RUBBER RESEARCH INSTITUTE OF SRI LANKA

Annual Review 2019

Rubber Research Institute of Sri Lanka

Annual Review - 2019

1st January 2019 to 31st December 2019

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

Head Office & Laboratories
Dartonfield
Agalawatta

Board Office & Laboratories
Telewela Road
Ratmalana

CONTENTS

RUBBER RESEARCH BOARD OF SRI LANKA

BOARD OF MANAGEMENT

Members appointed by the Hon Minister of Plantation Industries

Mrs Vishaka Sooriyabandara, Chairperson, Rubber Research Board (up to 22.11.2019)
Ms M K D N Madampe, Treasury Representative
Mr R A D S Ranatunga, Representative, Ministry of Plantation Industries
Mr Justin Seneviratne, Group Director, Lalan Rubber (Pvt) Ltd.
Mr R C Peiris, Chief Executive Officer, Kotagala Plantation PLC
Mr Anusha Perera, Chief Executive Officer, Balangoda Plantation PLC
Dr J D H Wijewardana, Secretary/Director, Sri Lanka Council for Agricultural Research Policy (w.e.f. 31.01.2019)
Dr D T K Bernard, Chairman, Sri Lanka Council for Agricultural Research Policy (w.e.f. 18.06.2019)
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Mr T Thangarajah, Union Representative (w.e.f. 12.02.2019)
Mr D C Nathaniel, Smallholders' Representative (w.e.f. 21.03.2019)
Dr L M K Tillekeratne, Representative for CRTA (w.e.f. 16.09.2019)

Ex-Officio Members

Mr R B Premadasa, Director General, Rubber Development Department
Mr S S Poholiyadda, Managing Director, RPC Plantation Management Services

STANDING COMMITTEES

Estate Committee

Mrs Vishaka Sooriyabandara, Chairperson, Rubber Research Board (up to 22.11.2019)
Dr V H L Rodrigo, Additional Director, RRI
Dr (Mrs) P Seneviratne, Deputy Director - Research (Biology), RRI
Dr Susantha Siriwardena, Deputy Director - Research (Technology), RRI
Mr Nissanka Seneviratne, Director, Kotagala Plantations Ltd.
Mr Jagath Hettiarachchi, Senior Manager, Paiyagala Estate
Mr Prince Gunasekera, General Manager, Namunukula Plantations Ltd.
Mr P A Lukshaman, Senior Manager, Dartonfield Estate
Mr B S S Hewage, Senior Accountant, RRI

Audit and Management Committee

Ms M K D N Madampe, Chairman of the Committee, Treasury Representative
Mr R B Premadasa, Director General, Rubber Development Department
Mr R AD S Ranatunga, Representative, Ministry of Plantation Industries

In attendance
Ms Nilani Jayasiri, Audit Superintendent, Ministry of Plantation Industries
Dr V H L Rodrigo, Additional Director, Rubber Research Institute
Mr S Hewage, Senior Accountant, RRI
Ms S Senadheera, Internal Auditor, RRB
Mr Susantha Dissanayake, Senior Administrative Officer

Scientific Committee
Members of RRISL
Mrs Vishaka Sooriyabandara, Chairperson, Rubber Research Board (up to 22.11.2019)
Dr V H L Rodrigo, Additional Director, RRI
Dr (Mrs) G P W P P Seneviratne, Deputy Director Research (Biology), RRI
Dr S Siriwardena, Deputy Director Research (Technology), RRI
Dr D M A P Dissanayake, Head, Advisory Services Dept., RRI
Dr (Mrs) D G Edirisinghe, Head, Rubber Technology & Development Dept., RRI
Dr (Mrs) S P Withanage, Head, Genetics & Plant Breeding Dept., RRI
Dr (Mrs) B W Wijesuriya, Principal Research Officer, Biometry Section, RRI
Dr N M C Nayanakantha, Head, Plant Science Dept., RRI
Dr (Mrs) T H P S Fernando, Head, Plant Pathology & Microbiology Dept., RRI
Dr (Mrs) E S Munasinghe, Principal Research Officer, Adaptive Research Unit, RRI
Dr (Mrs) K V V S Kudaligama, Principal Research Officer, Biochemistry & Physiology Dept., RRI
Dr (Mrs) R P Hettiarachchi, Principal Research Officer, Soils & Plant Nutrition Dept., RRI
Dr (Mrs) A P Attanayake, Senior Research Officer, Raw Rubber & Chemical Analysis Dept., RRI
Dr K K Liyanage, Senior Research Officer, Genetics & Plant Breeding Dept., RRI
Mr T U K Silva, Senior Research Officer, Plant Science Dept., RRI
Mrs B M D C Balasooriya, Research Officer, Adaptive Research Unit, RRI
Mrs D S A Nakandala, Research Officer, Plant Science Dept., RRI
Mrs M K R Silva, Research Officer, Plant Pathology & Microbiology Dept., RRI
Mrs P V A Anushka, Research Officer, Genetics & Plant Breeding Dept., RRI
Mr W D M Sampath, Research Officer, Rubber Technology & Dept., RRI
Mr P K K S Gunaratne, Advisory Officer, Advisory Services Dept., RRI
Mr J K S Sankalpa, Research Officer, Agricultural Economics Unit, RRI
Mr K Adikari, Research Officer, Raw Rubber & Chemical Analysis Dept., RRI
Mrs I H K Samarasinghe, Research Officer, Polymer Chemistry Dept., RRI
Mrs T T D Dahanayake, Research Officer, Genetics & Plant Breeding Dept., RRI
Mrs H A Ruwani Jayawardane, Research Officer, Soils & Plant Nutrition Dept., RRI
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Mr Yashoda Somaratne, Research Officer, Polymer Chemistry Dept., RRI

Mr Y C Yohan Sudusinghe, Research Officer, Raw Rubber Process Development & Chemical Engineering Dept., RRI
Mr P A Lukshaman, Senior Manager (Estate), RRI

Members representing the Industry and other Institutions
Mr R A D S Ranathumga, Director (Development), Ministry of Plantation Industries,
Mrs W K Chathurangi, Assistant Director (Development), Ministry of Plantation Industries
Mr Sampath Manthirinayake, Director, PMMD
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Mr K M A S Wijeratne, Superintendent, Agalawatte Plantations PLC, Kiriwanaketiya Estate, Mahagama
Mr K Fernando, Superintendent, Agalawatte Plantations PLC, Culloden Estate, Neboda
Mr D Wekunagoda, Superintendent, Agalawatte Plantations PLC, Doloswella Estate, Nivithigala
Mr R A D I Ramanayake, Superintendent, Agalawatte Plantations PLC, Watapotha Estate, Nivithigala
Mr D P A Perera, DGM, P.B. 06, Balangoda Plantations PLC, Palmgarden, Ratnapura
Mr D K Wijerathne, Superintendent, Balangoda Plantations PLC, Rambukkande Estate, Rathnapura
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Mr U A Karunanayake, Manager, Elpitiya Plantations PLC, Devithurai Estate, Ethkandura
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Mr S D Munasinghe, Superintendent, Kegalle Plantations PLC, Eadella Estate, Polgahawela
Mr B M J A Moonamalle, Superintendent, Kegalle Plantations PLC, Atale Estate, Atale
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Mr Gamini N Ratnayake, DGM, Horana Plantations PLC, Neuchatel Estate, Neboda
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Mr N B Seneviratne, Director – Low Country, Kotagala Plantations PLC, Regional Office, Ellakanda, Horana
Mr J N Hettiarachchi, Senior Manager, Kotagala Plantations PLC, Paiyagala Estate, Dodangoda
Mr L A D J Perera, Senior Manager, Kotagala Plantations PLC, Delkith Estate, Baduraliya
Mr R Tennakoon, Senior Manager, Kotagala Plantations PLC, Padukka Estate, Padukka
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Mr C Amaratunga, RGM, Kahawatte Plantations PLC, Regional Office, Pelmadulla Estate, Kahgawatte
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Mr K G A I Jayasinghe, Superintendent, Kahawatte Plantations PLC, Wellandura Estate, Kahawatte
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Mr D Tennakoon, Senior Manager, Kahawatte Plantations PLC, Pelmadulla Estate, Kahawatte
Mr U Millangoda, Asst. Manager, Kahawatte Plantations PLC, Poranuwa Estate, Kahawatte

Mr U Premathilake, Kelani Valley Plantations PLC, Director, No 400, Deans Rd, Colombo 10
Mr B Gunasekara, GM, Kelani Valley Plantations PLC, Panawatte Estate, Yatiyantota
Mr S Fernando, RGM, Kelani Valley Plantations PLC, Kiriporuwa Estate, Yatiyantota
Mr R M U S Jayasundara, Manager, Kelani Valley Plantations PLC, Urumillewa Estate, Bulathkohupitiya
Mr R L Obesekare, Senior Manager, Kelani Valley Plantations PLC, Edarapola Estate, Bulathkohupitiya
Mr E Welikala, DGM, Kelanivalley Plantation PLC, Kelani Estate, Yatiyantota
Mr P K A H Thilakaratne, Senior Manager, Kelani Valley Plantation PLC, We-oya Estate, Yatiyantota
Mr W P S B Abeywardana, Senior Manager, Kelani Valley Plantation PLC, Dewalakanda Estate, Dehiowita
Mr P De S A Gunasekara, GM, Namunukula Plantations PLC, No 310, High Level Rd, Nawinna, Maharagama
Mr J B Weerasekara, Superintendent, Namunukula Plantations PLC, Pallegoda Estate, Darga Town
Mr H Rajapaksha, Superintendent, Namunukula Plantations PLC, Sirikandura Estate, Matugama
Mr Albert Peiris, GM, Lalan Rubbers (Pvt) Ltd, No 54, Kirulapana Avenue, Colombo 06
Mr D Amarathunga, GM, Lalan Rubbers (Pvt) Ltd, Malwana, Biyagama
Mr N Senavirathne, GGM, Lalan Rubbers (Pvt) Ltd, Sapumalkande Group, Deraniyagala
Mr R Alahakoon, GGM, Lalan Rubbers (Pvt) Ltd, Udabage Group, Deraniyagala
Mr I Wakkumbura, Manager, Lalan Rubbers (Pvt) Ltd, Mahaoya Group, Dehiowita
Mr B Madagama, Superintendent, Maturata Plantations Ltd, Andapana Estate, Kamburupitiya
Mr L M A C Bandara, Superintendent, Maturata Plantations Ltd, Wilpita Estate Akuressa
Mr M H P Gunarathna, Superintendent, Maturata Plantations Ltd, Diddenipota Estate, Matara
Mr R Seneviratne, DGM, Pussellawa Plantations PLC, Elston Estate, Puwakpitiya
Mr K M C Prasan, Senior Manager, Pussellawa Plantations PLC, Halpe Estate, Thummodara
Mr C Jayalath, Asst. General Manager, Pussellawa Plantations PLC, Pussella Estate, Parakaduwa
Mr L M Amarathunga, Superintendent, Pussellawa Plantations PLC, Salawa Estate, Hanwella
Mr D Daswatte, DGM, Watawala Plantations PLC, Talangaha Estate, Nakiyadeniya
Mr C Fernando, Executive Director, Malwatte Valley Plantations PLC, No 280, Dam Street, Colombo 12

Mr R M V Ratnayake, Group Manager, Malwatte Valley Plantations PLC, Moralioya Estate, Ruwanwella
Mr S Seneviratne, Seneviratne Group, D.J. Wijesiriwardana Mawatha, Mt. Lavinia
Mr N M Amaraekara, Consultant, 37/9, Terrence Av, Mt. Lavinia
Mr Jayantha P Muthutantri, Consultant, No.4/4, Nelum Mw, Sirimal Uyana, Mt. Lavinia

Provident Fund Committee

Mrs Vishaka Sooriyabandara, Chairperson, Rubber Research Board (up to 22.11.2019)
Dr V H L Rodrigo, Additional Director, RRI, Member
Mr D M S Dissanayake, Senior Administrative Officer, Secretary
Mr B S S Hewage, Senior Accountant, RRI, Treasurer
Mr T B Dissanayake, Experimental Officer, Elected Committee Member
Mr P K K S Gunarathna, Advisory Officer, Elected Committee Member
Mr J A S Chandrasiri, Experimental Officer, Elected Committee Member

Chairman's Office & Board Secretariat

Chairperson	- Mrs Vishaka Sooriyabandara (up to 22.11.2019)
Acting Secretary to the Board	- Dr Wasana Wijesuriya, PRO (up to 28.02.2019)
	- Mrs Padma Balasooriya (w.e.f. 05.04.2019)
Personal Assistant to the Chairman	- Mrs Padma Balasooriya
Management Assistants	- Mrs H N Kanchana
	- Mrs P S Ishara (up to 15.07.2019)

Lawyers
Attorney General
Attorney General's Department
(Government Institutions)
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Bankers
Bank of Ceylon
Corporate Branch
75, Janadhipathi Mawatha
Colombo 1

Auditors
Auditor General
Auditor General's Department
No.306/72, Polduwa Road,
Battaramulla

Bank of Ceylon
Agalawatta

Contact details:

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Dartonfield, Agalawatta

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Additional Director	034 - 2248458
Deputy Director Research (Biology)	034 - 2295610
General	034 - 2247426
	034 - 2247383
	034 - 2295540
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Website	www.rrisl.lk

Board Office and Rubber Chemistry & Technology Laboratories
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Telephones:	
Chairman	011 - 2635019
Fax	011 - 2633353
Admin Dept. Telephone/Fax	011 - 2635142
Director	011 - 2633351
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Deputy Director Research (Technology)	011 - 2633352
General	011 - 2635851
	011 - 2635852
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Sub stations

Nivitigalakele - Substation, Matugama
Genetics and Plant Breeding Department & Training Centre
Telephone: 034 - 2247368, 034 - 2247199
e-mail: rrigpb@sltnet.lk

Kuruwita - Substation, Ratnapura
Telephone: 045 - 2262115, 045 - 3460537

Polgahawela - Substation, Polgahawela
Telephone: 037 - 2244120

Moneragala - Substation, Moneragala
Telephone: 055 - 3600707

Website: www.rrisl.lk

RUBBER RESEARCH INSTITUTE OF SRI LANKA

STAFF

DIRECTORATE

Additional Director	V H L Rodrigo, BSc Agric (SL), MSc (Essex) PhD (Wales)
Deputy Director Research (Bio.)	Mrs G P W P P Seneviratne, BSc (SL), PhD (Bath)
Deputy Director Research (Tech.)	S Siriwardene, BSc (SL), MSc (Australia) PhD (Malaysia)

RESEARCH DEPARTMENTS

Agronomy Departments

Genetics and Plant Breeding	*(at Nivithigalakele Substation, Matugama)*
Head of Department	Mrs S P Withanage, BSc Agric (SL), MSc (India), PhD (Malaysia)
Senior Research Officer	K K Liyanage, BSc Agric (SL) MPhil (SL), PhD (China)
Research Officers	***Mrs P V A Anushka, BSc Agric (SL)
	Mrs T T D Dahanayake, BSc Agric (SL)
Experimental Officers	T B Dissanayake
	T M S K Gunasekera
	H P Peries, Dip. Agric (Kundasale)
	Mrs A K Gamage, BSc (SL)
Technical Officers (Research & Development)	B W A N Baddewithana, BSc Agric. (SL), MPhil (SL)
	Mrs N S Jayasinghe, BSc Agric. (SL) (from August)
Management Assistant (Clerical)	Mrs S D P K L Peiris

Plant Science	*(at Dartonfield, Agalawatta)*
Head of Department	N M C Nayanakantha, BSc (SL), MSc (India), PhD (India)
Senior Research Officer	T U K Silva, BSc Agric (SL), MPhil (SL)
Research Officers	Mrs D S A Nakandala, BSc Agric (SL), PhD (SL)
	W D M N de Alwis, BSc (SL) (from August)
Experimental Officers	Mrs G A S Wijesekera (up to May)
	Mrs R K Samarasekera

Experimental Officers	D L N de Zoysa
	P D Pathirana, BSc (SL)
	P K W Karunathilake, Dip. Agric (Ratnapura)
Technical Officers	R Handapangoda, BSc Agric (SL)
(Research & Development)	Mrs E U M de Z Dissanayake, HNDT (Agric) BSc (SL), MSc (SL)
	Miss W K S W Watawala, BSc (SL)
	R P D Priyadharshana, BSc (SL)
	Miss H M Subsinghe, BSc (SL)
	Mrs U N Udaya Kumari, BSc (SL)
	Miss W M D Wickremakumari, BSc Agric. (SL) (from August)
	H D H C Arunasiri, HND (Agric) (from August)
Management Assistants (Clerical)	Mrs H D D E Jayawardena
	Mrs Aruni de Almeida

Plant Pathology and Microbiology *(at Dartonfield, Agalawatta)*

Head of Department	Mrs T H P S Fernando, BSc (SL), MPhil (SL), PhD (SL)
Research Officer	Mrs M K R Silva, BSc Agric (SL), MSc (SL)
Experimental Officers	Mrs B I Tennakoon, Dip. Agric (Kundasale)
	Mrs E A D D Siriwardene, BSc (SL)
	S C P Wijayaratne, NDT Agric (Hardy)
	E A D N Nishantha, Dip. Agric. (Ratnapura), BIS (Agric) (SL)
Technical Officers	P W Balasooriya, BSc (SL) (up to June)
(Research & Development)	Miss R D N S Gunasekera, Dip. in Agric. (up to January)
	Miss A H M N R Abeyrathna, BSc (SL) (from August)
	D A N Mallikaarachchi, BSc (SL) (from August)
Management Assistant (Clerical)	Mrs K A D Y Madushani Lanka

Soils and Plant Nutrition *(at Dartonfield, Agalawatta)*

Principal Research Officer	Mrs R P Hettiarachchi, BSc (SL), MPhil (SL), PhD (SL)
Research Officers	Mrs H A R K Jayawardana, BSc Agric. (SL), MSc (SL)
	L A T S Liyanaarachchi, BSc Agric. (SL) (from August)
Experimental Officers	Miss V U Edirimanne, BSc (SL)
	Miss A P Thewarapperuma
	P D T C Gunatilleke, NDT (Agric)

Technical Officers	Mrs Eranga de Silva, NDT
(Research & Development)	G C Malawaraarachchi, Dip. in Agric. (Hardy)
	Mrs M Kulathunga, BSc (SL)
	Mrs R M Baddevidana, BSc (SL)
	Mrs P D S D O Rathnasooriya, BSc (SL)
	M H W Gayan, BSc (SL)
	B M K Rangana, BSc (SL) (from August)
Management Assistant (Stenography)	Mrs K A D L Rupasinghe Perera
Biochemistry and Physiology	*(at Dartonfield, Agalawatta)*
Principal Research Officer	Mrs K V V S Kudaligama, BSc (SL), MPhil (SL), PhD (SL)
Research Officer	Miss N P S N Karunaratne, BSc (SL)
Experimental Officer	M K P Perera, BSc (SL)
Technical Officers (Research & Development)	Mrs P A D T L Madushani, Diploma in Agric.
	Miss N N Abewardena, BSc (SL)
	L T B K Fernando, BSc (SL) (from August)
Management Assistant (Clerical)	Mrs H A Manoji Erandika
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Head of Department	D M A P Dissanayake, BSc Agric. (SL) PhD (Aberdeen)
Advisory Officer	P K K S Gunaratne, BSc Agric. (SL)
Assistant Training Officer	Miss K G P Manahari, BSc (SL)
Rubber Extension Officers	R M S Ratnayake, NDT Agric. (Hardy)
	D E P M Nanayakkara, Dip. Agric. (Aquinas)
	Nihal Gamage, Dip. Agric. (Angunakolapelessa)
	S G G Wijesinghe
	I P L Kithsiri
	J A S Chandrasiri (from November)
	W P G D C P K Senanayake, NDT Agric. (Hardy)
	T L Ramanayake, BSc (SL)
	A R Kulathunga, BSc (SL)
	H G M G Jayasinghe, BSc (SL)
	Mrs K K I Jayasundera, BSc (SL)
	D S Dissanayake, BSc (SL)
	K D K L Siriwardena, BSc (SL)
	Mrs G R Tennakoon, BSc (SL)
	Miss R R N D Thara, BSc Agric. (SL) (from Sept.)

Rubber Extension Officers	P V S Madubashana, BSc Agric. (SL) (from Sept.)
	M N P de Silva, BSc Agric (SL) (from Sept.)
	E W S Ruwan Kumara, BSc (SL) (from August)
	S M A Samarakoon, Dip. Agric. (Kundasale) (from November)
Management Assistants (Clerical)	Mrs J N R Jayasinghe
	Mrs S M Kaluarachchi
	R G A S Dharmaratne
	T R C Silva
	P Sachini Ishara
	Mrs K Y G P M Kumari, BA (SL) (up to Sept.)

Technology Departments

Rubber Technology and Development *(at Telewela Road, Ratmalana)*

Head of Department	Mrs D G Edirisinghe, BSc (SL), MSc (SL) MPhil (UK), PhD (SL)
Research Officers	W D M Sampath, BSc (SL)
	Mrs U A Weerasinghe, BSc (SL) (from August)
Experimental Officer	Mrs G M Priyanthi Perera, BSc (SL), MSc (SL)
Technical Officers (Research & Development)	V G M J Abeywardena, NDT
	Miss S G P Bhagayawedha, NDT
	K I D P Perera, BSc (SL)
	Miss P K I L Jayaratne, BSc (SL)
	K N D Tillekeratne, BSc (SL) (from August)
	Mrs E N N Nanayakkara, BSc (SL) (from August)
	A H R W M N Gunawardena, BSc (SL) (from September)
Management Assistant (Clerical)	Miss S M D S R de A Wijeratne

Polymer Chemistry *(at Telewela Road, Ratmalana)*

Research Officers	**Mrs I H K Samarasinghe, BSc (SL)
	Y R Somaratne, BSc (SL) MSc (SL)
Experimental Officer	Mrs N Jayawardane, Dip. Agric. (Bibile)
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	Mrs P 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 Maduranga

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 Officers	Mrs C S Lokuge
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	Miss M U D S Weerasinghe, BSc (SL)
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	K A S T Koswatta, BSc (SL)
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Management Assistant (Clerical)	Miss W D D Samanmali

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	WA S Bandara, BSc (SL) (from August)
Management Assistants (Clerical)	Mrs H A Janani Lakshika, BA (SL)
	Mrs P D S Dilhani

Sections/Units

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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) (from Sept.)
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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)

Research Officer	Mrs B M D C Balasooriya, BSc Agric. (SL)
Technical Officers (Research & Development)	P M M Jayatilleke, NDT (Agric.) Mrs N M Piyasena, Dip. in Agric.
Management Assistant (Clerical)	Mrs M A Randima Srimalee

Agricultural Economics Unit	*(at Dartonfield, Agalawatta)*
Research Officers	J K S Sankalpa, BSc (SL), MSc (SL) Miss P G N Ishani, BSc Agric. (SL)

Library and Publications Unit	*(at Dartonfield, Agalawatta)*
Librarian & Publication Officer	Mrs N C D Wijesekara, BA (SL)
Library Assistant & Assistant Publication Officer	Mrs R M Amaratunga, Intermediate; Lib. Sci. Doc. & Info. (SLLA)
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 C P Peiris, BSc (SL)

Management Divisions

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

Senior Administrative Officer	D M S Dissanayake, BSc (Mgt.) (SL), MHRM (SL)
Registered Medical Practitioner	M Subasinghe
Administrative Officer	Mrs P Mandalawatta (Dip. in HRM) (up to Nov.)
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 Kumari
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 Assistants (Clerical)	A T Senaratne
	Mrs A R M de Alwis
	Mrs K A Geetha, BA (SL) (up to Sept.)
Telephone Operator	Mrs G D D Kalamini
Internal Audit Unit	*(at Dartonfield, Agalawatta)*
Internal Auditor	Mrs M S I Senadeera, IFA, IPFA, IRCA, LICA, FPFA, PGDM
Management Assistant (Clerical)	M A D W K Tillakeratne
Works Section	*(at Dartonfield, Agalawatta)*
Resident Engineer	K A D K Chathuranga, BSc (Eng.)
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 C S Wickremasinghe (up to July)
	Mrs K K D K P Ranaweera
	Mrs M S W H Kumari, BSc (SL)
	Udaya Samantha Munindradasa, BA (SL)
Accounts Section	*(at Dartonfield, Agalawatta)*
Senior Accountant	S S Hewage, CPFA (UK), CBA, FPFA
Accountant	Mrs A M Lasanthi, BSc (SL), MBA (SL), CBA, APFA
Management Assistants (Accounting)	Mrs R Handungoda
	Mrs G P Kukulewithana
Management Assistants (Clerical)	Mrs C Dissanayake
	A K D A Wickremasinghe
	Mrs S I K Pathirage
	Mrs S A Niluka Harshani
	Mrs K K D Y L Ranaweera
	Miss K K T L Jayasekera
	Mrs R P Thilini
	J A J R Lakmal, BA (Mgt.)
	K A Dilan Sampath
	Mrs Erandi Kanchana Jayasinghe, BA (SL)
	Mrs S R Sinhabahu
	Harith Kalutharawithana, BSc (SL)

Management Assistants (Clerical)	G N K Gunasena
	Mrs K G P Hasara
Cashier	Mrs G A D D Jayawardena

Sub – stations & Estates

Kuruwita Sub-Station	*(at Kuruwita)*
Field Officer	D D A Jayathunga, Dip.in Agric.
Management Assistants (Clerical)	D S Jayasinghe
	K D P Senaratne

Polgahawela Sub-Station	*(at Narampola Estate, Nungamuwa, Yatigaloluwa)*
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 (Nivitigalakele)	B M Siriwardena

* Study leave (overseas)
** Study leave
*** No pay leave

Awards

Dr D M A P Dissanayake, Head of the Advisory Services Department, RRI received the Award in Recognition of his Lifetime Contribution to the Research and Development in the Rubber Sector at the 7th Symposium on Plantation Crop Research- 2019, Marino Beach Hotel, Colombo, 4-6th November, 2019.

Dr (Mrs) Dilhara Edirisinghe, Head of the Rubber Technology & Development Department, RRI received the award for "Scientific Excellence" in the Rubber Sector during 2016-2018 at the 7th Symposium on Plantation Crop Research- 2019, Marino Beach Hotel, Colombo, 4-6th November, 2019.

Dr N M C Nayanakantha, Head of the Plant Science Department, RRI received an Award for the "Contribution made to Rubber Industry during 2016-2018" at 7th Symposium on Plantation Crop Research, 4-6th November, 2019, Colombo.

Dr N M C Nayanakantha received the "Best Overall Presentation Award" for his paper entitled "*Moringa oleifera* leaf extract as a biostimulant on growth and other physio-chemical attributes of rubber (*Hevea brasiliensis*) under drought and heat stress conditions" presented at 7th Symposium on Plantation Crop Research- 2019, Marino Beach Hotel, Colombo, 4-6th November, 2019.

Dr N M C Nayanakantha received "High Minds Idea Master Award" for the "Best Rubber Industry Participation" in the Leadership and Capacity Building Training Programme for young rubber industry professionals conducted by High Brand Team and Organized by the Ministry of Industry and Commerce under the Programme of "Rubber Cluster Young Network (RCYN) "in the Rubber Master Plan, 28-30th August 2018. The awarding ceremony was held at Golden Rose Hotel, Boralesgamuwa on 21st May 2019.

Mrs N P S N Karunarathne, Research Officer, Department of Biochemistry and Physiology of RRISL received the award for the 'Best Presentation in the Rubber Sector' at 7th Symposium on Plantation Crop Research 2019 for the paper 'Effectiveness of commercially available selected water- based and oil- based ethephon formulations as a yield stimulant of rubber (*Hevea brasiliensis*) (N P S N Karunarathne, K V V S Kudaligama, L T B K Fernando, N N Abewardhana, P D T L Madushani, M K P Perera, P Seneviratne and V H L Rodrigo)

The BEST PAPER award in the 'Rubber sector' was received to Mrs I H K Samarasinghe at the 7th Symposium on Plantation Crop Research 2019 held at Colombo, Sri Lanka for the paper titled 'Effect of nitrosamine safe diisopropyl xanthogen polysulfide accelerator on cure and static mechanical properties of natural rubber compounds' (I H K Samarasinghe, D G Edirisinghe, S Walpalage and S M Egodage).

List of Abbreviations

ANRPC	- Association for Natural Rubber Producing Countries
COP	- Cost of Production
CSD	- Civil Security Department
EU 28	- European Union Countries
FEAS	- Finite Element Analysis & Simulation Centre
GRT	- Ground Rubber Tyre
HP	- Hand Pollination
IPT	- Intake per Tapping
IRRDB	- International Rubber Research & Development Board
IRSG	- International Rubber Study Group
NR	- Natural Rubber
NIPM	- National Institute of Plantation Management
NSA	- Net Sale Average
PMI	- Purchasing Managers' Index
PRI	- Plastic Retention Index
REO	- Rubber Extension Officer
RSS	- Ribbed Smoked Sheets
SMR	- Synthetic Mixed Rubber
SR	- Synthetic Rubber
TOCOM	- Tokyo Commodity Exchange
TPD	- Tapping Panel Dryness
TSR	- Technically Specified Rubber
YPH	- Yield per Hectare

RUBBER RESEARCH INSTITUTE OF SRI LANKA

DIRECTOR'S REVIEW

V H L Rodrigo

This review comprises an overview of the local and international scenario of the rubber industry and then the major directions of research and development (R&D) activities in the institute to address the current issues in the industry. Details of research in each division are given in separate sections. Key obstacles for R&D are also mentioned briefly. Further, improvements made in administrative and financial functions of the institute are given.

Rubber industry of Sri Lanka

Rubber production and consumption

The natural rubber (NR) production of the country in the year 2019 has decreased by about 8% from the previous year to 75,700 tonnes. This could be attributed to the slow rate of recovery of NR prices at the market and less demand from major consumers in the world. When compared to the values in 2017 and 2018, slightly improved rubber prices with intermittent fluctuations were observed in 2019. However, total NR consumption in the country has estimated as 115,700 tonnes which have been attributed to a 14% decline against the previous year. The rubber industry will face severe drawbacks in the supply side which may finally result in a drastic effect on the flourishing rubber products manufacturing industry in the country.

Rubber extent

The total extent of rubber lands in the country at the end of 2019 has been recorded as 137.5 thousand hectares with about 75-80% under tapping. Accordingly, there has been a slight increase in rubber extent from the previous year. This could particularly be attributed to new planting in Monaragala and Ampara districts.

