203
T1 - 4 l in 5 day interval	0.87	1.09
T2 - 4 l in 6 day interval	0.94	1.02
T3 - 4 l in 7 day interval	0.87	0.83
T4 - 8 l in 5 day interval	0.84	1.12
T5 - 8 l in 6 day interval	0.94	1.03
T6 - 8 l in 7 day interval	0.90	1.00
T7 - 12 l in 5 day interval	0.88	0.86
T8 - 12 l in 6 day interval	0.76	0.80
T9 - 12 l in 7 day interval	0.87	0.93

Accordingly, application of 4 l weekly seems sufficient to cultivate rubber at the age of four years in this region. Also, further studies are required to assess the possibility of using reduced amounts of water.

At the latter part of the dry period, physiological measurements such as stomatal conductance and relative water content of rubber leaves were taken.

No significant difference in stomatal conductance was found among treatments under both clones in the morning and evening of the day (Table 4).

Table 4. *Stomatal conductance of rubber leaves under different watering systems*

Watering system	Stomatal conductance ($\mu molm^{-2}s^{-1}$)			
	RRIC 121		RRISL 203	
	Morning	Evening	Morning	Evening
T1 - 4 l in 5 day interval	0.38	0.25	0.20	0.23
T2 - 4 l in 6 day interval	0.47	0.22	0.36	0.30
T3 - 4 l in 7 day interval	0.29	0.06	0.45	0.22
T4 - 8 l in 5 day interval	0.32	0.20	0.34	0.27
T5 - 8 l in 6 day interval	0.31	0.27	0.19	0.12
T6 - 8 l in 7 day interval	0.38	0.12	0.40	0.39
T7 - 12 l in 5 day interval	0.43	0.14	0.26	0.31
T8 - 12 l in 6 day interval	0.36	0.29	0.23	0.26
T9 - 12 l in 7 day interval	0.30	0.16	0.35	0.21

Further, there was no significant difference observed in relative water content (%) of rubber leaves among the treatments in both clones (Table 5).

Table 5. *Relative water content of rubber leaves under different watering systems*

Watering system	Relative water content (%)	
	RRIC 121	RRISL 203
T1 - 4 l in 5 day interval	85.68	84.98
T2 - 4 l in 6 day interval	84.13	84.53
T3 - 4 l in 7 day interval	84.89	84.64
T4 - 8 l in 5 day interval	88.68	88.72
T5 - 8 l in 6 day interval	87.17	87.55
T6 - 8 l in 7 day interval	84.17	84.88
T7 - 12 l in 5 day interval	87.81	88.29
T8 - 12 l in 6 day interval	87.14	86.31
T9 - 12 l in 7 day interval	84.34	84.38

The soil moisture contents (%) within the watering cycle were measured (VWC) and no significant difference was observed among the treatments under both clones (Table 6).

Table 6. *The moisture content of soils under different watering systems*

Watering system	Soil moisture (%)	
	RRIC 121	**RRISL 203**
T1 - 4 l in 5 day interval	1.6	1.6
T2 - 4 l in 6 day interval	1.4	1.5
T3 - 4 l in 7 day interval	1.6	1.5
T4 - 8 l in 5 day interval	1.4	1.2
T5 - 8 l in 6 day interval	1.4	1.6
T6 - 8 l in 7 day interval	1.3	1.0
T7 - 12 l in 5 day interval	1.8	1.2
T8 - 12 l in 6 day interval	1.7	1.5
T9 - 12 l in 7 day interval	1.4	1.2

The above mentioned physiological parameters further confirm the sufficiency of applying 4l of water weekly to maintain rubber cultivation at the age of four years during dry periods (E S Munasinghe, V H L Rodrigo, P M M Jayathilake and N M Piyasena in collaboration with Genetics & Plant Breeding Department).

Increase land productivity through technology adoption (ARU/02)

Farmer perceptions and economics of technology adoption in the smallholder rubber sector in Sri Lanka

The study was started to assess the awareness, perception and adoption of recommendations in the rubber smallholder sector in Sri Lanka. It was carried out in four traditional rubber growing districts: Kegalle, Kurunegala, Gampaha and Kandy. A pre-tested semi-structured questionnaire survey was used as the data collection tool for the cross-sectional data collection. A stratified random sampling technique was adopted for sampling.

It was hypothesized that there is a causal link between awareness, perception and adoption of recommended practices. To model this phenomenon, three behavioral equations were developed as depicted in Equations [1] to [3].

$$AwI_i = \alpha_0 + \alpha_1 CwE_i + \alpha_2 EV_i + \alpha_3 TR_i + \alpha_4 NTR_i + \varepsilon_{1i} \quad [1]$$

$$PER_i = \delta_0 + \delta_1 AwI_i + \delta_1 MoRS_i + \delta_2 GoHH_i + \delta_3 EPR_i + \delta_4 EOL_i + \delta_5 EAL_i + \delta_6 EH_i + \delta_7 EinF_i + \varepsilon_{2i} \quad [2]$$

$$AdI_i = \beta_0 + \beta_1 PER_i + \beta_2 TE_i + \beta_3 ADL_i + \varepsilon_{3i} \quad [3]$$

Where;

$AwIi$=Awareness Index; $CwEi$= Contacts with Extension; EV_i=Number of extension visits;TR_i=Whether attended to training programms; $NTRi$=Number of training protrammes attended; $MoRSi$= Member of a Rubber Society;

$PERi$=Perception Index; $GoHHi$=Gender of Household Head; EPR_i=Education – Primary; $EOLi$= Education – OL; $EALi$= Education – AL; EHi= Higher education; $EinF$=Experience in Farming; TEi= Total Extent; $ADLi$= Average Distance to Land; $\varepsilon 1i$ $\varepsilon 2i$, $\varepsilon 3i$ are error terms.

Simple additive indices of awareness, perception and adoption were constructed and were used as the dependent variable in the simultaneous awareness-perception-adoption model. The indices were constructed as;

$$AwI_i = \frac{\sum_{i=1}^{n} Awareness_i}{n}$$

$$PER_i = \frac{\sum_{i=1}^{n} Perception\ score_i}{n}$$

$$AdI_i = \frac{\sum_{i=1}^{n} Adoption_i}{n}$$

Where, n is the number of recommendations.

Since this model carries endogenous variables on the right-hand side of the equations [AwI and PER], 'Three Stage Least Square' technique was used to estimate this system of equations. Analysis was done using STATA 16 econometric software. The results of the analysis are given in Table 7.

Table 7. *Results of the Three-Stage Least Square estimation of the adoption model*

	Coef.	Std. Err.	Z	P>z	[95% Conf. Interval]	
Awareness						
Contacts with extension	0.054	0.024	2.270	0.023	0.007	0.102
Extension visits	0.009	0.007	1.180	0.237	-0.006	0.023
Training received	0.059	0.017	3.550	0.000	0.027	0.092
No of training	0.007	0.002	3.170	0.002	0.003	0.011
Constant	0.707	0.023	31.120	0.000	0.662	0.751
Perception						
Awareness Index	1.982	0.349	5.680	0.000	1.298	2.665
Member of Rubber Society	0.137	0.036	3.840	0.000	0.067	0.207
Gender of household head	0.019	0.044	0.440	0.660	-0.067	0.106
Education - Primary	-0.053	0.147	-0.360	0.718	-0.340	0.234
Education - OL	0.042	0.139	0.300	0.763	-0.231	0.315
Education - AL	0.149	0.144	1.040	0.300	-0.133	0.431
Higher education	0.237	0.166	1.430	0.153	-0.088	0.562
Experience in farming	-0.002	0.001	-1.260	0.208	-0.005	0.001

	Coef.	Std. Err.	Z	P>z	[95% Conf. Interval]	
Constant	0.435	0.238	1.830	0.067	-0.031	0.901
Adoption						
Perception Index	0.129	0.028	4.600	0.000	0.074	0.184
Total extent	0.001	0.001	0.950	0.340	-0.001	0.002
Average distance to land	0.001	0.002	0.350	0.723	-0.003	0.004
Constant	0.344	0.062	5.590	0.000	0.224	0.465

According to the results, the awareness index shows significance in the perception equation and the perception index shows significance in the adoption equation. All except one of the variables related to extension effort are significant in the awareness regression. One major extension tool, training programs show significance in improving awareness of recommendations. In the sample, 71.4% had attended training on rubber cultivation or processing. Contacts with extension agents also returned a positive and significant sign. 89.02% of farmers said that they have contact with the Rubber Extension Officers. However, extension visits in the past three months have become non-significant. 41.64% of the farmers in the sample reported that there were no visits by the extension officers to them in the last three months. Thus, organizing training programs and proper extension service proves to be fruitful in creating awareness about various technological advancements in rubber cultivation. The perception is highly influenced by awareness. Membership in a rubber society shows a strong significance and a positive relationship. Such memberships denote peer effect and hence farmers who have access to it have formed a favorable perception of technologies than farmers who have no access. However, only 57% of farmers in the sample are members of society (B M D C Balasooriya, P Seneviratna and N M Piyasena).

On-farm behaviour of smallholder rubber farmers in traditional rubber growing areas

This study was started to identify the on-farm productivity and production variability among smallholder rubber farmers in traditional rubber growing areas. Kegalle and Kurunegala districts were selected for the study representing the Wet and Intermediate Zones of the country. Ten smallholder rubber fields were selected in each district for the data collection, and data were collected on yield and number of tapping days. Yield data collected from 10 smallholder fields are summarized and shown in Figure 1. An average yield of 1,357 kg/ha and 1,385 kg/ha were reported from Kegalle and Kurunegala districts, respectively. Figure 2 shows the number of tapping days in each month (B M D C Balasooriya, P Seneviratne and N M Piyasena).

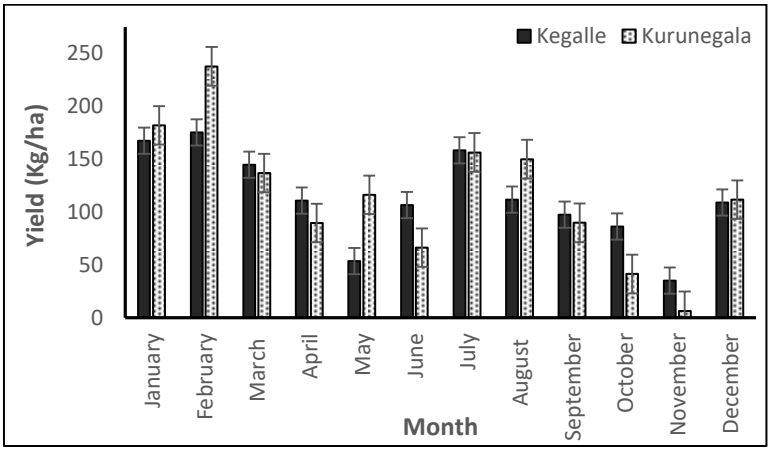


Fig. 1. Seasonal yield variation during the year 2021

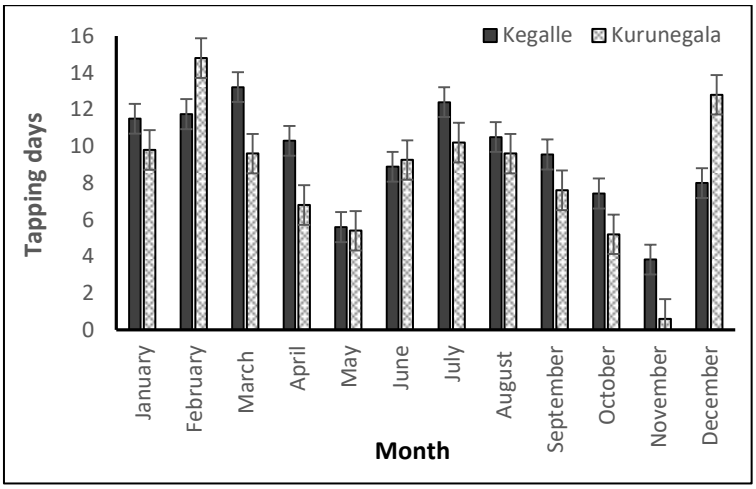


Fig. 2. Variation in tapping days during the year 2021

Socioeconomic improvement in plantation workers (ARU/03)

Psychosocio-economic status of the rubber plantation workforce

This study was commenced to identify the psychosocio-economic status of the rubber plantation workforce. A semi-structured pre-tested questionnaire survey was conducted to collect data on gender issues, child protection and education systems among plantation workers. The data collection was completed in the estates managed by the institute: Dartonfield, Gallewatta, Nivithigalakele, Kuruwita, Polgahawela and Moneragala. Data collection from Regional Plantation Companies; Geekiyanakanda, Eladuwa, Culloden are in progress (B M D C Balasooriya, E S Munsinghe, V H L Rodrigo and N M Piyasena).

Impact of COVID-19 pandemic on the livelihood of estate workers

This study aimed to assess the impact of the COVID-19 pandemic on the livelihood of estate workers. Data collection was done through a semi-structured questionnaire survey. In the initial step, the questionnaire survey was carried out in the estates under the Rubber Research Institute: Dartonfield, Galewaththa, Nivithigalakele and Kuruwita,. The sample consisted of 34% male workers and 66% female workers who are in the age range of 23 to 65 years. About 21% of the samples were infected with COVID-19. One death of a family member was reported due to the disease.

RRISL-managed estates provided 100% job security during the COVID-19 pandemic period. As reported by the estate workers, working days offered by the estate had not been changed during the period, and there were no delays in paying salaries. Workers who were infected with COVID-19 or in quarantine did not attend to work during the periods concerned. Further, some workers failed to attend to work during the lockdown and the peak disease-spreading periods due to safety reasons. This period varied from 1-3 months, causing the reduction of their salary from 10% to 100%. During the period, 7% of the workers tended to use 30- 50% of their bank deposits, 25% fixed assets and jewelry to cover their living expenses.

There was a high positive perceived response (77%) of estate workers on the availability of food items. That means the majority of the workers had access to food items. Growing vegetables in the home garden was done by 28% of estate workers, while 35% of the workers had managed part of their food needs with already available resources in their home gardens and surroundings.

In terms of the affordability of goods and services (financial status), 30% of estate workers were on a negative perception, while 50% were on a neutral perception. Only 20% of estate workers reported that they had sufficient finances for goods and services during the COVID-19 pandemic compared to the pre-pandemic status. Among the workers, 13% reported that they were not able to afford food items during the pandemic period as before. About 28% said that they had to cut down their medical expenses, while nearly a 60% of them were not able to afford appliances required for online education. This concludes that purchasing power of estate workers for goods and services had been substantially affected by COVID-19.

During the period, 100% of the workers showed negative responses to "household violence has increased against women and girls". That means no increase in gender discrimination or household violence during the period in their community (B M D C Balasooriya, E S Munasinghe, V H L Rodrigo and N M Piyasena).