NR exports and imports

Sri Lanka has exported around 13,003 tonnes of natural raw rubber in the year 2019 against the year 2018, which was 13,981 tonnes of exports. Weak demand for the raw rubber at the international market would have attributed to this slight reduction.

Rubber manufacturing sector

Earnings through raw rubber exports were Rs.4.3 billion in the year 2019 against Rs.5.1 billion in the year 2018. Export earnings from finished products were recorded as Rs.154 billion in 2019, showing an increase of about 9% against the previous year. Export earnings from semi-processed rubber have reported as Rs.0.7

billion in the year 2019, while it was Rs.0.63 billion in the year 2018. Accordingly, total export earnings from the rubber industry remained at Rs.160 billion showing an 8.5% increase from the previous year.

Global rubber industry review

Natural rubber supply

Total world NR production increased to 13,764 thousand tonnes in 2019 against the year 2018, which was around 13,864 thousand tonnes. World NR production has increased by 4.4% according to ANRPC statistics. This is mainly due to the favourable markets in the major markets in the Asia Pacific region during the mid of the year.

NR average yield

Despite the yield decline recorded in Thailand, China, India, Indonesia, Vietnam and Sri Lanka, yield per hectare has increased in Malaysia and Cambodia during 2019. The expansion in mature area reflects the large scale planting undertaken during the period from year 2005 to 2012. Average annual yield of Sri Lanka has been recorded as 667 kg/ha/year in the year 2019 while it was 774 kg/ha/year in the year 2018.

Global NR demand

Total NR demand was estimated as 13,702 thousand tonnes in 2019 showing a 2.2% decline from the previous year. This showed an oversupply of about 62,000 tonnes of NR during the reference period.

World NR price movement

Despite of the declining trend prevailed in most of the market starting from the year 2011 to 2016, prices experienced an increase in the year 2017. However the rubber prices has declined slightly in the year 2018 against the year 2017. Afterwards, global rubber prices was slightly higher throughout the year 2019. In Sri Lanka, annual average RSS3 price in 2019 was US$ 1.86 per kg showing slightly higher value against US$ 1.84 recorded in 2018. The average price of RSS3 was recorded as US$ 1.66 in Bangkok against the previous year average value of US$ 1.56. Average Indian RSS4 has increased to US$1.89 from US$ 1.84 per kg against the previous year. According to the predictions of ANPRC countries, global natural rubber prices are likely to further decline due to slower economic growth and weaker demand from the major consumers in the world.

Research and development focus

Considering the continuity of low rubber price situation amidst high cost of production, associated decline in rubber production in the country and lack of skilled workers for rubber cultivation, research and development (R&D) activities were aimed

at increasing the overall land productivity, reducing the cost of production, avenues for attracting workers and promoting indirect benefits of rubber cultivation. In addition, developing new avenues for value addition and processing raw rubber in healthy and environmental friendly manner were in high priority. Whilst encouraging to adopt good agricultural practices for sustainable productivity, low frequency tapping systems were promoted as a practical means of reducing cost of production and retaining skilled harvesters in the industry by providing extra income. Research on new planting techniques for better field establishment, slow release fertilizer for increase in fertilizer use efficiency, convenient weed management system and new high value intercrops for rubber to increase the overall income of rubber lands continued. Further, focus on clone development was multifaceted having the directions of high yielding, disease tolerance, timber production and drought resistance. Also, research began on identifying clone specific latex quality parameters for niche markets. Whilst assisting to cultivate rubber in nontraditional areas, the institute focused on developing a carbon trading project for voluntary carbon market with rubber cultivated in Ampara and Monaragala districts. Development of new rubber compounds for product manufacturing industries, new approach for manufacturing low protein centrifuged latex, natural based additives in rubber product manufacture and use of safer chemicals in raw rubber manufacture were looked into. In disease management, the highest priority had to be given to delimit the outbreak of Pestalotiopsis leaf disease. Also, rubber growers were assisted with the control of White Root Disease. Whilst targeting the technology transfer with more strategic approaches, an android mobile application was introduced initially to disseminate the knowledge on raw rubber manufacture. Also, the institute were able to hold 7th Symposium on Plantation Crop Research with the assistance of other plantation crop research institutes.

An acceptable level progress was shown in the Finite Element Analyses & Simulation Centre managed as a private public partnership at the institute. Further, Rs.50 Mn were received from the treasury through the Export Development Board to establish tyre testing facilities at the institute.

Obstacles for research

Having sufficient funds allocated to the institute, the biggest obstacle for research has been the lack of qualified senior scientists resulted from unattractive remuneration packages in operation for such high caliber positions. To be competitive, those should be made in par with the salary structures in national universities. This requires immediate attention of policy makers and all well-wishers of the rubber industry; else, it is inevitable to have substandard research in near future.

Administrative and financial functions

Director position of the institute had been vacant during the year and also, there was any no functioning Board of Management towards the beginning and the end of the year. Both resulted in some delay in decision making process. However, expected

performance levels were achieved to a considerable extent by the end of the year. In view of improving the human resource, employees (particularly in research and technical grades) were provided with both local and international trainings and exposure events. In total, 22 were sent abroad for the participation in training programmes, conferences and workshops in the countries; *viz*. Malaysia, India, Singapore, China, Thailand, Cambodia, Australia and Myanmar, whilst attended in local programmes. Recruitments were done in the categories of AR 1, MA 4, MA 2-2 and PL 3.

Revaluation of assets except the lands and buildings of the institute was completed. Computer based asset management system was introduced along with the annual board of survey programme. Logbook recording system was introduced for effective traceability in research. In view of minimizing the cash handling in long distance field visits, the fuel coupon system of the Sri Lanka Petroleum Corporation was introduced to the institute owned vehicles.

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 of Plantation Industries 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 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 2019.

GENETICS AND PLANT BREEDING

S P Withanage

DETAILED REVIEW

Staff

Dr (Mrs) S P Withanage, Head of the Department, Dr K K Liyanage, Senior 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, Technical Officer and Mrs S D P K L Peiris, Management Assistant were on duty throughout the year.

Dr K K Liyanage obtained his PhD with effect from 28th May from Kunming Institute of Botany, Kunming, China with affiliated to Mae Fah Luang Unversity.

Mrs P V A Anushka, Research Officer was on no pay leave with effect from 18th October and Mrs T T D Dahanayake, Research Officer was on study leave from 01st September to December 31st to complete her Master of Philosophy degree at the University of Ruhuna.

Mrs N S Jayasinghe and Mr A N Mallikarachchi have assumed duties as Technical Officers with effect from 22nd August and Mr A N Mallikarachchi was temporally transferred to the Plant Pathology and Microbiology Department for a period of six months.

Research students

- I N Amarasekara a student from the Faculty of Agriculture, University of Ruhuna carried out her final year research project on "Quantitative gene expression analysis of selected genes to screen drought tolerance of *Hevea* clones" under supervision of Dr (Mrs) S P Withanage.

- K L M Kalpani a student from the Faculty of Agriculture, University of Ruhuna carried out her final year research project on "Selection of superior genotypes at early stage of the rubber (*Hevea brasiliensis*) breeding cycle" under supervision of Dr (Mrs) S P Withanage.

- S D T S Gunasekara a student from the Faculty of Agriculture, University of Ruhuna carried out her final year research project on "Study toward the Development of a relationship between *ref* gene expression and yield potential of *Hevea* Clones" under the supervision of Dr (Mrs) S P Withanage.

Training students

- D R Bamunuarachchi a student from Horizon campus, Malabe and M K D E Madushani a student from Advance Technological Institute (ATI), Labuduwa completed their six months In-plant training programme under the supervision of Dr (Mrs) S P Withanage.

Meetings/Seminars and Workshops attended

Officer/s	Subject/Theme	Date	Organization/Place
SP Withanage	CARP/NCCIA*Meeting	21st January	CARP/Colombo
	CARP/NCCIA*Meeting & Project evaluation	8th & 22nd February	CARP/Colombo
	Workshop on Biosafety	26th & 27th February	Ministry of Mahaweli Development & Environment, BMICH, Colombo
TTD Dahanayake	Workshop on Biosafety	28th February	
SP Withanage	Board Presentation	28th February	RRISL, Ratmalana
	CARP/NCCIA*Meeting	1st March	CARP/Colombo
	CARP/NCCIA*Meeting	21st March	CARP/Colombo
	Workshop on Current Status and Future Directions in Agronomy in Sri Lanka	28th & 29th March	CARP/Rice Research Institute, Bathalagoda
	Meeting on Allocation of Neuchatle Land to the RRISL	4th April	Estate Plantation Co-operation, BBC building/Colombo
TT Dhanayake	Workshop on Plant Stress Biology	18th-20th April	ICGB**New Delhi
SP Withanage	CARP/NCCIA*Meeting	16th May	CARP/Colombo
SP Withanage KK Liyanage PVA Anushka TTD Dahanayake	Workshop on Stress Management	22nd May	RRISL, Dartonfield
SP Withanage	Workshop on Biosafety	3rd & 4th July	NSF, Colombo
SP Withanage KK Liyanage PVA Anushka TTD Dahanayake	Scientific Committee Meeting	5th July	RRISL, Rathmalana
SP Withanage	IRRDB Plant Breeders' Meeting	8th -12th July	IRRDB & Malaysian Rubber Board, Malaysia
KK Liyanage PVA Anushka TTD Dahanayake	Technology update	8th July	RRISL Dartonfield

Officer/s	Subject/Theme	Date	Organization/Place
SP Withanage	CARP/NCCIA*Meeting	29th July	CARP/Colombo
	Meeting on Easton Province rubber growing	22nd - 23rd August	Monaragala/Ampara District Secretariat and MPI
	Workshop on Risk Analysis of GMO/FFPs	30th August	NSF, Colombo
	Judging of "Sahasak Nimavum" Invention Exhibition	20th, 21st and 22nd September	Sri Lanka Exhibition & Convention Centre Colombo
SP Withanage KK Liyanage PVA Anushka TTD Dahanayake	Plantation Crop Research Symposium	4th, 5th & 6th November	Marino Beach Hotel, Colombo, RRISL, CRI TRI and SRI jointly
SP Withanage	CARP/NCCIA*Meeting	21st November	CARP/Colombo

***** National Committee of Crop improvement and Agronomy

** International Center for Genetic Engineering and Biotechnology

LABORATORY AND FIELD INVESTIGATIONS

Analysis of antioxidant gene expression in tapping panel dryness (TPD) affected rubber tree (*Hevea brasiliensis* Muell. Arg.) and the effect of exogenous application of ascorbic acid on alleviating TPD (Research funded by NSF-RG/2015/BT/01)

This study was started to analyze the differential expression of some key antioxidant genes between TPD affected and healthy rubber trees by using semi-quantitative real-time PCR. The identification of such genes is vital for designing a treatment or further remediation to minimize the economic losses caused by TPD. The results showed that the *HbMnSOD* and *HbCAT* genes were down-regulated in TPD affected rubber clones and it might lead to accumulation of ROS which causes TPD (S P Withanage and P K G S S Bandara).

Identification of high yielding genotypes of rubber (Hevea brasiliensis) *at the early stage of their breeding cycle using rubber elongation factor (ref) gene and promoter*

Rubber elongation factor (*ref*) is a major protein that involves in rubber biosynthesis and ref protein is highly homologous to the *ref* gene. This research was conducted to analyse the nucleotide sequence of ref gene and promoter of seven genotypes selected from 2011 hand pollinated progeny and wild accessions. No difference in nucleotide sequence was observed among high and low yielding genotypes and wild accessions. Further gene expression studies for *ref* gene and promoter is suggested (S P Withanage, T M S K Gunasekara and A K Gamage).

Functional analysis of the promoter sequence regions of the rubber elongation factor gene from Hevea brasiliensis *(CARP granted collaborative project - NARP/16/WUSL/APM/01 in Faculty of Plantation Management, Wayamba University and Department of Chemistry, University of Colombo)*

Rubber elongation factor protein is the major protein that is tightly bound to the surface of large rubber particles in latex. It represents around 10-60% of the total protein in the whole latex but is absent in C-serum. However, it shows differential expression among clones of *H. brasiliensis.* The specific research objectives of this study are cloning and characterization of the distal promoter sequence of the rubber elongation factor gene from high yielding and low yielding *Hevea brasiliensis* clones and functional analysis of the promoter region of the *ref* gene.

Sequence analysis of the *ref* promoter showed the presence of conserved proximate promoter elements TATA box, CAAT box and GTICONSENSUS. Presence of cis-acting elements characteristics of light and dehydration responsive genes in the promoter suggests inducible *ref* gene expression by drought and light. Genomic DNA extracted from clone RRIC 121, amplified with *ref* promoter-specific primers produces a 670bp target fragment. This product was cloned in PGEM–T easy vector (S P Withanage, D P S T G Attanayake, T T D Dahanayake and N S Jayasinghe**).**

Screening of drought tolerance in selected clones of Hevea brasiliensis (I &II)

Identification of drought tolerant *Hevea* clones that are able to withstand the drought stress, the rubber cultivation was expanded to non-traditional rubber growing areas in the dry and intermediate zones where soil and atmospheric drought conditions prevail.

I. Preliminary screening of clones RRISL 2005, RRISL 2006 and RRISL 2100

Epicuticular wax content does not significantly differ among the three clones. But the significant difference was found in diffusion rate, chlorophyll content and average quantum, photosynthetic yield of photo system II between water-stressed plants and their controls.

Quantitative real-time PCR analysis showed that stress-responsive Mitogen Activate Protein (MAP) kinase gene was up-regulated in the clone RRISL 2005 has better drought tolerance and the moderate and low levels of drought tolerance in clones RRISL 2006 and RRISL 2100 respectively (S P Withanage and N S Jayasinghe).

II. Analysis of the impact of soil moisture stress on the clone RRISL 203, RRISL 121 and RRIM 600

The experiment was conducted to identify the level of soil water stress tolerance in RRISL 203 and RRIC 121 against the tolerance level of RRIM 600

which has been already identified as a drought-tolerant clone. All three clones showed a significant difference for chlorophyll content, stomatal conductance, and quantum photosynthetic yield between treatment and controls. The difference is higher in RRIC 121. In quantitative real-time PCR, CAT gene (Catalase) was up-regulated in both clones RRIC 121 and RRISL 203 and showed the possibility of tolerance for soil moisture stress (S P Withanage and N S Jayasinghe)

Detection of suitable yield parameters for precise early selection of high yielding genotypes

Three genotypes as 1992 HP-129, 1992 HP-124 (RRISL Centennial 4) and 1992 HP-132 (RRISL Centennial 5) evaluating under estate collaborative trial at Kuruwita, were taken to the study. Other than annual girth measurements, yield and bark thickness, the density of latex vessels, the average diameter of latex vessels, and the number of latex vessels were studied to develop suitable yield parameters. It has observed around 50% negative correlation between the density of latex vessels and diameter. Also over 50% positive correlation was observed between girth and the diameter of latex vessels.

The high yielding clone RRISL 203 was higher in density but lower the diameter while RRISL 205 a low yielder is in the other way around. Based on latex vessel density, it is to be studied more number of the selected genotypes of mother plant nursery to validate their yield performances, especially when selecting the outstanding genotypes to be evaluated under small and large scale field trials in parallel. Studies are continued further with 2012 hand-pollinated progenies to predict the genetic potential between yields with different bark anatomical traits of the laticiferous using the hierarchical agglomerative method. Twenty genotypes from 2012 HP progeny were taken to develop the model. Around 25 - 75% accuracy was identified when genotypes were selected at the early stage of mother plant nursery. The model was validated when early identified genotypes were successfully recognized as high yielding and low yielding. Both high and low yielding genotypes should be selected at an early stage as indirect selection criteria (S P Withanage, H P Peiris, T M S K Gunasekara, A K Gamage and N S Jayasinghe).

Hand pollination programme

The annual hand pollination programme was not done this year and accelerated the preliminary evaluation of previous years' HP progenies (S P Withanage, K K Liyanage, P V A Anushka, T T D Dahanayake, B W A N Baddewithana and T M S K Gunasekara).

Developing the *Hevea* breeding garden

The agronomic practices were continued at *Hevea* breeding garden at Neuchatel estate. 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, P V A Anushka, T M S K Gunasekara and B W A N Baddewithana).

Multilateral clone exchange programme

Memorandum of understanding has been 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. Around twenty four plants from each clone that received were established in bud wood nursery at Neuchatle estate and the multiplication process is continued to conduct their adaptability trials (Table 1).

Out of twenty two foreign clones, seventeen clones received from India, Myanmar and Thailand and Cote d'Ivoire are prepared to establish and test their adaptability and performances at large scale clonal trials.

Table 1. *Details of the clonal plots (Bud woods) established at Neuchatle estate*

Country	Clones received	Number of plants
Thailand	RRIT 251	24
	RRIT 3904	24
	RRIT 3604	24
	RRIT 226	23
	RRIT 408	24
India	RRII 414	24
	RRII 417	24
	RRII 422	23
	RRII 429	24
	RRII 438	23
Myanmar	ARCPC 24/4	25
	ARCPC 6/22	26
Total		**288**

(S P Withanage, K K Liyanage, P V A Anushka, T T D Dahanayake, 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 year old 2013 hand pollinated progeny was subjected to repeated evaluation. The progeny was characterized for yield parameters on girth, latex yield and bark thickness. The girth was measured in individual genotype at the height of 45cm from the ground level and

tapping was done at the same height. Morris-Mann tapping was processed during the cropping months (October - December). Latex from five consecutive tappings done at S/2 d3 was collected into a single tube and the dry weights were measured. According to the yield measurements of two consecutive tapping cycles (g/t/t), it was observed around eight genotypes recording over 44 g/t/t including two out-standings (recorded over 95 g/t/t) (Table 2). Topmost selections will be confirmed after further evaluation of three more yield cycles and other performances. Overall disease incidences, especially for *Corynespora* leaf fall disease during the year was recorded with the help of the Plant Pathology Department.

Table 2. *Yield (g/t/t) and girth of the best performing genotypes from five years old 2013 hand pollinated progeny (seedlings) established in mother plant nursery at Nivitigalakele in 2014*

Genotype	Yield (g/t/t) in two consecutive tapping cycles	Girth (cm) at 45cm height from ground level
2013 HP 62	114.5	50.5
2013 HP 60	95.65	57.5
2013 HP 68	61.6	52.0
2013 HP 59	51.95	45.0
2013 HP 28	50.8	47.0
2013 HP 81	49.95	51.5
2013 HP 77	45.15	55.0
2013 HP 8	44.1	52.5

(S P Withanage, P V A Anushka, A.K. Gamage, B W A N Baddewithana and T M S K Gunasekara)

Evaluation of previous hand pollinated (HP) progenies

Small Scale Clone Trials

The details of the small scale clone trials which were maintained and monitored during the year under review are given in Table 3. The Duncan's Multiple Range Test values for the mean girth, yield and bark thickness were taken where ever possible and are given below. Mean values without a letter in common are significantly different ($P < 0.05$).

Table 3. *Details of Small Scale Clone Trials*

HP year	Site	Planting season	Current status
2000	Delkeith IV & V	June 2003	9th year of tapping
	Elston VIII & IX	July 2003	9th year of tapping
2002	Pallegoda I	July 2007	6th year of tapping
2002	Eladuwa II	May 2009	5th year of tapping
2004	Eladuwa Trial I	July 2009	5th year of tapping
2007	Kuruwita Substation (seedlings)	July 2009	4th year of tapping
1995	Yatadola	July 2011	4th year of tapping
2006	Payagala	July 2012	3rd year of tapping
2005	Monaragala	Nov 2014	3rd year of tapping
2008	Galewatta	Nov 2016	Immature
2010	Eladuwa	Nov 2016	Immature
2011	Eladuwa	Oct 2018	Immature

(S P Withanage, K K Liyanage, P V A Anushka, T T D Dahanayake, T B Dissanayake, H P Peiris, T M S K Gunasekara, A K Gamage, B W A N Baddewithana, W A D R Tharanga and Y S L Kumaranayake).

Evaluations at Dalkeith estate (GPB/BST/HPS/2000/04 and 05), Nivitigalakele substation (GPB/BST/HPS/2000/06 and 07) and Elston estate (GPB/BST/HPS/ 2000/08 and 09)

Dalkeith estate Trial IV (GPB/BS/HPS/2000/04) & Trial V, GPB/BST/HPS/ 2000/05

In trials IV and V, 112 genotypes derived from two families (RRIC 121 × PB 235 & PB 235×RRIC 121) (56 from each family) and 98 genotypes from two families [BPM 24 × PB 260 (53) and RRIC 121 × PB 260 (45)] had been planted in a completely randomized block design with three single tree plots per clone respectively. Yield data for eight years and sixteen years' girth and bark thickness of individual genotype were analyzed. It is arranged to carry out further evaluation on different categories as latex, latex-timber, timber-latex and timber clones. Six genotypes with promising latex-timber properties were selected from both trials and are given in Table 4.

Table 4. *Mean girth, yield and bark thickness of the best performing genotypes in trials IV & V at Dalkeith estate, planted in 2003*

Trial	Genotype	Mean girth of the sixteenth year (cm)	Mean bark thickness (mm)
IV	2000 HP-935	102^{a}	6.9
	2000 HP-585	110^{ab}	7.0
	2000 HP-638	103^{abc}	7.7
	2000 HP-875	102^{abcd}	6.7
	2000 HP-568	99.8^{abcde}	9.9
V	2000 HP-1198	116.5^{a}	9.2
	2000 HP-1212	105.5^{ab}	6.4
	2000 HP-1141	100.3^{abc}	7.9

(S P Withanage and A K Gamage)

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

The mean girth of clones in 13th year were grouped using Duncan's multiple range test and topmost promising HP entries at Kuruwita Substation are given in Table 5. Top-ranked HP entries in Kuruwita Substation had yielded from 35.37g/t/t to 68.63 g/t/t.

Table 5. *Mean yield and girth of the best performing HP entries of the 2001 HP progeny planted in 2006 in Kuruwita Substation*

Kuruwita Sub-station		Kuruwita Sub-station	
Clone	**Yield (g/t/t)**	**Clone**	**Mean girth (cm)**
2001 HP-170	68.63^{a}	2001HP-220	73.2^{a}
2001 HP-179	47.84^{b}	RRIC 121	70.0^{ab}
RRIC 121	46.38^{b}	2001HP-185	68.0^{abc}
2001 HP-185	40.08^{b}	2001HP-179	65.1^{abcd}
2001 HP-203	39.81^{b}	2001HP-205	64.0^{bcde}
2001 HP-89	39.61^{b}	2001HP-183	63.1^{bcde}
2001HP-183	39.36^{b}	2001HP-227	62.8^{bcde}
2001 HP-220	37.78^{bc}	2001HP-207	61.8^{bcde}
2001 HP-207	37.45^{bc}	2001HP-89	60.3^{cdef}
2001 HP-205	35.37^{bc}	RRISL 203	59.2^{cdef}

(P V A Anushka, S P Withanage, T M S K Gunasekara and H P Peiris)

Evaluation of 2002 HP clones

Pallegoda estate (GPB/BST/HPS/2002/01)

Eleventh-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 6. Genotype 2002-18 has performed better in comparison to control clone RRISL 203. Yield data collection was disturbed due to bad weather.

Table 6. *Mean girth of best performing HP entries selected from the 2002 HP progeny planted in 2007*

Clone	Mean girth (cm)
2002 - 77	97.6[a]
2002 - 18	73.4[b]
RRISL 203	71.9[bc]
2002 -17	69.6[bcd]
2002 -11	69.2[bcd]
2002 -14	67.3[bcd]
2002 - 24	66.8[bcd]
2002 - 96	66.4[bcd]
2002 - 71	65.1[bcd]
2002 - 69	64.9[bcd]

(P V A Anushka, S P Withanage, K K Liyanage 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.

Tenth-year girth was taken at the height of 150 cm from the bud union and mean girth values are shown in Table 7. Although third year yield data collection was started, only three test tapings were possible. However, according to the available data, genotype 2002 HP-138 recorded the highest yield around 54.24 g/t/t and the second highest was around 42,49g/t/t in genotype 2002 HP-30. However, the yield of control clone RRIC 121 was recorded 41.36 g/t/t (Table 7).

Table 7. *Mean girth and yield (g/t/t) of control clones and best performing HP entries selected from the 2002 HP progeny planted in 2009 at Eladuwa*

Clone	Mean yield (g/t/t)	Mean girth (cm)
2002 HP-138	54.24[a]	79.5[a]
2002 HP-30	42.49[ab]	67.4[b]
RRIC-121	41.36[bc]	63.6[bc]
2002 HP-66	41.14[bc]	67.1[b]
2002 HP-62	38.72[bcd]	55.1[defg]
2002 HP-9	38.23[bcd]	59.4[bcd]
2002 HP-19	38.07[bcd]	59.1[bcd]
2002 HP-93	37.07[bcd]	66.1[b]
2002 HP-78	28.28[cde]	52.3[defg]
2002 HP-58	26.14[de]	47.5[fg]

(S P Withanage, K K Liyanage, P V A Anushka, 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 ninth year girth was taken. The HP entry 2004–347 showed significantly higher girth and two entries were ranked above the clone RRIC 121 (Table 8).

Table 8. *Mean girth for 9th year of the best performing HP-entries selected from the 2004 HP-progeny planted at Eladuwa estate*

Clone	Mean girth (cm)
2004 HP-347	64.0[a]
2004 HP-178	62.8[a]
2004 HP-48	62.0[ab]
RRIC 121	62.0[ab]
2004 HP-107	61.7[abc]
2004 HP-228	60.6[abc]

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

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

Eleventh year girth data were collected for the seedling progeny and family means are given in Table 9. Family **RRIC 130 x GP 1-2** recorded the highest girth.

Third year tapping data were collected from the above progeny and family means are given in Table 10. Family **RRIC 130 x GP 44-24** recorded the highest yield (g/t/t).

Table 9. *Family mean girth of 2007 HP - progeny at the Kuruwita Substation planted in 2008*

Clone	Mean girth (cm)
RRIC 130 x GP 1-2	68.5[a]
RRIC 130 x GP 21-163	68.0[a]
RRIC 130 x GP 22-137	67.8[a]
PB260 x IAN 45/710	62.9[a]
RRIC 130 x GP 10 -154	62.3[a]
IAN 45/710 x PB 260	62.2[a]
RRIC 130 x GP 44 - 24	53.7[a]

Table 10. *Family mean yield of 2007 seedling HP progeny planted in 2008*

Clone	Yield (g/t/t)
RRIC 130 x GP 44-24	66.21[a]
IAN 45/710 x PB 260	37.65[b]
PB 260 x IAN 45/710	34.81[b]
RRIC 130 x GP 22-137	34.03[b]
RRIC 130 x GP 21-163	28.36[b]
RRIC 130 x GP 10 -154	27.42[b]
RRIC 130 x GP 1-2	18.75[b]

(T T D Dahanayake, S P Withanage, K K Liyanage, P V A Anushka 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 was raised by double selfing of Corynespora susceptible clone RRIC 103, were established at Monaragala substation with control clones RRIC 100, RRIC 103, RRIC 52, PB 86 and RRISL 201. A Complete Randomized Block Design was used with ten replicates per genotype. According to the results of molecular screening done against Corynespora leaf fall disease with already selected polymorphic markers, few genotypes were selected for further studies. Trees in the Monaragala trial were prepared for following year hybridization programme focus on true (pseudo – as parents are not nearly homozygous lines) hybrids. However, the trial at Galewatta was discontinued due to high number of vacancies (S P Withanage, K K Liyanage, P V A Anushka, T T D Dahanayake and W A D R Tharanga).

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 off shoots etc. were done according to RRISL recommendations. Third year girth was taken and mean girth values of best performing six genotypes are given in Table 11 with the control clones. However, very poor girth was observed in all genotypes including control clones due to insufficient fertilizer application.

Table 11. *Mean girth for third year for HP-entries of best performing six genotypes with their control clones of the 2004 HP - progeny planted at Eladuwa estate*

Clone	Girth (cm)
2010 HP-38	13.1[a]
2010 HP-25	12.3[ab]
2010 HP-9	12.2[ab]
2010 HP-35	12.0[abc]
2010 HP-4	11.4[abcd]
2010 HP-22	11.2[abcd]
2010 HP-42	11.1[abcd]
2010 HP-12	10.5[abcd]
2010 HP-11	10.4[abcd]
RRISL 2001	7.7[f]

(S P Withanage, T T D Dahanayake, P V A Anushka, 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 12a (registered clones) and 12b (unregistered clones) show the planting sites, year of planting and girth measurements at 150 cm for the year under review and for the previous two years.

Table 12a. *Mean annual girth measurements for registered clones of ECTs (Estate/RRISL Collaborative Trials)*

Clone	Site	Year of planting	Mean girth (cm)		
			2017	2018	2019
RRISL 201	Dammeria B	2010	43.4	46.1	56.2
	Eladuwa	2009	54.7	56.9	58.9
RRISL 203	Monaragala	2009	47.0	50.0	51.4
	Eladuwa	2009	52.7	57.1	59.4
	Wewassa	2011	46.4	52.1	53.0
	Lagos	2011	53.2	56.4	58.3
	Muwankanda	2010	48.5	49.0	51.7
	Dammeria B	2010	39.4	40.2	40.7
	Kamburupitiya (University)	2011	58.5	61.6	63.9
RRISL 208	Dartonfield	1994	76.9	78.6	78.7
	Lagos	2013	40.2	48.7	51.2
	Moralioya	2010	NT	56.7	58.5
	Dammeria B	2010	37.1	NT	NT
	Eladuwa	2009	53.5	56.6	58.7

Clone	Site	Year of planting	Mean girth (cm)		
			2017	2018	2019
RRISL 210	Payagala	2006	64.6	67.1	NT
RRISL 211	Dartonfield	1994	79.0	78.9	NT
RRISL 216	Dartonfield	1994	79.6	82.7	84.7
RRISL 219	Dartonfield	1994	89.3	90.0	93.0
	Kuruwita	2008	50.6	52.5	54.8
RRISL 2000	Kuruwita	2005	69.1	71.3	73.5
RRISL 2001	Dammeria B	2010	52.7	55.7	56.2
	Muwankanda	2010	52.2	55.0	NT
	Dammeria B (Hanipe Dev.)	2011	53.7	55.7	56.2
	Wewassa	2011	NT	46.8	47.2
	Lagos	2013	40.3	49.5	51.5
RRISL 2003	Lagos	2013	43.7	51.1	52.7
RRISL 2006	Lagos	2013	33.3	42.1	45.8
	Monaragala	2009	53.1	57.4	59.4
	Eladuwa	2009	55.3	57.5	59.6
	Moralioya	2010	NT	59.3	61.6
RRISL 2100	Monaragala	2009	53.6	57.0	58.1
	Edalla	2010	52.8	54.0	56.0
	Kuruwita	2011	47.9	50.8	52.3
RRISL Centennial 3	Kuruwita	2009	57.4	58.0	60.5
	Monaragala*	2009	49.6	53.2	54.6
	Eladuwa	2010	60.3	64.2	66.0
	We-oya	2010	55.7	57.4	59.7
	Edalla	2010	57.4	59.8	62.4
	Kuruwita	2010	53.2	56.5	58.4
	Siriniwasa	2011	56.9	58,8	61.8
	Lagos	2013	45.0	55.8	55.3 (at 150cm height)
RRISL Centennial 4					
	Kuruwita	2007	56.5	57.6	58.3
	Eladuwa	2009	53.4	54.8	56.3
	Monaragala	2009	52.7	56.0	57.1
	Lagos	2011	53.8	58.6	60.4
RRISL Centennial 5	Eladuwa	2009	56.1	57.9	59.4
	Kuruwita	2007	59.9	62.5	64.3

Table 12b. *Mean annual girth measurements of un-registered 2004 - entries selected to ECTs (Estate/ RRISL Collaborative Trials)*

Clone	Site	Year of planting	Girth in cm		
			2017	2018	2019
86-10	Kuruwita	2009	48.0	50.4	51.9
86-87	Kuruwita	2009	50.8	53.5	55.0
87-235	Kuruwita	2008	50.0	53.8	56.1
95-55	Lagos	2013	43.4	56.1	56.0 (150cm)
RRIC 100 seedlings	Kuruwita	2005	68.9	71.0	72.2

(S P Withanage, K K Liyanage, P V A Anushka, 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)

Yield of ECTs (Estate/RRISL Collaborative Trial) - GPB/BST/ECT/95/01

The average estate yields obtained from ECT trials are given in Table 13.

Table 13. *Average yield (g/t/t) and the percentage of BB of the clones in the 15th year of tapping, of ECT trials at Galewatta*

Clone/Selected HP- entry	Average yield (g/t/t)	Current BB %
RRISL 208	67.95	**52**
RRISL 211 (S2 d2) *	80.21	**20**
RRISL 211 (S2 d3) *	73.25	**16**
RRISL 216	36.95	**12**
RRISL 219	32.08	**11**

*Tapping system followed

(S P Withanage, K K Liyanage, P V A Anushka, 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)

Screening of new genotypes developed using the germplasm of Hevea obtained from 1981 IRRDB expedition to the Amazon (RRI/ECT collaborative trial 2011- Yatadola estate)

Ten genotypes selected from 1995 hybridization programme where non-Wickham clone GPS 1 was used as the male parent, were characterized. Annual girth and yield data collection was done twice a month, plot-wise (Table 14). The trial was taken to further study with bark anatomy analysis for precise selection.

Table 14. *Second year average yield (g/t/t) and mean girth and their DMRT values of collaborative trial 2011-Yatadola estate*

Clone	Mean yield 2019 (g/t/t)	Clone	Mean girth (cm) and their DMRT groups
95 HP-55	29	95 HP-1	59.0^{a}
95 HP-1	21	95 HP-41	58.6^{a}
95 HP-19	21	RRISL203	57.6^{ab}
95 HP-41	20	95 HP-33	56.9^{abc}
RRISL203	17	95 HP-23	56.8^{abc}
95 HP-29	16	95 HP-21	56.3^{abcd}
95 HP-13	15	95 HP-55	55.7^{abcd}
95 HP-21	15	95 HP-13	54.6^{bcde}
81 HP-69	15	95 HP-29	54.2^{cde}
95 HP-23	14	95 HP-19	53.5^{de}
95 HP-33	9	81 HP-69	52.5^{e}

(S P Withanage and A K Gamage)

Conservation and evaluation of the IRRDB germplasm (GPB/GP/85/2)
Multiplication and evaluation of the genotypes collection of Hevea obtained from 1981 IRRDB expedition to the Amazon (under new development proposal for Annual budget 2014 - GPB/GP-NC)

Multiplication, establishment and scientific evaluation of the *Hevea* germplasm collection was started with the aim of enhancing productivity through genetic improvement and management of genetic resources of *Hevea* (S P Withanage, K K Liyanage, P V A Anushka, T T D Dahanayake, B W A N Baddewithana and T M S K Gunasekara).

Testing of promising clones for sub-optimal conditions

Objectives of the project is, evaluation of adaptability and performance of new promising clones in non-traditional rubber growing areas (sub-optimal conditions). All trails are conducted as RRI/smallholder collaborative manner.

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

Seven experimental plots were established at Padiyathalawa/Maha Oya 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 15.

Table 15. *Details of smallholder/RRI collaborative trials at Eastern Province and the seventh 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	48.0
				RRISL 203	43.8
				RRISL 2005	46.7
				RRISL 2006	41.6
SRT-EP 12/2	Indrani Kusumalatha Marawa Padiyathalawa	IL2	>1600	RRISL 203	57.6
				RRIC 121	54.4
				RRISL 2001	55.6
				RRISL 2006	51.0
SRT-EP 12/3	AM Sumanawathi Helakomana Padiyathalawa	IL2	> 1600	RRISL 203	47.2
				RRIC 100	44.6
				RRISL 2005	48.1
				RRISL 208	42.7
SRT-EP12/4	HM Wimalasena Kudaharasgala Mahaoya	IL2	> 1600	RRISL 208	45.1
				RRISL 2005	47.1
				RRIC 100	44.1
				RRISL 203	40.5
SRT-WP 12/8	Ranjith Thambawita Bandaragama Panadura (Kalutara district – Control Trial)	WL 1a	>3300	RRISL 208	56.2
				RRISL CEN 3	57.3
				RRISL 2001	58.2
				95 HP-55	62.1
				RRISL 203	55.0
				RRIC 100	55.4
				RRISL 211	54.0
				RRISL 2005	55.1

(S P Withanage, P V A Anushka, K K Liyanage, 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 16).

Table 16. *Details of smallholder/RRI collaborative clone trials planted in 2013 in the Eastern Province and the sixth 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 13/1	HM Jayarathna 17-1 C Lathugala Warankatagoda	DL2a	> 1300	RRIC 121 (210)	41.0
SRT-EP 13/4	HM Saman Kumara 17/1 B Lathugala Warankatagoda	DL2a	> 1300	RRISL 203 (210)	41.3
SRT-EP 13/5	M Chandrani Ranasingha 51 B – 2 Lathugala Warankatagoda	DL2a	> 1300	RRISL 203 (210)	37.4

(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 17 with their fifth year mean girth.

Table 17. *Details of smallholder/RRI collaborative clone trials planted in 2014 in the Eastern Province and the fifth 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 14/1	G Senevirathne Mahaoya	IL2	>1600	RRIC 121	32.5
SRT-EP 14/2	M Senevirathne Mahaoya	IL2	> 1600	RRISL 2001	26.7
SRT-EP 14/3	AM Jayasekara Mahaoya	IL2	>1600	RRISL 2006	31.6
SRT-EP 14/4	T M Amarasena Mahaoya	IL2	>1600	RRISL 2005	32.1

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

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. Girth data were taken and given in Table 18. One trial was established in Kataragama. Girth data on the second year was taken and details are given in Table 19.

Table 18. *Details of smallholder/RRI collaborative clone trials planted in 2015 in Uva Province and fourth years 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)
Bibile (collaborate with World Vision)					
SRT-UP 15/1-WV	HM Punchibanda Ilukpathana	IL1c	>1300	RRISL 2001 (215)	21.9
SRT-UP 15/2-WV	AM Karunawathie Ilukpathana	IL1c	>1300	RRISL 2001 (215)	16.5
SRT-UP 15/3-WV	HMW Wijekumara Kudumirisketiya Ilukpathana	IL1c	>1300	RRISL 2001 (430)	23.0

Table 19. *Details of smallholder/RRI collaborative clone trials planted in 2016 in Uva Province and third years 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 Diyawaragmmana Junction, Sella Rd Kataragama	DL 5	>650	RRISL 2001 RRISL 203 (215)	31.6 19.8

(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 20.

Table 20. *Details of smallholder/RRI collaborative clone trials planted in 2015 in North Central Province and fourth years mean girth data*

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)	19.2
				RRISL 2006 (500)	11.9

(S P Withanage, K K Liyanage, P V A Anushka and T B Dissanayake**)**

PLANT SCIENCE

N M C Nayanakantha

DETAILED REVIEW

Staff

Dr N M C Nayanakantha, Head of the Department, Mr T U K Silva, Senior Research Officer, Mrs D S A Nakandala, Research Officer, Mrs R K Samarasekara, 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, Miss W K S W Watawala, Miss H Subasinghe, Mr D Priyadarshana and Mrs N Udayakumari, Technical Officers, Mrs D E Jayawardena and Mrs P D A H M A de Almeida, Management Assistants were on duty throughout the year.

Retirements:

Mrs G A S Wijesekera, Experimental Officer, who served in the department for about 39 years helping the research activities retired on 03.05.2019. Her valuable contribution towards the betterment of the rubber industry is greatly appreciated.

New appointments

Mr M N de Alwis, Experimental Officer, was promoted to the post of Research Officer with effect from 22.08.2019. Ms W M D Wickramakumari and Mr H G H C Arunasiri were appointed as Technical Officers with effect from 22.08.2019.

Research students

- Ms W A V Prathibha, Sabaragamuwa University of Sri Lanka, Belihuloya, conducted her final year research project on "Effect of size and color of polybags on growth of rubber (*Hevea brasiliensis*) plants under nursery conditions" under the supervision of Dr N M C Nayanakantha.

- Ms P H D N Jayangani, UvaWellassa University, Badulla, conducted her final year research project on "Effect of hydro and chemical priming on seed germination and seedling growth of rubber (*Hevea brasiliensis*)" under the supervision of Dr N M C Nayanakantha.

Conferences/Seminars/Training Programmes/Workshops/Exhibitions organized/ conducted

Officers involved	Subject/Theme	Number of programmes	Beneficiary/Client
NMC Nayanakantha	7th Symposium on Plantation Crop Research	1	Stake holders of rubber, tea, coconut and sugarcane
	Symposium on Plant Health	1	University representatives, representatives from Crop Research Institutes, Plantation Companies
MN de Alwis	Nursery Management	04	Agriculture School (Kuruwita) Kelani Valley Plantation Agalawatta Plantation
	Field Establishment & Immature upkeep	04	Agriculture School (Kuruwita) Kelani Valley Plantation Agalawatta Plantation
MN de Alwis DLN de Zoysa	Bud grafting	05	Rubber Development Department Agriculture School (Kuruwita) Kelani Valley Plantation Agalawatta Plantation
PKW Karunatilaka	Tapping	34	Plantation Companies (Managers, Asst. Managers, Field Officers, Smallholders, University students and Agriculture Diploma students

Seminars/Conferences/Meetings/Workshops attended

Officer	Subject	Organization
NMC Nayanakantha	Committee Meeting on Agronomy and Crop Improvement	Sri Lanka Council for Agricultural Research Policy, Colombo
	Workshop on Soil Fertility and Agronomy	International Rubber Research and Development Board (IRRDB), Malaysia

Officer	Subject	Organization
NMC Nayanakantha	Workshop on Current Status and Future Directions of Agronomy Research in Sri Lanka	Rice Research and Development Institute, Batalagoda
	Progress Review Meetings	Ministry of Plantation Industries
	Meeting on 13 year education and new subject on Plantation Crop Research	National Institute of Education (NIE), Maharagama
	TEC Meetings for purchase of rubber plants for STARR project	Office of the STARR Project, Battaramulla
	TEC Meetings for purchase of polybags for government nurseries	Rubber Development Department
NMC Nayanakantha TUK Silva SA Nakandala MN de Alwis RK Samarasekara DLN de Zoysa PD Pathirana PK W Karunatilaka EUM de Z Dissanayake	7th Symposium on Plantation Crop Research	Jointly organized by Rubber Research Institute, Coconut Research Institute, Tea Research Institute & Sugarcane Research Institute
NMC Nayanakantha TUK Silva SA Nakandala	Scientific Committee Meeting	Rubber Research Institute of Sri Lanka

Services

Testing the quality of polythene

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

Supplying of marking plates

About 325 marking plates (d2 and d3) were issued to stakeholders (N M C Nayanakantha and W Karunatilaka).

Issuing authentic budwood

About 500 meters of budwood were issued to some departments of RRISL and for nurseries belong to RPCs (N M C Nayanakantha and R Handapangoda).

Nursery inspection

Government, RPC and Private nurseries were inspected and details are given in Tables 7-9 (N M C Nayanakantha, M N de Alwis, L N de Zoysa and R Handapangoda).

Visits

Advisory	-	48
Experimental	-	420
Nursery inspection	-	49
Total	-	517

LABORATORY INVESTIGATIONS

Tissue culture

No lab work was done during the period. Tissue culture laboratory is being renovated 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)

Wintering and flowering (CC/2003/1/a)

General observations on wintering were made in the fields at Galewatta. Wintering completed during the second week of February (N M C Nayanakantha and P D Pathirana).

Seed production (CC/2003/1/b)

Data were not collected during the period and data gathered so far are being analyzed (N M C Nayanakantha and P D Pathirana).

Investigation on alternative and cost effective sowing media for river sand for germination of rubber seeds

Rubber seeds were sown in the following sowing media in Gurugoda and Middeniya nurseries in 2018. Each treatment had 4000 seeds.

Control : River sand
Treatment 1 : Coir dust (leached)
Treatment 2 : Rubber wood saw dust
Treatment 3 : Elephant dung (dried)
Treatment 4 : Rubber wood chips
Treatment 5 : Purified sea sand

Germinated seeds were transplanted in black polythene bags filled with soil. Polybags were arranged in a nursery according to an RCBD with five blocks, 30 plants per treatment. Growth attributes of rubber seedlings were assessed after three months from transplanting. Ten plants from each treatment were removed and growth parameters *viz.*, stem diameter, plant height, number of leaves, chlorophyll content and dry weights of shoots and roots were recorded. Results are shown in Tables 1-2.

Table 1. *Effects of sowing media on seedling attributes of rubber after three months of transplanting into polybags*

Treatments	**Stem height (cm)**	**Stem diameter (mm)**	**No. of leaves**	**Leaf chlorophyll content (SPAD value)**
River sand (control)	58.9±3.07^{ns}	6.8±0.17^{b}	8.2±0.73^{ns}	8.9±0.86^{ns}
Coir pith	55.4±2.52	7.4±0.26^{ab}	8.2±0.58	8.6±3.05
Reclaimed sea sand	71.0±4.05	7.6±0.27^{a}	3.0±0.48	9.2±1.26
Fine quarry dust	55.8±2.31	6.9±0.21^{b}	2.6±0.58	7.2±1.29
Course quarry dust	56.7±2.39	7.3±0.18^{ab}	3.0±0.80	8.2±1.17
P value	0.0516	0.0373	0.0783	0.4918
LSD ($p \leq 0.05$)		0.5737	-	-

Means followed by the same letter (s) are not significantly different at $p \leq 0.05$, according to Duncan's Multiple Range Test (DMRT). ns: non-significant, ± indicates the standard error of the mean.

Table 2. *Effect of sowing media on dry weights of shoots and roots of rubber seedlings after three months of transplanting into polybags*

Treatments	**Dry weight (g) of shoot**	**Dry weight (g) of root**
River sand (control)	10.1±0.35^{ns}	4.1±0.26^{ns}
Coir pith	10.4±1.21	5.3±0.82
Reclaimed sea sand	14.5±1.10	4.6±0.46
Fine quarry dust	9.8±0.66	3.8±0.18
Course quarry dust	11.2±1.00	3.7±0.30
P value	0.089	0.2256

ns: non-significant, ± indicates the standard error of the mean.

(N M C Nayanakantha and E U M De Z Dissanayaka)

Priming of rubber seeds for improved germination dynamics, seedling and budded plant attributes and tolerance to abiotic stresses

Fresh rubber seeds were soaked (primed) in solutions of urea and $ZnSO_4$ for 24 hours as shown below;

T1:	Control,	T2:	Water,	T3:	0.05% Urea,
T4:	0.10% Urea,	T5:	0.15% Urea	T6:	1% $ZnSO_4$,
T7:	2% $ZnSO_4$				

Unprimed seeds were used as the control and water soaking treatment was considered as the mock treatment. Seeds were sown in a germination bed filled with sand according to a Randomized Complete Block Design (RCBD) with three blocks. There were 3 replications of 50 seeds each in each treatment in each block, with a total of 1050 seeds. Germination beds were watered once daily. Cumulative seed germination percentage was recorded at 7, 9, 11, 13, 15 and 17 days after sowing and results are shown in Table 3.

Table 3. *Effects of priming treatments on germination of rubber seeds*

	Germination percentage after				
Treatments	**7 days**	**9 days**	**11 days**	**13 days**	**17 days**
T1	12.7 ± 2.7^{c}	24.0 ± 5.0^{c}	28.0 ± 4.2^{c}	28.7 ± 3.7^{d}	30.0 ± 3.1^{d}
T2	40.7 ± 2.9^{a}	54.0 ± 4.2^{a}	55.3 ± 3.5^{a}	60.7 ± 4.7^{ab}	67.3 ± 5.5^{a}
T3	12.0 ± 1.2^{c}	26.0 ± 3.1^{c}	30.0 ± 2.3^{c}	34.7 ± 2.7^{d}	36.7 ± 3.7^{cd}
T4	22.0 ± 3.1^{bc}	35.3 ± 5.5^{bc}	41.3 ± 5.3^{abc}	46.0 ± 4.6^{bc}	49.3 ± 4.7^{cb}
T5	25.3 ± 2.9^{bc}	46.7 ± 0.7^{ab}	57.3 ± 3.3^{a}	62.7 ± 4.7^{a}	64.7 ± 3.7^{ab}
T6	31.3 ± 8.1^{ab}	42.7 ± 6.4^{ab}	49.3 ± 8.7^{ab}	54.0 ± 8.7^{ab}	59.3 ± 10.2^{ab}
T7	18.7 ± 4.1^{bc}	32.7 ± 3.5^{bc}	38.7 ± 4.1^{bc}	49.3 ± 3.3^{abc}	62.7 ± 1.3^{ab}
P value	0.0075	0.0121	0.0088	0.0038	0.0004

All the treatments, except for urea at 0.15% concentration, significantly increased germination percentage as compared to the control after 13 days of sowing (N M C Nayanakantha, P H D N Jayangani and U N Udayakumari).

Evaluation of clonal seedling (CS) populations for their rooting attributes and growth performance for better tolerance to abiotic stress conditions (CS/2013/DF)

A repeat trial was not established and data gathered so far are being analyzed (N M C Nayanakantha, G A S Wijesekera and U N Udayakumari).

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

This experiment was commenced in 2017. However, a repeat trial was not conducted in 2019. Data gathered so far are being analyzed (N M C Nayanakantha, G A S Wijesekera and U N Udayakumari).

Effect of polybag colour/material/size on growth of seedlings

i. Effect of polybag size on growth of seedlings and budded plants

Polybags, black colour and gauge 300, of different sizes *viz.*, standard size (6''×15'') as control and reduced sizes (T1; 5''×13'', T2; 5''×15'', T3; 6''×13'') as treatments were used in this experiment. Growth attributes of seedlings, such as stem diameter, shoot height, number of leaves, chlorophyll content, leaf area, length of tap root, dry weight of shoots and roots were measured. Budgrafting was done using green budding technique and grafting success was recorded. Results revealed that there were no significant differences ($p \leq 0.05$) in budgrafting (Fig. 1). Shoot attributes of budded plants at two leaf whorl stage and root attributes of budded plants at one leaf whorl stage are shown in Tables 4-5.

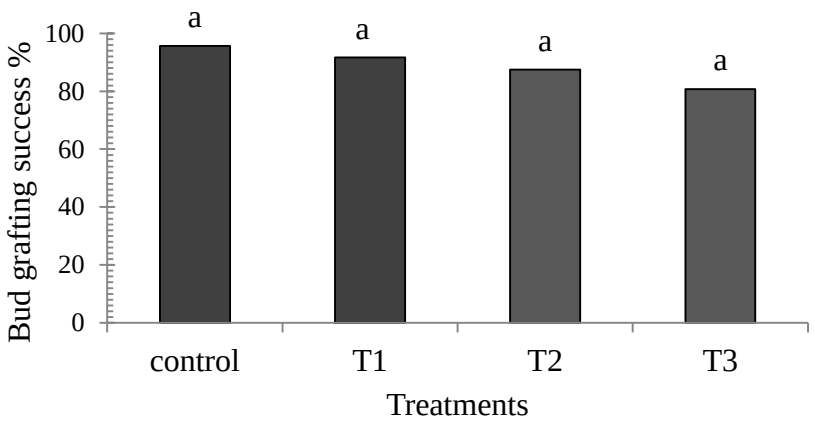

Fig. 1. Effect of the size of polybag on percentage budgrafting success. Mean values followed by the same letter are not significantly different at $p \leq 0.05$, according to Duncan's Multiple Range Test.

Table 4. *Effect of the size of polybag on shoot attributes of budded plants at two leaf whorl stage*

Treatments	Length of shoot (cm)	Diameter of shoot (mm)	Branch angle (°)	Number of leaves	Chlorophyll content (SPAD value)
Control (6"×15")	30.8±1.0	6.5±0.2	27±2.5	15±1.3	41.2±2.1
T1 (5" ×13")	29.2±5.6	6.1±0.6	29±4.0	14±2.1	34.2±7.6
T2 (5" ×15")	34.2±4.2	6.9±0.5	27±3.4	17±1.2	40.5±0.9
T3 (6 "×13")	25.4±2.3	5.4±0.2	33±3.0	14±1.3	44.8±2.7

Table 5. *Effect of the size of polybag on root attributes of budded plants at one leaf whorl stage*

Treatments	Dry weight of tap root (g/plant)	Dry weight of ESR/SR (g/plant)
Control (6 "×15")	9.3±1.13[a]	1.1±0.16[a]
T1 (5" ×13")	8.6±0.47[a]	1.2±0.24[a]
T2 (5" ×15")	10.6±1.92[a]	1.8±0.31[a]
T3 (6 "×13")	8.9±0.75[a]	1.6±0.22[a]

Mean values followed by the same letter are not significantly different at $p \leq 0.05$, according to Duncan's Multiple Range Test. ESR: Early Secondary Roots; SR: Secondary Roots

Since no significant differences were observed for root attributes of seedlings and no remarkable differences were recorded for budded plants raised in different sizes of polybags, reduced sizes of polybags can be substituted to standard size polybags to raise seedlings in nurseries to minimize the cost and overcome other handling problems. With this conclusion, the above experiment was terminated (N M C Nayanakantha, W A V Prathibha and U N Udayakumari).

ii. Effect of polybag colour on growth of seedlings and budded plants

Polybags (black and transparent) of gauge 300 and 6"x15" size were used as treatments in this experimental trial conducted in the government nursery at Egaloya in 2018. Polybags were established in a Randomized Complete Block Design with 6 blocks with 5 plants for each treatment in each block. Thirty plants were allocated for each treatment.

Growth attributes of rubber seedlings such as stem diameter, shoot height, number of leaves and chlorophyll content were recorded. Budgrafting was done using green budding technique. Results revealed that there were no significant differences ($p \leq 0.05$) in budgrafting success (Fig. 2). Growth attributes of budded plants raised in transparent or black colored polybags at two leaf whorl stage are shown in Table 6.

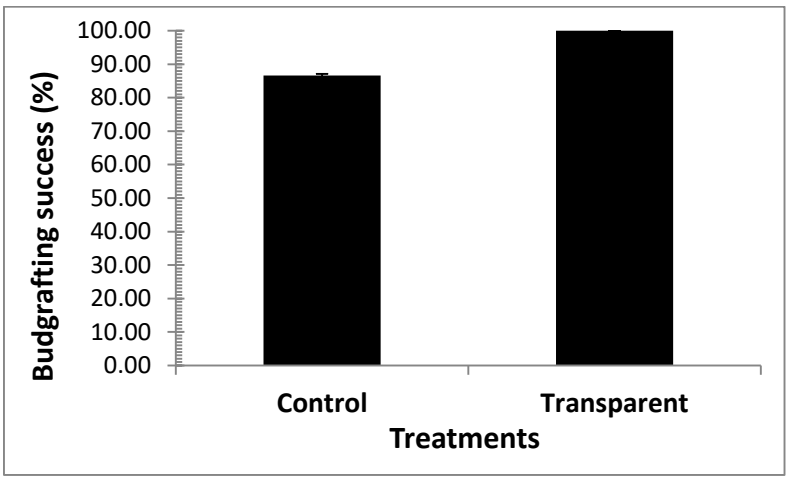

Fig. 2. Effect of the color of polybag on percentage budgrafting success of seedlings

Mean values followed by the same letters are not significantly different at $p \leq 0.05$, according to Least Significant Difference test

Table 6. *Effect of the color of polybag on shoot attributes of budded plants at two leaf whorl stage*

Treatments	Length of shoot (cm)	Diameter of shoot (mm)	Number of leaves	Chlorophyll content (SPAD value)
Control (black)	30.6±2.8	5.8±0.2	15±1.1	40.8±0.8
Transparent	28.6±2.4	5.6±0.5	15 ±1.2	46.8±2.5

Since the price of a transparent polybag is higher than a black color polybag, use of black color polybags is cost effective to raise seedlings in nurseries in the wet zone. With this conclusion, the above experiment was terminated (N M C Nayanakantha and E U M de Z Dissanayake).

Vegetative propagation of elite mature individuals – (CP/2001/2) – Dartonfield

This experiment was terminated as only a single tree of clone 28/59 (Udabage) is remaining in the field to record data and plants of both elite seedlings of Nahalla and Dapiligoda did not show a satisfactory girth increment when compare to the control (RRISL 2001) trees (P Seneviratne and G A S Wijesekera).

Bud grafting

Rejuvenation of budwood plants - Egaloya Nursery

This experiment was terminated due to poor growth of plants and maintenance issues (P Seneviratne and G A S Wijesekera).

Irrigation systems for rubber nurseries

Drip and sprinkler irrigation systems designed for the RDD nursery and immature rubber fields at Padiyathalawa in 2018 were successfully installed and commissioned to the RDD nursery at Padiayathalawa.

Micro-irrigation systems for immature rubber fields in the dry zone

Mini sprinkler or spray jet and drip irrigation systems were installed at two immature rubber fields in Malayalapuram in Kilinochchit in 2018 in order to investigate on physiological, morphological and growth performance of immature rubber plants under micro-irrigated conditions. However, almost all the plants died in the year 2019 due to severe drought condition prevailed in most months of the year along with high temperature in the day time. Therefore, this experiment was terminated (D S A Nakandala, M N de Alwis and D L N de Zoysa).

Budwood nurseries

BN/2008/Dolahena, BN/2012/DF, BN/2014/Gallewatta, BN/2017/Olikanda and BN/2017DF

Bud wood nurseries at Dartonfield, Olikanda and Gallewatta were maintained throughout the year. Weeding, manuaring, pollarding and application of fungicide were done at regular intervals. The budwood nursery at Dolahena was uprooted and the land was cleared for establishing a new budwood nursery. Budded plants of about 32 numbers of clones were produced in a young budding nursery for establishing in the budwood nursery in 2020 (N M C Nayanakantha, P Seneviratne and R Handapangoda).

Budwood nursery for clone identification purposes (2010/DF)

Pollarding and regular maintenance were done throughout the year (N M C Nayanakantha and L N de Zoysa).

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 7-9.

Table 7. *Details of RPC nurseries established in 2019*

Regional Plantation Company	No. of estates having nurseries	No. of nurseries for the RPCs	No. of plants established in 2019	No. of plants certified as Y.B in 2019
Kelanivalley	3	3	27,000	13,400
Kegalle	7	15	196,000	57,250
Kotagala	4	6	69,500	7,000
Pussellawa	4	7	74,000	18,400
Namunukula	1	1	-	13,000
JEDB	1	1	3,000	60,000
Hapugasthenne	1	1	20,500	-
Balanagoda	1	1	10,000	-
Elpitiya	1	1	20,000	-
Malwattavalley	3	3	65,000	-
Total	**26**	**39**	**485,000**	**169,050**

Table 8. *Details of government nurseries established in August 2018, January 2019 and August 2019*

Name of the nursery	Season	No. of plants established	No. of plants certified
Egaloya	2018 Aug.	331,500	90,000
	2019 Jan.	162,850	55,000
	2019 Aug.	225,900	-
Gurugoda	2018 Aug.	218,000	79,000
	2019 Jan.	155,470	-
	2019 Aug.	168,700	-
Karapincha	2018 Aug.	125,000	54,000
	2019 Jan.	100,000	-
	2019 Aug.	91,000	-
Meerigama	2018 Aug.	-	-
	2019 Jan.	-	-
	2019 Aug.	-	-
	2018 Aug.	417,000	180,000
	2019 Jan.	325,000	-
Welikadamulla	2019 Aug.	251,600	-
Middeniya	2018 Aug.	92,550	26,000
	2019 Jan.	100,640	-
	2019 Aug.	75,800	-
Moneragala	2018 Aug.	333,320	186,000
	2019 Jan.	260,000	69,000
	2019 Aug.	261,900	-

Name of the nursery	Season	No. of plants established	No. of plants certified
	2019 Jan.	100,000	-
	2019 Aug.	92,800	-
Grand Total		**3,943,880**	**760,000**

Table 9. *Details of private nurseries established in 2019*

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Region	No. of nurseries	No. of plants established	No. of plants certified
Kegalle	15	195,500	156,050
Ratnapura	7	150,000	70,000
Monaragala	1	9,500	-
Total	23	355,000	226,050

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

Planting techniques

Stumped buddings experiment (SB/2016/Moneragala)

The experimental field was established at Moneragala Substation in November 2016. Regular maintenance including manuaring and circle weeding was done throughout the year.

Weak and dead plants were replaced with root bole plants and stumped budded plants in 2018. Annual girth data of two types of plants (root bole and stumped budded) along with initially established plants remaining in the field are shown in Table 10.

Table 10. *Growth of stumped budded plants, root bole plants and initially established plants*

Treatments	Girth (cm)	Girth increment (cm)
Weak/dead plants replaced with whole plants with root boles	13.7±0.87	2.6±0.32
Weak/dead plants replaced with stumped budded plants	12.2±0.88	2.4±0.65
Initially established plants remaining in the field	20.6±0.37	6.7±0.18

Growth of normal plants established in the field in 2016 showed a satisfactory girth increment when compared to stumped budded or root bole plants established in 2019 (Table 10).