Developing a project to approach the voluntary carbon market with the rubber cultivation in Eastern and Uva Provinces for the sustainable rubber industry (Treasury Funded Development Project)

The project was initiated with the objective of developing a carbon trading project to obtain Verified Carbon Standards (VCS) for 2,500 ha of new rubber cultivations in the Uva and Eastern Provinces. Preparation of Project Description Document (PDD) was completed in collaboration with Carbon Consulting Company (CCC) and the project was listed in one of the most recognized international accredited VCS registry; VERRA. The ground-level validation of the project was completed by a third-party accredited auditor; Epic Sustainability Services (Pvt) Ltd.

Identification of GPS locations of *ca*. 2,000 ha of new rubber smallholdings in Moneragala and Ampara districts was done in collaboration with Smallholder Tea and Rubber Revitalization (STaRR) Project.

A workshop on 'Role of Rubber in Climate Change, Carbon Footprint & Carbon Trading' was conducted to aware high officials of rubber related government organizations.

The Carbon footprint of rubber related government organizations; the Rubber Research Institute of Sri Lanka, the Rubber Development Department of Sri Lanka and the Thurusaviya Fund was calculated as 542, 754 and 17 CO2e tons, respectively (V H L Rodrigo and E S Munasinghe).

BIOMETRY

Wasana Wijesuriya

DETAILED REVIEW

Staff

Dr (Mrs) Wasana Wijesuriya, Principal Research Officer, Mr Dilhan Rathnayaka, Research Officer, Mr Vidura Abeywardene Experimental Officer, Mrs S N Munasinghe, Management Assistant were on duty throughout the reporting year.

Research students

The following students are registered for postgraduate studies under the supervision of Dr (Mrs) Wasana Wijesuriya.

- L A T S Liyanaarachchi - Continued work for his MPhil on "Indicator-based identification, forecasting and mapping of droughts in Sri Lanka" at the Wayamba University.
- Ms P W Jeewanthi - Commenced work for her MPhil on "Forecasting rainfall anomalies and modeling rainfall extremes to minimize the risk in Agriculture Sector" at the Postgraduate Institute of Agriculture, University of Peradeniya.
- A M U K Attanayaka - Continued work on "Rubber cultivation in non-traditional areas: Factors influencing adoption by smallholders in Ampara district of Sri Lanka" for his MSc, at the Postgraduate Institute of Agriculture, University of Peradeniya.
- U I Ranasinghe - Continued work on "Socioeconomic and agronomic reasons for substandard growth of immature rubber in Eastern Province of Sri Lanka" for his MSc, at the Postgraduate Institute of Agriculture, University of Peradeniya.
- M D N Gunaratne - Started work on "Modeling climate change and assessing financial risk of climate change on agriculture sector in Sri Lanka" for his PhD prgoramme at the Faculty of Management and Finance, University of Colombo.

Seminars/Training/Workshops addressed/conducted

Dr (Mrs) Wasana Wijesuriya and Mr Dilhan Rathnayaka conducted the following training programmes organized by RRISL. Mr Vidura Abeywardene assisted in practicals on meteorological data recording.

Subject/Theme	Beneficiary/Client
Climatic conditions and rainfall distribution in rubber growing areas	Participants of the Advanced Certificate Course in Plantation Management, Officers of Rubber Development Department

Seminars/Conferences/Workshops/Meetings/Training sessions addressed

Officer	Subject/Theme	Organization
Wasana Wijesuriya	Liaison Officer's report of the Socioeconomic specialist group of IRRDB	IRRDB
Dilhan Rathnayaka	Experiences during the 2020/21 North-East monsoon season	Department of Meteorology
	Experiences during the 2021 South-West monsoon season	Department of Meteorology

Seminars/Conferences/Meetings/Workshops attended

Officer	Subject/Theme	Organization
Wasana Wijesuriya	Workshop series in National Climate Change Data Sharing Network	Ministry of Environment
	Workshop on Role of Rubber in Climate Change, Carbon Footprint & Carbon Trading	RRISL & Ministry of Plantation
Wasana Wijesuriya & Dilhan Rathnayake	Experiences during the 2020/2021 North East and 2021 South-West monsoon season - Monsoon Forums	Department of Meteorology
	Scientific Committee Meetings	RRISL

RESEARCH AND DEVELOPMENT

The Biometry section focused its activities on two different programmes; *viz.* improving the reliability of interpretations through appropriate statistical methods (BM 01) and improving the knowledge base on climate, climate change & variability for better decision making in rubber growing areas (BM 02).

Improving the reliability of interpretations through appropriate statistical methods (BM 01)

Statistical consultancy (BM/01/a)

Statistical consultancy is provided on designing experiments and questionnaires, statistical analyses, designing and developing databases and interpretation of experimental results to the fellow scientists at RRISL and industry stakeholders on request (W Wijesuriya and D Rathnayaka).

Development, modification and application of appropriate statistical methods for agronomic, socio-economic and industrial experiments in the rubber sector (BM 01/b)

The objective of this activity is to employ appropriate statistical techniques for research in the rubber sector and to familiarize the statistical techniques among the researchers to encourage the proper use of these methods.

Improving the knowledge-base on climate, climate change and variability for better decision-making in rubber growing areas (BM 02)

Maintenance and establishment of meteorological and agro-meteorological stations (BM/02/a)

Maintenance and data recording is being done in the meteorological stations owned by RRISL by visiting and inspecting these sites and by providing instruments when necessary. These include the AGROMET station at Dartonfield and rainfall stations in Moneragala, Kuruwita, Nivitigalakele, Polgahawela, Galewatta and Nivitigalakele. An automatic weather station was installed in the Kegalle Regional Advisory Office in December 2021 and recording observations will commence next year.

The data and information pertaining to these stations are explained in the Meteorological Summary of the Annual Review (W Wijesuriya, D Rathnayaka and O V Abeywardene).

Maintenance of databases on meteorological data in rubber growing areas (BM/02/b)

The database with daily meteorological data collected at Dartonfield AGROMET station was properly maintained. Monthly reports were prepared from this daily database and sent to the Department of Meteorology. Daily rainfall records of this station are also sent to National Building and Research Organization (NBRO) for issuing landslide warnings. Rainfall records of substations, *viz.* Moneragala, Kuruwita, Nivitigalakele and Polgahawela were also maintained in a database. These data were made available to researchers and organizations on request. Data pertaining to the current year appear in the Meteorological Review of the Annual Review of RRISL.

A database is maintained on rainfall experienced in rubber-growing areas of Sri Lanka. Monthly rainfall values experienced in rubber growing areas are given in Table 1. It was noted that 2021 was a year with above-average precipitation in most of the rubber-growing areas (W Wijesuriya, D Rathnayaka and V Abeywardene).

Analysis of data to identify changes in patterns and trends in rainfall, identification of drought impacts and spatial analysis of droughts (BM/02/c)

The occurrence of extreme events in rubber-growing areas

The occurrence of extreme rainfall and temperature events are important indicators of climate change. Extreme weather events have become a common and important phenomenon in the study of climate change. According to Intergovernmental Panel on Climate Change (IPCC) 2021 report, the occurrence of extreme events is defined as a value of a weather component above the upper threshold value or below the lower threshold value in a specific region. Generally, it is an accepted fact that these extreme events have an impact on both human society and the natural environment. In rubber cultivation, the major agronomic practices are linked mainly with the rainfall pattern. Therefore, rainfall anomalies and extreme events have detrimental effects on rubber cultivation.

This study employed rainfall data from 1983 to date in selected stations, representing Wet, Intermediate and also areas where rubber cultivation is recently introduced. The indices recommended by the World Meteorological Organization are being used in this ongoing study (Dilhan Rathnayaka and W Wijesuriya).

Appropriate use of statistical methods in rainfall analysis: Detecting monotonic and sequential trends

Trend analysis is one of the most popular statistical approaches which has been extensively used in meteorological sciences for analysis of the variation in hydro-meteorological variables in recent decades. Broadly speaking, trends occur in two ways: a gradual change over time that is consistent in direction is called a monotonic trend and an abrupt shift at a specific point in time is called a step trend or a sequential trend.

This study was aimed at introducing appropriate statistical approaches in detecting monotonic and sequential trends, employing rainfall data recorded at the Dartonfield AGROMET station. The monthly series for the 12 months and the 04 seasonal series for the period 1980 to 2020 recorded at the Meteorological station at Dartonfield, Agalawatta in the Agro-ecological Region, WL1a were used in this study. Except for February, none of the months exhibited monotonic trends, and the seasonal rainfall series also did not show any trends. Sequential trend which is indications of abrupt changes were observed only for the February series at the point of 1987 and also no indication in the seasonal rainfall series. Fig. 1(A) depicts the temporal variation in the "February" series which exhibits a monotonic trend. Fig. 1(B) depicts the variation in May, which does not exhibit a monotonic trend (Dilhan Rathnayaka and W Wijesuriya).

Table 1. *Monthly rainfall in rubber growing areas in 2021*

	Rainfall (mm)										
Month	Hanwella WL 1a	Ratnapura WL 1a	Agalawatta WL 1a	Galle WL 2a	Kekanadura IL 1a	Nittabuwa WL 3	Kurunegala IL 1a	Monaragala IL 1c	Uhana DL 2a	Matale WM 3b	Badulla IM 1a
Jan	264.8	183.8	390.8	195.8	69.0	355.7	158.9	193.0	434.0	352.1	112.6
Feb	37.8	72.0	248.6	15.4	37.0	3.7	3.6	68.1	179.7	0.0	67.6
Mar	284.5	308.8	419.0	122.4	26.0	166.4	66.6	192.0	92.9	22.4	162.4
Apr	169.2	212.6	272.8	407.5	189.0	169.4	165.0	204.3	99.7	183.8	136.5
May	641.4	742.4	956.8	294.8	318.0	839.7	467.9	138.7	131.6	0.0	224.0
Jun	692.2	548.5	660.7	215.4	161.6	794.0	214.7	100.5	30.5	55.7	61.5
Jul	281.9	368.5	507.6	202.1	208.0	243.7	103.5	106.1	89.0	174.5	70.9
Aug	212.6	377.1	260.7	140.0	80.2	187.4	81.3	127.0	130.3	164.8	235.7
Sep	461.0	407.7	425.4	140.8	159.0	288.3	194.0	199.8	126.4	144.4	104.8
Oct	555.3	508.0	568.6	216.2	262.0	430.0	318.2	266.4	194.0	359.8	322.8
Nov	583.1	487.4	667.8	473.7	330.0	442.8	717.6	226.3	267.0	646.5	251.6
Dec	108.6	193.7	237.9	210.6	178.0	100.1	47.7	183.6	312.2	53.8	209.8
TOTAL (mm)	**4292.4**	**4410.5**	**5616.7**	**2634.7**	**2017.8**	**4021.2**	**2539.0**	**2005.8**	**2087.3**	**2157.8**	**1960.2**
Rainy days	**196**	**253**	**262**	**216**	**121**	**214**	**166**	**159**	**121**	**131**	**159**

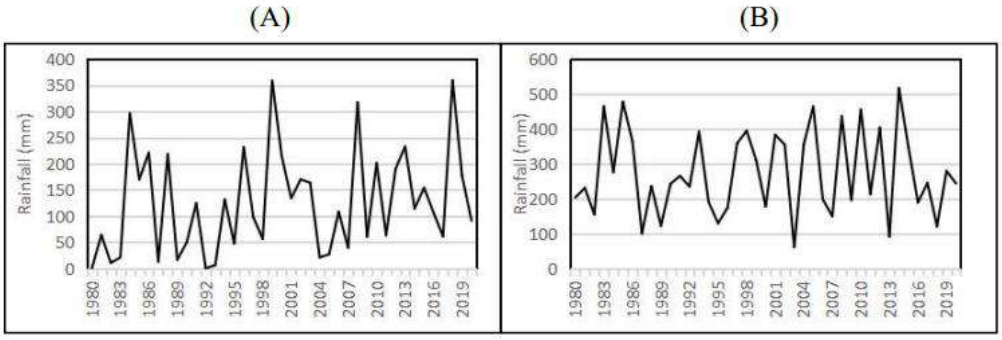


Fig.1. The time series plot for the months of February (A) and December (B) for the Dartonfield Meteorological Station

Rainguard application and low-frequency tapping systems in rubber plantations as adaptations to climate change by escaping rainfall events

This study was initiated to evaluate rainguard application and low-frequency tapping systems as adaptation measures to changing climate. The probability theory will be applied and the efficiency of these adaptation strategies will be evaluated with respect to month and seasons. The data collection for this study is in progress (W Wijesuriya, Dilhan Rathnayaka and V Abeywardene).

Comparison of conventional methods for estimating missing precipitation data

Estimation of missing precipitation data is important as it increases the reliability of research findings. This study was focused on comparing the efficiency of spatial and temporal methods and finding the most appropriate missing values estimation method for different climate zones in Sri Lanka. The main location and surrounding locations were selected for each climate zone and monthly precipitation data were collected from 1980 through 2020. Three temporal methods and four spatial methods were used for estimating missing values. Measurements of errors were used for selecting the most appropriate method for estimating missing values for each location.

Spatial methods have performed better than temporal methods in all seven climate zones. The missing values in the Low Country Wet Zone and Up Country Wet Zone could be estimated using Normal Ratio methods. The Aerial Precipitation Ratio method is the most suitable for estimating missing values in the Mid Country Wet Zone and Low Country Intermediate Zone. Inverse Distance weighting method performed well in Mid Country Intermediate Zone, Up Country Intermediate Zones and Low Country Dry Zone (Postgraduate research study of P W Jeewanthi under the supervision of Dr Wasana Wijesuriya and Prof L H P Gunaratne)

Suitability of Machine Learning Algorithms for Estimating Missing Precipitation Data

The reliability of climate research depends on the continuity and consistency of data. Thus, it is a vital requirement to fill the gaps in the precipitation data series prior to conducting the research. Machine Learning (ML) algorithm is a trending topic due to its high accuracy and robustness of the estimates. Studies on the suitability of different ML algorithms estimating missing data are scanty in Sri Lanka. Therefore, this study was focused on investigating the suitability of different ML algorithms for estimating missing precipitation data.

Locations belonging to seven major Agro-ecological Zones were selected in this study for representing the whole country. One main location and three to four surrounding locations were selected from each zone considering the data availability and geographical location. Monthly precipitation data for the period, 1980 to 2020 were used in selected locations.

Sixty values were deleted randomly in the main location (five values per month) and the deleted values were considered as missing values. The balance data set was used for training ML algorithms and the missing values were estimated using ML algorithms; namely, Linear Regression, Artificial Neural Network, Support Vector Machine, Decision tree, Gradient Boosted tree, Random forest, Boosting ensemble tree and Bagging ensemble tree.