Performances of clones PB 86 and RRIC 100 (2013)

Young budded plants of clones PB 86 and RRIC 100 were established in 2013 at Gallewatta in order to compare the growth and yield performances of two clones. Weeding, manuaring and other agronomic practices were done throughout the year. Girth data of two clones are shown in Table 11.

Table 11. *Mean girth of two clones after four years*

Clone	Mean girth (cm)	Girth increment (cm)
PB 86	41.5±1.04	3.39
RRIC 100	53.5±0.97	8.22

(P Seneviratne and R Handapangoda)

Study on growth, morphological characters and grafting success of rubber clones in different Agro - climatic Zones of Sri Lanka - 2014

This study was undertaken to ascertain the growth, morphological and bud grafting performances of eight clones (*i.e.*; RRIC 121, RRIC 100, RRIC 102, RRISL 2001, RRISL 203, RRISL 217, PB 86 & PB 260) grown in wet, intermediate and dry zones of the country. Growth data recorded for four years were analyzed. Accordingly, it was concluded that RRIC 121 has a higher growth rate and number of budwood in bud wood nurseries in wet, intermediate and dry zones. RRIC 102 followed by RRISL 217 has the lowest growth rates in the wet zone whilst RRISL 203 and RRIC 100 have the lowest growth rates in the intermediate and dry zones respectively. With this conclusion, this experiment was terminated (P Seneviratne, N M C Nayanakantha and R Handapangoda).

Northern Province Planting

Kilinochchi (PT/2015/Kilinochchi)

Growth data were recorded in plants established in 2015 of three clones *viz.*, RRIC 121, RRISL 203 and RRISL 2001 in September 2019. Plants were established in 2015. According to the results, poor growth was recorded in all clones (Table 12). This could be attributes to the adverse climatic conditions coupled with poor maintenance. Manuaring could not be done as planned due to limited visits made to the field. The farmer has no interest in maintaining the field.

Table 12. *Mean annual girth of trees after 4 years of planting*

Clone	Girth (cm)
RRIC 121	15.8±0.48
RRISL 203	15.2±0.62
RRISL 2001	14.5±0.35

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

Kilinochchi (PT/2017/Kilinochchi)

Experimental fields were established in four farmer fields in Malayalapuram in 2017. Growth of the immature plants was satisfactory in 2018. However, majority of plants in three farmer fields died mainly due to the prevalence of severe drought condition with long dry spells in most of the months of the year. Plants in one farmer field could survive as the field was located in an area having some water resource. Limited visits were made to experimental fields due to poor financial situations and therefore, maintenance of the fields had not been done up the levels expected. With this situation, this experiment had to be terminated (N M C Nayanakantha, M N de Alwis, D S A Nakandala and D L N de Zoysa).

Kilinochchi (PT/2018/Kilinochchi)

An experimental trial was established at four farmer fields at Malayalapuram in Kilinochchi in 2018 with the objective of selecting a suitable planting material. Young budded plants at two leaf whorl and four leaf whorl stages were established. However, majority of plants in all four farmer fields died due to prevalence of severe drought condition with long dry spells in most of the months of the year. Limited visits were made to experimental fields due to poor financial situations and therefore, maintenance of the fields had not been done up the levels expected. Nevertheless, died plants were replaced with new plants in this year with the onset of North-east monsoonal rain in October (N M C Nayanakantha, D S A Nakandala, M N de Alwis and D L N de Zoysa).

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

A new experiment was commenced in Kekirawa, Anuaradhapura in order to study the establishment rate and growth of rubber under suboptimal climatic conditions prevailing in drier areas. Two whorled rubber plants (about 600 numbers) were selected and transplanted in large sized gunny bags filled with different potting media as shown in Table 13.

Table 13. *Composition of the media used to prepare root bole plants*

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

Two whorled young budded plants raised in standard sized polybags (6"x15") were used as the control. Root bole plants were kept in the nursery itself for another 2-3 months until three leaf whorled stage before being planted in the field. Two farmer's fields were selected and in each field, plants were established in four blocks having 25 plants from each treatment in each block (so that 100 plants from each treatment), according to a randomized complete block design (RCBD) with the on-set of North-east monsoonal rains in October 2019 (M N de Alwis, D S A Nakandala, N M C Nayanakantha, D L N de Zoysa, R Handapangoda and W M D Wickramakumari).

Cultural practices during immature phase

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

The Table 14 shows growth and yield parameters of the clones tested under four different densities. Girth of trees decreased considerably with the increase of planting density. Bark thickness (BT) of trees did not vary among the treatments. In RRIC 121, percentage trees in tapping are more or less similar across the planting densities tested. However, percentage trees in tapping decreased with increased planting density for RRIC 100. In general, the yield (g/t/t) of individual tree decreased with increase in planting density. No marked differences were recorded for YPH values among densities.

Table 14. *Effect of planting density on growth and yield parameters of rubber. (a): Girth of trees (cm) and thickness of bark (mm) at 150cm height, % trees in tapping (b:) yield of trees (g/t/t) and estimated YPH (kg/ha/year)*

(a)

Density	RRIC 100				RRIC 121			
	Girth (cm)	BT (mm)	% Trees in tapping	Tappable trees/ha	Girth (cm)	BT (mm)	% Trees in tapping	Tappable trees/ha
500	78.2	11.9	53.3	266	101.4	11.8	49.1	246
600	78.9	11.5	49.1	295	85.1	11.0	52.6	316
700	70.4	11.4	46.8	328	82.3	11.5	50.6	354
800	70.5	11.6	38.8	310	79.7	10.6	52.4	419

(b)

Density (tree/ha)	RRIC 100		RRIC 121	
	Yield (g/t/t)	Yield (kg/ha/y)	Yield (g/t/t)	Yield (kg/ha/y)
500	39.6	1012	57.3	1308
600	47.6	1456	35.4	1316
700	25.7	790	44.6	1552
800	28.3	1141	35.1	1526

(T U K Silva, V H L Rodrigo and H Subasinghe)

Low density trial at Gallewatta and Nivithigalakele - 2012

Annual girth and yield data were recorded and are shown in Tables 15-18. More than 70% of trees of both clones under both planting densities reached the tappable girth (50 cm or above) at Gallewatta whilst only trees under low density at N'Kelle reached the tappable girth. Highest g/t/t and YPH values were recorded for RRISL 203 under both planting densities at Gallewatta (Table 17). Nevertheless, higher g/t/t and YPH values were recorded for RRISL 2001 as compared to that for RRISL 203 at both D2 and D3 tapping frequencies and under low density (Table 18).

Table 15. *Mean girth of trees under different densities at Gallewatta*

Clone	Spacing	No. of trees planted	No. of tappable trees	% of tappable trees	Mean girth (cm)
RRISL 2001	14'x15'	212	164	77.35	54.1±1.30
RRISL 203	14'x15'	426	334	78.40	54.9±0.77
RRISL 2001	16'x16'	291	219	75.25	55.1±0.97
RRISL 203	16'x16'	394	337	85.35	52.1±0.31

Table 16. *Mean girth of trees under low density* (16'x16') *at Nivithigalakelle*

Clone	No. of trees planted	No. of tappable trees	% of tappable trees	Mean girth (cm)
RRISL 2001	358	316	88.27	49.5±0.86
RRISL 203	296	235	79.40	50.4±0.86

Table 17. *Mean g/t/t and YPH values under different densities at Gallewatta*

Clone	No. of trees planted	Spacing	g/t/t	YPH
RRISL 2001	212	14'x15'	29.7	2381.6
RRISL 203	426	14'x15'	36.9	2914.1
RRISL 2001	291	16'x16'	31.1	2408.0
RRISL 203	394	16'x16'	47.0	3761.5

Table 18. *Mean g/t/t and YPH values under low density (16' X 16') at Nivithigalakelle*

Clone	Assessment	Tapping frequency	
		d/2	d/3
RRISL 203	g/t/t	31.86	39.35
	YPH	1752.63	3148.11
RRISL 2001	g/t/t	36.54	39.66
	YPH	2009.76	3172.85

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

Low density trail at Kandakadu, Polonnaruwa - 2013

Mean girth of plants measured at 120 cm above ground level and intercropped with banana was 38.5(±0.62) cm. General maintenance in the experimental field was done (P Seneviratne, N M C Nayanakantha, M N de Alwis and R Handapangoda).

Exploitation

Longer tapping cycles through shorter tapping cuts - Pitiakanda Estate

This experiment was commenced in 2009 with the clone RRIC 117. Mean g/t/t values are given in Table 19.

Table 19. *Annual mean yield/tapping for the period from January to December 2019*

Treatments	No. of trees	No. of tapping days	g/t/t	Brown bast %
T1: S/4 d3 + 5% Ethrel (once a month)	41	110	44.9	4.9
T2: S/3 d3 + 2.5% Ethrel (once a month)	42	110	41.3	11.9
T3: S/2 d3 + 2.5% Ethrel (4/year)	31	110	54.0	9.7

(P Seneviratna, N M C Nayanakantha, R K Samarasekara and W K S W Watawala)

An experimental trial was commenced in May 2018 to investigate on the effect of shorter tapping cuts on yield of rubber. A tapping block of RRIC 121 from 2011 clearing was selected. The treatments were the same as in the previous experiment and annual mean yield/ tapping in terms of g/t/t are given in Table 20.

Table 20. *Annual mean yield/ tapping for the period from January to December 2019*

Treatments	No. of trees	No. of tapping days	g/t/t	Brown bast%
T1: S/4 d3 + 5% Ethrel (once a month)	101	110	25.3	5.9
T2: S/3 d3 + 2.5% Ethrel (once a month)	97	110	29.1	7.2
T3: S/2 d3 + 2.5% Ethrel (4/year)	97	110	36.6	10.3

(N M C Nayanakantha, R K Samarasekara and W K S W Watawala)

Winter rest experiments

Kuruwita (Clones RRIC 100, RRIC 121 & RRISL 203)

Annual mean yield/ tapping in terms of g/t/t for the period from January to December 2019 are given in Table 21.

Table 21. *Annual mean yield/tapping for the period from January to December 2019*

Treatments	g/t/t		
	RRIC 100	**RRIC 121**	**RRISL 203**
T1 - Tapping without winter rest	30.6	36.3	31.8
T2 - Rested during winter period	31.6	37.4	34.5
T3 - d6 tapping practiced only during winter period	30.1	36.1	32.3

(P Seneviratne, N M C Nayanakantha, R K Samarasekara and W K S W Watawala)

Kumarawatta estate, Moneragala (clones RRIC 121 & RRISL 203)

Annual mean yield/tapping in terms of g/t/t for the period from January to December 2019 are given in Table 22.

Table 22. *Annual mean yield/tapping for the period from January to December 2019*

Treatments	g/t/t	
	RRIC 121	**RRISL 203**
T1 - Tapping without winter rest	34.9	32.0
T2 - Rested during winter period	33.4	28.9
T3 - d4 tapping practiced only during winter period	32.4	31.3

(P Seneviratne, N M C Nayanakantha, R K Samarasekara and W K S W Watawala)

Night/Early morning tapping experiments (NT/2019)

There was a belief that tapping in the night or early morning would give a higher yield than that in the normal time from 6.00-8.00 am. Therefore, experimental trials were commenced at Gallewatte (wet zone) and Moneragala (intermediate zone) to investigate on the effect of time of tapping on yield parameters.

NT/2019/Gallewatta

A rubber clearing of RRIC 121 established in 2006 at Gallewatte was selected. Total of 90 trees were selected and there were six blocks each with 15 trees. The tapping system was D3 with stimulation and rainguards. For a given tapping day, six blocks were tapped at six different time intervals *viz.*, 3.00 am, 4.00 am, 5.00 am, 6.00 am, 7.00 am and 8.00 am respectively. Accordingly, each block was tapped at all six time intervals at 6 tapping days (16 normal days) and that was considered as one rotation. In this manner each tree was tapped at different time intervals on different days. 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. Rainfall data were collected from the Biometry Unit of RRISL. Results are shown in Figures 3-4 and in the Table 23. Results revealed that there were no significant differences in yield obtained at different time intervals (Figs. 3-4) and maximum of 0.04% yield increase could be obtained when tapped from 5.00 am to 7.30 am as compared to that from 6.00 am to 8.30 am (Table 23).

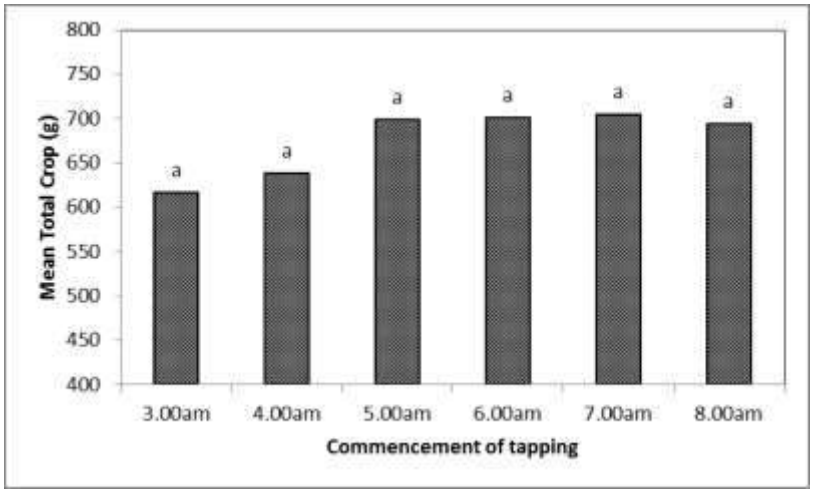


Fig. 3. Mean total crop of 15 trees/tapping at 72 tapping days

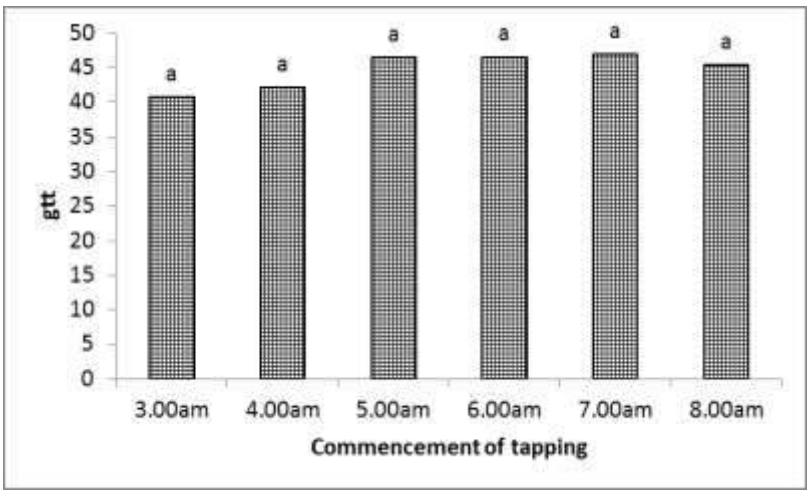


Fig. 4. Mean g/t/t for 72 tapping days

Table 23. *Estimated yield and the percentage difference with respect to 6.00-8.30 am*

Start time	End time	Estimated yield (g/t/t)	% difference with respect to 6.00am - 8.30am
3.00 am	5.30 am	54.99	-5.76
4.00 am	6.30 am	57.26	-1.87
5.00 am	7.30 am	58.38	0.04
6.00 am	8.30 am	58.35	0
7.00 am	9.30 am	57.17	-2.02
8.00 am	10.30 am	54.98	-6.01

(N M C Nayanakantha, R K Samarasekera, W Karunatilaka and W K S W Watawala)

NT/2019/Moneragala

A rubber clearing of RRIC 121 established in 2007 at Yudaganawa, Moneragala was selected. Total of 90 trees were selected and there were six blocks each with 15 trees. The tapping system was D2 without stimulation and rainguards. For a given tapping day, six blocks were tapped at six different time intervals *viz.*, 2.00 am, 3.00 am, 4.00 am, 5.00 am, 6.00 am and 7.00 am respectively. Other all practices were similar to that in the experiment at Gallewatte. Results are shown in Figures 5-6 and the Table 24. Results revealed that there were no significant differences in yield obtained at different time intervals (Figs. 5-6) and maximum of 6.68% yield increase could be obtained when tapped from 2.00 am to 4.30 am as compared to that from 6.00 am to 8.30 am (Table 24).

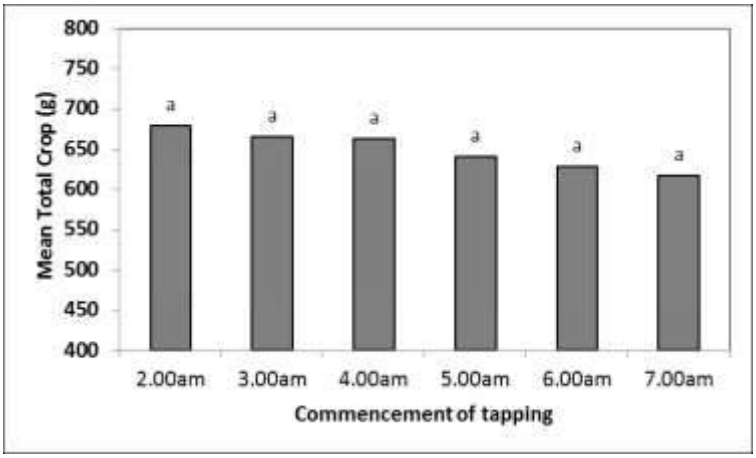


Fig. 5. Mean total crop of 15 trees/tapping for 90 tapping days

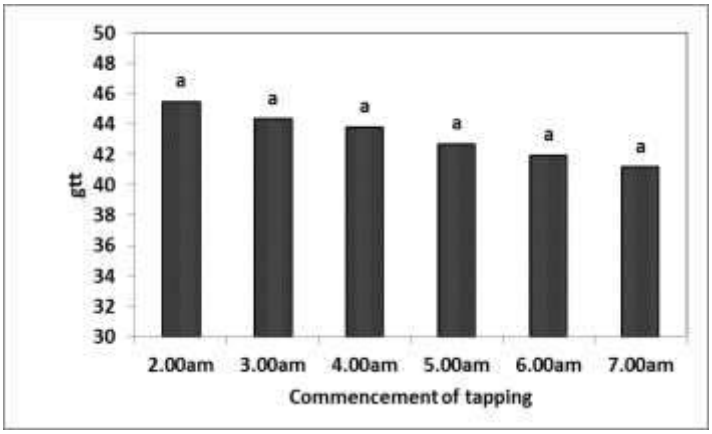


Fig. 6. Mean g/t/t for 72 tapping days

Table 24. *Estimated yield and the percentage difference with respect to 6.00 am - 8.30 am*

Start time	End time	Estimated yield (g/t/t)	Percent (%) difference with respect to 6.00 am - 8.30 am
2.00am	4.30am	56.04	6.68
3.00am	5.30am	55.05	4.79
4.00am	6.30am	54.13	3.05
5.00am	7.30am	53.29	1.45
6.00am	8.30am	52.53	0
7.00am	9.30am	51.83	-1.31
8.00am	10.30am	51.22	-2.49

(N M C Nayanakantha, R K Samarasekera, W Karunatilaka and W K S W Watawala)

Tapping Panel Dryness

Testing remedies to address tapping panel dryness problem (TPD/2016)

Application of antioxidants - Pitiakanda Estate (Clone RRIC 121)

This study was commenced in 2016. A tapping block was selected from 2004 clearing of RRIC 121 at Pitiyakanda Estate and treatments were applied as shown in Table 25. Annual mean yield/tapping in terms of g/t/t for the period from January to December 2019 are shown in Table 25.

Table 25. *Annual mean yield/tapping for the period from January to December 2019*

Treatments	g/t/t
T1: Control, S/2 d3 + 2.5% Ethrel (4/year)	21.8
T2: T1 + 5% Moringa Leaf Extract (once a month)	28.4
T3: T1+ 100 µM SNP (once a month)	27.9
T4: T1+ 5% Banana Leaf Extract (once a month)	25.0
T5: T1+ 10% Moringa Leaf Extract (once a month)	27.9
T6: T1+150 µM SNP (once a month)	24.9
T7: T1+ 10% Banana Leaf Extract (once a month)	23.6

There appears some yield improvements in response to application of antioxidants as compared to control **(**N M C Nayanakantha, R K Samarasekara and W K S W Watawala).

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

This study was commenced in 2017. Sixty trees were selected from 2007 clearing of RRISL 203 at Menerigama Division in Padukkka estate and two treatments were introduced as follows. Annual mean yield/tapping in terms of g/t/t for the period from January to December 2019 are shown in Table 26.

Table 26. *Effect of tapping frequency on yield of RRISL 203*

Treatments	g/t/t
S/2 d3	23.3
S/2 d2	19.8

A slight increase in g/t/t values was recorded when tapped at d3 frequency as compared to tapped at d2 frequency (Table 26) (N M C Nayanakantha, R K Samarasekera and W K S W Watawala).

Impact of different bark consumption rates associated with additional days of latex harvesting on growth, yield and economical implications of rubber plantations

This study was planned to determine the impact of different bark consumption rates associated with additional days of latex harvesting (over the recommendation) on growth, yield and financial implications of rubber plantations.

(a) On station experiment (BCR/2013/Kuruwita)

Growth parameters, *i.e.* girth of trees and thickness of bark at 1.5 m height were measured. No significant differences were recorded for the above parameters in each clone (Figs. 7-8). Yield and yield determinants, *i.e*. daily latex yields in terms of latex

volume and metrolac reading (% dry rubber content) and census of tapping panel dryness were recorded. Also, rainfall, number of wet days and tapped days were recorded. Five tapping systems (treatments) were employed as shown below for four clones, *i.e.* RRIC 100, RRIC 102, RRIC 121 and RRIC 133. Trees imposed with treatment four were stimulated with 2.5% ethephone (1.6g per tree) at three months interval.

T1. S/2 d2 with Rainguards (RG), No Recovery tappings (NRT)
T2. S/2 d2 with recommended number of RT per month (3 RT)
T3. S/2 d2 with 5 RT per tree per month
T4. S/2 d3+ ET 2.5% With rainguards (Tapping once in three days & NRT)
T5. S/2 d1 Daily tapping

High yields in terms of g/t/t were recorded in trees imposed with T4 due to the effect of low frequency harvesting and ethephone stimulation (Figs. 9-10). Out of the four clones, the highest yield per tree per tapping was recorded in RRIC 121 (Figs. 9-10).

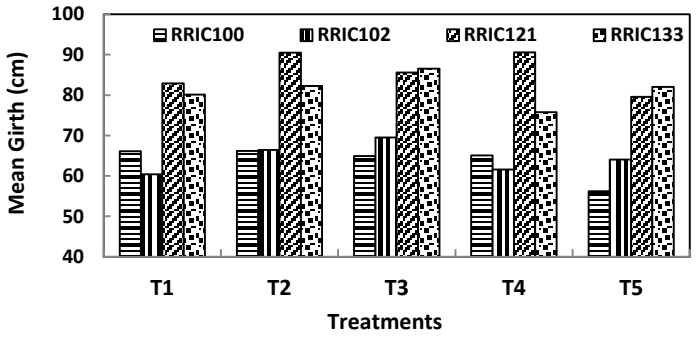


Fig. 7. Mean girth (cm) of different clones with different treatments at the end of year 2019

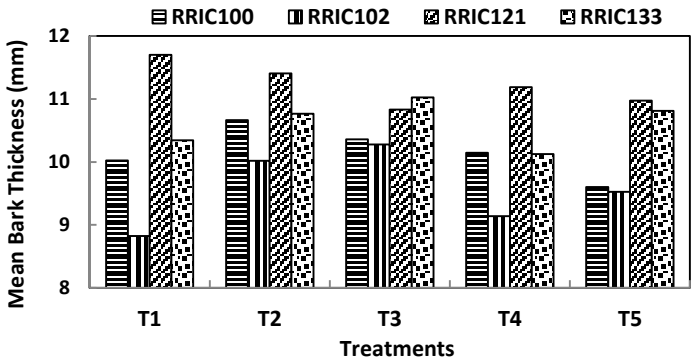


Fig. 8. Mean bark thickness (mm) of different clones with different treatments at the end of year 2019

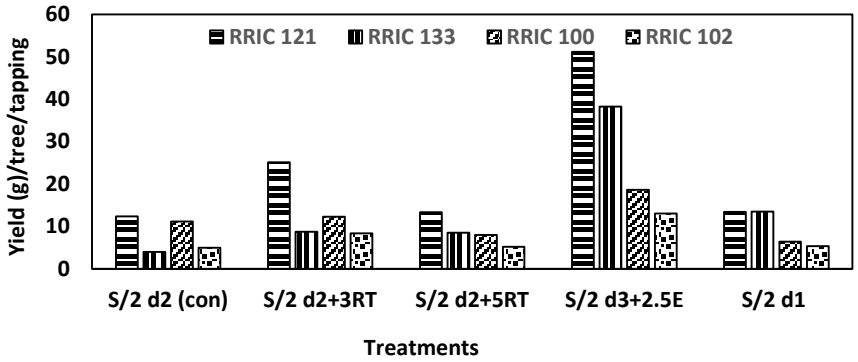


Fig. 9. Mean dry rubber yield (g) per tree per tapping in four clones with five treatments recorded from January to December 2019

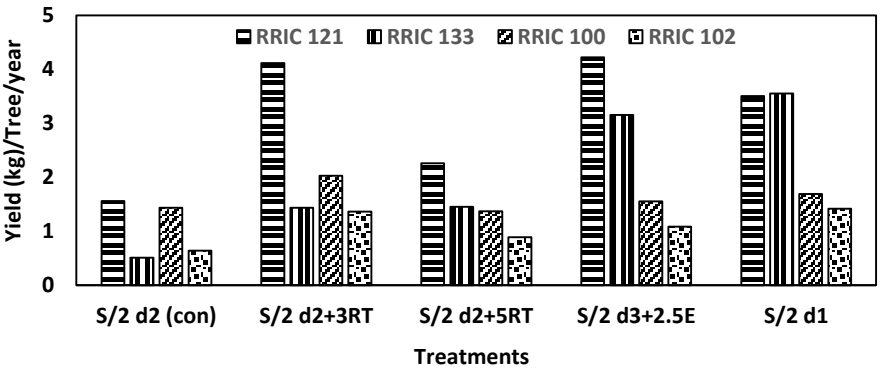


Fig. 10. Dry rubber yield (kg) per tree per annum in four clones with five treatments recorded from January to December 2019

(T U K Silva, P Seneviratne, W Senevirathna and H Subasinghe)

(b) Multi location panel data assessments under different tapping systems practiced by growers

Data were not collected during the year and also the data collected so far are being analyzed (T U K Silva, P Seneviratne, W Senevirathna and H Subasinghe).

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

The objective of this experiment was to investigate on possibilities to increase the productivity of rubber plantations through the management of bark consumption rates upon tapping. A rubber field established in 2006 with RRIC 121 at Sirikandura estate was selected. Six tapping systems were employed as treatments (Table 27) and were replicated three times according to a randomized complete block design (RCBD).

Growth and yield in demarcated plots were recorded as pre-treatment measurements before imposing treatments (Table 28).

Table 27. *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/2D d6 5% ET (Monthly)

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

Table 28. *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)	Mean g/t/t
T1	69.8	8.0	45.04
T2	73.1	8.4	39.86
T3	72.3	7.8	25.82
T4	69.0	8.0	36.42 * 28.77*
T5	68.7	7.3	43.98
T6	70.5	7.2	35.73

* g/t/t recorded from supplementary holiday tapping

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

Intercropping

Growing long term perennial crops in rubber lands - IC/S/2001/1 - Kuruwita

Growth of rubber trees with respect to the girth measured at 150 cm height was recorded (Table 29). Higher girth values were recorded in trees under wider within row systems, *i.e.* T3 and T4 than under other systems. There were no commercial yields from fruit crops during the year.

Table 29. *Mean girth (cm) of rubber trees under different treatments. Measurements were taken at 150 cm height*

Main treatments	Sub treatments				
	Sole rubber	Tea	Cinnamon	Durian/Jak	Rambutan
T1 (3m×3m) -15m	78.1	78.3	72.4	84.8	74.5
T2 (3m×3m) -18m	77.3	83.5	74.0	74.5	74.1
T3 (3.5m×3.5m) -15m	77.0	84.0	81.5	81.1	78.3
T4 (3.5m×3.5m) -18m	82.8	87.4	79.4	85.6	83.6

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

Growing economical crops along the rubber fence (IC/F/2010/1) - Hapugastenna

Five crops, *i.e*. cinnamon, areca, rattan, messengiana and cane palm were established along the fence in 2010. Cinnamon showed better performances and was harvested. Also, reasonable amount of cut leaves could be harvested from messengiana. This experiment was terminated in the end of this year and data collected so far are being analyzed (T U K Silva, D Priyadarshana and H Subasinghe).

Growing economical crops along the rubber fence (IC/F/2011) - Moneragala

Out of the four crops, *i.e.* cinnamon, rattan, areca and teak, better growth (60 cm girth) was recorded in teak with 100% survival. This experiment was terminated due to the less survival rates of the other three crops (T U K Silva, D Priyadarshana and H Subasinghe).

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

This was established as an intercropping demonstration field in the RRISL substation, Moneragala. Growth of rubber trees in terms of girth under different planting systems is given in Table 30.

Table 30. *Girth (cm) of rubber trees under different intercropping systems and spacing arrangements*

Intercropping system	Spacing (m) of rubber	Girth of rubber (cm)
Rubber x Pineapple	Single row system	58.7
Rubber x Banana	2.5m x 7.75m	51.0
Rubber x pomegranate/Guava	Single row system	52.3
Rubber* x pomegranate*/Guava*	2.5m x 12m	38.7
Rubber x Cinnamon	Paired row system	58.0
Rubber x Mango/Rambutan	(3m x 3m) - 18m	51.8

*planted in 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 obtained in 2018 under the title "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".

Rubber x Intercropping trials in Moneragala and Ampara districts

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

Two hectares of land were selected from a farmer at Kumbukkana, Moneragala. Four fruit crops [Orange, Sour soup (Anoda), Guava and Papaya] were established under rubber with 2.5m x 7.75m and 2.5m x 12.0m spatial arrangements. Planting of both rubber and fruit crops were done following the recommendations of RRISL and Department of Agriculture. The growth of rubber in terms of basal girth and height after 12 months are shown in the Table 31. Growth of intercrops after the same period is shown in the Table 32.

Table 31. *Mean basal girth (cm) and plant height (m) of rubber trees under different treatments and under different spatial arrangements*

Main treatment (spatial arrangement of rubber)	Sub treatment (Intercrop)	Basal girth (cm)	Plant height (m)
2.5m x 12.0m	Sour soup	78.0	2.09
	Orange	51.0	1.84
	Guava	79.0	1.96
	Papaya	74.9	1.64
2.5m x 7.75m	Sour soup	66.3	1.84
	Orange	63.2	1.69
	Guava	50.4	1.32
	Papaya	68.2	1.82

Table 32. *Mean basal girth (cm) and height (m) of intercrops under different spatial arrangements of rubber*

Main treatment	Sub treatment (Intercrop)	Basal girth (cm)	Plant height (m)
2.5m x 12.0m	Sour soup	10.9	1.62
	Orange	7.9	1.00
	Guava	9.2	1.53
	Papaya	34.4	1.86
2.5m x 7.75m	Sour soup	9.8	1.52
	Orange	7.2	0.91
	Guava	9.7	1.75
	Papaya	31.0	1.59

(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 at Hingurana, Ampara. Four fruit crops (Orange, Sour soup, Guava and Papaya) were established under rubber with 2.5m x 7.75m spacing system. However, establishment rates of fruit crops were not satisfactory as expected due to the long dry spell prevailed. Therefore, re-establishment was done in this year with different fruit crops such as Sour soup, Guava, Pomegranate and Moringa. Planting of both rubber and fruit crops were done as per the recommendations of RRISL and Department of Agriculture (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 field at Hingurana and Mahaoya 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 2.5m x 7.75m spacing system. However, planting of intercrops could not be completed in some areas of both sites due to prevalence of a severe drought conditions during May - September of the year under review (T U K Silva, N M C Nayanakantha, H Subasinghe and D Priyadarshana).

Rubber x Short term crops trial in Kilinochchi (IC/ST/2018/4)

Three farmer fields in Kilinochchi were selected for growing short term crops with rubber as intercrops in 2018. However, almost all rubber plants along with "Thibbatu" plants grown as intercrops died due to the prevalence of a severe drought condition in most months of the year. Died rubber plants were replaced with new plants with the onset of North-east monsoonal rains in the year under review along with *Aloe vera* ("*komarika"*) plants as an intercrop (N M C Nayanakantha and P D Pathirana).

Intercropping Agarwood with Rubber (IC/AW/2015)

Gyrinops walla, Aquilaria crassna and *Aquilaria subintegra* were established as intercrops under rubber and under three different planting systems in 2015. Growth data of agarwood plants in terms of girth and girth increment are shown in Table 33. The highest girth was recorded in *A. crassna* planted under paired and single row systems of rubber with full sunlight condition. The highest girth increment was recorded in *A. crassna* followed by *A. subintegra* and the lowest was recorded in *G. walla* (Table 33). Under natural shading system, the highest girth was recorded in *A. crassna.* However, girth increment was more or less same in both *A. crassna* and *A. subintegra* under natural shade with rubber.

Table 33. *Growth attributes of three agarwood species after 52 months of planting*

Planting system of rubber	Agarwood species	Girth of plants (cm)	Girth increment (cm)
Double row	*Aquilaria crassna*	56.4±1.4	1.9±0.6
	Gyrinops walla	25.0±0.9	1.0±0.05
	Aquilaria subintegra	53.0±1.5	1.9±0.2
Single row	*Aquilaria crassna*	55.7±2.1	2.1±0.3
	Gyrinops walla	20.8±1.7	1.0±0.1
	Aquilaria subintegra	54.3±2.4	2.1±0.3
Natural shade	*Aquilaria crassna*	30.4±3.0	1.3±0.1
	Gyrinops walla	15.3±3.0	1.0±0.1
	Aquilaria subintegra	29.9±0.3	1.5±0.1

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

NRC Project (Grant No. 18-088)

A research grant was awarded from National Research Council (NRC) titled "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 in 2018. One-acre farmer field was selected at Hingurana, Ampara for the experiment and about 200 rubber plants of RRIC 121 were established in 2018 with 2.5m x 7.75m spacing system. Growth data such as girth and height of the plants were recorded before imposing treatments. According to the girth data, evenly girthed rubber plants were selected for imposing treatments (Table 34). Each treatment was replicated for 12 plants in three blocks according to a Randomized Complete Block Design (RCBD). Growth and physiological attributes of plants were recorded at various time intervals. Leaf samples were collected for molecular biological studies leading to gene expressions.

Table 34. *Treatments imposed on rubber plants*

Treatment No.	Treatment
T1	Control
T2	Water
T3	100 µM SNP
T4	200 µM SNP
T5	0.1 mM SA
T6	0.2 mM SA
T7	5% MLE
T8	10% MLE

SNP: Sodium nitroprusside, SA: Salicylic acid, MLE: Moringa leaf extract.
(N M C Nayanakantha, S A Nakandala, T U K Silva, P Seneviratne, D Priyadarshana, H Subasinghe and W Karunatilaka)

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 and Mrs M K R Silva, Research Officer were on duty throughout the year. Experimental Officers, Mrs B I Tennakoon, Mrs E A D D Siriwardene, Mr S C P Wijayaratne and Mr E A D N Nishantha, worked throughout the year. Ms R D N S Gunasekera and Mr P W Balasooriya, Technical Officers resigned from duties with effect from 14th January and 18th June 2019 respectively. Miss A H N R Aberathne and Mr D A N Mallikaarachchi Technical Officers assumed duties with effect from 23rd August 2019. Mrs K A D Y Madushani Lanka, Management Assistant was on duty throughout the year. Mr P L P B Nishantha worked as a Temporary Research Assistant under the Development Project - 23/1/15 and Miss K L K Shehani assumed duties with effect from 16th September 2019 as a Technical Assistant under the NSF Project RG/2016/AG/01.

Research grants received

Source and Grant No	Duration	Title of the Project	Allocation	Status
Ministry of Plantation Industries **Development Project - 23/1/15**	May 2016 - 2020	Identification of the Potential Pest and Disease Problems of Rubber in Non-Traditional Areas to Develop Improved Management Strategies	20 Rs.Mn.	In progress
National Science Foundation **NSF Project: RG/2016/AG/01**	May 2016 - 21st Jan. 2021	Investigations on biological control measures for WRD of rubber to improve integrated disease management strategies	2.071 Rs.Mn.	In progress
Ministry of Plantation Industries **Development Project - 23/1/17**	2018 - 2022	Improvement of strategies to manage white root disease in rubber plantations	42.99 Rs.Mn.	In progress

Research students

Dr (Mrs) T H P S Fernando supervised the research projects of the following undergraduate/postgraduate students.

Name	Duration	University	Project title
Buddhika Nirmali Gurusinghe (Final year project)	Jan 2019 - July 2019	Eastern University Sri Lanka	Strategies for the improvement of control measures against Cockchafer grub infestation in rubber plantation
UA Shamalie Madushanki (Final year project)	August 2019 - December 2019	Uva Wellassa University	Effectiveness of different trade products of hexaconazole & tebuconazole against *Rigidoporus microporus*
AHMNR Aberathne (MSc)	2018 - 2020	University of Kelaniya	Characterization of *Colletotrichum* species causing CLD in rubber in Sri Lanka
PLPB Nishantha (MPhil)	2019 - 2022	University of Sri Colombo	Screening of selected *Hevea brasilinsis* grown under suboptimal ecological conditions in Sri Lanka against foliar disease and for physiological performance
LTBK Fernando (MPhil)	2018 - 2021	University of Sri Jayawardenapura	Formulation of ethephon based low cost yield stimulant for commercial rubber plantations in Sri Lanka
PW Balasooriya	November 2016 - December 2019	University of Colombo	Application of indigenous soil micro flora as biological control measures for white root disease of rubber growing lands in Sri Lanka

Committees attended

Officers	Subject	Organization
THPS Fernando MKR Silva	Scientific Committee Meeting	Rubber Research Institute of Sri Lanka
THPS Fernando	National Plant Protection Committee	CARP
THPS Fernando	Pesticide Technical's Advisory Committee	Department of Agriculture
THPS Fernando	Pesticide Sub-Committee	Department of Agriculture

Training programmes attended (Foreign)

Officers	Programme	Duration
THPS Fernando	The MRB-IRRDB Workshop on Soil Fertility, Good Agricultural Practices (gap) and Productivity, Kuala Lumpur	08th - 13th April 2019

Training programmes conducted

Dr (Mrs) T H P S Fernando and 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 and Mr E A D N Nishantha 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	425
Advisory	69
Other (Pestalotiopsis work)	408
Total	902

LABORATORY AND FIELD INVESTIGATIONS

Chemical Control of *Hevea* Diseases (23/P/01)

Chemical control of white root disease to revise the present recommendation

Investigations were done to revise the present chemical recommendation against the white root disease. This was conducted in a 3½ years old immature rubber field. Tebuconazole (250 EW) at the concentrations of 1% and 0.5% (4 liters per each tree) and hexaconazole (50g/l) at the concentrations of 1%, 2%, 2.5% and 5% (4 liters per each tree) were tested for the efficacy having an initial disease index of each tree. The experiment was conducted at the Talgaswala Estate, Elpitiya. The results showed that 1% tebuconazole effectively checked the disease while 5% hexaconazole was also capable of controlling the disease effectively. The progress of the recovery will be monitored for another year.

teboconazole (Folicur 250 EC)

T1 - 40 ml of the chemical dissolved in 4 liters of water
T2 - 20 ml of the chemical dissolved in 4 liters of water

hexaconazole (Hayleys hexaconazole 50 g / L)
T3 - 40 ml of the chemical dissolved in 4 liters of water
T4 - 80 ml of the chemical dissolved in 4 liters of water
T5 - 100 ml of the chemical dissolved in 4 liters of water
T6 - 200 ml of the chemical dissolved in 4 liters of water
T7 - Control (no fungicide application)
(T H P S Fernando and S C P Wijayaratne Funded by the Development Project - Grant 23/1/17)

Rehabilitation of White root disease patches - Dartonfield Estate

White root disease patches were rehabilitated at Galewatta, Dartonfield 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 and Cloterlaria) to trace out any remaining inocula. A pineapple cultivation was established in view of providing an additional income for the grower. The field was generally maintained and indicator plants were examined for the detection of the disease. The experiment is in progress (T H P S Fernando and S C P Wijayaratne: Funded by Development Project 23/1/17).

Establishment of demonstration plots for the chemical controlling of white root disease* (Table 1) *(23/ 01 /17)

Table 1. *Establishment of demonstration plots for the chemical controlling of white root disease*

District	Area	Stakeholder	No of affected plants	Chemical application	No of recovery plants
Galle	Pitigala	Upali Galaboda	92	1st Application 2nd Application	90
	Pitigala North	WA Chandrasiri	21	1st Application 2nd Application	21
	Urapola	Sunil	189	1st Application 2nd Application	189
Kegalle	Rambukkana	Upali Seneviratne	39	1st Application 2nd Application	39
	Kotiyakumbura	SD Karunasena	75	1st Application 2nd Application	74
	Ruwanvella	Nalanda Estate	42	1st Application 2nd Application	-

District	Area	Stakeholder	No of affected plants	Chemical application	No of recovery plants
Matara	Morawaka	Gunapala	200	1st Application 2nd Application	200
Rathnapura	Kiriella	Hettiarachchi	75	1st Application 2nd 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 2nd Application	75
Kalutara	Horana	Samila	100	1st Application 2nd Application	100
	Horana	MD Dharmasena	30	1st Application 2nd Application	30
	Welimanana	KK Siril	20	1st Application 2nd Application	20
	Thebuwana	HD Premarathne	35	1st Application 2nd Application	35
	Thebuwana	Sunil Ranasinghe	16	1st Application 2nd Application	16
	Meegahathenna	Duminda	100	1st Application 2nd Application	100
	Maggona	Shantha Visenthi	60	1st Application 2nd Application	58
	Millewa	Koshan	70	1st Application 2nd Application	68
	Millewa	Hemachandra	18	1st Application 2nd Application	18
	Nivithigalakele	N'Kele, RRI		Patch rehabilitation	-
	Galewatta	D/F, RRI		Patch rehabilitation	-
	Rannagala	Rannagala Estate	12	1st Application 2nd Application	12
	Yatadola	Premasiri	32	1st Application 2nd Application	32
	Bulathsinghala	NG Jayasena	23	1st Application 2nd Application	22
	Lihiniyawa	Sarath Fernando	170	1st Application 2nd Application	168
Kegalla	Ruwanvella	Nalanda Estate	42	1st Application 2nd Application	40
Kalutara	Maggona	Shantha Visenthi	60	1st Application 2nd Application	58

District	Area	Stakeholder	No of affected plants	Chemical application	No of recovery plants
Kalutara	Millewa	Koshan	70	1st Application 2nd Application	58
Kegalla	Ruwanvella	Nalanda Estate	42	1st Application 2nd Application	40
Kalutara	Millewa	Hemachandra	18	1st Application	18
Gampaha	Delgoda	KGH Dharmawardena	42	1st Application	40
Galle	Baddegama	Sarath Amarasiri	52	1st Application 2nd Application	50
Kalutara	Nivithigalakele	N'Kele, RRI		Patch rehabilitation	-
Kalutara	Galewatta	D/F, RRI		Patch rehabilitation	-
Kalutara	Yatadola	Premasiri	32	1st Application	32
Kalutara	Bulathsinghala	NG Jayasena	23	1st Application	23
Kalutara	Lihiniyawa	Sarath Fernando	170	1st Application	160
Kalutara	Rannagala	Rannagala Estate	12	1st Application	11
Gampaha	Delgoda	KGH Dharmawardena	42	1st Application 2nd Application	40
Galle	Baddegama	Sarath Amarasiri	52	1st Application 2nd Application	50

(T H P S Fernando, M K R Silva, E A D D Siriwardena, B I Tennakoon and S C P Wijayaratne: Funded by Development Project 23/1/17)

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

Data collection was continued in the collaborative adaptability trial with the Adaptive Research Unit, in Polgahawela to evaluate the repellent chemical for the smallholder conditions in the Intermediate Zone (M K R Silva, T H P S Fernando, B I Tennakoon).

Screening of effective chemicals to control Brown root disease

In the field trial established to screen the effectiveness of the two systemic fungicides: tebuconazole and hexaconazole on the control of the brown root disease in a four year-old clearing at Badalkumbura, the trees under all three treatments did not exhibit any brown root disease symptom after one fungicide application. The treatments used were tebuconazole (Folicur 250 EW) in 1% concentration,

hexaconazole (Hayzole 50 EC) in 1% concentration and hexaconazole (Hayzole 50 EC) in 2% concentration. Therefore, five more field trials were established to screen the effectiveness of the lower concentrations of the two fungicides: on the control of the brown root disease. These experiments were in three, four, five and six year-old clearings at Badalkumbura. The initial infection level was assessed and rank was given for each tree before the application of the fungicides. The treatments used were tebuconazole (Folicur 250 EW) in 0.25%, 0.5%, 0.75% and 1% concentrations (M K R Silva, T H P S Fernando, R L C Wijesundera and B I Tennakoon).

Alternative chemicals for the management of the bark cracking disorder

Trials established in Pussalla Estate, Woodend Estate and Sorana Estate are being monitored for the recovery. Assessments were on the bark rot level at the collar region, foliar symptoms and formation of latex pads. The experiment is in progress as a substitute for Mancozeb (T H P S Fernando and E A D N Nishantha).

Biology of Pests (23/P/02)

Variability of* Rigidoporus microporus *isolates from different rubber growing agro-climatic areas

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 2). The gaps of knowledge in view of improving the management strategies of white root disease were also reported.

Table 2. *WRD survey with reference to Mucuna, cover crop*

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

Productivity improvement through the studies on the biology and molecular biology of pests

Studies on the mode of transmission of brown root disease

The different modes of brown root disease transmission were tested in potted rubber seedlings. Inoculated rubber root segment, and inoculated mixture of rice bran

and saw dust, an arthrospore suspension and basidiospore suspensions were investigated for the effectiveness. Forty seedlings (in 10 polybags) were used to test each mode of inoculation. Another 40 seedlings without inoculation were kept as the control. In all three treatments, mycelial starter culture of isolate 9: the most pathogenic isolate in the isolate collection was used. Four months after the inoculation, based on the signs and symptoms, a plant health score was assigned for the foliar symptoms as; 0 (no infection), 1 (slight yellowing and/(or) bucking condition), 2 (remarkable yellowing and/(or) bucking condition) and 3 (total wilting of the foliage). Then all the seedlings were uprooted and signs and symptoms on the collar region and the roots of the seedlings were observed and a plant health score was assigned for each uprooted seedling as; 0 (no infection), 1 (mycelial crust with root decay <50%), 2 (mycelial crust with root decay >50%) and 3 (plant death).

Table 3. *The mean score values of the Plant Health Score assigned for different modes of inoculation*

Mode of Inoculation	**Mean score value of the Plant Health Score (root)***	**Mean score value of the Plant Health Score (foliar)***
With inoculated Root segments	44.5	48.0
With inoculated mixture of rice bran and saw dust	100.5	100.5
With arthrospore suspension	36.5	33.0
With basidiospore suspension	36.5	33.0
Control	36.5	33.0

*Note that the critical difference is 12.47

Accordingly, the artificial inoculation of the rubber seedlings with inoculated mixture of rice bran and sawdust has shown a significantly higher effect on the disease development in seedlings under both root and foliar observations (at the accuracy level of 0.001). Moreover, among root and foliar symptom observations, non-significant variations have been shown (M K R Silva, T H P S Fernando, R L C Wijesundera and B I Tennakoon).

The symptom development of brown root disease of rubber

The inoculation of the potted rubber seedlings was performed with the inoculated mixture of rice bran and sawdust. For the observation of foliar and collar symptoms, seedlings were inoculated with a pathogenic isolate of *P. noxius* and another set of seedlings was kept as the control without inoculation. Starting after two months of inoculation, the development of signs and symptoms of the disease was investigated five times, at 2-weeks interval. To observe the underground signs and symptoms, destructive samplings were carried out. Based on the signs and symptoms,

a plant health score was assigned (as described under the mode of transmission of brown root disease). At the end of the period, in the most affected plants, the similar signs and symptoms of those of the disease plants in the field were seen. The symptom development has shown a similar pattern under both root and foliar observations. The succession of the disease development based on the variation of the mean score value of the plant health score is shown in Table 4.

Table 4. *The mean score values of the Plant Health Score assigned for different inoculation durations*

Duration after the inoculation	Mean score value of the Plant Health Score (root)*	Mean score value of the Plant Health Score (foliar)*
Two months	6.00000	6.37500
Two and half months	15.06250	20.56250
Three months	25.93750	25.18750
Three and half months	27.75000	25.18750
Four months	27.75000	25.18750

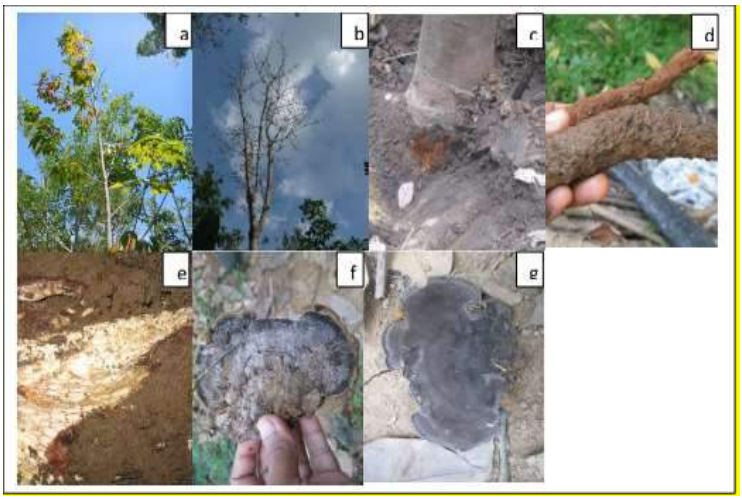
*Note that the critical difference is 6.67

According to the results, the root symptom development of the artificially inoculated rubber seedlings has been initiated to accelerate at the duration of 2.5 months of the inoculation and has shown a significantly higher symptom development at the 3.5 months of the *P. noxious* (at the accuracy level of 0.001). However, the plant health score has been stabilized thereafter. The foliar symptom development of the artificially inoculated rubber seedlings has initiated at the duration of 2 months of the inoculation and at the 2.5 months, 3 months, 3.5 months and four months of the inoculation, the plant health score has shown significantly higher values compared to that at the two months (at the accuracy level of 0.001). However, as similar to the root symptom development, the plant health score has been stabilized after 3.5 months (M K R Silva, T H P S Fernando, R L C Wijesundera and B I Tennakoon).

Symptomatology of brown root disease under field conditions

Seventy disease incidences reported from different agro ecological regions were used for this trial. The above ground symptoms were recorded in each infected tree and the collar and root symptoms were also recorded by partially exposing the root system. It was observed that the disease has shown a variety of signs and symptoms. The above-ground symptoms of brown root disease were similar to those caused by other root diseases. Slow plant growth, yellowing and wilting of leaves, defoliation and branch dieback were the major above-ground symptoms (Fig. 1a &

1b). Roots infected with *P. noxius* initially have exhibited a brown discoloration of the wood just beneath the bark (Fig.1c). Tawny brown gummy rhizomorphs were firmly fixed to the outer bark surface with an encrustation of sand and stones on the root surface. They could be identified as the characteristic diagnostic signs of the disease (Fig. 1d). The inner bark was covered with the white to brownish mycelial mat. Although the deadwood was initially discolored with a reddish brown colour, it later had become white, dry, and honey-combed (Fig. 1e). Bracket-like fructifications were observed on the basal trunk of diseased trees at 02 incidences. The fructification was hard dark brown on the upper side and dark grey on the underside (Fig. 1f & 1g).



a) yellowing and wilting of leaves
b) branch dieback
c) brown discoloration of the wood just beneath the bark
d) encrustation of sand and stones on the root surface
e) honey-combed wood
f) fruiting bodies (upper surface)
g) fruiting bodies (lower surface)

Fig. 1. Symptoms of the brown root disease of rubber plants

In none of the incidence, an above-ground mycelial sleeve which is reported to be a common sign of the pathogen in most other host species, was not observed. In addition to these signs and symptoms, dryness of the trees in early tapping was another mode of complaint on brown root disease. According to the reported incidences, the borer attack was also a common secondary attack which is frequently complained in the drier areas (M K R Silva, T H P S Fernando, R L C Wijesundera and B I Tennakoon).

Influence of soil moisture on the development of the brown root disease

Survival on cellophane buried in soil

For the assessment of survival ability of the *Phellinus noxius* in different moisture levels, the ability of the fungus (established on pieces of cellophane) to emerge was tested in different volumetric moisture percentages. Soils were placed in

separate plastic containers (60 cm high × 45 cm diameter). In the containers, the volumetric water content of the soils was adjusted to 3%, 6%, 9%, 12%, 15%, 18%, 21% and 24% as three replicate containers were there for each moisture level. Wetted and autoclaved pieces of cellophane (2×2 cm) were placed on Malt Extract Agar plates and *P. noxius* cultures of the isolate 9 were inoculated for 3 weeks at room temperature. After the incubation, well-colonized cellophane pieces were buried 5 cm below the soil surface of each plastic container. Thirty pieces of cellophane were used for each container. The containers were covered and the pieces of cellophane were harvested at 12 weeks. The percentage of pieces of cellophane from which the fungus emerged over the total number of cellophane pieces showed a variation among different volumetric moisture percentages of the containers and the highest survival ability was shown at the 10% moisture level (Fig. 2).

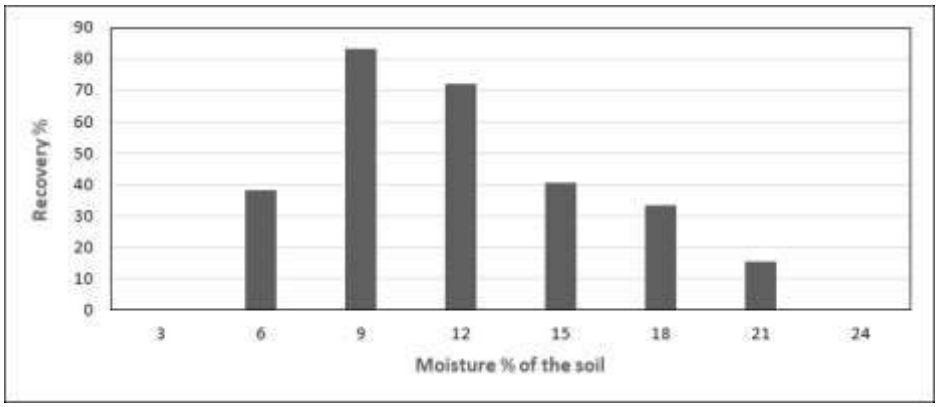


Fig. 2. The variation the fungal recovery percentages of cellophane pieces at different volumetric moisture percentages of the containers

Survival in infested wood buried in soil

The survival ability of the *P. noxius* pathogen in infested wood buried in soil having different moisture levels 3%, 6%, 9%, 12%, 15%, 18%, 21% and 24%. Soil of each treatment was placed into a separate plastic container and wood sections were buried in the soil. The containers were sealed with tape to maintain constant soil moisture. At the end of the duration, the wood sections were taken out and 50 wood fragments (about 3 × 6 mm) were cut from each wood section and placed on selective medium at the room temperature (Fig. 3).

The percentage of wood fragments from which the tested fungi emerged after 2 weeks of incubation over the total number of wood fragments showed a variation among different volumetric moisture percentages of the containers and the tested

levels. The fungal recovery was highest at 10% soil moisture level (M K R Silva, T H P S Fernando, R L C Wijesundera and B I Tennakoon).

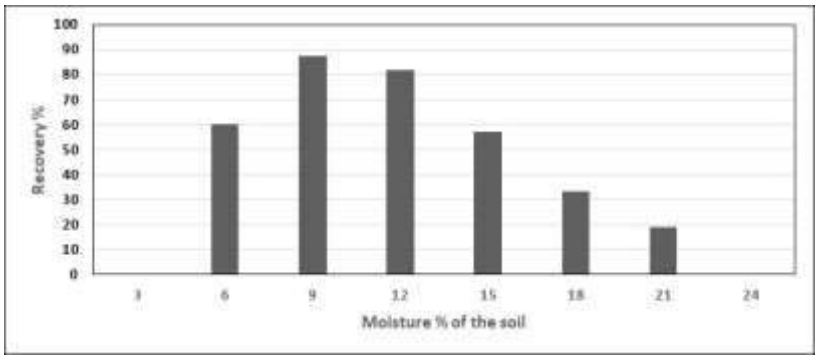


Fig. 3. The variation the fungal recovery percentages of buried wood fragments at different volumetric moisture percentages of the containers

Influence of Agro-climatic conditions on the development of the brown root disease

The field trial established at Moneragala to investigate the influence of agro-climatic conditions on the spread of the disease was generally maintained. The incidence and severity of the disease were monitored (M K R Silva, T H P S Fernando, R L C Wijesundera and B I Tennakoon).

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

Screening of clones against Corynespora leaf fall disease (CLFD)

The incidence of Corynespora leaf fall disease was mild during the year 2019. The pathogen isolates were obtained from non-traditional rubber growing areas (Table 5) (T H P S Fernando, E A D D Siriwardena and E A D N Nishantha).

Maintenance of nurseries for screening purposes – Ratnapura District

Fifty *Hevea* clones have been established at the Kuruwita substation Ratnapura for clonal evaluation against Corynespora leaf fall disease. The disease was reported from RRIC 121 plants. The cultures are being studied (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

Fifty *Hevea* clones have been established at the Moneragala substation, Moneragala for clonal evaluation against Corynespora leaf fall disease (T H P S Fernando, M K R Silva, S C P Wijayaratne: Funded by Development Project 23/1/15).

Establishment of a nursery for screening purposes - Padiyathalawa

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 - Dartonfield

Fifty *Hevea* clones have been established at the Dartonfield Estate, RRISL 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

Forty eight *Hevea* clones have been established at the Dartonfield Estate, RRISL for clonal evaluation against Corynespora leaf fall disease (T H P S Fernando, M K R Silva, B I Tennakoon: Funded by Development Project 23/1/15).

Table 5. *Results of the Survey on Corynespora leaf fall disease conducted in 2019*

Clone	ADSI *	Clone	ADSI *
RRIC 121	0	RRISL221	0
RRIC 102	0	RRISL222	0
RRIC 130	0		
RRISL 203	0		
PB 260	0	RRISL2000	0
RRIC 133	1.0	RRISL2002	0
RRISL 201	1.3	RRISL2004	0
RRISL 205	0	RRISL2005	0
RRISL206	0	RRISL2006	0
RRISL210	0	GPS 1	0
RRISL211	0	PB 255	1.0
RRISL215	0	PR 255	0
RRISL216	0	PR 305	0
RRISL217	1.0	RRII 105	1.0
RRISL219	0	PB235	0
RRISL2001	0	BPM 24	0
RRISL2003	0	RRISL 200	N/A
RRISL 218	1.2	Centennial 2	0
RRISL 204	0	Centennial 3	1.1
RRISL 202	2.0	Centennial 4	0
RRISL 220	0	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

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

The WRD survey - Government Nurseries

A preliminary survey was done in the government nurseries to detect the white root disease condition. Various disease conditions have been revealed and the disease should be managed under the white root disease management project to be started in 2020 (T H P S Fernando, M K R Silva, B I Tennakoon, E A D D Siriwardena and S C P Wijayaratne, Funded by WRD Project 23/1/17).

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)

The below experimental sites were monitored for the incidence of economically important diseases.

Selected sites

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

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

Surveillance of potential pests and disease outbreaks to avoid unwanted sudden disease epidemics in view of maintaining the productivity levels

Biological Control of *Hevea* Diseases (23/P/05)

Identification of indigenous soil microflora as biological control measures for white root disease of rubber growing lands in Sri Lanka

An effective biopesticide to control* Hevea *root diseases: mass production of the inocula

Use of talc powder as the solid carrier material

Talc powder was evaluated as the carrier material to produce bio-formulation of *Trichoderma*. Carrier material (250 g) was placed in polythene bags and autoclaved at 121°C and at a pressure of 15 lb inch2 for 20 min. spore suspension (approximately 1×10^7 /ml) was prepared using 7 days old cultures of *Trichoderma*

which were grown on PDA medium. The spore suspension was prepared in sterilized distilled water and mixed with 10 g autoclaved talc (Fig. 4). Then each formulation was allowed to dry under room temperature for a few days. Air-dried powder was kept in Eppendorf tubes and autoclaved Petri dishes and then stored under room temperature. The formulation was tested at 30 days intervals to measure the spore concentrations (the survival ability of *Trichoderma* sp).