The ML algorithm which records the lowest Mean Absolute Error, Root Mean Square Error and the highest correlation coefficient between actual and the estimated values was considered as the most appropriate ML algorithm for estimating missing values in a particular zone. The estimated precipitation values of ML algorithms had strong positive correlations (>0.70, n=60) with the actual values. Boosting ensemble method provided a more accurate estimation of missing precipitation data in the seven major Agro-ecological Zones in Sri Lanka (Postgraduate research study of P W Jeewanthi under the supervision of Dr Wasana Wijesuriya and Prof L H P Gunaratne).

Collaborative Research

1. Introduction and establishment of new fuelwood growing models in selected *Lands of smallholder rubber farmers*

This project is funded by the Food and Agriculture Organization under its strategic area "Promoting sustainable biomass energy production and modern bio-energy technologies". The details of activities conducted during this year are presented in the review of the Advisory Services Department. This is a collaborative project between Advisory Services Department, Agricultural Economics Unit and the Biometry Section.

2. Assessment of Spatial Impacts of Climate Change on the Plantation Sector in Sri Lanka

This study has been selected for funding by the National Science Foundation (NSF) under the National Thematic Research Projects (NTRP) related to Thrust Area 2 - "Climate Change Resilience on Settlements, Human Health and Infrastructure". The main objective of this project is to assess the spatial impacts of climate change in terms of Geographic, Economic and Social Vulnerability in the Plantation Sector of Sri Lanka. This project is a collaborative one including Wayamba University, Department of Meteorology, Department of the Environment and Energy, the Government of Australia, Tea Research Institute, Coconut Research Institute, Sugarcane Research Institute and RRISL. The Covid-19 pandemic situation has seriously affected the progress of this project. The analysis of data and information are in progress [Dr (Mrs) Wasana Wijesuriya and Mrs Dammika Balasooriya represent the research team of this project].

3. Application of Machine Learning in SMART Agriculture

Collaborative research was conducted with the University of Moratuwa predicting the age of rubber plantations and land utilization extent using Machine Learning techniques. SMART agriculture has been attracting greater attention from the agricultural research community to enhance current practices through machine learning technique incorporation. This study explores the possibility of using machine learning techniques in conjunction with remote sensing imagery of profiles of vegetation indices such as Normalized Difference Vegetation Index and Normalized Difference Moisture Index to classify rubber plantations by age and size/type, estimate tree density and the extent of land use for rubber plantations in the Western and Central provinces of Sri Lanka (Wasana Wijesuriya, Lakshman Rodrigo, J K S Sankalpa, Sangeeth Liyanaarachchi & Dilhan Rathnayaka).

4. Use of remote sensing and Geographic Information Systems (GIS) for rubber plantation management

The overall objective of this project is to develop the GIS and Remote Sensing assisted technology-based precision farming model to improve sustainable and efficient land use in the rubber sector. The specific objectives are; Modeling acquired satellite remote sensing data using GIS assisted platform and link with rubber land use data and information in selected rubber lands, to test and evaluate spatial data models in decision making in rubber plantation management using Dartonfield estate as a case, make aware and disseminate information on the use of spatial modeling in rubber plantation management. The collaborating institute is Genesis (Pvt) Ltd., Sri Lanka (L A T S Liyanaarachchi, Wasana Wijesuriya, J K S Sankalpa, P G N Ishani and Dilhan Rathnayaka).

5. Response Surface Analysis for estimation of Bowl efficiency in Centrifuged Latex production process

A response surface design was done for the estimation of bowl efficiency based on skim screw length and feed tube diameter. The experiments of several factories were completedand the statistical analyses were done to identify the optimal conditions of skim screw length and feed tube diameter to maximize the bowl efficiency in the centrifuged latex production process. This experiment was designed and analyzed on the request of Dipped Products Pvt. Ltd. (Wasana Wijesuriya and Dilhan Rathnayaka).

6. Involvements in IRRDB activities

Dr Mrs Wasana Wijesuriya continued to assist IRRDB in attending to the duties of the Liaison Officer of the Socioeconomic Specialist Group during 2021. Although during the Annual meeting of IRRDB in Myanmar in 2019, the proposal submitted to conduct a Workshop on "Understanding fundamentals in GIS and geo-spatial applications" and a Conference on "GIS for Better Decision Making" was approved, it could not be held either in 2020 or 2021 due to the Covid-19 endemic situation. The liaison officer's report for 2021 of the socioeconomic specialist group was presented at a virtual meeting *via* zoom platform on the 30th March 2021.

AGRICULTURAL ECONOMICS

J K S Sankalpa

DETAILED REVIEW

Staff

Mr J K S Sankalpa, who has been promoted to Senior Research Officer on 1st April, was on duty throughout the year. Mrs P G N Ishani, Research Officer, was on maternity leave from 18th February and commenced duties on 29th June.

Seminars/Conferences/Meetings/Workshops attended

Mr Sankalpa attended the following during the year under review.

Activity	Organisation
Scientific Committee Meeting	Organized by Rubber Research Institute of Sri Lanka

Mrs P G N Ishani attended the following during the year under review

Activity	Organisation
Scientific Committee Meeting	Organized by Rubber Research Institute of Sri Lanka
Training Course on Agricultural Policy Analysis	Postgraduate Institute of Agriculture, University of Peradeniya

Services

Research support

Various cost-benefit and economic analyses were carried out on the request of other researchers.

Database management

A database on auction prices in Sri Lanka and International rubber prices was updated throughout the year. Agricultural Economics Unit analysed the rubber price and rubber products export performance quarterly and presented the information to both the industry and the Plantation Sector.

Rubber marketing in Sri Lanka

Colombo auction is the main mode of disposal of rubber manufactured in factories. The number of auctions conducted by the Ceylon Chamber of Commerce under the Colombo Rubber Traders' Association (CRTA) was 50 during this year.

All these were updated and recorded in a database. The monthly average prices of major raw rubber categories are given in Table 1.

Prices of Ribbed Smoked Sheets (RSS)

The monthly average of RSS1 and RSS3 are given in Figures 1(a) and 1(b), respectively. The highest average price of RSS1 was Rs.515, recorded in November. Yearly average prices of all grades of RSS were higher than that of the previous year (2020). Higher prices compared to the previous year were recorded starting from the beginning of the year 2021. The average RSS1 price difference against the previous year was around Rs.102. The yearly average RSS1 price has increased by 28.5% when compared to 2020. This was mainly due to supply chain disruption prevailing in the international market.

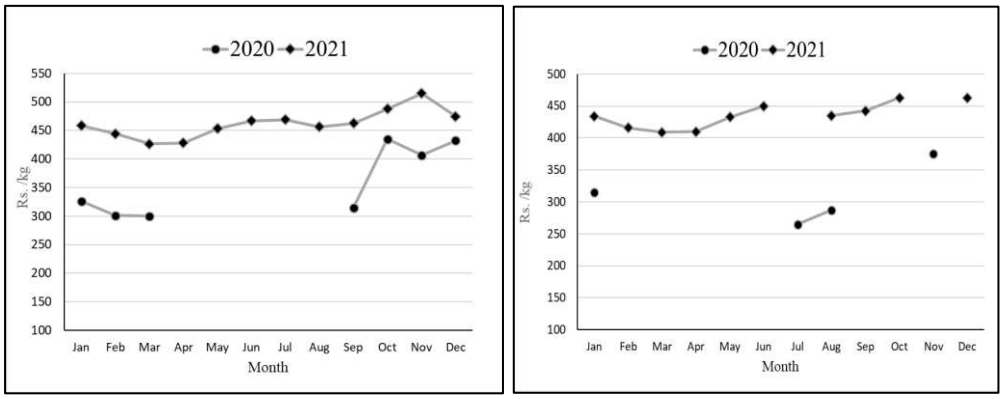


Fig.1. The monthly average prices of RSS 1 (a) and RSS 3 (b) in 2020 & 2021

Prices of Latex Crepe (LC)

Prices of Latex Crepe1X for 2020 and 2021 are shown in Figure 2. LC1X prices have remarkably increased during the middle of the year 2021. The gap between the LC prices was high at the end of the year and prices were gradually increased up to November and prices were increased remarkably at the end of the year. The average LC1X price ranged from Rs.496 (January) to Rs.721 (November) during 2021. The average price of LC1X was Rs.637 which was a 77% improvement compared to the previous year.

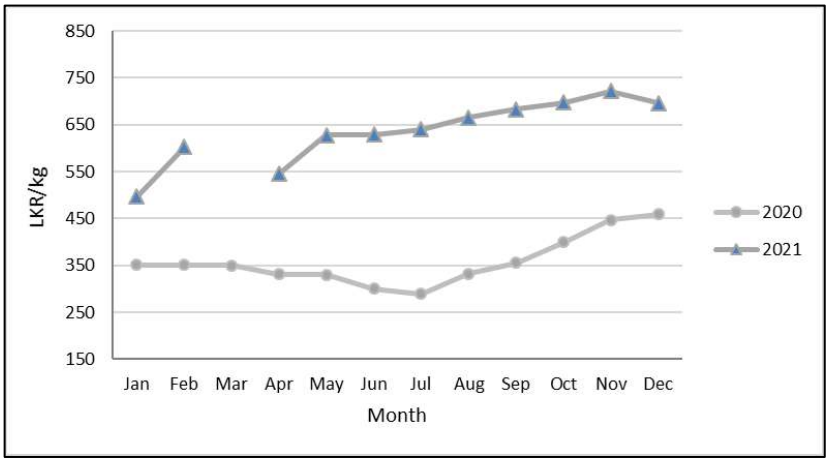


Fig. 2. The monthly average nominal LC1X price in the years 2020 and 2021

RESEARCH

The following studies were conducted in 2021.

Analysis of global trade of rubber products (AE/01)

World trade data from 2015 to 2020 were gathered from trade statistics and the trend and growth performance of various rubber products from major exporters were analyzed.

Global rubber production and consumption:

The world rubber market is mainly concentrated in China, the USA, Japan, India and Malaysia. They were the top five rubber (natural and synthetic) consuming countries in 2020. China was the world's largest rubber consumer, consuming 10.22 Million tonnes in 2021, making up 34% of the world's total rubber consumption. Thailand produced 4.37 million metric tonnes of natural rubber in 2020, which accounts for a 35% share of global natural rubber production in 2020. Both consumption and production of synthetic and natural rubber have shown negative growth in 2020 compared to the previous year.

Global rubber products trade:

The value of world rubber and rubber products export was about US$ 161 billion in 2015, and it has remarkably increased up to about US$ 171 billion in 2020. Global trade statistics showed that a significant fraction (about 58%) of the rubber products trade earnings derived from pneumatic, retreated and solid tyre trade during 2015-2020. However, in 2020 the demand for pneumatic tyres and retreated tyres has shown a negative growth of 11% and 12% respectively when compared to the

previous year. The earnings from other products including other articles of vulcanised rubber, tubes, pipes and hoses of vulcanised rubber and gloves of vulcanised or unhardened Rubber have also made a remarkable contribution to the rubber products earnings (Fig. 3).

With the emergence of the Covid pandemic situation in 2019, the demand for gloves of vulcanised or unhardened rubber has increased remarkably. Compared to 2019, the total demand for gloves has grown by 106% in 2020.

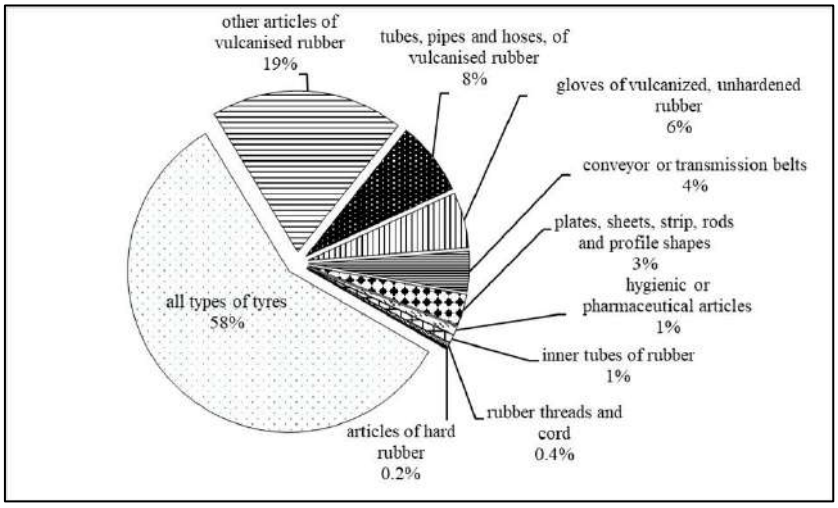


Fig. 3. Share of different rubber products in global rubber products exports (average from 2015 - 2020)

Trade information of the top five exporters and importers of new pneumatic tyres in the global market during 2015-2020 are presented in Table 2.

Table 1. *The monthly Auction Prices of Rubber (Latex .Crepe, Sheet and Scrap) in the year 2021*

Month	RSS Prices (Rs.)					Latex Crepe prices (Rs.)					Scrap Crepe Prices (Rs.)				
	RSS1	RSS2	RSS3	RSS4	RSS5	LC-1X	LC-1	LC-2	LC-3	LC-4	1Xbr	2Xbr	3Xbr	4Xbr	Flat Bark
Jan	459	444	434	447	390	496	496	484	474	424	371	350	350	345	330
Feb	444	426	416	404	393	602	597	575	556	469	370	367	359	355	359
Mar	427	420	409	395	.	.	.	508	498	418	382	357	344	337	.
Apr	428	420	410	399	384	545	543	526	508	436	397	351	353	323	340
May	454	448	433	415	399	628	618	635	575	507	425	418	410	394	383
Jun	467	.	450	.	.	630	625	603	562	449	439	431	441	430	.
Jul	469	445	.	.	.	640	640	614	572	419	413	412	421	413	.
Aug	457	444	435	415	418	665	662	623	560	416	413	413	417	414	.
Sep	463	455	443	431	430	684	682	646	560	440	432	433	430	428	419
Oct	488	476	463	454	450	698	694	656	574	460	449	445	450	442	434
Nov	515	.	.	.	.	722	715	655	582	482	446	443	441	437	435
Dec	475	487	463	475	455	697	690	598	507	428	412	413	412	409	395
2020 Average	462	446	436	426	415	637	633	594	544	446	412	403	402	394	387

Table 2. *Global export and import markets of new pneumatic tyres (HS 4011)*

Exporters (2015-2020)				Importers (2015-2020)			
	Market size (US$ Billion)	Share %	Rate of growth (%)		Size of the market (US$ Billion)	Share %	Rate of growth (%)
China	14.02	19	-1	**USA**	14.57	19	-1
Thailand	4.51	6	9	**Germany**	6.61	9	-1
Germany	5.58	7	-2	**France**	3.44	5	-1
Japan	4.89	7	-5	**Mexico**	3.03	4	-4
USA	4.71	6	-4	**Canada**	2.96	4	-4

Sri Lanka holds the number one position in Retreated and Solid Tyres exports in the global market, followed by Germany and Netherlands. During this period except for Sri Lanka and Germany other three countries showed a negative growth rate. The USA is the number one importer of Retreated and Solid Tyres followed by Germany and the Netherlands (Table 3).