Use of compost as the solid carrier material

The compost based *Trichoderma* inocula was prepared in large scale.

Cultural and reproductive characteristics of the effective *Trichoderma* isolates

Most effective *Trichoderma* isolates were selected to study the colony morphology on the medium PDA (Table 6). The production of conidia was also assessed and the spore length and the width were also measured using seven-day old cultures and spores were collected from these cultures (Fig. 5). Percentage germination of the spores was taken every three hours up to 72h to study the effect of the time on germination (Table 7) (T H P S Fernando, Shehani Liyanage, Poorna Balasuriya and E A D D Siriwardene: This project is partially funded by National Science Foundation-Project NSF 03.30x).

Fig. 4. Talcum powder as a carrier media

Table 6. *Colony morphology and reproductive morphology of Trichoderma isolates*

Isolate name	Colony morphology			Reproductive morphology	
	Form	Margin	Elevation	Spore length (µm)	Spore width (µm)
Iso 2	Circular	Filiform	Criteriform	2.15	1.32
Iso 8	Circular	Entire	Criteriform	1.39	0.84
Iso 13	Circular	Entire	Flat	5.0	4.0
Iso 15	Circular	Filiform/Entire	Flat	2.32	1.2
Iso 16	Circular	Entire	Flat	1.51	1.06
Iso 17	Irregular	Filiform	Flat	2.06	1.3
Iso 23	Circular	Entire	Flat	2.25	1.5

Table 7. *Germinated spores of most effective isolates*

Isolate No.	Time (hr)	Mean spore germination (%)
2	6	7.1
	24	26.1
	72	95.1
8	6	35.0
	24	67.7
	72	80.0
13	6	43.2
	24	58.5
	72	85.2
15	6	8.0
	24	19.8
	72	84.7
16	6	26.0
	24	58.0
	72	95.0
17	6	18.3
	24	66.6
	72	73.0
23	6	33.7
	24	81.0
	72	98.0

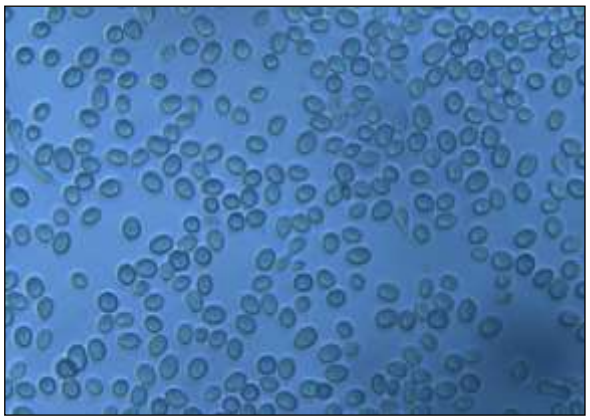


Fig. 5. Conidial morphology of *Trichoderma* spp.

Identification of antagonistic plants to control brown root disease

Based on the proven antagonistic ability on other closely-related fungi, four prospective plant species: Galangale *(Alpinia galanga* (L.) Willd.*)*, Wild ginger *(Curcuma xanthorrhiza* Roxb.*)*, Ginger *(Zingiber officinale* Roscoe*)* and Garlic *(Allium sativum* L.*)* were tested against *P. noxius*. The diethyl ether extracts (of under-ground parts) obtained from each of these four plant species were tested against two isolates of the fungus *P. noxius*: isolate 7 and isolate 9 (isolates 9 and 7 being the highest and lowest pathogenic respectively among the *P. noxius* isolates of the collection). The Assessment was performed in Poisoned Food Technique and the percent inhibitions of growth (I) were calculated with respect to the control in each of the treatments. Analysis of variance was done for the I values after carrying out the Arc sine transformation. Subsequently, the mean separation was done with Duncan's Multiple Range Test (DMRT).

According to PFT results, the four prospective antagonistic plant species showed a variation in the growth reduction of both *P. noxius* isolates. Among the three concentrations, a variation was present and interactions were observed among the two variables: antagonistic plant species and the concentration of the extract (Figs. 6 & 7).

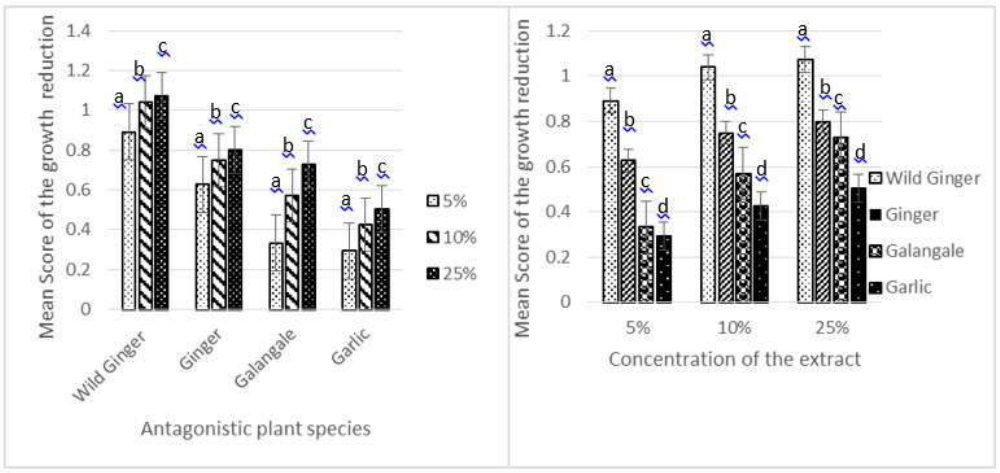


Fig. 6. Mean scores of the growth reduction at different concentrations of the antagonistic plant species: *P. noxius* isolate 9. *Values in the same cluster with the same letter are not significantly different at DMRT at P=0.05

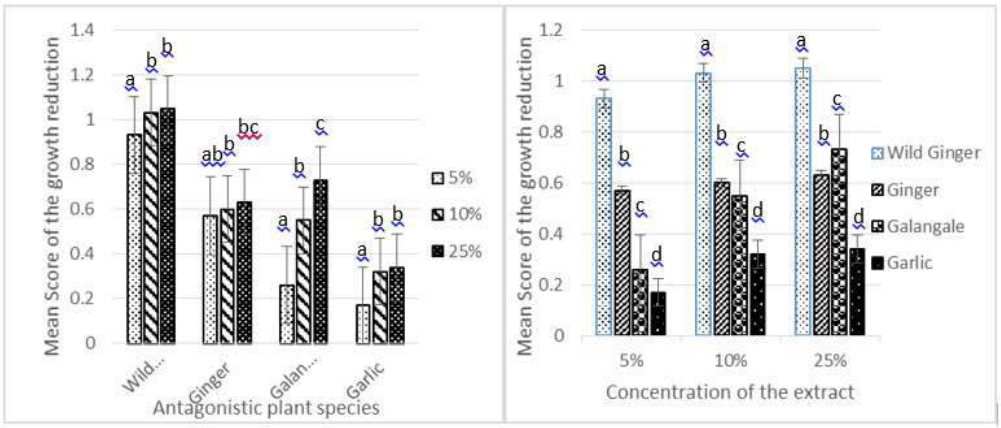


Fig. 7. Mean score of the growth reduction at different concentrations of the antagonistic plant species: *P. noxius* isolate 7. *Values in the same cluster with the same letter are not significantly different at DMRT at P=0.05

At all three concentrations, wild ginger (*Curcuma xanthorrhiza)* had the highest inhibition rate against both isolates and its inhibitory effect was significantly higher than that of the other three species. Therefore, it could be concluded that wild ginger *(Curcuma xanthorrhiza)* is having a potential to be used as a biological agent

towards the effective management of the brown root disease of rubber (M K R Silva, T H P S Fernando, R L C Wijesundera and B I Tennakoon).

Surveillance of potential pests and disease outbreaks to avoid unwanted sudden disease epidemics in view of maintaining the productivity levels (PP/04)

Report on the new Leaf Fall Disease in Rubber Plantations

In July 2019, a new leaf disease epidemic was spreading in Sri Lanka in wet rubber growing districts *viz.* Kalutara, Rathnapura and Kegalle. The first epidemic of this disease had been reported from Malaysia in 2017 - 2018 period reaching epidemic proportions. Later, the disease spread to Indonesia devastating many rubber clones. Later, this disease had been reported from India and Thailand. It has been reported from Indonesia that severe infections of this disease cause leaf fall up to 100% and has the potential to reduce latex yield up to 30 - 50%.

According to a brief survey carried out collaboratively by the Rubber Development Department, Advisory Services Department and the Plant Pathology Dept. of RRI around 5000 ha were under this disease at the end of the year 2019. Immediate actions were made to; educate the Extension staff and the growers regarding the symptoms of the disease (Fig. 8), to isolate the causative pathogens of the disease and to stop further spread of the disease. Moreover, a chemical controlling programme was launched to control the disease incidence and the severity and also to save the other economically important cultivations of the country.

At the meeting held in the Ministry of Plantation Industries and Export Agriculture, the importance of building up the readiness to control this disease was highlighted. There was a scarcity of proper spray machines to apply the fungicide solutions above 40 ft high for the mature rubber plantations. Since RDD and STARR project are mandated to look after the rubber smallholder sector in the country, a request was made to make the sprayers available in the country as it was of utmost importance for the protection of the cultivations. This action will contribute towards fulfilling a vital requirement of the protection aspects of any cultivation in the country. Furthermore, this action will be helpful in the prevention of the further spread of the disease.

- To save the disease free areas (Southern, Eastern, North Eastern and Northern Provinces) Implementation of inland quarantine activities - A disease surveillance is required. And follow up training programmes.
- To chemically control further spread of the disease. Rubber farmers especially smallholders are financially not strong enough to implement a disease controlling programme under the prevailing low NR prices.
- To draw a long-term research plan to formulate an effective disease management system

(T H P S Fernando, M K R Silva and all the staff of Plant Pathology & MB Dept.)

Fig. 8. Characteristic symptoms on the newly reported leaf fall disease

Advisory visits and training programmes (PP - 08)

The staff of the department made 46 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, M K R Silva, B I Tennakoon, E A D D Siriwardene and S C P Wijayaratne).

The staff of the department served as the resource personnel in training Estate Managers, Assistant Superintendents and Field Officers. Students from Universities and Technical Colleges were also trained on departmental activities. Mr Priyantha Peiris covered all audio visual aspects with regard to the training programmes organized by the institution (T H P S Fernando, M K R Silva, B I Tennakoon, E A D D Siriwardene and S C P Wijayaratne).

SOILS AND PLANT NUTRITION

R P Hettiarachchi

DETAILED REVIEW

Staff

Dr (Mrs) R P Hettiarachchi, Principal Research Officer and Mrs H A R K Jayawardana, Research Officer were on duty throughout the year. Mr T S Liyanaarachchi joined the department as a Research Officer with effect from 17th July 2019. Dr (Mrs) R P Hettiarachchi participated the International Workshop on "Soil fertility, good agricultural practices (GAP) and productivity" from 9th to 12th April at Melaka, Kuala Lumpur, Malaysia. Miss V Edirimanna and Miss A Thevarapperuma completed the training program on Atomic Absorption Spectrophotometer from 19th to 21st June at Melbourne Australia. Miss V Edirimanna, Miss A Thevarapperuma, Mr T Gunathileke Experimental Officers, Mrs K E de Silva, Mr G C Malawaraarachchi, Mr M W H Gayan, Mrs K M M E K Kulatunga, R M Baddevidana Technical Officers and Mrs L Rupasinghe English Stenographer were on duty throughout the year. Mrs P D S D O Rathnasooriya was on maternity leave from 11th November. Mr B N K Rangana joined the department as a Technical Officer with effect from 23rd August 2019. Experimental Officer Mr J A S Chandrasiri and Technical Officer Mrs N S Siriwardena were transferred to Advisory Service Department (with effect from 11.11.2019) and Raw Rubber and Chemical Analysis Department (with effect from 18.07.2019) respectively.

Research students

- K T T Samaranayake, a student from Faculty of Applied Sciences, Uwa Wellassa University of Sri Lanka conducted a part of her final year research project on "Phosphorus availability in rubber growing Boralu series soils" under the supervision of Dr (Mrs) R P Hettiarachchi.

Seminars/Trainings/Workshops/Conferences/Meeting

Officer	Subject	Organization
RP Hettiarachchi	Presentation on "Slow release fertilizers to enhance soil nutrient levels and plant growth of immature rubber (*Hevea brasiliensis*)"	Soil Science Society of Sri Lanka
	Presentation on "Effectiveness of coir and rubber latex based slow release fertilizer on growth of immature rubber (*Hevea brasiliensis*) and soil nutrient availability"	7th Crop Symposium, RRI, TRI, CRI, SRI

Seminars/Training Programmes/Workshops/Exhibition attended

Officer	Subject	Organization
RP Hettiarachchi	Fertilizer Advisory Committee Meeting	Ministry of Agriculture
	Scientific Committee Meeting	Rubber Research Institute
	Launching of the United Nations Global Campaign and Science - Policy – Political Dialogue on Sustainable Nitrogen Management from 23rd to 24th October, 2019	Ministry of Mahaweli Development & Environment
	Country Specific Integrated Plant Nutrition Systems (IPNS) Modules for Major Crops and Cropping Systems	Department of Agriculture Horticulture, Research and Development Institute
	First Nitro-Innovation Exhibition	Ministry of Plantation Industries
	Sri Lanka to lead the united Nations Campaign on Sustainable Nitrogen Management	Ministry of Mahaweli Development & Environment
	Discussion on Glyphosate Import, Distribution and Usage	Ministry of Plantation Industries
	Workshop on the use of bio engineering methods to mitigate landslides	Sri Lanka Council of Agricultural Research Policy
HARK Jayawardana	Scientific Committee Meeting 7th Crop Symposium	Rubber Research Institute RRI, TRI, CRI, SRI

Visits

Advisory	7
Experimental	95
Others	68

LABORATORY AND FIELD INVESTIGATIONS

Soil fertility management

Isolation of effective microbes for soil fertility enhancement

Root samples were collected from different sites of the *Boralu* series belong to wet zone low country (WL4) agro-ecological region, representative of great soil group of red yellow podzolic (RYP). Five different sites were chosen to reflect different stages of rubber tree; immature and mature with different management practices having *Mucuna* and *Pueraria* as cover crops. Root samples were collected from randomly selected plants representing above mention sites at 0 - 15 cm topsoil layer at

1 m and 30 cm radius from the base of the rubber plant. Root samples were suspended in 100 ml sterilized water and were serially diluted with sterilized water following a dilution series up to 10^{-6}. Samples of 100µl from each were spread on nutrient agar (NA) and were incubated at 28 ± 2°C for 24 to 48 hours. Morphologically different twenty bacterial colonies were isolated for further evaluation.

Monitoring of growth in N-free medium

Individual bacterial isolates were inoculated into 100 ml of N-free medium and incubated for 1-7 day period with continuous shaking at 60 rpm. Incubated cultures were observed for their color change during the experimental period (Table 1). Based on the observation of bacterial growth in N-free medium, nine bacterial isolates coded as B1, B2, B3, B8, B9, B10, B12, B19, and B20 had an ability to fix atmospheric nitrogen and grow well in N-free medium and they could be selected as the best ones compared to other bacterial isolates.

Table 1. *Colour change of different bacterial isolates in N-free growth medium*

Isolate No.	**Incubation period**						
	1 day	**2 days**	**3 days**	**4 days**	**5 days**	**6 days**	**7 days**
B1	**Y**	Y	Y	Y	Y	Y	Y
B2	**Y**	Y	Y	Y	Y	Y	Y
B3	PY	**Y**	Y	Y	Y	Y	Y
B4	G	PY	PY	PY	PY	**Y**	Y
B5	G	G	G	G	G	Y	Y
B6	G	G	G	PY	PY	Y	Y
B7	G	G	G	G	G	G	G
B8	PY	**Y**	Y	Y	Y	Y	Y
B9	**Y**	Y	Y	Y	Y	Y	Y
B10	G	PY	**Y**	Y	Y	Y	Y
B11	B	B	B	B	B	B	B
B12	PY	**Y**	Y	Y	Y	Y	Y
B13	G	G	G	**G**	PY	**Y**	Y
B14	G	PY	PY	PY	**PY**	PY	PY
B15	G	G	G	G	G	G	G
B16	G	G	G	G	G	G	G
B17	G	G	G	**G**	G	**Y**	Y
B18	G	G	G	G	G	Y	Y
B19	**Y**	Y	Y	Y	Y	Y	Y
B20	PY	**Y**	Y	Y	Y	Y	Y

Y- yellow PY - pale yellow B - blue G - green

Determination of pH

Individual species of all bacteria were inoculated into 100 ml of Yeast Manitol Broth (YMB) and the N-free medium, were incubated for 1 to 7 day period with continuous shaking at 60 rpm. pH of the incubated cultures was measured using a pH meter. All bacteria had an ability to reduce the original pH in YMB medium from 7.0 to 3.5-6.5. Isolates 1, 2, 4, 6, 7, 10, 12 and 20 reduced their pH from 7.0 to 3.5-4.5 while 3, 5, 8, 9, 11, 13, 14, 15, 16, 17, 18 and 19 reduced the pH from 7.0 to 5.5-6.5. Their behavior in the N-free medium was different from YMB medium. The growth medium acidity in N-free medium showed three distinct clusters. Isolates 13, 12, 2, 9, 8, 4, 3, 20 and 1 reduced their initial pH from 7.0 to 4.8-5.3 while 15, 11, 10, 7, 17, 6, 19, 18 and 5 reduced their initial pH to 5.4-6.1. Isolates 16 and 14 maintained their initial pH at 7.0 or varied within slightly basic range 7.0-7.3. Bacterial isolates grow well in YMB medium which includes all nutrients required for the growth and reduced their original pH of 7.0. The N-free medium does not have nitrogen and the bacterial cultures had an ability to fix atmospheric nitrogen could have an ability to grow well in N-free medium and reduced their original pH of 7.0. Further, most of the selected morphologically different bacterial isolates showed rapid growth accompanying the acidification of the culture media.

Estimation of phosphorus solubilization

Solubilization of precipitated insoluble phosphates in solid agar medium has been used as the initial criterion for the isolation of phosphate solubilizing microorganisms. Serially diluted bacterial suspensions were poured on to petri dishes with insoluble phosphate and incubated for 2-3 days period. However, bacterial cultures failed to produce solubilization zones around their colonies with the medium with sparingly soluble phosphates: ERP and HERP (R P Hettiarachchi and K E de Silva).

Decomposition of kitchen garbage and selection of suitable medium for earthworms

Four different media were prepared in 0.216 m^3 pits according to the experimental design in Table 2 and were arranged as a randomized complete block design (RCBD).

Table 2. *Details of different treatments*

Treatment	Treatment combination
T1	Kitchen Garbage + Compost + Green manure + Banana stem fragments (1:1:1:1)
T2	Kitchen Garbage + Compost + Banana stem fragments (1:1:1)
T3	Kitchen Garbage + Banana stem fragments (1:1)
T4	Compost + Banana stem fragments (1:1)

After the placement of different media according to the experimental design, three species of earth warms: *Eudrilus, Lumbricus and Eisenia* were introduced to each replicate in all treatments. At the end of one, two and three months after the establishment of treatments the total count of different earth warm population was measured by hand sorting. *Eudrilus spp* was identified as the most prominent earth warm at the end of first month and second month (Fig. 1, Fig. 2, Fig. 3). Except earth warms, some other larva stages of Housefly, Soldier fly and fruit fly could also be observed throughout the experimental period of three months. At the end of third month very low count of earth warms could be observed. However, there is a possibility of using kitchen garbage as suitable media to multiply earth warm *Eudrilus spp*. Further, *Eudrilus spp* can effectively be used for the preparation of compost at home garden level without any expense (R P Hettiarachchi and K M M E K Kulatunga).

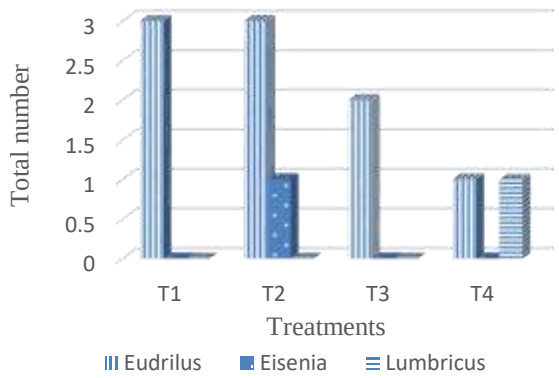


Fig. 1. Effect of different medium on earth warm count at the end of one month

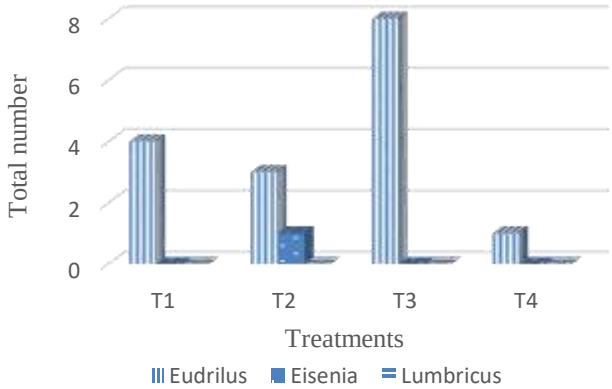


Fig. 2. Effect of different medium on earth warm count at the end of two months

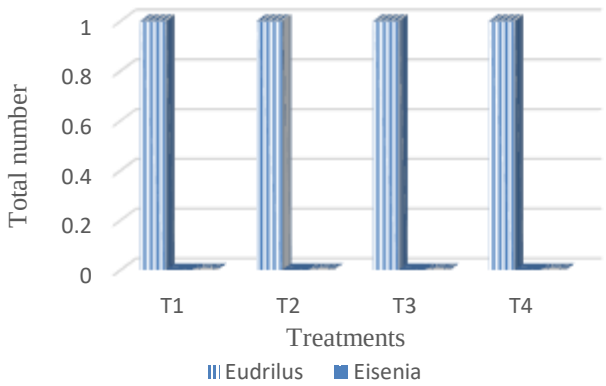


Fig. 3. Effect of different medium on earth warm count at the end of three months

Rehabilitation of degraded lands

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

This experiment was started in 2015 at Panawatta and Ekerella estates. Details of the experiment were included in the 2015 Annual Review. Four and half years after the establishment of the treatments at Ekerella estate, significant enhancement of soil fertility parameters such as organic carbon, available P, cation exchange capacity (CEC), exchangeable K and Mg could be observed with the combined use of agro management practices compared to normal estate practices. However, no significant differences could be observed with soil pH, total N and exchangeable Ca (Table 3). At this stage significantly higher girth of immature rubber plants and leaf nutrient contents, nitrogen, phosphorus, potassium and magnesium could be observed with combined use of agro management practices compared to normal estate practices (R P Hettiarachchi, V Edirimannne, T Gunathilake and G C Malawaraarachchi).

Table 3. *Soil fertility parameters after 4½ years of the establishment of combined use of agro management practices compared to normal estate practices at Ekerella estate*

Assessment	Combined use of agro management practices	Normal estate practices
pH	5.49[a]	5.38[a]
Organic carbon (%)	1.68[a]	1.03[b]
Total N (%)	0.13[a]	0.1[a]
Available P (ppm)	30.8[a]	26[b]
Cation exchange capacity (cmol+/Kg)	3.5[a]	2.6[b]
Exchangeable K (ppm)	164[a]	102[b]
Exchangeable Mg (ppm)	44[a]	30[b]
Exchangeable Ca (ppm)	88[a]	85[a]

Means with same letters in a rows are not significantly different at $p < 0.05$.

Organic manure application for rubber nursery plants

Evaluation of the effectiveness of compost on rubber nursery plants

This experiment was started in 2016 and the experimental designed was explained in the Annual Review 2016. This experiment was repeated to confirm the previous results of before and after the bud grafting stage. Plant growth assessments, plant height and diameter were measured at the end of the first, second, and third months after planting. Plant height showed no significant differences among treatments at the end of one month and two months after planting. At the end of three months, significantly lower plant height could be observed with T4 treatment compared to other treatments. There is a possibility of temporary nutrients immobilization with the highest amount of compost including T4 treatment compared to other treatments. Further plant diameter was measured at one month, two months and three months after planting did not show any significant differences among treatments (Table 4).

Table 4. *Effect of different compost applications on plant height and diameter of rubber nursery plants at one month, two months and three months after planting*

Treatments	Plant height (cm)			Plant diameter (mm)		
	One month	Two months	Three months	One month	Two months	Three months
T1(soil +50g compost)	37.14[a]	55.06[a]	94.07[a]	4.2[a]	5.6[a]	6.9[a]
T2(soil +100g compost)	28.81[a]	46.96[a]	90.14[ab]	4.0[a]	5.3[a]	6.5[a]
T3(soil +150g compost)	28.74[a]	46.61[a]	82.00[ab]	4.1[a]	5.4[a]	6.9[a]
T4(soil +200g compost)	24.10[a]	40.45[a]	79.15[c]	4.2[a]	5.4[a]	6.8[a]

(R P Hettiarachchi, G C Malawaraarachchi and M W H Gayan)

Organic and inorganic mulching for weed control in immature rubber plantations

The study was initiated in the year 2017 to test the effect of Paddy straw, oil palm refuse, Polythene and Shade net on weed control around the base of the rubber plants in comparison to normal estate management practices.

Paddy straw and oil palm refuse materials were regularly applied in three months intervals. The weed control and weed regeneration observations of the paddy straw and oil palm refuse mulch treatments during the four quarters were similar to that of the first three months that are mentioned in the Annual Review 2018. The Polythene mulch showed 100% weed control for two years of its application and subsequently the Polythene was damaged gradually and was not suitable for effective weed control. The shade net mulch showed 100% weed control even at the end of the year 2019 which was significantly effective than the polythene mulch. Therefore, it was concluded that Polythene mulch would effectively control weeds for two years period with regular maintenance by pruning the overgrowing creepers at three months intervals. It also would be a good solution for the prevailing labor shortage condition in rubber plantations. The labor reduction by the application of mulching materials is also presented in the Annual Review 2018. Oil palm refuses mulch would be also beneficial for controlling weeds in immature rubber plantations while saving on labour. It would also help to recycle oil palm waste. It was also concluded that the oil palm refuse was significantly effective than the paddy straw mulch as described in the Annual Review 2018. The testing on polythene, paddy straw and oil palm refuse treatments was concluded but shade net was maintained further to determine the effective period for weed control (H A R K Jayawardana, T Gunatilleke and A P Thewarapperuma).

Fig. 4. Weed control under the shade net after 2½ years of application

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

The combined use of inorganic and organic fertilizers is one of the way that can enhance productivity in more environmental friendly manner. The study was started in the fourth quarter of the year 2019 to investigate the effect of partially burned paddy husk (PBPH) on plant growth of immature rubber plants and possibility of using PBPH to reduce the level of the inorganic fertilizer applied for plants. Paddy husk is a nutrient rich organic source and consist of beneficial element silicon.

This study is carried out to investigate the effect of fertilizer application at levels of 100%, 75% or 50% of the recommendation in combined with PBPH application on the growth of immature rubber plants. An immature rubber field at 6 months after field planting was selected as the experimental site located at Baddehenegoda estate. Split plot design was adopted with two main plots were with PBPH and without PBPH. Three sub plots of different percentages of fertilizer, F1 (100%), F2 (75%) and F3 (50%) with four replicates including 5 plants per replicate. Guard rows (untreated plants) were kept in between treated plants. Pre-treatment soil samples were collected for analyzing soil parameters and pre-treatment height and the diameter of the plants were recorded using a measuring tape and a digital vernier caliper respectively (H A R K Jayawardana, T Gunatilleke and A P Thewarapperuma).

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 2016. Two sites in each area of Mahaoya, Padiyathalawa and Moneragala were included to evaluate the effectiveness of different fertilizer treatments on immature rubber plants. One site was the second year and the other site was in third year after establishment at Padiyathalawa and Mahaoya areas. However, both sites were in the second year at the Moneragala area. Second-year plants at Moneragala, Padiyathalawa and Mahaoya areas showed no significant differences in plant girth between treatments *i.e*. R/SA 7:9:9:3, R/SA 7:9:9:3 + 2K, modified new fertilizer mixture R/SA 7:4:18:6 and R/U 12:14:14. However higher girth values could be observed with R/SA based mixtures including treatments: R/SA 7:9:9:3, R/SA 7:9:9:3 + 2K, modified new fertilizer mixture R/SA 7:4:18:6 compared to R/U based mixture including treatment: R/U 12:14:14 (Table 5). Third-year plants at Mahaoya and Padiyathalawa areas showed significantly higher plant girth in the treatment R/SA 7:9:9:3 compared to other treatments: R/SA 7:9:9:3 + 2K and R/U 12:14:14. However, no significant difference could be observed between two treatments: R/SA 7:9:9:3 and modified new fertilizer mixture R/SA 7:4:18:6 (Table 6). Leaf analysis data showed no significant differences for P, K & Mg contents between treatments. Further, significantly the lowest leaf N content could be observed with urea based fertilizer treatment R/U 12:14:14 compared to sulphate of ammonia based fertilizer treatments:

R/SA 7:9:9:3, R/SA 7:9:9:3 + 2K, modified new fertilizer mixture R/SA 7:4:18:6 (Table 7).

Table 5. *Effect of different fertilizer mixtures on plant girth of second year immature rubber plants*

Treatment	Plant girth (cm)
(T1) R/SA 7:9:9:3	14.1[a]
(T2) R/SA 7:9:9:3 +2K	14.3[a]
(T3) R/SA 7:4:18:6 (New mixture)	13.9[a]
(T4) R/U 12:14:14	13.0[a]

Table 6. *Effect of different fertilizer mixtures on plant girth of third year immature rubber plants*

Treatment	Plant girth (cm)
(T1) R/SA 7:9:9:3	21.3[a]
(T2) R/SA 7:9:9:3 +2K	16.6[b]
(T3) R/SA 7:4:18:6 (New mixture)	18.8[ab]
(T4) R/U 12:14:14	16.8[b]

Table 7. *Effect of different fertilizer mixtures on leaf nutrient contents of third year immature rubber plants*

Treatment	Leaf Nutrients			
	Leaf N (%)	Leaf P (%)	Leaf K (%)	Leaf Mg (%)
(T1) R/SA 7:9:9:3	2.84[a]	0.26[a]	0.96[a]	0.24[a]
(T2) R/SA 7:9:9:3 +2K	2.78[ab]	0.26[a]	0.98[a]	0.24[a]
(T3) R/SA 7:4:18:6 (New mixture)	2.68[b]	0.26[a]	0.96[a]	0.23[a]
(T4) R/U 12:14:14	2.54[c]	0.26[a]	0.95[a]	0.22[a]

(R P Hettiarachchi, V Edirimannne, T Gunathilake and G C Malawaraarachchi)

Slow release fertilizer application

Coir based slow release fertilizer application for immature rubber plants

An experiment was laid down at Raigama estate, Horana to study the effectiveness of encapsulated coir bricks (ECB) on soil fertility and their influence on mineral composition of rubber leaves and growth of RRISL 203 *Hevea* genotype. Plants were manured according to the experimental design mentioned in 2016 Annual Review. Nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg) containing fertilizer mixture R/U 12:14:14 and kieserite were applied as two different ECB and 100% RRISL recommended inorganic fertilizers for immature rubber was applied as the control treatment.