Table 3. Global export & import markets of retreated & solid tyres (HS 4012)

Exporters (2015-2020)				Importers (2015-2020)			
	Market size (US$ Million)	Share %	Rate of growth (%)		Market size (US$ Million)	Share %	Rate of Growth (%)
Sri Lanka	328.06	13	0.3	**USA**	373.77	15	-3.9
Germany	271.13	11	2.14	**Germany**	212.69	8	2.17
Netherlands	165.83	7	-4.37	**Netherlands**	136.28	5	-1.9
USA	141.74	6	-2.91	**France**	161.94	6	2.51
France	151.51	6	-0.07	**Canada**	91.11	4	-1.29

In the glove market, Malaysia was the largest exporter and the USA was the largest importer from the period of 2015 to 2020. All exporters showed a remarkably higher growth rate of this product during this period. Sri Lanka ranked as the ninth-largest glove exporter with an 18% positive growth rate (Table 4)

Table 4. *Global export and import of gloves of vulcanised or unhardened rubber (HS 4015)*

Exporters (2015-2020)				Importers (2015-2020)			
	Size of the Market (US$ Billion)	Share %	Rate of Growth (%)		Size of the Market (US$ Billion)	Share %	Rate of Growth (%)
Malaysia	4.55	50	25	**USA**	2.83	31	17
China	0.96	11	59	**Germany**	0.68	8	18
Thailand	1.28	14	23	**Canada**	0.28	3	50
Indonesia	0.29	3	16	**UK**	0.46	5	50
Germany	0.3	3	20	**Japan**	0.49	5	19

(P G N Ishani, J K S Sankalpa, W Wijesuriya and Abewardena O V)

Smallholder farmers' willingness to continue rubber replanting, Sri Lanka (AE/02)

A study was conducted to analyse the effect of socioeconomic determinants of smallholder farmers' willingness to cultivate rubber in the Kegalle District, Sri Lanka. It uses the utility maximization theory and logit model and analyses household-level data collected from 404 smallholder farmers in Sri Lanka. Our results show that about 71% of farmers are willing to continue (WTC) rubber replanting and farm and household characteristics significantly affect farmers' WTC rubber replanting. All the variables included in the logit model were in the expected sign except for the variables GEND, MARKT, TYPE, and LAND. The coefficients and marginal effects of the variables are presented in Table 5.

The most significant determinants are harvesting on a shared basis, family labour in latex harvesting, non-farm income, society participation, other agricultural income, institutional support, income generation from rubber farming, and education of household head. We suggest considering these factors when targeting agricultural policies to provide an enabling environment for smallholder rubber farming.

Table 5. *Empirical results of the Logit model estimates*

	Dependent variable=WTC rubber farming (W_f)	
Variables	**Coefficients**	**Marginal effects**
INCM	0.219 (0.099)**	0.037 (0.017)**
EDU	0.090 (0.047)*	0.015 (0.008)*
LBR-family	0.556 (0.301)*	0.102 (0.054)*
LBR- shared basis	1.077 (0.345)***	0.181 (0.054)***
OTINC	0.770 (0.254)***	0.134 (0.043)***
NONINC	0.988 (0.270)***	0.169 (0.043) ***

	Dependent variable=WTC rubber farming (W_f)	
Variables	**Coefficients**	**Marginal effects**
INST	0.453 (0.257)*	0.081 (0.047)*
SOCT	0.713 (0.264)***	0.121 (0.043)***
AGE	-0.005 (0.011)	-0.001 (0.002)
GEND	-0.475 (0.316)	-0.079 (0.049)
HOUSE	0.016 (0.090)	0.003 (0.015)
LAND	-0.322 (0.362)	-0.055 (0.062)
MARKT	-0.349 (0.274)	-0.058 (0.044)
TYPE	-0.072 (0.331)	-0.012 (0.056)
Constant	-1.209 (1.053)	
Log-pseudo likelihood	-208.958	
Wald test	49.19***, $p = 0.0001$	
LH	$\chi^2(389) = 405.17$, $p > \chi^2 = 0.275$	
Observations	404	

*** P < 0.01, ** P < 0.05 and * P < 0.1; Robust standard errors are presented in parenthesis; the reference labour category is hired labour

(J K S Sankalpa , W Wijesuriya, P G N Ishani and OV Abewardena)

Use of GIS in rubber plantation management (AE/05)

AEU has been involved in the externally funded research project (collaborative research between RRI and Genesis (Pvt) Ltd.) which is titled "use of GIS in rubber plantation management". The field data collection was completed during the year and the preparation of GIS layers was in progress. We selected Halugama estate, Meerigama, Dartonfield estate, Agalawatta, and Kuruwita estate, Kuruwita as the experimental sites. All satellite images were acquired through Genesis servers and raw images were processed at the Dartonfield GIS laboratory environment. Satellite images with 30 m multi-spectral resolution which facilitates the identification of rubber canopy status were acquired for the analysis. We collected secondary data relevant to rainfall and temperature (minimum, maximum, and mean) from the Biometry section of RRISL. Field data falling into yield (latex harvested), year of planting, and the extent of the field were collected from the Dartonfield and Kuruwita estates. The spatial variability of soil parameters was tested by the Soils and Plant Nutrition Department of RRI and preparation of GIS layers was in progress.

Interim results indicate the progress of the Spatial Decision Information Management System (SDIMS) of three estates. Accordingly, the rubber yield variation map of the Dartonfield estate is shown in Figure 4. SDIMS preparation is in progress with the other field information.

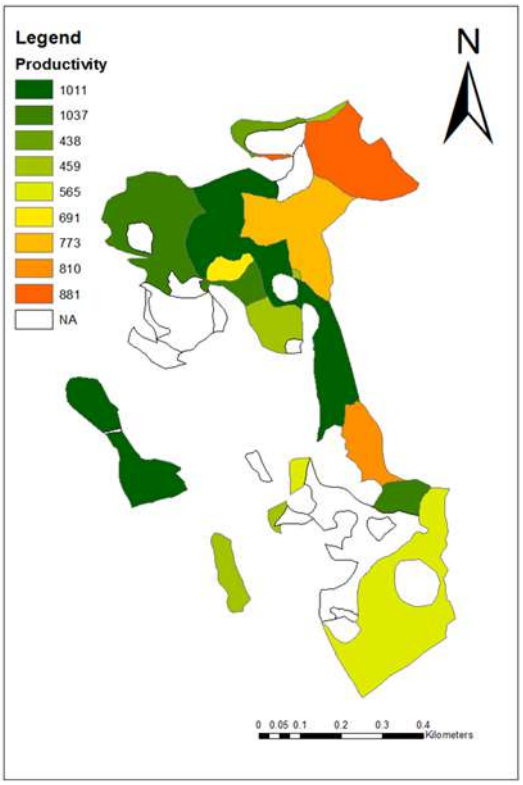


Fig. 4. Yield map of Dartonfield estate

Updating databases on the rubber industry, analysis of rubber end products manufacturing sector & other economic evaluations (AE/05)

The Agricultural Economics unit has conducted several studies to analyse the rubber international trade and rubber prices that prevailed in the international and local markets. The aim was to present the current status in the local and international markets and thereby assist the stakeholders in taking suitable measures to improve the gains from the rubber industry. Fig. 5 (a) shows the raw rubber exports and imports of Sri Lanka from 2016 to 2021.

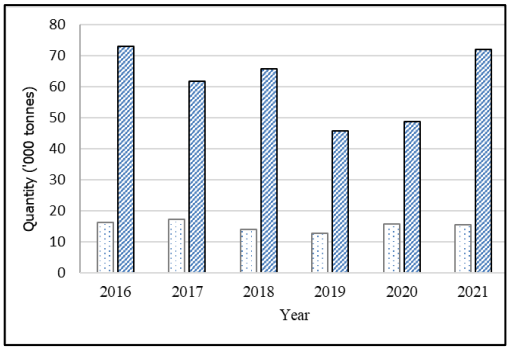


Fig. 5 (a). Raw rubber exports and imports quantities

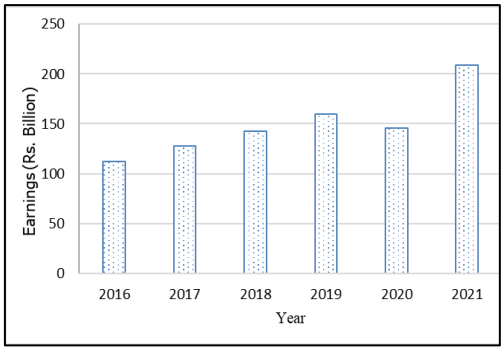


Fig. 5 (b). Earnings from end products and semi-processed products

Fig. 5 (b) shows the earnings from rubber end products from 2016 to 2021. The quantity of raw rubber export has decreased by 2% in the year 2021 against the previous year. The average export quantity was in a declining trend for the period of 2017-to 2021. Earnings from rubber finished and semi-processed products have increased by 43% year on year from 2020 to 2021. Earnings from finished and semi-processed were recorded as LKR. 209 billion in the year 2021 while, it was LKR.145 billion in the year 2020.

LIBRARY AND PUBLICATION

N C D Wijesekara

DETAILED REVIEW

Mrs N C D Wijesekara, Librarian and Publication Officer, Mrs R M Amaratunga, Library Assistant & Assistant Publication Officer, Mrs D N C Amaratunga, Library Assistant & Publication Assistant (Rathmalana) Mr P M Prema Jayantha, Management Assistant and one Library Attendant were on duty throughout the year. Mr N L D Linton, Library Attendent, who served the Rubber Research Institute for 22 years retired on 03rd Sept. 2021. We are happy to place on record that his contributions for general upkeep of the Library and dedication for all duties assigned, are commendable.

GENERAL

The Library could acquire a store fitted with a dehumidifier to protect all bound volumes of Journals. The Library was rearranged for ease referencing and the floor carpet was replaced.

Publications

There was a huge backlog in all RRISL publications especially Rubber Puwath, Bulletin and the Journal. It is with great pleasure that we list the following publications completed during the year under review.

The Rubber Handbook, Volume 1: Agronomy which had been out of print since 2011, was revised and published printing 1500 hard copies. The Advisory Circular on Establishment of Rubber in Dry Climates was also printed, 4500 copies from each Sinhala and English. Due to the Covid 19 related issues followed by the economic crisis, only the Rubber Puwath Vol. 29 was printed and distributed through Rubber Extention Officers and Rubber Development Officers at the price just to cover the printing cost. All other publications were uploaded to the Institute's Website (www.rrisl.gov.lk). The list of other publications done during the year is given below:

- Rubber Puwath

  Vol. 30, 2020
  Vol. 31, 2021
  Vol. 32, 2021
  Vol. 33, 2021

- RRISL Bulletin
  - Vol. 54, 2017
  - Vol. 55, 2018
  - Vol. 56, 2019

- RRISL Journal
  - Vol. 97, 2017
  - Vol. 98, 2018
  - Vol. 99, 2019
  - Vol. 100, 2020

- Annual Review - 2020

- Annual Report - 2020

DARTONFIELD GROUP

P A Lukshaman

DETAILED REVIEW

Mr P A Lukshaman Senior Estate Manager, Mr Dinesh Achinda, Mr M N S Pavinda Management Assistants, Mr T D Harsha, Acting Factory Officer, Mr B M Siriwardena, Field Officer and Mr K A Sarath Kumara, Mr Jagath Nakandala and Mr Lasantha Sampath, Acting Junior Assistant Field Officers were on duty throughout the year.

The Group cadre stood as follows at the end of the year.

Senior staff	01
Assistant staff	07
Minor staff	04
Total	**12**

Hectarage summary - Dartonfield group

Hectarage summary of the Dartonfield Group is given in Table 1.

Table 1. *Land distribution (ha) of Dartonfield group*

	Dartonfield division	Gallewatte division	Nivitigalakele division	Total
Mature area	14.24	118.71	33.76	166.71
Immature area	21.68	45.48	9.56	76.72
Cinnamon under power line	1.00	1.63	0.28	2.91
State land take in	0.27	-	-	0.27
Nurseries	7.01	-	2.00	9.01
Paddy/Deniya land	0.75	1.22	1.22	3.19
Waste land	0.19	0.18	-	0.37
Earth slipped area	4.88	1.26	-	6.14
Jungle	0.80	0.50	1.03	2.33
Rocky areas	2.14	6.07	2.76	9.35
Roads	2.92	6.57	0.36	9.85
Building	16.92	4.44	7.79	28.99
Play Ground	1.00	-	-	1.00
Abandoned Area	-	-	12.31	12.31
Proposed Cinnamon Ns.	0.20	-	-	0.20
Streams	0.45	-	2.17	2.62
Grand total	**74.29**	**184.35**	**73.24**	**331.88**

Rainfall

The annual rainfall recorded for the year was 5,049.1 mm with 176 wet days. Annual rainfall and wet days of the group for the past five years are given in Table 2.

Table 2. *Annual rainfall and wet days of the group for the past five years*

	2017	2018	2019	2020	2021
Rainfall (mm)	4,068.1	3,773.3	4389.7	3376.8	5,049.1
Wet days	188	195	204	177	176

Crop

A total crop of 111,752 kg has been harvested against the estimated crop of 184,571 kg (60%) showing a difference of 72819 kg. The crop and YPH (kg) of the Dartonfield group from 2017 to 2021 are given in Table 3.

Table 3. *The crop and YPH (kg) of the Dartonfield group from 2017 to 2021*

Hect.	2017		2018		2019		2020		2021	
	176.05		178.02		178		181.97		166.71	
Division	Crop	YPH	Crop	YPH	Crop	YPH	Crop	YPH	Crop	YPH
Dartonfield	19,124	649	19,477	841	15,683	677	17,774	767	10,387	681
Gallewatta	106,531	938	119,458	986	104,699	865	116,501	932	79,771	672
N'kele	35,800	1,086	39,600	1,173	300,34	890	31,696	939	21,595	640
Group total	161,455	917	178,535	1,003	150,416	845	165,971	912	111,752	666
Group estimate	185,606	1,054	193,037	1,084	197,295	1,108	197,393	1,085	184,571	1,107

Low crop harvested due to the experience of continues unexpected rainfall and due to that affected Pestolopsis more seriously.

Tappers productivity

The average IPT during the last five years is given in Table 4.

Table 4. *The average IPT (kg) of the Dartonfield group from 2017 to 2021*

	2017	2018	2019	2020	2021
Dartonfield	6.4	7.1	6.7	6.8	5.1
Gallewatte	7.6	7.9	7.1	8.0	6.4
Nivitigalakele	8.4	8.7	7.8	9.2	7.0
Group average	**7.6**	**8.0**	**7.2**	**8.0**	**6.4**

Continues unexpected rainfall also result of more No tapping days and also month of May to December had only 30% - 50% of remain leaf due to Pestolopsis.

Tapping days

Annual break down of Normal tapping (NT), Late tapping (LT), Double tapping (DT), and No tapping of Dartonfield estate is given in Table 5.

Table 5. *Actual number of tapping days of Dartonfield group during last five years*

	2017	2018	2019	2020	2021
Normal tapping	224	222	201	217	171
Late tapping	02	6	19	11	35
Cash/Double tapping	(18)	(25)	(21)	(18)	(03)
No tapping	69	52	80	52	76
Rain guard tapping	69	85	65	85	82
Slight rain	01	-	-	-	01
Total no of tapping days	296	313	285	313	289

Rainguards

Total areas of 166.71 hectares were rainguarded during the year and an additional crop of 27,999 kg was harvested which amounts to 25.05% of total crop harvested. Additional tapping days done with rainguards during the year were 57, 108 and 114 for Dartonfield, Galewatta and Nivithigalakele respectively. Profit generated due to rain guarding was Rs,946,271.91 and profit per hectare was Rs.43,343.76.

Table 6. *Income/Expenditure statement on fixing of rainguards (Rs/kg)*

	Dartonfield Division	Gallewatta Division	Nivithigalakale Division	Total
Hectare	7.29	119.21	33.76	160.26
No. of rainguards fitted	1,804	31,015	6,925	39,744
Additional crop (kg)	2,020	18,493	7,486	27,999
Rainguard cost per kg.	69.24	68.92	38.50	63.17
Tapping cost per kg.	204.01	204.01	204.01	204.01
C.O.M. Rs/kg.	49.56	49.56	49.56	49.56
Total cost Rs/kg.	322.81	322.49	292.07	316.74
N.S.A. Rs./kg.	564.83	564.83	564.83	564.83
Additional profit Rs./kg.	242.02	242.34	272.76	248.09
Total profit (Rs.)	488,880	4,481,593	2,041,88	4,065,836.16
Additional profit per hectare (Rs.)	67,061.78	37,594.10	60,482.27	43,343.76

Total profit and profitability per hectare

The total profit and profit per hectare were Rs.6,966,796.71 and Rs.41,789.91 for the year under review.

Table 7. *Comparative statement of the revenue profit per kg and profit per hectare for the past five years*

	Years				
	2017	**2018**	**2019**	**2020**	**2021**
Mature area (ha)	176.05	178.02	178.02	181.97	166.71
Total profit/(loss) (Rs.)	6,207,944.75	(2,319,169.65)	(8,226.251.04)	5,448,827.93	6,966,796.71
Profit/(loss) per ha. (Rs.)	35,262.40	(13,027.58)	(46,209.70)	29,943.55	41,789.91

2018 and 2019 Estate was loss due to very low NSA as explain below Table 8.

Cost of production and productivity

Table 8. *Labour rates and break down of cost of production from 2017 to 2021 (Rs./kg.)*

	2017	**2018**	**2019**	**2020**	**2021**
1. Labour wages	805	805	805.00 up to Jan. & 855.00 from Feb.	855.00	855.00 up to Mar. & 1150.00 from Mar.
2. Cost of production	280.55	268.43	330.91	300.90	502.49
2.1 Tapping	122.77	115.63	139.94	138.17	204.01
2.2 Manufacture	34.47	33.08	35.35	38.94	49.56
2.3 General charges	97.29	98.10	124.18	94.87	113.03
2.4 Mature/area upkeep	26.02	21.62	31.44	28.92	38.65
2.5. Administrative	-	-	-	-	97.23
3. N.S.A.	319.00	255.44	276.22	333.73	564.83
4. Profit/(loss) per kg	38.45	(12.99)	(54.69)	32.83	62.34

Manufacture

Out of the latex crop of 100,358 kg harvested, 75,508 kg has been graded as Pale Crepe No. 01 which is 75%. Details are given in Table 9.

Table 9. *Summary of grades manufactured during the year*

Grade	**Quantity (kg.)**	**Percentage %**
Latex crepe No.1	755,08	75
Latex crepe No.2	4,175	04
Latex crepe No.3	3,800	04
Latex crepe No 4	16,875	17
Total	**100,358**	**100**
RSS No.01	-	-
RSS No.02	-	-
RSS No.03	-	-
RSS No.04/05	-	-

Grade	Quantity (kg.)	Percentage %
Total	**-**	**-**
Scrap crepe No. 1	10,536	92
Scrap crepe No.2	522	05
Scrap crepe No.3/4	336	03
Total	**11,394**	**100**
Grand total	**165,971**	**-**

Different types of rubber manufactured, percentage of grades received for pale crepe, and scrap crepe are shown in Figures 1(a), and (b).

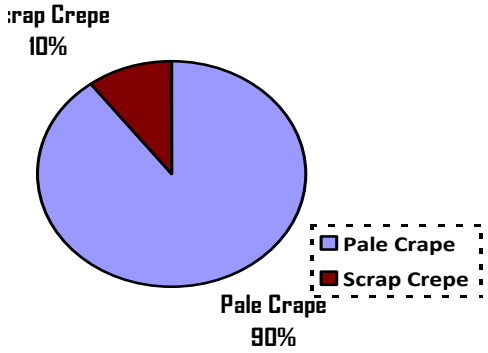


Fig. 1(a). Grade Percentages of different types of rubber manufactured Pale Crepe

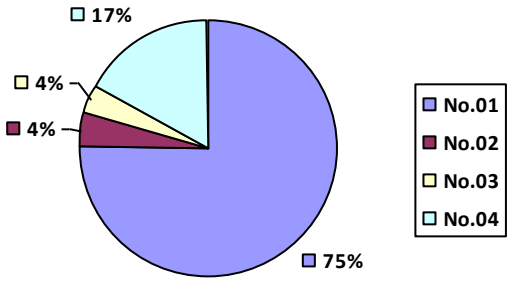


Fig. 1(b). Percentage of grade of Pale Crepe manufacture

Dartonfield Estate Group has received the best Auction prices of sheet rubber category one (Pale Crepe) for 17 times during out of 24 dispatches of the year 2021 (Table 10). The highest value for the best price received for the Pale Crepe was LKR.

725.00 In Nov. 2021 and higher prices have been enhanced by the favorable market condition prevailed during the latter part of the year.

Table 10. *Best Auction prices received in the year 2021 by the Dartonfield estate Group*

Date	Category	Quantity sold (kg)	Price at auction (LKR/kg)
2021.02.11	LCR No.1x	2,285	610
2021.02.25	LCR No.1x	4,950	600
2021.04.01	LCR No.1x	2,700	530
2021.05.06	LCR No.1x	4,050	610
2021.06.04	LCR No.1x	1,825	620
2021.06.25	LCR No.1x	1,800	635
	LCR No.1	1,950	
2021.07.01	LCR No.1x	1,100	625
2021.07.08	LCR No.1x	950	625
2021.07.22	LCR No.1x	625	640
	LCR No.1	450	
2021.08.05	LCR No.1x	2,075	660
2021.08.26	LCR No.1x	3,325	680
2021.09.02	LCR No.1x	750	690
2021.09.23	LCR No.1x	1,900	680
2021.10.14	LCR No.1x	2,075	680
2021.11.25	LCR No.1x	2,050	725
2021.12.09	LCR No.1x	1,075	690
2022.01.04	LCR No.1x	2,275	650

KURUWITA SUB - STATION

P A Lukshaman

DETAILED REVIEW

Staff

Mr P A Lukshman Senior Manager (Estate) covered up the duties the Manager position of this Substation, Mr D S Jayasinghe, Management Assistant, Mr D D A Jayathunga Field Officer and K K S Dinesh General Worker were on duty throughout the year. Mr K D P Senarathna Management Assistant was transferred to the Advisory Services Department Kiriella with effect from 09.08.2021 and Mrs E P S L Erawwala Field Supervisor was appointed temporarily to cover up her duties with effect from 09.08.2021.

The estate cadre stood as follows at the end of the year.

Intermediate staff	-	01
Assistant staff	-	02
Minor staff	-	02

Hectarage

A summary of the hectarage is given in Table 1.

Table 1. *Details of land distribution (ha) in Kuruwita Sub-station*

Land type	Extent (ha.)
Mature area	79.36
Nurseries	2.25
Tea area	3.49
Paddy	1.00
Buildings, Gardens and Road	10.23
Water Tank	0.01
Unsuitable for planting	3.66
Total	**100.00**

Crop

A total crop of 62,444 kg was harvested during the year, recording a decrease of 17,013 kg from the previous year's crop.

Low crop harvested due to the experience of continues unexpected rainfall and due to that affected Pestolopsis more seriously.

The actual yield per hectare (YPH) was 786.8 kg. This is a decrease of 214.4 kg when compared with the previous year's crop.

The yields per hectare (YPH) for the past five years are given in the Table 2.

Table 2. *Yield per hectare for the past five years*

YPH (kg)	Year				
	2017	**2018**	**2018**	**2020**	**2021**
Estimated	1,318.57	1,320.61	1,271.00	1,238.60	1,219.6
Actual	1,086.67	1,025.11	911.10	1,001.20	786.8

The yield per hectare recorded (kg) for each month during the year is given in Table 3.

Table 3. *Actual yield per hectare (kg) recorded for each month during the year*

Month	YPH (kg)
January	77.5
February	70.3
March	72.7
April	60.0
May	59.1
June	82.5
July	87.8
August	59.6
September	49.1
October	60.7
November	37.2
December	69.8

Tapper productivity

The average intake per tapper at the end of the year was 6.1 kg. The average IPT during the last five years are given in Table 4.

Table 4. *The average intake per tapper (IPT) (kg) for the last five years*

IPT (kg)	Year				
	2017	**2018**	**2019**	**2020**	**2021**
Intake per tapper	9.0	8.6	7.3	7.4	6.1

Rainfall

The annual rainfall recorded during the year was 5396.8 mm with 177 wet days (Table 5).

Table 5. *Annual rainfall figures and the number of wet days of the estate for the past 5 years*

	Year				
	2017	**2018**	**2019**	**2020**	**2021**
Rainfall (mm)	4,768.4	4,560.8	3976.8	3428.3	5396.8
Wet days	246	244	226	*138	*177

* From 2020, a day having more than 5mm rainfall was considered as a rainy day which was only 1mm before 2020

Tapping days

There were 316 tapping days recorded during the year (Table 6). This was possible merely due to the use of rainguards.

Table 6. *The Average number of tapping days of the Kuruwita Sub Station for the past five years*

	Year				
	2017	**2018**	**2019**	**2020**	**2021**
01.Total tapping days	**321**	**324**	**323**	**337**	316
1.1 Normal	203	232	250	241	189
1.2 Late	-	-	11	-	17
1.3 Rain Interference	40	-	-	-	-
1.4 Rainguarded Tapping	78	92	62	96	110
02. Recovery Tapping	-	-	-	-	-
03. No tapping	44	41	42	29	48

When compared with the last year there was a decrease in normal tapping days from 241 to 189 days during the year which is due to heavy rain prevailing throughout.

Rainguard

Due to the use of rain guards an additional 110 tapping days were recorded during the year. This contributed to 41% of the total crop securing an additional profit of Rs.7,944,963.18

An analysis of the use of rain guards for the years 2018, 2019, 2020 and 2021 is given in Table 7.

Table 7. *An analysis of the use of rainguards (Rs/kg)*

	Year			
	2018	**2019**	**2020**	**2021**
Hectarage (ha.)	64.96	70.25	79.36	67.15
Number of raiguards fitted	22,758	23,212	23,150	18,480
Additional tapping days	92	62	96	110
Number of kilos harvested	18,419	12,113	19,558	25,667
Regard cost per (kg.)	49.76	82.55	26.75	21.37
Tapping cost (Rs./kg.)	105.14	127.94	127.79	192.91
Total cost (Rs./kg.)	154.90	210.49	154.54	214.28
N.S.A (Rs./kg.)	244.89	263.54	311.69	523.82
Additional Profit (Rs./kg.)	89.99	53.05	157.15	309.54
Total Profit (Rs.)	1,657,525	642,594	3,073,539	7,944,963
Additional profit per hectare (Rs.)	25,516.10	9,147.25	38,729.07	118,316.65

Total profit and profitability per hectare

The total profit and profit per hectare were Rs.5,076,072.76 and Rs.63,962.61 respectively for the year 2021.

Table 8 gives a comparative statement of the mature extent, total profit and profit per hectare for the past five years.

Table 8. *Comparative statement of the mature extent, total profit and profit per hectare for the past five years*

	Year				
	2017	**2018**	**2019**	**2020**	**2021**
Mature extent (ha.)	77.66	79.16	79.36	79.36	79.36
Total profit (Rs.)	3,727,550.47	(2,908,957.77)	(5,363,084.36)	1,535,903.81	5076072.76
Profit per hectare (Rs.)	47,998.33	(36,747.82)	(67,579.19)	19,353.63	63962.61

2018 & 2019 Estate was loss due to very low NSA as explained below in Table 9**.**

Cost of production and profitability

The cost of production has increase by Rs.150.17 per kg when comparing with the previous year (Table 9). Labour rate and the breakdown of the cost of production (Rs/kg) for the past five years are given in Table 9.

Table 9. *Labour rate (Rs.) and the breakdown of the cost of production from 2017 to 2021(Rs./kg.)*

	Year				
	2017	**2018**	**2019**	**2020**	**2021**
Labour rate (with EPF/ETF)	805.00	805.00	805.00 up to Jan. and 855.00 from Feb.	855.00	855.00 up to Mar. and 1150.00 from Mar.
Cost of production	250.01	279.36	337.71	292.36	442.53
Tapping cost	99.08	108.80	134.74	137.41	205.40
Manufacturing	32.65	36.33	33.11	37.12	45.41
General chargers	92.38	97.16	135.40	89.49	157.64
Field & cultivation cost	25.90	37.07	34.47	28.35	34.08
N.S.A	294.18	244.89	263.54	311.69	523.82
Profit per kg.	44.17	(34.47)	(74.17)	19.33	81.29

POLGAHAWELA SUB STATION

P A Lukshaman

DETAILED REVIEW

Mr P A Lukshaman, Senior Estate Manager overlooked the activities of the Substation and Mr D P Nuwan Dissanayaka, Management Assistant was on duty throughout the year.

Hectarage summary

	Hectarage
Mature	17.75
Immature	1.50
Cashew	0.25
Rocks	23.60
Total	**43.10**

Crop

Total crop of 16,828 kgs have been harvested against the estimated crop of 22,160 kgs which is a decrease of 5,080 kgs. The total crop, YPH and IPT for 2017, 2018, 2019, 2020 and 2021 are given in (Table 1).

Table 1. *Total crop (kg), YPH (kg) and IPT (kg) for the years of 2017, 2018, 2019, 2020 and 2021*

Year	Hectare	Crop (kg)	YPH (kg)	IPT (kg)
2017	11.75	7,661	652	9.6
2018	13.75	14,710	1,070	9.9
2019	17.75	15,678	883	9.4
2020	17.75	17,080	962	8.8
2021	17.75	16,828	948	8.0

Low outturn and has been caused due to low frequency of tapping enhanced by Covid 19 situation.