Plant girth measurements were taken at 120 cm from the ground level at the end of forty two months (3½ years) after commencement of the treatments. Plant girth showed no significant differences among treatments at the end of 3½ years after planting (Table 8).

Another experiment was started to evaluate the same treatment combinations at Geekiyanakanda estate in May 2018. Significantly higher plant girth could be observed ten months after planting with ECB treatments (T2 and T3) compared to control treatment (T1). Second measurement was taken at nineteen months after planting which showed significantly higher girth values with one ECB treatment (T2) compared to other treatments, T1 and T3 (Table 9). However, ECB treatments (T2 and T3) gave higher or equal growth parameters compared to control treatment (T1) in each and every interval at both experimental sites. On the above ground, there is a possibility of using single application of both ECB as a substitute for three/four application of conventional fertilizers recommended for immature rubber.

Table 8. *Effect of different fertilizer applications on growth of immature rubber plants at Raigama estate*

Treatments	**Mean girth (cm)**
	At the end of 42 months (3½ years)
(T1) Conventional fertilizer application	25.73[a]
(T2) ECB type 1	25.85[a]
(T3) ECB type 2	27.84[a]

Table 9. *Effect of different fertilizer applications on growth of immature rubber plants at Geekiyanakanda estate*

Treatments	**Mean girth (cm)**	
	At the end of 10 months	**At the end 19 months**
(T1) Conventional fertilizer application	7.02[b]	11.74[b]
(T2) ECB type 1	7.79[a]	15.42[a]
(T3) ECB type 2	7.57[a]	12.01[b]

Values in the same column followed by the same letter are not significantly different at p=0.05. (R P Hettiarachchi and K E de Silva)

Slow release fertilizer based reusable porous tube (RPT) application for immature rubber plants

An experiment was laid down at Ganepalla estate, Yatiyanthota to study the effectiveness of RPT on soil fertility, and their influence on the mineral composition of rubber leaves and growth of rubber plants. Young budding plants were established in the field and were manured according to the experimental design shown in Table 10.

Nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg) containing fertilizer mixture R/U 12:14:14 and kieserite were applied as two different RPT (T2 & T3) and 100% recommended inorganic fertilizers as the control treatment (T1).

Table 10. *Treatment combinations of the RPT experiment*

Treatment	Description
T1	275g of NPK mixture R/U 12:14:14 and 75 g of Kieserite in 4 application
T2	One application of RPT Type 1; NPK mixture R/U 12:14:14 and Kieserite mixed with filling medium No.1
T3	One application of RPT Type 2; NPK mixture R/U 12:14:14 and Kieserite mixed with filling medium No.2

Treatments were arranged in a randomized complete block design with five replicates and 25 plants per each replicate. RPTs were applied once at the beginning of the experiment and fertilizers for control treatment were applied at three months intervals as four split applications during the first year. Stem diameter was taken at 15 cm above the ground level of the plant at 6 months after the planting of young budding plants. At the same time, soil and leaf samples were collected for nutrient analysis and to assess other soil fertility parameters; soil pH and organic carbon content. The assessment of plant diameter, leaf nutrient contents of N, P, K and Mg showed significantly higher value with RPT type 2 (T3) compared to control treatment (T1). Further, RPT type 1 (T2) gave significantly higher or comparable values for the above mentioned assessments compared to control treatment (T1) (Table 11) (R P Hettiarachchi, V Edirimannne, T Gunathilake and M W H Gayan).

Table 11. *Effect of different fertilizer applications on growth and major leaf nutrient contents of immature rubber plants*

Treatments	Plant diameter (cm)	Leaf nutrients (%)			
		N	P	K	Mg
T1 (Control)	2.138^{b}	2.95^{b}	0.23^{b}	0.717^{c}	0.215^{c}
T2 (RPT type1)	2.192^{b}	3.08^{ab}	0.237^{ab}	0.782^{b}	0.240^{b}
T3 (RPT type2)	2.487^{a}	3.22^{a}	0.262^{a}	0.905^{a}	0.272^{a}

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

Soil fertility parameters were measured as organic carbon, total N, available P, exchangeable K and Mg also showed same pattern that could be observed related to leaf nutrients and plant diameter (Table 12).

Table 12. *Effect of different fertilizer application treatments on soil pH, organic carbon, total N, available P, exchangeable K, and Mg of the top 0-5 cm soil layer at the end of six months after planting*

Treatments	pH	Organic carbon %	Total N%	Available P (ppm)	Exchangeable K (ppm)	Exchangeable Mg (ppm)
T1 (Control)	5.6[a]	1.0[b]	0.10[b]	25.2[c]	60.4[c]	21.1[b]
T2 (RPT type 1)	5.6[a]	1.0[b]	0.11[a]	27.8[b]	63[b]	21.9[b]
T3 (RPT type 1)	5.8[a]	1.3[a]	0.12[a]	31.1[a]	68.1[a]	32.7[a]

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

Modification of fertilizer recommendations of *Hevea* with reference to plant, soil and field parameters (*Capital Project)* - 0363K

Nine and eleven different soil associations were identified and mapped in Colombo and Kurunegala districts respectively (Figs. 5 and 6). Estates were randomly selected as sampling sites in main soil associations in Colombo, Kurunagala and Ratnapura districts. Soil and leaf samples were collected for different analysis: soil samples were analyzed for 11 parameters and leaf samples were analyzed for major nutrients, Nitrogen, phosphorus, potassium and magnesium. Moreover, field parameters such as yield, growth, topography of the land, fertilizer application history and soil management practices were collected from the same sites to determine fertility levels of the lands accurately (Tables 13, 14 & 15).

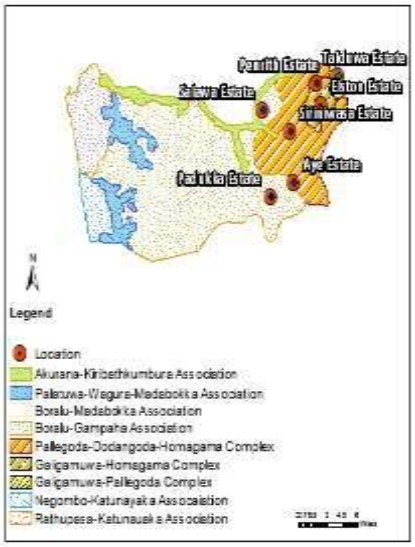


Fig. 5. Identification of different soil associations in Colombo district

Fig. 6. Identification of different soil associations in Kurunegala district

Table 13. *Identified sampling units in Colombo district and details of sample collection*

Sample associations	Site (Estate)	Extent (ha)	Data collection		Parameters analyzed
			Soil	Leaf	
Kurunegala-Kurunegala-Balangoda Assosiation	Pitiyakanda Group	80	10	10	150

Table 14. *Identified sampling units in Kurunegala district and details of sample collection*

Sample associations	Site (Estate)	Extent (ha)	Data collection		Parameters analyzed
			Soil	Leaf	
Undifferentiated soils variable and drainage derived from alluvial material	Mahawela	48.71	10	10	150

Table 15. *Identified sampling units in Ratnapura district and details of sample collection*

Sample associations	Site (Estate)	Extent (ha)	Data collection		Parameters analyzed
			Soil	Leaf	
Pallegoda-Dodangoda-Homagama Complex	Ayre	98.86	13	13	195
	Siriniwasa	71.54	12	12	180
Boralu-Gampaha Assosiation	Salawa	70	9	9	135
Galigamuwa-Homagama Complex	Elston	460	23	23	345

Services

Land selection and suitability for rubber cultivation

Under the routine land selection programme 500.5 hectares of land were surveyed for the suitability of rubber cultivation and four land suitability reports were issued. Details of the surveys are given in Table 16 (R P Hettiarachchi, G C Malawaraarachchi and all the staff of the department).

Table 16. *Details of the land selection program*

Place (GS Division)	Extent surveyed (ha)
Thibirigolla, Damana	12.0
Wadinagala, Damana	35.0
Paragahakele, Namaloya	8.5
Moneragala	355.0
Thanamalwila	90.0
Total	500.5

Site-specific fertilizer recommendation by soil and foliar survey programme

Under this programme 5,508 hectares of mature rubber fields were surveyed and 33 fertilizer recommendations were given for the next three years of 2020-2022. Details of the survey are given in Table 17 (R P Hettiarachchi, A Thewarapperuma and all the staff of the department).

Analytical services

Under this programme various samples received from estates, smallholders, universities and other private organizations were analyzed according to the SLS methods. Approximately 1,152 samples (4,787 parameters) including 377 fertilizer samples from rubber growers were analyzed to assure application of good quality fertilizers to their rubber lands. Analytical service issued 115 analytical reports and details of the service are given in Table 17 (R P Hettiarachchi, K E de Silva, V Edirimanna, and all the staff of the department).

Table 17. *Details of the Analytical services and Site Specific Fertilizer Recommendation program*

Name of the Company/Estate		Analytical services		Site specific fertilizer recommendation programme		Income	
		No of Reports	No of Samples	No of Reports	Surveyed Extent (ha)	Out Side Analytical service (Rs.)	Site Specific fertilizer recommendation programme (Rs.)
1	AgStar	1	1			675.00	
2	Ambedeniya estate	3	9			6075.00	
3	Atale estate	4	9			6075.00	
4	Bibila estate	2	10	1	222.40	9625.00	28912.00
5	CMW Factory	1	1			675.00	
6	Colombo	2	21			14175.00	
7	Edella estate	4	6			4050.00	
8	Eladuwa estate	3	15	1	94.99	10125.00	12348.70
9	Elston estate	1	1	1	429.59	950.00	55846.70
10	Etana estate	1	7			4725.00	

Name of the Company/Estate		Analytical services		Site specific fertilizer recommendation programme		Income	
		No of Reports	No of Samples	No of Reports	Surveyed Extent (ha)	Out Side Analytical service (Rs.)	Site Specific fertilizer recommendation programme (Rs.)
11	Frocester estate	2	27			22825.00	
12	Gannoruwa	1	31			20925.00	
13	Halpe estate	1	3	1	471.14	2025.00	61248.20
14	Halwathura estate	4	16			13675.00	
15	Hathbawa estate	3	8	1	136.10	5400.00	17693.00
16	Higgoda estate	1	5			3375.00	
17	Hilstream estate	1	9			6075.00	
18	kobowella estate	2	18			12150.00	
19	Madeniya estate	2	9	1	109.70	6075.00	14261.00
20	Mahaoya estate	15	16	1	568.65	10800.00	73924.50
21	Mirishena estate	3	30			28875.00	
22	Miriswatta estate	6	12	1	57.00	8100.00	7410.00
23	Miyanawita estate	6	9			6075.00	
24	National Fert. Secretariat	3	36			24300.00	
25	Neuchatel estate	2	27			30875.00	
26	Pallegama estate	2	17			11475.00	
27	Pallegoda estate	4	9			6075.00	
28	Palmgarden estate	1	5			3375.00	
29	Parambe estate	1	5			3375.00	
30	Pelawatta estate	4	12			8100.00	
31	Pitiyakanda estate	1	1			675.00	

Name of the Company/Estate		Analytical services		Site specific fertilizer recommendation programme		Income	
		No of Reports	No of Samples	No of Reports	Surveyed Extent (ha)	Out Side Analytical service (Rs.)	Site Specific fertilizer recommendation programme (Rs.)
32	Rajarata University	1	48			38525.00	
33	Rambukkanda estate	2	21			14175.00	
34	Salawa estate	1	2	1	234.01	1350.00	30421.70
35	Sapumalkanda estate	3	8	1	242.61	5400.00	31539.30
36	Sirikadura estate	3	6			4050.00	
37	Starr project	2	6			9050.00	
38	Sunderland estate	1	2			1350.00	
39	Udabage estate	7	16	1	69.94	10800.00	9092.20
40	Udapola estate	1	5			3375.00	
41	Weniwella estate	4	7	1	198.68	4725.00	25828.40
42	Yataderiya estate	1	2			1350.00	
43	Yatadola estate	2	4			2700.00	
44	Kelani estate			1	88.67		11527.10
45	Kalupahana estate			1	85.85		11160.50
46	Moralioya estate			1	155.82		20256.50
47	Baddegama estate				63.67		8271.90
48	Urumiwela estate			1	164.55		21391.50
49	Keragala estate			1	105.58		13725.40
50	Hunuwella estate			1	146.14		18998.20
51	Hulandawa estate			1	16.67		2167.10

Name of the Company/Estate		Analytical services		Site specific fertilizer recommendation programme		Income	
		No of Reports	No of Samples	No of Reports	Surveyed Extent (ha)	Out Side Analytical service (Rs.)	Site Specific fertilizer recommendation programme (Rs.)
52	Adawatta estate			1	65.00		8450.00
53	Shawland estate			1	26.05		3383.90
54	Dammaria B estate			1	54.47		7081.10
55	Kiribathgala estate			1	157.97		20536.10
56	Smallholder			1	20.40		1350.00
57	Illuktenna estate			1	90.16		11720.80
58	Reucastle estate			1	268.50		34905.00
59	Kiriporuwa estate			1	214.26		27853.80
60	Pambegama estate			1	314.00		40820.00
61	Madampe estate			1	157.00		20410.00
62	Madolsima estate			1	16.04		2085.20
63	Pussella estate			1	175.20		22776.00
64	Dewalakanda estate			1	287.67		37397.10
	Total	**115**	**512**	**33**	**5508.48**	**388625.00**	**714792.90**

BIOCHEMISTRY AND PHYSIOLOGY

K V V S Kudaligama

DETAILED REVIEW

Staff

Dr (Mrs) K V V S Kudaligama, Principal Research Officer covered the duties of the Head of Biochemistry & Physiology department whilst managing the research and development work of the department. Mrs N P S N Karunarathne, Research Officer, Mr M K P Perera, Experimental Officer, Mrs P D T L Madushani, Technical Officer, Mr L T B K Fernando, Technical Officer and Ms H A M E Hettiarachchi, Management Assistant were on duty throughout the year. Ms N N Abewardhana, assumed duties as a Technical Officer with effect from 22.08.2019.

Research students

Student name	University	Research Topic
AKD Malsha Binuwangi	University of Kelaniya	Induction training programme for Bachelor of Science
AMPD Abeykoon	University of Ruhuna	Induction training programme for Bachelor of Science (Agriculture)
BGIP Thilakasiri KMP Kumara KPCD Weerasooriya SMINP Senanayeka	Sri Lanka School of Agriculture, Labuduwa, Galle	Induction training programme of National Diploma in Technology (Agriculture)

Seminars/Conferences/Workshops/Exhibitions attended

Officer/s	Subject/Theme	Organization
KVVS Kudaligama	National Symposium on Sustainable Plantation Management 2019	NIPM
	IRRDB Conference – 2019	IRRDB
	Forum on Current Socio-economic Issues and their Impact on Rubber Production Sector Performance	RRISL
NPSN Karunarathne	National Symposium on Sustainable Plantation Management 2019	NIPM
	International Workshop on Statistical Applications in Socio-economic Research	RRISL

Officer/s	Subject/Theme	Organization
	Forum on Current Socio-economic Issues and their Impact on Rubber Production Sector Performance	RRISL
	Workshop on effective publication writing	University of Sri Jayawardenapura
	Workshop on Molecular Biology	Genetics & Plant Breeding Dept., RRISL

Training programmes conducted

Officer/s	Subject/Theme	
KVVS Kudaligama	Low intensity harvesting methods	Training program for Faculty of Agricultural Sciences, Aquinas University Collage
	Use of stimulant in low intensity harvesting	Induction Course for Planter Trainees, NIPM
	Use of stimulant in low intensity harvesting	Plantation Crop Production Technology- training program for Teachers
	Effective introduction of new LIH systems to address current issues in rubber plantation industry (capital project)	Training programs and technology transfer programs for RPCs, Smallholders, REOs, RDOs and Thurusaviya Officers

Field visits

Advisory - 66 visits
Experimental - 192 visits
Miscellaneous - 08 visits

Sample testing

% Dry rubber content of latex - 60 samples
Commercial Ethephon mixtures - 16 samples

LABORATORY AND FIELD INVESTIGATIONS

Low intensity harvesting to improve 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 with 2.5% oil based ethephon as the yield stimulant was continued in 04 tapping blocks of RRIC

121 genotype in Gallewatte division, Dartonfield estate which was replanted in 2010 (Field No: 2010/5.58). Daily yields were monitored as dry rubber content and volume of latex together with scrap weight. Average actual tapping days under S/2 d4 system was 76. In all four blocks average DRC% of latex was 40%. Variation of yield of blocks were mainly due to the degree of mixing clones (Table 1).

Table 1. *Average yield of four tapping blocks harvested with S/2 d4 system at Gallewatta division of Dartonfield estate*

Tapping system	Actual tapping days	DRC (%)	GTT (g)	IPH (kg)	YPT (kg)	YPH (kg)
S/2 d4-Block 1	77	40	48.26	14.48	5.72	1115
S/2 d4-Block 2	76	40	63.86	19.16	6.68	1456
S/2 d4-Block 3	76	40	56.51	16.95	6.61	1288
S/2 d4-Block 4	76	40	47.70	14.31	4.48	1088
Average	**76**	**40**	**54.08**	**16.23**	**5.87**	**1237**

Eight tapping blocks from 2010 replanting (Field No:2010/5.17) at Nivithigalakele division of Dartonfield estate have been selected for commercial level testing of S/2 d4 fields mixed with RRIC 121 and RRISL 203. Total number of tapping days under d4 frequency was 75 and average productivity of the field was 1586 kg. With the proportion of mixing of clones, productivity of the blocks varied (Table 2).

Table 2. *Average yield of eight tapping blocks harvested with S/2 d4 system at Nivithigalakele division of Dartonfield estate*

Tapping system	Actual tapping days	DRC (%)	GTT (g)	IPH (kg)	YPT (kg)	YPH (kg)
S/2 d4 Block 1	75	40	55.03	16.51	4.13	1651
S/2 d4 Block 2	75	40	48.80	14.64	3.66	1464
S/2 d4 Block 3	75	39	53.82	16.15	4.04	1615
S/2 d4 Block 4	75	40	52.95	15.88	3.97	1588
S/2 d4 Block 5	75	40	51.29	15.39	3.85	1539
S/2 d4 Block 6	75	40	63.78	19.13	4.78	1913
S/2 d4 Block 7	75	40	50.26	15.08	3.77	1508
S/2 d4 Block 8	75	40	46.92	14.08	3.52	1408
Average	**86**	**39.88**	**52.86**	**15.86**	**3.97**	**1586**

(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 rubber plantation industry (Special capital project 36.1.17)

Rs.109.564 Mn worth direct Treasury funds were received through a special capital project to popularize recommended low intensity harvesting systems to rubber growers in Sri Lanka. Overall objective of the project is to provide 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. Awareness programmes were conducted for Rubber Development Officers of Rubber Development Department attached to Kegalle, Rathnapura, Kalutara, Colombo, Gampaha, Kurunegala, Matale and Kandy Districts. To improve the knowledge on adaptation, 17 awareness programmes were conducted on RDO ranges of above districts and 103 ha of smallholdings were established with LIH systems (Table 3). Rubber Extension Officers of Advisory Services Department of RRISL were also trained on this.

Table 3. *District wise details of the smallholders established S/2 d4 low intensity harvesting systems*

District	No of smallholders	Extent (ha)
Kalutara	48	14.09
Kegalle	33	50.30
Rathnapura	5	2.56
Colombo	3	1.13
Gampaha	20	15.98
Kurunegala	11	8.99
Kandy	8	6.11
Total	**133**	**102.79**

In fourteen estates which belong to two Regional Plantation Companies, about 979 ha were established with S/2 d4 system (Table 4).

Table 4. *Details of estates established with S/2 d4 low intensity harvesting systems*

Estate	Extent (ha)
Elston	150.80
Pambegama	179.48
Keeragala	24.96
Hemingford	28.10
Pussella	139.08
Eheliyagoda	75.75
Sunderland	23.25

Estate	Extent (ha)
Halpe	125.50
Salawa	22.68
Ayr	92.79
Siriniwasa	19.81
Penrith	44.17
Diurampitiya	31.62
Hapugasthenna (Rubber)	20.60
Total	**978.59**

Awareness programmes for Officers, Field staff and workers of the Agalawatta Plantation PLC were conducted to facilitate establishing S/2 d4 harvesting system in their estates (K V V S Kudaligama, V H L Rodrigo, P Seneviratne, N P S N Karunarathne, M K P Perera, L T B K Fernando, P D T L Madushani and N N Abewardhana).

Effectiveness of commercially available water-based and oil-based ethephon formulations as yield stimulants for rubber

Two types of commercial ethephon mixtures *i.e.* water-based and oil-based presently marketed in Sri Lanka as yield stimulants of rubber were tested for their effectiveness. Though the yield performance of these mixtures had been studied, no proper investigation had been done on effectiveness on factors affecting latex regeneration and latex flow.

Mature rubber plantation with RRIC 121 genotype tapped on BO-1 with S/2 d4 (half spiral once in four days) system with monthly application of 1.6g of 2.5% ethephon was selected for the study. Yield related factors and latex physiological parameters of trees stimulated with two types of commercial ethephon mixtures were determined on each tapping day.

Daily latex volume per tree, daily dry rubber yield per tree (g/t/t), latex thiol content, latex polyphenol content, plugging index showed a similar pattern of variation between the trees stimulated with water-based and oil-based ethephon over the period observed and the variations were statistically insignificant between the two types of stimulations (Table 5).

Oil-based ethephon stimulated trees had a significantly higher latex dry rubber content than water-based ethephon. Average inorganic phosphorous content was significantly higher in trees stimulated with water-based ethephon than with oil-based ethephon. In most of the tapping days, flow duration with oil based stimulation is more than that with water based stimulation (Table 5). Even though the physiological parameters of latex showed some variations between the two types of ethephon, yielding capacity for a particular period did not vary significantly between trees applied with water-based and the oil-based ethephon (N P S N Karunarathne, K V V S Kudaligama, P D T L Madushani, L T B K Fernando 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 in Kandakadu (Dry zone)

Growth and physiological performances of five different genotypes were assessed during 2019 in the field established at Kandakadu Army Farm. Stomatal conductance of leaves of different clones was assessed with different environmental factors (Table 6). Highest stomatal conductance was observed in RRIC 121 throughout the day whilst lowest was reported in PB 260 clone. The highest gap of variation of stomatal conductance during the morning and evening time of the day (23.92 cm/s) was observed in RRISL 2001 clone. Further, it could be observed that diurnal performance of RRISL 2001 in stomatal conductance with other environmental parameters is opposite from other *Hevea* genotypes tested during the study. Stomatal conductance of RRISL 2001 was observed to be reduced with increasing environmental temperature, increasing wind speed and decreasing relative humidity whilst other genotypes showed the opposite relationships. (Fig. 1, Table 6).

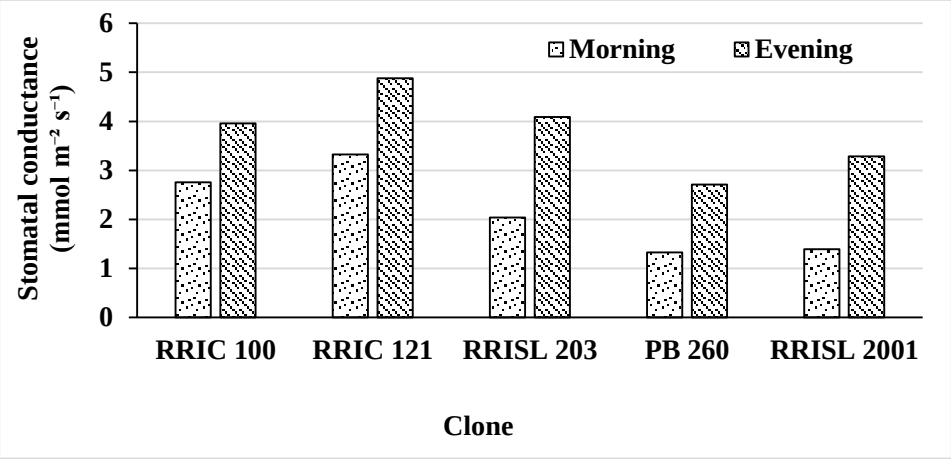


Fig. 1. Average stomatal conductance of different *Hevea* clones planted at Kandakadu experimental site

Table 6. *Average environmental condition at the time of measuring*

	Morning	Evening
Wind speed (kmph)	5.81	11.11
Temperature (^{0}C)	32.32	34.13
Relative humidity (%)	66.63	56.95

According to the results obtained, variation of height of different clones planted in fields at Kandakadu is PB 260> RRIC 121> RRIC 100> RRISL 203> RRISL 2001 as shown in Table 7. When considering height, number of whorls and stem diameters at different heights, better growth performance was observed in RRIC 121 out of five *Hevea* genotypes planted (K V V S Kudaligama, N P S N Karunarathne, M K P Perera and P D T L Madushani).

Table 7. *Average growth performances of the clones planted in Kandakadu experimental field*

Clone	# of Whorls	Stem diameter at different heights (cm)			Height (cm)
		at 01 inch	at 01 foot	at 02 feet	
RRIC 100	4	4.172	3.333	2.932	310.31
RRIC 121	4	4.504	3.553	3.125	352.10
RRISL 203	3	3.763	2.972	2.595	270.13
RRISL 2001	3	3.641	2.933	2.578	263.33
PB 260	3	3.167	2.524	2.205	370.00

Growth and physiological performance of different clones planted in Padiyathalawa (Intermediate zone)

Comparison amongst 10 different *Hevea* clones established in intermediate zone with regard to height, number of whorls and stem diameters at different heights are given in Table 8. RRIC 121 > RRISL 203> RRISL 2001> Centennial 3> RRISL 201> Centennial 4> RRIC 100> RRISL 2100> RRIC 102 are in the descending order in height of the tested clones reported during 2019. When considering number of leaf whorls, height and stem diameters at different heights, RRIC 121 clone has performed better than the other clones tested.

Table 8. *Average growth performances of the clones planted in Padiyathalawa experimental field*

Clone	# of Whorls	Stem diameter at different heights (cm)			Height (cm)
		01 inch	01 foot	02 feet	
Centennial 4	4	3.793	2.998	2.622	289.94
RRIC 102	2	2.224	2.208	1.840	128.61
RRISL 203	4	3.477	2.894	2.583	327.57
RRIC 121	4	3.605	3.114	2.666	349.31
RRIC 100	3	3.363	2.955	2.482	259.15
RRISL 2001	5	3.767	3.048	2.725	315.91
Centennial 3	4	3.462	2.910	3.050	311.73
RRISL 201	4	3.467	2.708	2.393	310.30
RRISL 2100	3	2.873	2.243	1.897	221.21

Growth and physiological performance of different clones planted in Meerigama (Wet zone)

The descending order of heights of different clones planted at Meerigama is RRISL 203> RRIC 121> RRISL 2001> PB 260 as shown in Table 9. Out of different *Hevea* genotypes, RRISL 203 performed better in growth parameters tested.

Table 9. *Average growth performances of the clones planted in Meerigama experimental field*

Clone	# of Whorls	Stem diameter at different heights (cm)			Height (cm)
		01 inch	01 foot	02 feet	
RRISL 203	5	6.017	5.003	4.413	493.46
RRISL 2001	5	5.584	4.722	4.132	409.18
RRIC 121	4	5.383	4.498	4.045	472.77
PB 260	4	4.287	3.529	3.045	305.91

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

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

Effect of biochemical components of latex that effect on quality of raw rubber

The aim of this study is to investigate the effect of different biochemical constituents on quality of raw rubber and to identify the relationship between each biochemical constituent with raw rubber properties. Polyphenols, proteins, thiols and carotenoids are major non- rubber components found in latex and available in different concentrations in different clones. During this study, contents of these constituents of five different clones were investigated along with raw rubber properties during high yielding (August - October) and wintering (February - April) periods (Fig. 2).

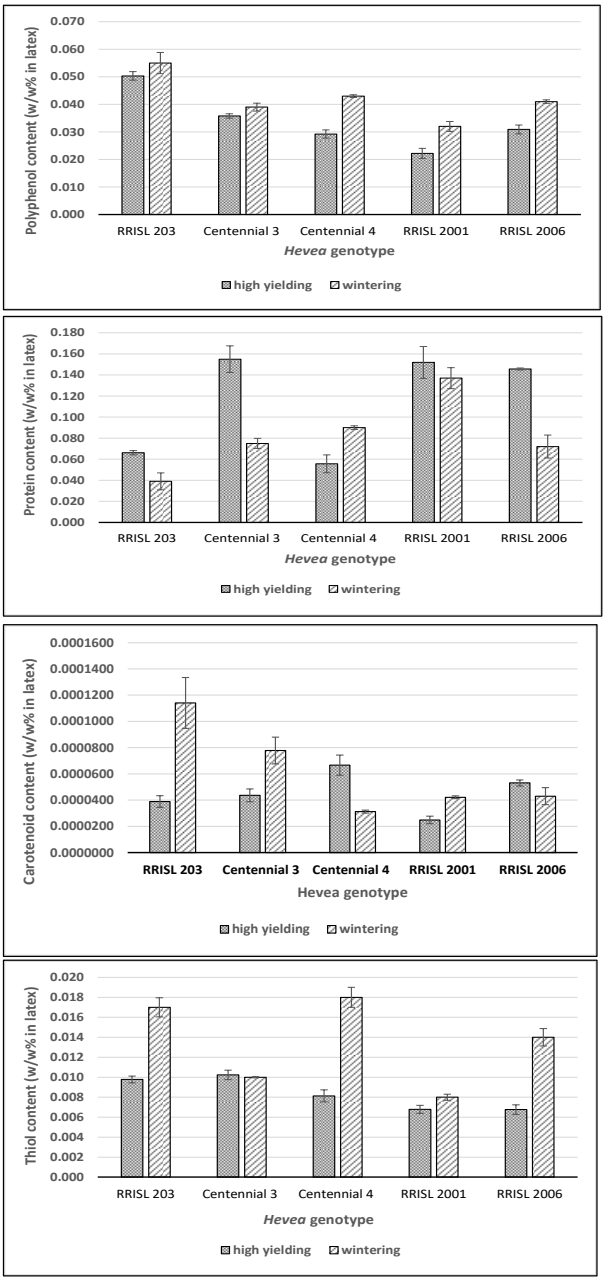


Fig. 2. Changes in biochemical components in rubber latex of selected *Hevea* genotypes during high yielding and wintering periods

In all clones polyphenol content during wintering season was higher than that during high yielding period. Highest polyphenol content which causes enzymatic browning of rubber could be observed in latex of RRISL 203 genotype during both high yielding and wintering periods amongst the *Hevea* genotypes tested. In both high yielding and wintering periods, the highest protein content was found in RRISL 2001 rubber clone. Even though, higher carotenoid contents could be observed in RRISL 203 and Centennial 3 clones during wintering season, Centennial 4 had the highest carotenoid content in the high yielding period. An increase of thiol content was observed during the wintering season than the high yielding season in most of the clones. Of the clones tested, RRISL 203 and Centennial 4 had relatively higher contents of thiol during wintering period whilst no significant change was observed during high yielding period (Fig. 2) (N P S N Karunarathne, K V V S Kudaligama, P D T L Madushani and N N Abewardhana).