Rainfall

The annual rainfall recorded for the year was 3,485.4 mm with 128 wet days (Table 2).

Table 2. *Annual rainfall and wet days of the estate for last five years*

	2017	2018	2019	2020	2021
Rainfall	1,974.8	2,683.7	2,170.5	2,385.5	3485.4
Wet days	164	153	139	118	128

Tapping days

Annual breakdown of Tapping days and No tapping days are given in Table 3.

Table 3. *Annual Tapping days and No tapping days of the estate for last five years*

	2017	2018	2019	2020	2021
Tapping days	223	293	310	301	313
No tapping days	142	72	55	65	52

Meteorological Summary

Dartonfield Station

Wasana Wijesuriya

The AGROMET station at Dartonfield, Agalawatta is maintained by the Biometry Section of the Rubber Research Institute of Sri Lanka. This station located in the Agro-Ecological Region $WL_{1a,}$ recorded an average annual rainfall of 4,126 mm during the last 20 years. Out of the 21 years since 2001, a total rainfall of less than 3,000 mm has been recorded only once during 2016 which was 2,966 mm (Fig. 1). The rainfall recorded in 2021 was 5,617 mm, which accounted for an increase of 54%, compared to the previous year. The annual rainfall in 2021 exceeded the average for the last 20 years (4,126 mm) by 1,491 mm which accounted for an increase of 36% compared to the long-term average. The rainfall total recorded this year is 43 mm less than that 2008 (5,660 mm) which was the highest recorded in 2001 to 2021 period. The average annual rainfall is marked as a horizontal line in Fig. 1.

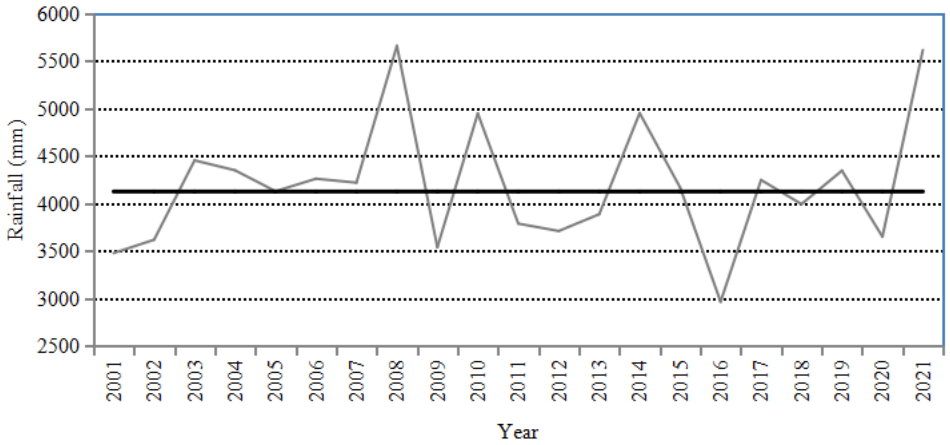


Fig. 1. Variation in annual rainfall at Dartonfield from 2001 to 2021

As indicated in Fig. 2, the rainfall distribution at Dartonfield during this year departed from the usual bimodal rainfall pattern. Remarkably high above-average monthly rainfall values were observed in May (373 mm-64%), November (280 mm-73%) and June (263 mm-66%). Above average rainfall values were also observed in January (235 mm-151%), February (135 mm-118%), July (195 mm-62%) and March (197 mm-89%). The months except April had rainfall totals close to the long-term average, where April recorded a below average rainfall (142 mm-34%). The

minimum monthly rainfall of 238 mm was recorded in December whilst the maximum monthly rainfall of 957 mm was recorded in May.

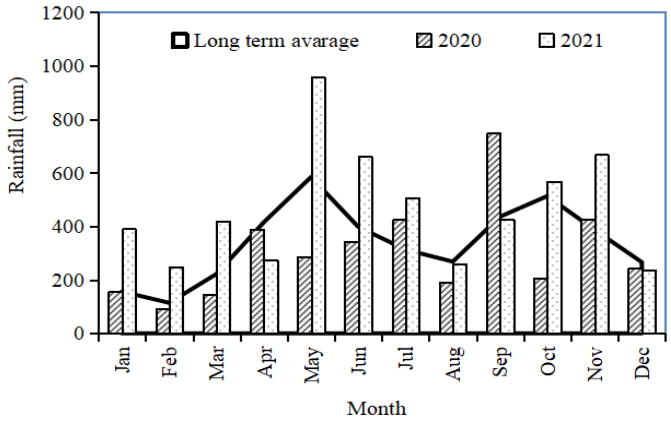


Fig. 2. Distribution of monthly rainfall in 2020 and 2021 at Dartonfield (The line graph indicates the long-term average)

The distribution of rainfall in different seasons at Dartonfield is given in Fig. 3. Rains during the South West season (May – September) carried most of the rains (2811 mm compared to the long-term average 1,564 mm) during 2021. This rainfall amount contributed 50% to the total rainfall, which is slightly higher than the long-term average contribution (48%). Rainfall during IM2 (October & November) in 2021 brought 1236 mm whilst IM1 (March & April) recorded a lower rainfall of 692 mm. During the North East season (December 2020 to February 2021), 883 mm of rain was recorded, which is comparatively higher (22%) than the long-term average contribution (15%) of this season.

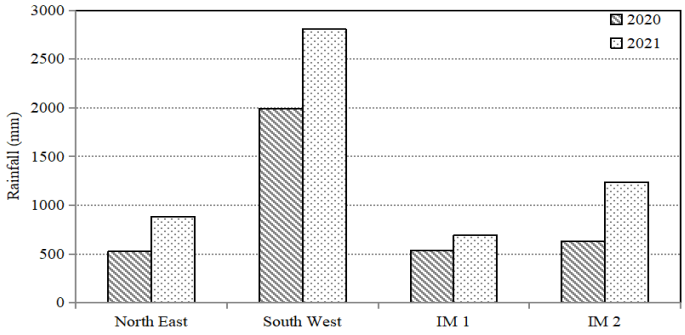


Fig. 3. Seasonal distribution of rainfall at Dartonfield in 2020 and 2021

The distribution of weekly rainfall is depicted in Fig. 4. Two dry weeks (weeks having a total rainfall less than 10 mm) were observed during this year. The highest weekly rainfall of 323 mm was observed in the 22nd standard week (28th May to 03rd June).

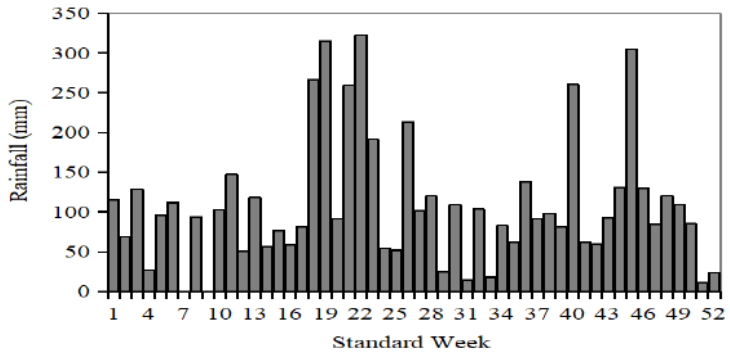


Fig. 4. Weekly variation in rainfall in 2021

There were 23 rainfall events that exceeded the hazardous limits for landslides (100 mm of rainfall during a day) reported during the year under review. A dry spell lasted over a month or more can have adverse impacts on rubber plantations. There were only 3 dry spells greater than or equal to 7 days (Table 1).

Table 1. *Details of dry spells at Dartonfield in 2021*

Dry spell No.	Period	No. of days
1	10th - 18th February	9
2	25th February - 5th March	9
3	22nd - 29th December	8

The amount of rainfall and the number of rainy days under low, moderate and high rainfall categories are listed in Table 2. The observed total number of rainy days of the year was 262, which was considerably higher than the long-term average of 220 days.

Rainfall at RRISL Substations

There are substations maintained by RRISL in Kuruwita (WL_{1a}), Narampola (IL_{1a} bordering WL_{2b}), Moneragala (IL_{1c}) and Nivithigala Kele (WL_{1a}). The annual rainfall totals of 5,387 mm, 3,486 mm, 1,718 mm and 4,494 mm were recorded, respectively, in Kuruwita, Narampola, Moneragala and Nivithigalakele stations during 2021. The details of rainfall in these stations are given in Tables 3 to 7.

Table 2. *Monthly variation of rainfall and rainy days in 2021 at Dartonfield, Agalawatta*

Month	Total rainfall (mm)	Average** (mm)	No of rainy days *	Avg.** Days	No. of days under each category			Evaporation (mm)
					0.3-2.5 (mm)	2.6-50 (mm)	>50 (mm)	
January	390.8	(156)	20	(11)	8	10	2	78.0
February	248.6	(114)	12	(09)	2	10	0	112.8
March	419.0	(222)	18	(13)	3	14	1	120.1
April	272.8	(415)	17	(18)	6	10	1	115.8
May	956.8	(584)	26	(24)	1	18	7	112.8
June	660.7	(398)	23	(23)	7	12	4	92.5
July	507.6	(313)	26	(22)	10	14	2	87.3
August	260.7	(268)	25	(20)	10	15	0	85.5
September	425.4	(436)	27	(22)	3	24	0	103.6
October	568.6	(513)	25	(23)	5	18	2	94.8
November	667.8	(387)	24	(20)	4	15	5	82.2
December	237.9	(266)	17	(15)	3	14	0	105.6
Total	5,616.7	(4,072.0)	260	(220)	62	174	24	1,191.0

* A rainy day is defined as a day with a rainfall ≥ 0.3 mm

** Average values for 1980-2005 are given in parentheses

Table 3. *Monthly variation of rainfall and rainy days in 2021 - Kuruwita*

Month	Total rainfall (mm)	No of rainy days *	No. of days under each category		
			0.3-2.5 (mm)	2.6-50 (mm)	>50 (mm)
January	296.6	18	6	12	0
February	52.2	9	2	7	0
March	390.5	18	4	12	2
April	358.9	15	3	12	0
May	775.4	21	5	16	0
June	583.6	19	5	14	0
July	511.9	22	3	17	2
August	372.9	24	7	15	2
September	541.2	26	3	20	3
October	512.4	30	9	20	1
November	654.8	23	6	17	0
December	336.8	16	3	11	2
Total	5,387.3	241	56	173	12

*A rainy day is defined as a day with a rainfall ≥ 0.3 mm

Table 4. *Monthly variation of rainfall and rainy days in 2021 - Nivithigalakele*

Month	Total rainfall (mm)	No of rainy days *	No. of days under each category		
			0.3-2.5 (mm)	2.6-50 (mm)	>50 (mm)
January	264.2	14	0	13	1
February	170.5	9	0	9	0
March	323.1	14	0	12	2
April	307.0	14	2	10	2
May	686.4	25	3	16	6
June	533.4	18	1	15	2
July	420.0	15	4	9	2
August	173.8	14	2	12	0
September	301.8	22	0	22	0
October	468.5	22	5	16	1
November	588.6	24	2	18	4
December	256.2	13	0	11	2
Total	4,493.5	204	19	163	22

*A rainy day is defined as a day with a rainfall ≥ 0.3 mm

Table 5. *Monthly variation of rainfall and rainy days in 2021 – Moneragala*

Month	Total rainfall (mm)	No of rainy days *	No. of days under each category		
			0.3-2.5 (mm)	2.6-50 (mm)	>50 (mm)
January	154.4	14	4	10	0
February	51.8	3	0	3	0
March	265.4	12	2	9	1
April	197.1	14	3	11	0
May	103.0	7	2	5	0
June	32.0	2	0	2	0
July	93.4	5	1	4	0
August	13.2	4	2	2	0
September	247.3	8	0	6	2
October	240.1	9	0	9	0
November	166.8	12	2	10	0
December	153.8	10	1	9	0
Total	1,718.3	100	17	80	3

*A rainy day is defined as a day with a rainfall ≥ 0.3 mm

Table 6. *Monthly variation of rainfall and rainy days in 2021 – Narampola*

Month	Total rainfall (mm)	No of rainy days *	No. of days under each category		
			0.3-2.5 (mm)	2.6-50 (mm)	>50 (mm)
January	151.5	12	0	12	0
February	4.4	1	0	1	0
March	197.5	14	3	10	1
April	251.8	11	1	9	1
May	654.4	24	4	17	3
June	352.2	12	0	9	3
July	163.2	11	0	10	1
August	190.3	14	3	10	1
September	226.1	16	1	15	0
October	446.0	9	0	9	0
November	842.1	25	1	20	4
December	6.0	2	1	1	0
Total	3,485.5	151	14	123	14

*A rainy day is defined as a day with a rainfall ≥ 0.3 mm

Other meteorological parameters

Table 7 depicts the monthly values of some important meteorological observations together with averages from 1980 to 2005 at Dartonfield. Daily fluctuations of the minimum and maximum temperatures at Dartonfield are illustrated in Fig. 5. During the year under review, the minimum temperature did not drop below

20 ^{0}C except once in February. The daily average temperature pattern was fairly steady with a mean annual temperature of 27.4 ^{0}C, which could be a favourable condition for rubber plantations. The lowest mean monthly minimum temperature of 22 ^{0}C was observed in February while the highest monthly mean maximum temperature of 32.9 ^{0}C was observed in February. However, any signs of adverse conditions concerning the temperature regime at Dartonfield were not reported during the year.

A total of 1,619 bright sunshine hours was received at an average rate of 4.4 hours/day which was comparatively lower than the respective figures observed during the last year. The distribution of bright sunshine hours during the year is depicted in Fig. 6. Bright sunshine hours exceeded 6 in 34% of the days, while in 45% of the days it was below 4 hours.

High morning Relative Humidity (RH) is favourable for high latex yields. Daily morning RH at Dartonfield in 2021 was observed in the range, 72% to 97%. The mean RH values recorded at 08:30 and 15:30 were 87% and 75%, respectively.

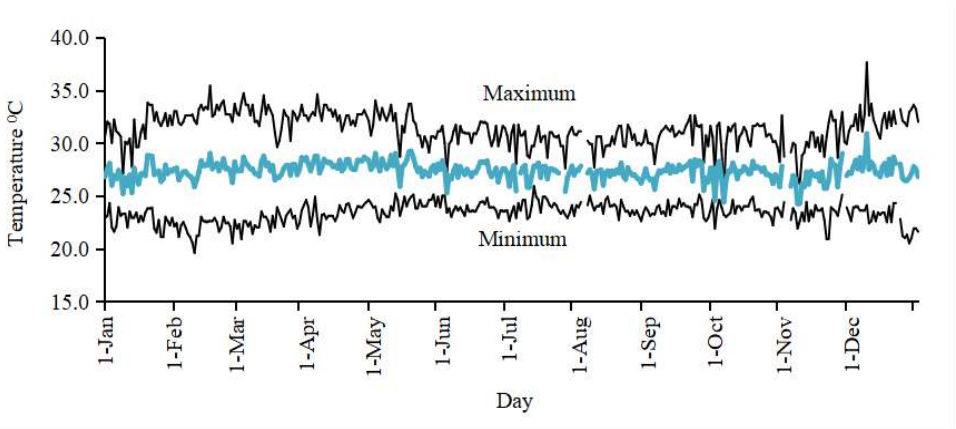


Fig. 5. Daily minimum, maximum and average temperature distributions in 2021

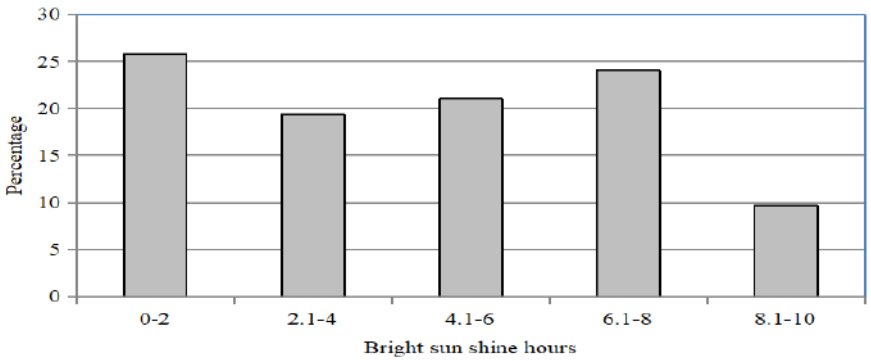


Fig. 6. Distribution of bright sunshine hours in 2021

Table 7. *Variation of observed meteorological factors at Dartonfield – 2021*

Month	(*Latitude $6^0$32'; Longitude 80.09 E; Altitude 65.50 mm)* *Temperature (^{0}C)*				Sun shine hours (hours/day)	Relative humidity (%)			Mean wind speed (kmh^{-1})
	Mean Max	Mean Min	Mean	No of days Min. Temp<20		8.30 am	No of days 8.30am>90%	3.30 pm	
January	31.3	22.8	27.0(26.7)	0	3.8	87 (88)	8	73(68)	0.11
February	32.9	22.0	27.4(27.1)	1	7.0	86(86)	6	62(65)	0.21
March	32.6	22.6	27.6(27.6)	0	5.4	83(85)	2	74(68)	0.22
April	32.5	23.5	28.0(27.8)	0	6.0	86(85)	6	69(75)	0.34
May	31.6	24.1	27.8(27.6)	0	3.4	87(88)	9	79(77)	0.60
June	30.8	23.8	27.3(26.9)	0	3.5	88(89)	11	79(77)	0.64
July	30.3	23.9	27.1(26.7)	0	3.2	91(89)	16	77(75)	1.34
August	30.3	23.8	27.1(26.6)	0	4.1	88(88)	7	78(74)	1.40
September	30.8	23.8	27.3(26.7)	0	4.2	90(88)	11	77(75)	1.09
October	30.6	23.6	27.1(26.6)	0	4.4	89(86)	9	78(77)	0.76
November	30.1	23.3	26.7(26.6)	0	3.9	86(85)	7	80(77)	0.61
December	32.4	22.8	27.6(26.7)	0	6.0	83(85)	3	71(73)	0.22

** Average values for 1980-2005 are shown in parentheses

List of Publications

Scientific Journals
(Bold type - Employees of Rubber Research Institute of Sri Lanka)

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GENETICS AND PLANT BREEDING

The annual hand pollination programme could not be carried out due to Covid -19 pandemic. The hand pollinated progeny of the year 2015 was characterized by yield and growth parameters to select the best genotypes and twenty-two genotypes were selected including four outstanding genotypes. The relationship between the expression of REF gene with the latex yield of rubber was identified to evaluate the possibility of using REF gene expression for precise early selection and accelerate the breeding procedure. REF gene expression was significantly up-regulated in these outstanding genotypes of 2015 hand pollinated progeny ie; 2015HP- 14, 2015 HP-26, 2015 HP- 48, and 2015 HP-24. The small scale and estate collaborative trials performed well and data were collected. The smallholder collaborative trials established in both traditional and non-traditional areas were maintained satisfactorily. Seven local selections were made from small-scale clonal evaluation, labelled as HP 91-58, HP 2002-201, HP 95-55, MT 11-76 (I), and MT 11-76 (II), and added to the breeding pool namely as Interim 1 to 5 respectively. Two new Estate/RRI collaborative trials were established at Yatiyantota, We-Oya estate, and Mawathagama, Notinhill estate.

The second adaptability trail of foreign clones was established at Galewatta division of Dartonfield group with twelve foreign clones. The average girth of the first year in the first adaptability trial established at Neuchattle Estate was analyzed and the highest girth was recorded for the clones RRIT 3904, RRII 422, and ARCPC 2/4, origin in Thailand, India, and Myanmar, respectively.

Tapping was started in the smallholder/RRI collaborative clone trials established in the Eastern province with the control trial at Kalutara district in 2012.

Both HbMnSOD and HbCAT genes were significantly up-regulated in TPD affected twelve years old trees of RRISL 203 at Eladuwa, where HbMnSOD gene showed a higher level of expression compared to HbCAT gene expression level.

PLANT SCIENCE

Shoot and root attributes of the seedlings were recorded at the time of transplanting from different height of germination beds. Height of the germination beds causes rapid elongation of the tap root in the germination beds and unless a sufficient height is provided in the germination bed, the tap root touches the ground and gets distorted or hardened. Bud-grafting success of the nursery experiment on effects of seed quantity was evaluated. Percentage success rate of budded plants which were transplanted from the treatment T3 (four folds) and T4 (five folds) was higher when compared the T1 (two folds) and T2 (three folds) of seed quantities taken for establishing rootstock nurseries. Three types of porous irrigation systems were evaluated and growth of irrigated plants with two porous units' system is satisfactory over manual watering.

A special capital project was granted in 2018 titled "Intercropping diverse crop plants (medicinal, fruit crops and multipurpose crops) under rubber in non-traditional areas to ensure economically and environmentally sustainable land use practice for rubber cultivation" ended this year. However, the trials established in farmer fields under this projects will be monitored under the RRI funds. Growth, yield and physiological data of different intercropping trials were assessed in wet and intermediate zones. New experimental trial on the "effects of different spacing for Rubber X Cardamom and Rubber X Cinnamon" were continued at Labugama and Kuruwita respectively.

Latex yields, growth and bark measurements were recorded in the tapping experiment at Sirikandura estate in order to optimize the bark management. The treatment which has an additional tapping cut for the holidays, i.e. T4 recorded the total value of 60.4 g/t/t in holidays to cover the additional cost to be paid for the tappper for holiday tapping. An alternative tapping tested (S/4 d1) for smallholder practice, i.e. daily tapping (S/2 d1) did not perform due to the shorter cut length. Yield and weather data were recorded for the early morning tapping experiment for few months.

42 nursery visits were made and about 851,600 plants were certified in RDD nurseries. Weak plants in RDD nurseries were discarded in collaboration with Rubber Development Department. Budwood nurseries were inspected for Rubber Development Department Nurseries. 30 advisory visits were made and 30 training programmes on nursery management, budgrafting and tapping were conducted.

PLANT PATHOLOGY AND MICROBIOLOGY

Incidence of the secondary leaf fall diseases, was mild during the refoliation period except for a few disease vulnerable sites. The newly reported leaf fall disease was named "Circular Leaf Spot Disease" (CLSD). The disease is primarily caused by four new Colletotrichum species namely; Colletotrichum siamense, C. fructicola, C. gigasporum and C. tropicale, and secondarily infected with three Pestalotioides genus: Pestalotiopsis spp. Neopestalotiopsis spp. and Pseudopestalotiopsis spp., which have been regarded as opportunistic weak parasites. During the year 2021, CLSD reached a severe condition mainly in the wet rubber growing districts. The department was awarded a development project worth Rs.49 Mn to "Develop strategies to manage the new leaf fall disease in rubber plantations". The studies on the biology and epidemiology of the pathogen isolates are in progress and an interim recommendation was issued by the RRISL for chemical control. Two systemic fungicides carbendazim (5g per liter) and hexaconazole (5 ml per liter) were recommended to be used alternatively. Since the vigour of the plants affects the severity of the disease incidence, the application of the fertilizer and the adoption of all the other good agronomic practices were also recommended. Based on the Corynespora screening programme, there were no disease reports from new clones. The disease remained at a mild level in traditional rubber growing areas and the severity of the disease in the nontraditional areas was comparatively higher. Incidence of Phytophthora diseases was also moderate except for a few disease-vulnerable sites. White root disease had become destructive and played an important role in reducing the tree stand in rubber plantations. Seventy demonstration plots have been established to demonstrate the efficiency of recommendations. White root disease patches were rehabilitated using integrated disease management systems: mechanical, biological and chemical methods. For rehabilitated plots, plant types such as banana, pineapple, ginger and cassava were identified to be used as indicator plants while providing some additional income to the grower. Antagonistic fungi isolated from Sri Lankan rubber growing soils have been identified by sequencing and among the culture collection, effective biological controlling agents were identified for White root disease and Brown root disease. Two effective basal media; compost and talc were found effective in carrying the antagonistic inocula to the soil. Two Trichoderma-based products were forwarded to the Registrar of Pesticides, Department of Agriculture for the registration. The product is currently being tested under commercial level. The national level culture collection maintained at the department was generally checked for the viability. Plant Growth Promoting Rhizobacteria was isolated from the rubber growing soils. Nitrogen fixing bacteria were isolated from the root nodules of Pueraria phaseoloides in view of identifying plant growth promoting micro-organisms. Wood decaying fungi were also isolated from the rubber decaying logs to be used in the acceleration of decaying purposes. The department conducted 20 training programmes on White root disease and new leaf fall disease management.

SOILS AND PLANT NUTRITION

Research activities on improvement of soil fertility, increasing fertilizer use efficiency, soil, water and nutrient conservation and weed control were continued. Special capital projects titled "Modification of fertilizer recommendation system of Hevea with reference to plant, soil and field parameters" and "Establishment of environmentally friendly, economically viable slow-release fertilizer techniques to improve crop performance and establishment of an accredited laboratory to supply good service to the rubber industry" were continued. Activities of the projects entitled "Enhancing soil fertility in degraded rubber lands by combined use of agro management practices such as inorganic fertilizer, biofertilizer, cover cropping and mulching with organics" and "A feasibility study on the potential for utilization of natural rubber processing wastewater for enhancement of soil fertility" were conducted with the funds of the National Research Council and Ministry of Environment, respectively. The use of partially burned paddy husks improved the girth of immature rubber plants. The preliminary study revealed promising results of using rubber effluent as a nutrient source for salad cucumber plants. A case study on the effect of fertilizer use on the incidence of Pestalotiopsis disease in rubber was conducted.

Inorganic fertilizer supplied in Reusable Porous Tubes (RPT) resulted in a higher girth of immature Hevea plants than the traditional way of applying fertilizer. Spatial variability of soil chemical properties of the Kuruwita experimental site was evaluated with the focus of establishing a management zone under mature rubber for variable rate fertilizer (VRF) application. Combined use of agro management (CAM) practices such as cover management, biofertilization, stone terrace, coconut husk, and vetiver terracing with a reduced amount of inorganic fertilizer application showed a 14% growth improvement compared to conventional fertilizer application only treatment. According to the leaf nutrient levels of immature rubber, deficient nutrient levels of nitrogen, potassium, magnesium, and excess or sufficient levels of phosphorus were identified in different conventional rubber growing soils. Furthermore, three distinct soil categories could be identified as Parambe, Homagama, and other rubber growing areas in terms of soil nutrients. Site-specific fertilizer recommendation programme was discontinued due to Covid 19 pandemic situation in the country and the planters were advised to follow the previous year's fertilizer recommendation for the year 2022 as well. Eight land suitability reports were issued for 379.7 ha under the land selection programme. Analytical service offered 39 analytical reports including 1244 parameters based on 87 fertilizer samples to assure the application of good quality fertilizer for rubber lands.

BIOCHEMISTRY AND PHYSIOLOGY

Technology transfer programmes on low-intensity harvesting systems and usage of ethephon were conducted to the Extension Officers of the Advisory Service Department and Rubber Development Department, Managers and Field Officers of RPC owned estates and rubber smallholders. Under a special capital project received to popularize low-intensity harvesting systems, about 1630 ha of smallholder and estate sector rubber fields have been adopted with the S/2 d4 low-intensity harvesting system.

Experimental fields established in non-traditional rubber growing areas have been monitored and investigations have been carried out to identify the best clones for the sub-optimal climatic conditions. Growth data were collected from experimental fields established at Padiyathalawa and Hambegamuwa with nine different Hevea clones developed by the Rubber Research Institute of Sri Lanka.

An experiment has been conducted to investigate the effect of new leaf disease on yield determinant latex physiological factors in collaboration with the Plant Pathology and Microbiology Department, RRISL.

Further investigations of locally formulated water-based and oil-based new ethephon formulations under the National Science Foundation research project RG/2017/AG/1 has been completed during the first quarter of the year. Further investigations on commercial scale testing have also been conducted.

ADVISORY SERVICES

The extension strategy focusing the farmer participatory development of selected rubber smallholdings was continued in each REO division in traditional rubber growing areas and 113 rubber smallholdings were developed as model rubber smallholdings. Twenty-nine rubber processing centers were developed as models and construction of 30 new RSS processing centers and rehabilitation of 09 substandard centers were attended. Thirty-one smallholdings were fixed with rain guards as demonstrations. Six smallholdings were established with different intercrops as models.

Smallholder training programmes were conducted educating 574 rubber smallholders and 91 estate staff (Field officers and estate workers) on general cultivation practices, rain guard fixation and processing aspects of rubber. Mobile Tapper Training Programmes were conducted covering both practical and theoretical aspects of tapping while, 60 new tappers were introduced into smallholder rubber sector and also, two hundred and ten semi-skilled rubber tappers from estate sector were trained as skilled tappers. The group extension programme called "Vihidum Sathkara" was effectively conducted providing advisory and extension services for 137 smallholdings in traditional rubber growing areas for necessary improvements. Three hundred and eighty two advisory visits were carried out to solve problems in technology adoption on the requests made by rubber smallholders. Nine hundred and seventy advisory visits were carried out to solve problems in model rubber smallholdings.

Under the project started in 2017 on "Introduction and Establishment of new fuel wood growing models in selected lands of smallholder rubber farmers" with FAO funding, 92 rubber smallholders were assisted to establish different fuel wood growing models by end of the year. Under the project started in 2021 on "Introduction and establishment of pasture in selected land of rubber smallholders in Kalutara District" with the collaboration of Milco Pvt Ltd, 14 rubber smallholders were encouraged to cultivate pasture covering 12 acres. Thirty nine rubber smallholdings were established with compost application covering a total of 82 acres in Kalutara, Kurunegala, Kandy/Matale, Kegalle, Matara, Galle, Colombo and Ratnapura Districts.

RUBBER TECHNOLOGY AND DEVELOPMENT

Natural rubber (NR) composites were produced with different size ranges of oil palm fiber synthesized in the laboratory and physico-mechanical properties, ageing properties and water absorption were evaluated. Also, polyethylene glycol-grafted graphite (PEG-g-Graphite) was synthesized and characterized using FTIR spectroscopy, XRD, TGA and SEM. Subsequently, a series of NR composites was prepared by varying the PEG-g-Graphite loading and physico-mechanical properties and sheet resistance were evaluated. In addition, a series of NR latex based cast films was produced with extracts of twelve plant-based natural materials at the request of a small scale latex based product manufacturer. Storage properties of the cast films were evaluated.

Different dry rubber based compounds for cable guide of motor cycles, bio-medical items, brake pads of bicycles and brake washers, NR based micro-cellular sheet, NR latex based fishing baits and compound to bind rubber waste were developed at the requests of rubber product manufacturers.

134, 169 and 139 tests on sole crepe samples, rubber compounds and rubber/polythene products, respectively were conducted at the requests of the rubber industry. 32 entrepreneurs/industry personnel and three groups of University students were trained at RRISL, Ratmalana on "Manufacture of NR based Products".

POLYMER CHEMISTRY

Research activities related to the project titled "development of property correlations for nitrosamine safe binary accelerator systems" were continued throughout the year.

The effect of bis[3-(triethoxysilyl)propyl]tetrasulfide or commonly known as Si-69 and polyethylene glycol (PEG) on the rubber-filler interactions of mica-filled natural rubber (NR) composites was studied. The NR/mica composites were characterised in terms of curing, physio-mechanical and thermal properties. The study revealed that the combination of Si-69 and PEG could enhance physico-mechanical properties of NR/mica composites.

More than a thousand samples of polymeric materials and compounding ingredients received from industry and academia were analyzed using advanced instrumentation including, Fourier transform infrared spectrophotometer (FTIR), Different Scanning Calorimeter (DSC), Dynamical Mechanical Analyzer (DMA) and Thermo-gravimetric Analyzer (TGA).

RAW RUBBER AND CHEMICAL ANALYSIS

The department provides analytical testing services as per industry demands and needs. Our scope is to empower the raw rubber producers, rubber exporters and, small and medium scale industrialists by providing internationally accepted testing facilities. The department offered testing, analytical and certification services on raw natural rubber and rubber chemicals to all sectors of the rubber industry. These services were also extended to, researchers departments of the institute, and various local institutions such as Universities, other research institutes as well as individuals including postgraduate students, consultants, and inventors, etc.

A total number of two thousand two hundred thirty seven tests were conducted for natural rubber latex, dry rubber, and processing chemicals. They included 1301 tests for dry rubber, 889 tests for latex and 28 tests for rubber processing chemicals. 363test certificates were issued on requests received from the respective parties for their quality assessment and marketing purposes. In addition, the department carried out miscellaneous analytical tests, troubleshooting activities, and two major research projects during the year. A mini research project was carried out as one of the trouble shooting activities to see the effect of bleaching agent concentration on dry rubber properties of crepe rubber.

A collaborative research project was conducted with Kelani Valley Plantations Pvt Ltd. to study the "Effect of residual Diammonium Hydrogen Phosphate (DAHP) content on Natural Rubber Centrifuged Latex Properties and Latex Film Properties. Another collaborative research project was conducted with the University of Ruhuna on the Purification and commercialization of pyrolytic carbon char generated from waste tire pyrolysis plants in Sri Lanka.

The department's staff provided two training programs on raw rubber and natural rubber latex testing for university undergraduates. Two factory visits were made for troubleshooting activities during the year.

RAW RUBBER PROCESS DEVELOPMENT AND CHEMICAL ENGINEERING

A detailed study on quantification and characterization of effluent water generated in Ribbed Smoked Sheets (RSS) and Crepe rubber manufacturing industries in Sri Lanka was carried out. A protocol for optimum utilization of milling water in the crepe rubber manufacturing process is recommended to prevent the use of excessive volumes of processing water during milling and to minimize the waste water generation. It was found that the water treatment could be restricted only for the effluent generated at the latex coagulation tanks and the waste water generated at the first three mill passes thereby reducing the total effluent treatment capacity by18% to 42% range in crepe rubber industry. In the manufacture of RSS, there is no significant difference in the quality of waste water generated at coagulation and milling stages. A comparative study carried out on degradability behaviour of Natural rubber and Nitrile gloves showed that hydrothermal treatment and exposure to UV radiation are the best degradation methods for NR gloves and NBR gloves, respectively among the candidate treatments studied. Effect of selected five carbon black (CB) grades (N134, N220, N330, N550 and N 990) on curing, and physico-mechanical properties of a natural rubber composite were evaluated. It was shown that only CB grade N 990 has a significant influence on delaying curing process and reducing physico-mechanical properties. A study carried out on the effect of hydrogen peroxide based hand sanitizing chemicals on the physico-mechanical properties of NR and NBR gloves has shown that there is no significant effect of application of sanitizer for a short period (eight hours at different frequencies). On the other hand, application of sodium hypochlorite as a disinfectant in tyre tread showed a gradual reduction of the surface appearance and development of roughness on the surface under the experimental conditions along with slight reduction of mechanical properties. A study carried out on characterization of dynamically vulcanized polypropylene (PP) and Skim Natural Rubber (SNR) (50/50) (compatibilized at 10 phr EPDM) with different $CaCO_3$ loadings showed that 15 to 20 phr of $CaCO_3$ is the optimum loading for SNR/PP blends.

ADAPTIVE RESEARCH

Awareness programmes were conducted to educate rubber growers on dry zone rubber cultivation in Nochchiyagama and Nachchaduwa of Anuradhapura district. Feasibility assessments on rubber cultivation were conducted and farmer participatory adaptive research trials were established in Nachchaduwa of Anuradhapura district and Katharagama of Moneragala district. The study conducted to identify the factors influencing the adoption of rubber cultivation among the smallholders in the Ampara district revealed that participation in seasonal training programmes, farmer age, education level and monthly income had a significant positive correlation whilst difficulty in accessing initial capital and distance to the rubber land from the farmer's home showed a significant negative correlation. The study conducted in the smallholder sector revealed that awareness leads to the formation of perceptions about recommendations which in turn encourages farmers to adopt the recommendations. During the COVID-19 pandemic period, RRISL-managed estates assured 100% job security to their workers been not reducing the working days offered. Identification of GPS locations of ca. 2,000 ha of new rubber smallholdings in Moneragala and Ampara districts was done in collaboration with Smallholder Tea and Rubber Revitalization (STaRR) Project. A workshop on 'Role of Rubber in Climate Change, Carbon Footprint & Carbon Trading' was conducted to aware high officials of rubber-related government organizations. The ground-level validation of the carbon trading project was carried out by a third-party accredited auditor. The carbon footprint of rubber-related government organizations; Rubber Research Institute of Sri Lanka, Rubber Development Department of Sri Lanka and the Thurusaviya Fund was calculated as 542, 754 and 17 CO2e tons, respectively.

BIOMETRY

The research plan 2021 of the Biometry section is focused on Biometrical aspects; especially on development, modification and application of statistical methodologies related to the needs of the rubber sector. Statistical methods, research support and studies on Climatology are the three major research and development focuses of the Biometry section. Research support extended to other departments included assisting the design of experiments, data analysis, design and analysis of surveys, interpretation of results and database management. Databases on meteorological data collected in the stations at Dartonfield, Moneragala and Kuruwita and rainfall data collected in stations at Nivitigalakele, Galewatta and Polgahawela were updated and provided the data for scientific purposes on request. Data collected from the Dartonfield AGROMET station were provided to the Department of Meteorology as monthly reports. The database on rainfall in rubber growing areas was updated for the reporting year. An automatic weather station was installed at the premises of the regional advisory office in Kegalle. The Officers of the Biometry section have been involved with multi-disciplinary studies with different departments of RRISL, Universities, other Crop Research Institutions and Regional Plantation Companies.

AGRICULTURAL ECONOMICS

Agricultural Economics Unit (AEU) has systematically reviewed the global rubber industry and rubber prices using world trade statistics. It highlighted some significant movements of the industry irrespective of the Covid-19 pandemic. It is of utmost importance to find the willingness of farmers to continue with rubber farming for the sustainability of the rubber industry. AEU has conducted a study to find the farmers' willingness and the effect of their socio-economic factors on rubber replanting using a case study in the Kegalle District of Sri Lanka. Approximately two-thirds of smallholder farmers are willing to continue with rubber farming while several socio-economic factors of farm households and government support are important in willingness. An externally funded collaborative project is in continuation to test and exemplify the use of Geographic Information System (GIS) and Remote Sensing (RS) techniques in rubber plantation management. Also, AEU has compiled and analysed the international trade of rubber products from Sri Lanka and rubber prices throughout the year. Also, some economic analyses were conducted on request from other departments and stakeholders.

LIBRARY AND PUBLICATION

The Library and Publication Unit continued with its regular services in collecting and disseminating information on natural rubber and related subject areas and also processing and publishing its periodicals. The Library and Publication Unit supported the staff of the institute by providing primary as well as secondary sources, maintaining permanent collections, and providing access to all necessary materials. The services provided by the Library include lending facilities for books and other printed materials, tracing references, facilitating inter-library loan, photocopying, indexing service for publications, circulating content pages of latest periodicals among researchers, current awareness service on updating the users on new arrivals of book and selective dissemination of information (SDI) service on demand.

Five proceedings were added to the reference section of the Library bringing the total collection up to 6214.

Twenty Journals were received on an exchange basis.

DARTONFIELD GROUP

A total crop of 111,752 kgs has been harvested during the year achieving 60.5% of the estimated crop. When comparing with the previous year, crop records a decrease of 32.6%. The crop harvested on wet days due to the rain guards was 27,999 kg which amounts to 25.05% of total harvested crop.

Average Yield per Hectare (YPH) for the year was 666 kg showing a decrease of 246 kg from the previous year.

The average intake per tapper recorded during the year was 6.4 kg from a tapping task of 195 trees. The highest intake per tapper of 8.9 kg was recorded from the 4.69 ha RRIC 121/102 PB260, PB 217 clone planted field in year 2007 on S/2 d4 low frequency systems with etheral stimulation (tapping task of 259 trees).

The total number of normal, late, rain guard & no tapping days recorded during the year were 171,35, 82 and 77 days, respectively.

Total rainfall recorded for the year was 5510.2 mm with 179 wet days showing 1819.7 mm up rainfall and 21 wet days than the values recorded in the previous year.

The Cost of Production (COP) and Net Sale Average (NSA) recorded for the year was Rs.502.49 and Rs.564.83 respectively, giving a profit of Rs.62.34 per kg and a total profit of Rs.6.9 Million. Profit per hectare recorded for the year was Rs.41789.91.

The average percentage of Pale Crepe grade No. 01 was 75% during the year.

KURUWITA SUB - STATION

The mature extent of the Kuruwita Sub Station was 79.36 hectares during the year.

A total crop of 62,444 kg was harvested during the year recording a decrease of 17,013 kg from previous year's crop.

The actual yield per hectare (YPH) was 786.8 kg. The average intake tapper (IPT) of the estate was 6.1 kg and this is a decrease of 1.3 kg when compared with the previous year.

The reduction in yield monthly has been caused due to several facts including the uneven distribution of Rainfall continuous appearance of leaf spot disease.

The total number of Normal, Late, Rainguarded and No tapping days recorded during the year were 189, 17, 110 and 48 respectively.

The annual rain fall recorded during the year was 5,396.8 mm with 177 wet days as against 3426.5mm with 138 wet days during the previous year.

The cost of production (C.O.P) and the net sale Average (N.S.A) for the year were Rs.442.53 and Rs.523.82 per kg respectively. The profit made for the year was Rs.5 million and the profit per hectare recorded for the year was Rs.63,962.61.

POLGAHAWELA SUB - STATION

A total crop of 16828kgs has been harvested during the year and it was 75.9% of the estimated crop. However, there was a 1.51% decrease from the value recorded for the previous year.

The YPH for the year was 948kg. This showed a decrease of 14kg (1.45%) over the last year value.

The average intake per tapper during the year was 8.0kg. The highest intake per tapper of 10.4kg was recorded from the 2008 field with a tapping task of 269 trees of clone RRIC121 tapped on S/2 d3 systems.

The total numbers of Normal, Late, and No Tapping Days during the year were 232,75,0 &L58, respectively.

Total rainfall recorded for the year was 3485.4mm with 128 wet days.

Out of the total manufactured RSS, the share of No.01 grade was 82%.

METEOROLOGICAL REPORT

The total annual rainfall at Dartonfield during this year was 5,617 mm, which accounted for an increase of 54%, compared to the previous year. The annual rainfall in 2021 exceeded the average for the last 20 years (4,126 mm) by 1,491 mm which accounted for an increase of 36% compared to the long-term average. Remarkably high above-average monthly rainfall values were observed in May (373 mm-64%), November (280 mm-73%) and June (263 mm-66%). The minimum monthly rainfall of 238 mm was recorded in December whilst the maximum monthly rainfall of 957 mm was recorded in May. There were 260 rainy days at Dartonfield in 2021.

Rains during the South West season carried most of the rains (2,811 mm compared to the long-term average 1,564 mm) during 2021. This rainfall amount contributed 50% to the total rainfall. During the North East season (December 2020 to February 2021), 883 mm of rain was recorded, which is comparatively higher (22%) than the long-term average contribution (15%) of this season.

There were 23 rainfall events that exceeded the hazardous limits for landslides (100 mm of rainfall during a day) reported during the year under review. A dry spell lasted over a month or more can have adverse impacts on rubber plantations. There were only 3 dry spells greater than or equal to 7 days.

The minimum temperature did not drop below 20 ^{0}C except once in February. The daily average temperature pattern was fairly steady with a mean annual temperature of 27.4 ^{0}C. Both the lowest mean monthly minimum and the highest monthly mean temperatures were recorded in February as 22^{0}C and 32.9^{0}C, respectively. A total of 1619 bright sunshine hours was received at an average rate of 4.4 hours/day which was comparatively lower than the respective figures observed during the last year. Daily morning RH at Dartonfield in 2021 was observed in the range, 72% to 97%. The mean RH values recorded at 08:30 and 15:30 were 87% and 75%, respectively.

The annual rainfall totals of 5387 mm, 3486 mm, 1718 mm and 4,494 mm were recorded, respectively, in Kuruwita, Narampola, Moneragala and Nivithigalakele stations maintained by RRISL during 2021. The respective rainy days for these stations were 241, 151, 100 and 204.

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