Biochemical and physiological screening of HP progenies

Biochemical and physiological assessment of latex of nine *Hevea* HP progenies along with RRISL 203 *Hevea* genotype as the reference clone was carried out at Yatadola estate on request of Department of Genetics & Plant Breeding. The contents of sucrose, inorganic phosphorus, thiol, polyphenols and dry rubber were determined as latex diagnostic tests during high yielding and wintering periods (Table 10).

Table 10. *Average sucrose (Suc), inorganic phosphorus (Pi), thiol (RSH), polyphenols (PP) and dry rubber content (DRC) of latex of different Hevea HP progenies and RRISL 203 clone during wintering (W) and high yielding (HY) periods*

HP progenies evaluation - Yatadola estate										
HP	**Suc (mM)**		**Pi (mM)**		**RSH (mM)**		**PP (mM)**		**DRC %**	
Progeny	**HY**	**W**	**HY**	**W**	**HY**	**W**	**HY**	**W**	**HY**	**W**
95/19	3.50	22.18	5.14	8.30	0.40	0.79	2.89	4.60	47.23	38.99
95/21	7.39	3.80	4.60	7.57	0.35	0.59	2.01	2.40	43.72	37.86
81/69	9.55	21.74	1.25	7.22	0.40	0.44	2.49	2.61	51.92	36.48
95/33	3.54	8.47	1.22	3.66	0.19	0.37	2.28	2.91	50.98	35.66
95/23	9.46	7.83	8.75	11.23	0.45	0.43	2.16	2.19	54.04	37.30
95/13	8.28	16.15	0.69	3.66	0.34	0.68	1.62	3.19	50.51	37.55
95/1	4.39	4.40	1.01	12.05	0.53	0.58	2.12	2.65	52.87	34.79
95/47	2.70	2.06	7.03	5.99	0.74	0.69	2.34	2.28	52.15	28.12
95/29	4.74	7.18	12.42	4.05	0.58	0.56	1.96	2.29	41.30	42.83
RRISL 203	10.47	7.08	1.77	8.33	0.57	0.27	2.28	3.59	50.12	30.16

According to the results, 95/23 and 95/47 HP progenies physiologically performed better compared to other HP progenies with higher latex inorganic phosphorus content, thiol content and DRC%. Even though, high DRC% and thiol content were found in HP 95/1 progeny, a very low value could be observed for latex inorganic phosphorus content. HP 95/29 progeny showed high inorganic phosphorus and thiol contents in latex whilst DRC% was lower during high yielding period. However, DRC% was found at a higher value compared to the other progenies during wintering period (Table 10) (N P S N Karunarathne, K V V S Kudaligama, P D T L Madushani and N N Abewardhana).

Development of in-country ethephon formulations to promote low cost harvesting systems for rubber plantations in Sri Lanka (National Science Foundation funded project No: RG/2017/AG/1)

Efficacy of a new ethephon formulation was tested against a commercially available formulation with small scale field trial. No significant variation had been observed in sucrose availability in laticifers with new ethephon formulation. Significantly higher thiol and lower inorganic phosphorous content of latex in trees may ensure long term sustainability of new ethephon formulation as a yield stimulant in *Hevea* (Fig. 3).

Duration of latex flow with existing ethephon formulation was significantly lower than that with new formulation. Average initial flow rate of trees applied with new formulation showed statistically significant decrease over existing formulation. Respective average initial flow rate values of new and existing formulations were 4.34 ml/min. and 4.74 ml/min. Plugging index of trees showed a significant difference among two ethephon formulations with averages of 2.00 and 2.47 with new and existing formulations, respectively (Table 11).

Average daily volume of latex per tree with application of new and existing formulations was 208ml and 223ml, respectively and statistically comparable. The DRC of latex varied in a similar pattern with both ethephon formulations, and significant variation has not been observed among two formulations. Dry rubber yield obtained from a tree with both ethephon formulations was statistically comparable. Average daily dry rubber yield of a tree was 83.32g and 87.75g, respectively with new and existing formulations (Table 11).

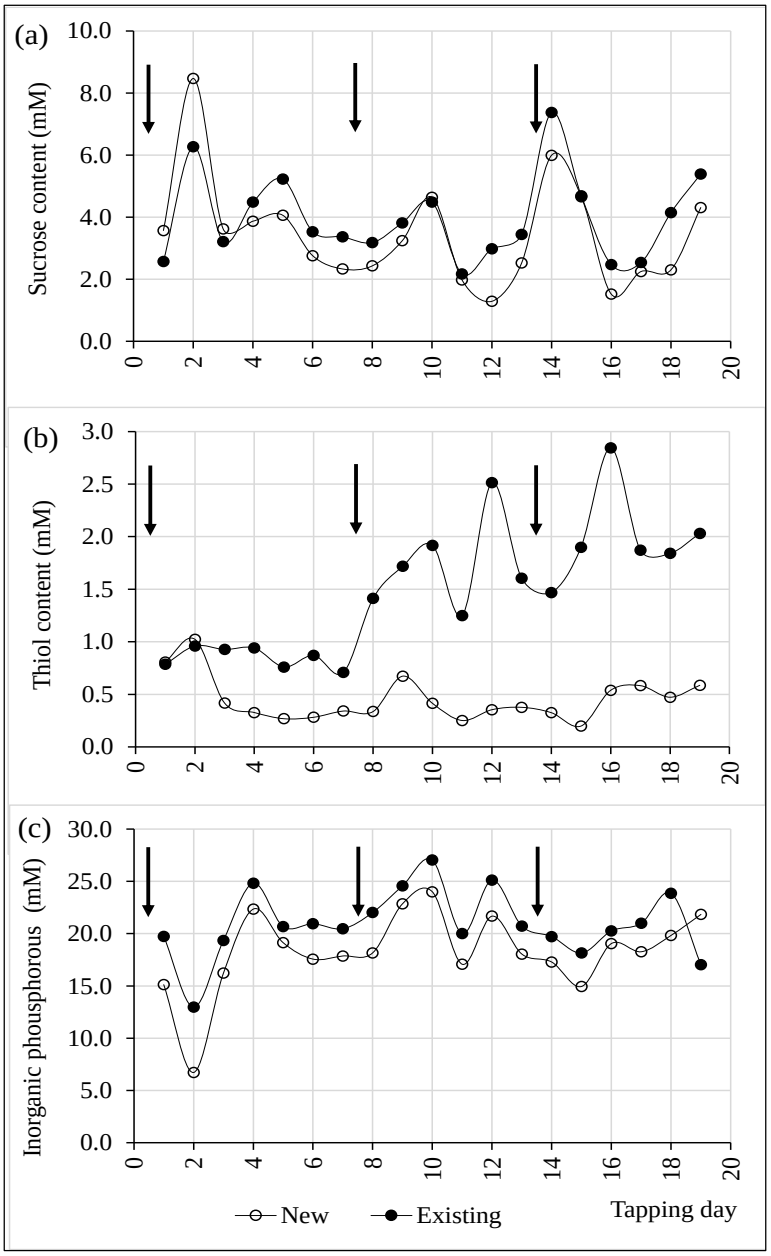


Fig. 3. Variation of latex (a). sucrose, (b). thiol and (c). inorganic phosphorous content of trees stimulated with two ethephon formulations (Time of ethephon application is indicated by arrows)

Table 11. *Average values of yield and latex flow parameters of trees stimulated with two ethephon formulations*

Yield and latex flow parameters	New ethephon formulation	Existing ethephon formulation
Latex volume per tree (ml)	207.90 ± 14.73	222.70 ± 15.68
Dry rubber content (%)	40.63 ± 0.50	39.78 ± 0.50
Latex yield per tree per tapping (g)	83.32 ± 4.97	87.75 ± 5.42
Latex flow duration (min)	180 ± 0.92	155 ± 0.81
Initial flow rate (ml/min)	4.34 ± 0.17	4.74 ± 0.18
Plugging index	2.00 ± 0.08	2.47 ± 0.14

Rubber field established in 2011 at Elston estate, Puwakpitiya has been selected to investigate effectiveness of locally formulated new formulation (Local-W) with two commercial ethephon mixtures available in the local market (*i.e*. Imported-M and Imported-E). Tapping system used was S/2 d4 system with application of 0.6g of 2.5% ethephon per tree at a rate of 10 rounds per year avoiding wintering period. Tapping had been started in 2018. Experiment was started in June, 2018. Tapping task size is 317 trees/tapper and for each formulation three tapping blocks were allocated. Intake per harvester in blocks applied with Local-W, Imported-W and Imported-M was 13.68, 14.13 and 13.53kg, respectively. Observed yield per hectare was 1554, 1606 and 1536 kg, respectively (Table 12).

Table 12. *Variation of yield parameters harvested with S/2 d4 system using different types of ethephon formulations*

Ethephon formulation	Intake per harvester (kg)	Actual yield per hectare (kg/yr)
Local-W	12.95	1554
Imported-M	13.38	1606
Imported-E	12.80	1536

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

Table 5. *Comparison of yield and physiological parameters of oil based and water based ethephon stimulated trees over the period studied*

Yield and physiological parameter	June		July		August	
	Oil based	**Water based**	**Oil based**	**Water based**	**Oil based**	**Water based**
Sucrose content (mM)	4.94±0.31[a]	4.08±0.23[b]	3.51±0.25[a]	3.40±0.17[a]	3.85±0.26[a]	3.92±0.28[a]
Inorganic phosphorus content (mM)	16.93±0.50[a]	20.75±0.54[b]	18.56±0.71[a]	22.87±0.47[b]	17.07±0.55[a]	20.68±0.33[b]
Thiol content (mM)	0.35±0.02[a]	0.37±0.02[a]	0.37±0.02[a]	0.39±0.02[a]	0.39±0.02[a]	0.42±0.02 [a]
Polyphenol content (mM)	1.71±0.04[a]	1.74±0.03[a]	1.49±0.06[a]	1.56±0.07 [a]	1.69±0.08[a]	1.71±0.08[a]
Dry rubber content in latex (%)	43.80±0.37[a]	40.63±0.36 [b]	42.69±0.47[a]	39.39±0.42[b]	42.13±0.50[a]	39.59±0.36[b]
Latex volume per tree (ml)	171.24±11.61[a]	161.43±11.96[a]	217.43±15.2[a]	220.86±15.65[a]	237.71±12.59[a]	239.33 ± 12.14[a]
Latex yield per tree per tapping (g)	82.66±4.28[a]	71.64±3.64[a]	92.19±5.80[a]	86.25±5.57[a]	101.61±5.45[a]	96.91±5.03[a]
Plugging index	2.44±0.09[a]	2.45±0.12[a]	2.42±0.11[a]	2.42±0.12[a]	2.57±0.93[a]	2.31±0.93[a]
Latex flow duration (min)	151.85±2.46[a]	151.33±2.33[a]	164.19±1.11[a]	148.29±1.77[b]	161.76±0.75[a]	151.61±2.14[b]

Note: Monthly means with same letters of each parameter are not significantly different at $p < 0.05$.

ADVISORY SERVICES

A Dissanayake

DETAILED REVIEW

Staff

The Head of the Department, two Regional Advisory Officers (RAOo), twenty one Rubber Extension Officers (REOo) and the Assistant Training Officer were on duty throughout the year. Mr P V S Madhubashana, E W S Ruwan Kumara, R R N D Thara and Nishantha De Silva were recruited as a Rubber Extension Officers and appointed to the Galle, Rathnapura and Kaluthara ranges. Mr R A D Ranawaka, Regional Advisory Officer Mr M Dharmadasa, Rubber Extension Officer Mrs Chithra, and Mrs Manori Kumari, Management Assistant retired from the service of ASD during the year under review. Mr J A Sarath Chandrasiri, Experimental Officer of the Plant Nutrition and Soil Science department and Ms Sachini Pothuwila, Management Assistant of Board office were transferred to the Advisory Services Department.

Conferences/Meetings/Seminars/Workshops/Foreign tours attended

Officer/s	Subject/s	Organization/s
A Dissanayake PKKS Gunaratna	IRC (International Rubber Conference) - Myanmar 2019	IRC
A Dissanayake PKKS Gunaratna	Progress Review Meetings	Ministry of Plantation Industries
A Dissanayake PKKS Gunaratna	Scientific Committee Meetings Technology Update Programmes Research Meetings	Rubber Research Institute of Sri Lanka
A Dissanayake PKKS Gunaratna	7th Symposium on Plantation Crop Research - RRISL	Rubber Research Institute of Sri Lanka
PKKS Gunaratna	IRRDB Fellowship and Training Programme, Thailand	IRRDB
PKKS Gunaratna	Workshop on “Combined Programme - Forward March Rubber Village” at Rubber Development Department	Rubber Development Department
PKKS Gunaratna	Workshop on “Adoption of New Extensionists Approach in AES in Sri Lanka” at Coconut Cultivation Board	Coconut Cultivation Board
PKKS Gunaratna	Meeting on Rubber Umbrella Programme	District Secretariat Office - Kegalle, Warakapola

PROGRESS OF PROJECTS AND SERVICES

Extension and advisory programmes were carried out under 04 thrust areas, to improve the productivity of the rubber smallholder sector, through enhancing the adoption rate of recommended technologies by RRISL.

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

Project 1 (ASD/01/A) Participatory development of selected rubber holdings 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). 46 immature and 58 mature holdings were fully developed as models (Fig. 1).

Fig. 1. Mature model rubber holding – Mr Shehan Senevirathne (Ruwanwella REO range)

Table 1. *Details of participatory development of selected rubber holdings*

Region	**No. of developed holdings**	
	Mature	**Immature**
Colombo/Gampaha	1	1
Kegalle	15	25
Kalutara	18	18
Ratnapura	2	3
Galle/Matara	10	11
Total	46	58
	104	

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

Advisory and extension support services were provided to maintain 18 "Model Rubber Processing Centres" to demonstrate the importance of the adoption of recommended practices to improve the quality of RSS to obtain maximum economic returns (Fig. 2) (Table 2).

Fig. 2. Model rubber processing center – B V Chandrawathi (Palindanuwara range)

Table 2. *Participatory development of rubber processing centers*

Region	No. of model centers developed
Colombo/Gampaha	2
Kegalle	7
Kalutara	4
Ratnapura	2
Galle/Matara	3
Total	18

Project 3 (ASD/01/C) Promotion of usage of rain guards

To popularize the rain guard technology as a short term strategy to increase the productivity of rubber smallholders, 31 demonstration plots were established under the supervision of Rubber Extension Officers (Table 3).

Table 3. *Details of rain guard demonstration holdings*

Region	No. of demonstration holdings established
Colombo/Gampaha	2
Kegalle	8
Kalutara	15
Ratnapura	2
Galle/Matara	4
Total	**31**

Project 4 (ASD/01/D) Construction, rehabilitation and modification of new and substandard Rubber Processing Centers

Advisory and extension services were provided for construction of 28 new RSS Production Centres and rehabilitation of 04 substandard processing centers, to maintain them as cost effective units according to the requests of owners (Table 4) (Fig. 3).

Fig. 3. Construction of a Rubber Processing Center – A K Konara (Gampaha range)

Table 4. *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	15	0
Kalutara	7	1
Ratnapura	2	1
Galle/Matara	3	2
Total	**28**	**4**

Project 5 (ASD/01/E) Promotion of area specific intercropping and mixed cropping systems

To popularize area specific intercropping systems to increase the income during immature period of rubber smallholdings, 4 intercropping demonstration plots were established (Table 5).

Table 5. *Area-specific intercropping and mixed cropping demonstration holdings*

Region	No. of demonstration	Type of intercrops
Kegalle	2	Pineapple - 02
Kalutara	1	Cocoa - 01
Ratnapura	1	Banana - 01
Total	**4**	

Project 6 (ASD/01/G) Participatory development of "Forward march" model rubber villages

The concept of establishment of "forward march rubber villages" is widen with the selection 03 villages (Ihala Naragala - Bulathsinhala REO range, Amithirigala - Yatiyanthota REO range and Yatiyana - Hakmana REO range) to up-grade as model villages. Basic data and information were collected and action plans were prepared. The project is in progress.

Project 7 (ASD/01/H) Projects related advisory visits in traditional rubber growing areas

Two thousand ninety nine pre-planned advisory visits were conducted by Rubber Extension Officers to solve technology adoption problems in the smallholdings selected for different projects of the ASD (Table 6).

Table 6. *Details of projects related advisory visits*

Region	Nature of advisory visit						
	Model farm development	Introduction of Intercropping Systems	Introduction of rain guard technology	Maintenance of model RSS	Construction of new RSS centers	Rehabilitation of substandard	Total
Colombo/Gampaha	43	0	07	8	9	0	**67**
Kalutara	294	06	105	30	81	7	**958**
Kegalle	275	14	79	42	78	0	**488**
Rathnapura	181	06	25	44	20	5	**281**
Galle/Matara	203	0	35	25	24	18	**305**
Total	**996**	**26**	**251**	**149**	**212**	**30**	**2099**

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

Project 8 (ASD/2/A) Individual advisory visits and demonstrations on requests of rubber smallholders

One hundred twenty five advisory visits and 27 demonstrations were made by REOo to solve technology adoption problems of rubber smallholders in relation to all agronomic and processing aspects (Table 7). A separate report was prepared by REOo on each visit and follow up actions were attended where necessary (Table 8).

Table 7. *Conducted demonstrations on requests of rubber stakeholders*

Type of demonstration	No. of demonstrations
Immature	
Removal of branches	2
Planting	1
Mature	
New panel marking	8
Tapping correction	2
Fertilizer application	1
Rain guard	1
New tapping knife	5
Disease	3
Other	2
Processing	
Sheet making	1
Other	1
Total	**27**

Table 8. *Details of individual advisory visits conducted on requests of stakeholders*

Region	No. of advisory visits made by REOo			
	Immature	**Mature**	**Processing**	**Total**
Colombo/Gampaha	2	12	3	17
Kegalle	1	26	9	36
Kalutara	7	38	4	49
Ratnapura	1	2	1	4
Galle/Matara	6	12	1	19
Total	17	90	18	125

The above advisory visits were categorized as follows (Fig. 4, 5 and 6).

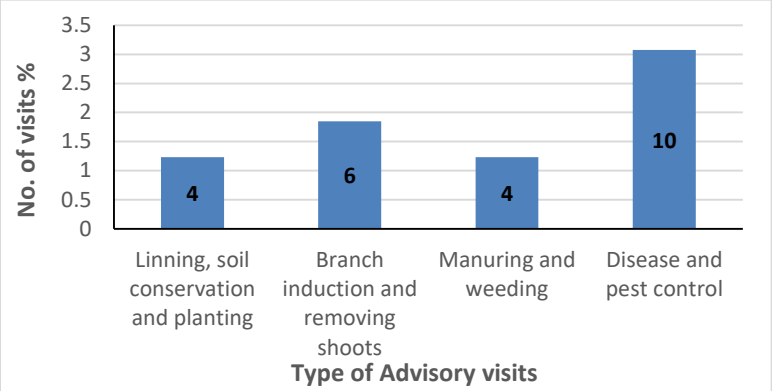


Fig. 4. Number of advisory visits conducted in immature holdings

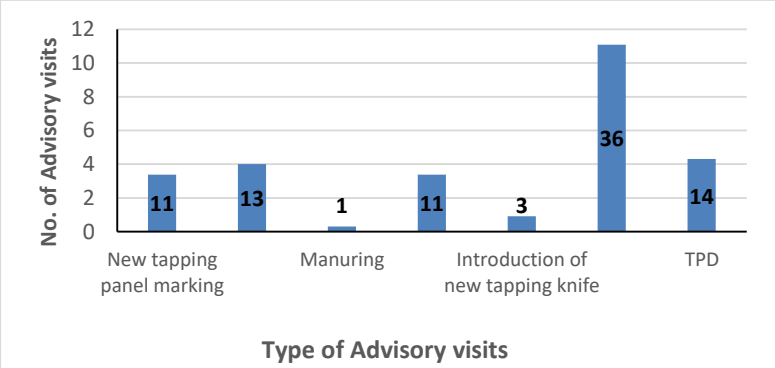


Fig. 5. Number of advisory visits conducted in mature holdings

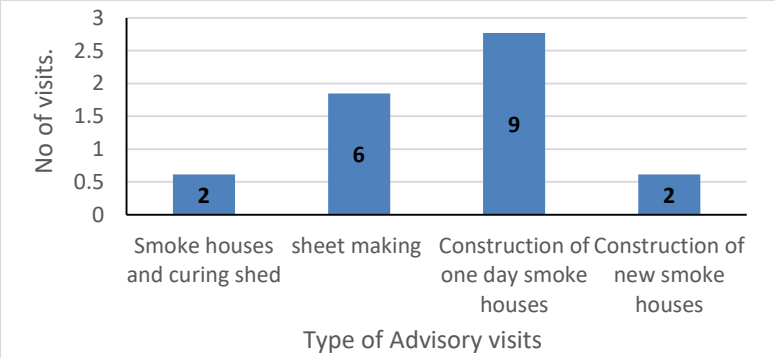


Fig. 6. Number of advisory visits conducted in processing centers

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, group extension programme called "*Vihidum Sathkara"* was effectively conducted for 259 small land units in traditional rubber growing areas for necessary improvements. A schematic representation of this activity is given in Figure 7.

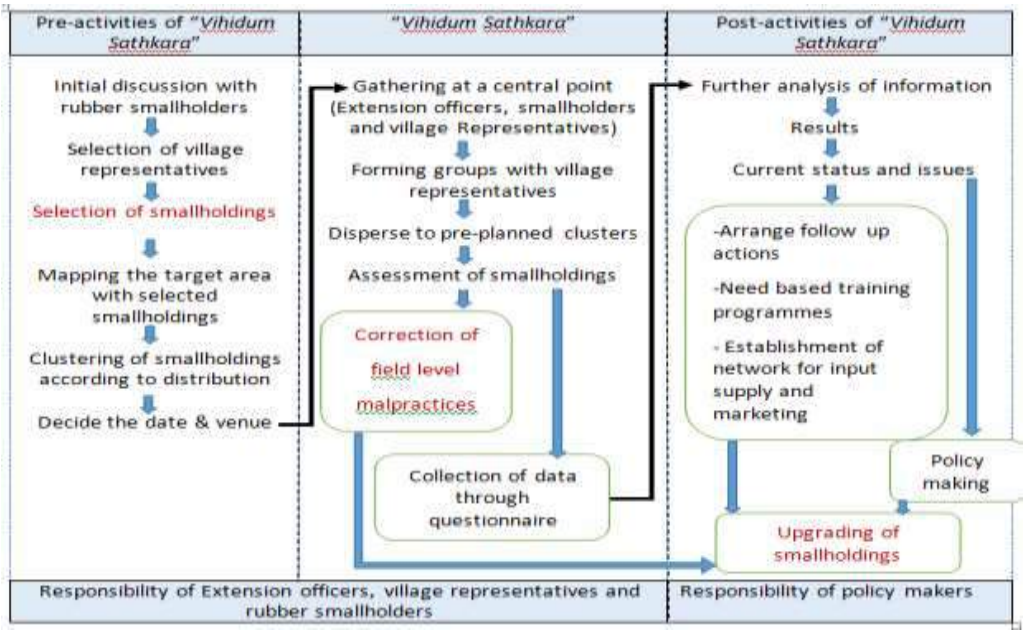


Fig. 7. Schematic representation of "Vihidum Sathkara" group advisory programme

Thrust area 03: Human resource development of all stake holders of the rubber smallholder sector

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

Farmer awareness training programmes were conducted to educate 122 smallholders and 244 estate staff (Field Officers and estate workers) on general cultivation and processing aspects of rubber and rain guard (Fig. 8). Participation from each estate for awareness programmes on general cultivation and processing aspects of rubber and rain guard can be summarized as below (Tables 9, 10 & 11).

Table 9. *Details of farmer participation for awareness programmes on general cultivation and processing aspects of rubber in estate sector*

Name	No. of participants
Kegalle Plantation (Field Officers)	28
Balangoda Plantation (Field Officers)	34
Elpitiya Plantation (Field Officers)	39
Total	**101**

Table 10. *Details of farmer participation for Awareness programmes on rain guard in estate sector*

Name	No. of participants
Halpe estate (RG Awareness programme)	13
Ayre estate (RG Awareness programme)	14
Salawa estate (RG Awareness programme)	39
Siriniwasa estate (RG Awareness programme)	47
Penrith estate (RG Awareness programme)	25
Total	138

Table 11. *Details of Tapper Training Programmes conducted for rubber tapper (smallholder sector)*

Region	No. of programmes	No. of semi-skilled tappers trained
Kegalle	1	17
Kalutara	1	20
Galle	1	85
Total	4	122

Fig. 8. Conducting field level awareness raising programme at Balangoda Plantation

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

As a solution to the tapper shortage in rubber growing areas, a programme covering both practical and theoretical aspects was conducted and 150 new Harvesting Assistants were introduced to the rubber industry after 10 days of training (Figs. 9 & 10) (Table 12).

Fig. 9. Conducting field level awareness raising programme at Sunderland estate

Fig. 10. Mobile tapper training school at Ratnapura Technology Transfer Center at Kiriella

Table 12. *Details of Tapper Training Programmes conducted for rubber tapper (smallholder sector)*

Region	No. of programmes	No. of new tappers trained
Kegalle	1	9
Ratnapura	1	55
Galle	2	86
Total	4	150

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

To upgrade the knowledge and skill levels of semi-skilled Harvesting Assistants, skill development training programmes were conducted to improve the quality of tapping of 273 selected Harvesting Assistants for smallholder sector and estate sector (Table 13 & 14) (Fig. 11).

Table 13. *Details of skill development programmes conducted for semi-skilled rubber tappers (smallholder sector)*

Region	No. of programmes	No. of semi skilled tappers trained
Colombo	1	65

Table 14. *Details of skill development programmes conducted for semi-skilled rubber tappers (estate sector)*

Region	No. of programmes	No. of semi skilled tappers trained
Pussellawa Plantation	1	70
Sanquar estate	1	21
Elpitiya Plantation	2	117
Total	4	208

Fig. 11. Tapping skill development programme conducted at Pussellawa Plantation

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

To improve the product quality of RSS produced by rubber smallholders, a full day training programme was conducted for the benefit of 10 selected RSS producers in Kegalle district at Technology Transfer Center, Kegalle.

Project 14 (ASD/03/G) Involvement of exhibitions

Contribution was made in one public exhibition (02 days) conducted at Rajarata University of Sri Lanka, Faculty of Agriculture.

Project 15 (ASD/03/F) Involvement of resource personnel

On request of different organizations following programmes were attended by REOs as resource personnel (Table 15).

Table 15. *Details of the services provided by REOs*

Name of the programme	Organization	Number of programmes
Quality improvement of RSS (One day)	Thurusaviya Fund	06
Farmer awareness (One day)	Thurusaviya Fund	08
Harvesters training (Fourteen days)	Thurusaviya Fund	07
Rainguard Awareness Programme	Thurusaviya Fund	02
Tapper Tanning School (One day)	Rubber Development Department	03
Rainguard Awareness Programme	Rubber Development Department	01
Special Programme on tapping at Vavuniya	Adaptive Research Unit of RRISL	01
Awareness programme for Rubber Development Officers, Thurusaviya Ofiicers and Rubber Extension Officers	Nivithigalakale Training Center	01
Awareness programs for students of Faculty of Agriculture, Rajarata University at Lalan Rubber Company and Polgahawela Epa Kanda estate	Rajarata University	01
Farmer awareness and training program (One day) in Monaragala and Ampara districts	STaRR Project	18
Awareness and tanning programs for field level Officers (One day) at DS division level	District Secretariat Office-Kegalle, Warakapola	02
Preparation of Hand book on field activities for Rubber smallholders in Non - traditional rubber growing areas	STaRR Project	01
Special Advisory visits at Monaragala, Haliela and Bandaragama	Rubber Development Department	03
Rubber Organic Plantation Certification programme	Lalan Rubber Company	01

Name of the programme	Organization	Number of programmes
Conducted lectures for Officers of Thurusaviya Fund	Thurusaviya Fund	01
Conducted lectures for Officers of Rubber Development Department	Rubber Development Department	01
Awareness Programmes for Officers of STARR Project	STaRR Project	01

Thrust area 04: Development of effective extension network in the smallholder rubber sector

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.

b) Rubber Techno Park at Monaragala substation

Road constructions in selected area for Techno Park at Monaragala substation was completed. Preparation of technical banners and other field works were in progress**.**

Introduction and establishment of new fuelwood growing models in selected lands of smallholder rubber farmers

A new project was started in 2017 as "Introduction and Establishment of new fuelwood growing models in selected lands of smallholder rubber farmers" under FAO funds with the collaboration of Biometry and Economics divisions. Eight different growing models were established for rubber smallholders as follows.

1. Rubber – Gliricidia – Pepper: Rubber spacing (8' x 27') (RGP)
2. Rubber – Gliricidia – Pepper: Rubber spacing (8' x 40') (RGP)
3. Rubber – Gliricidia – Pepper: Rubber spacing (8'x 60') (RGP)
4. Rubber – Gliricidia: Rubber spacing (8'x 27') (RG)
5. Rubber – Gliricidia: Rubber spacing (8' x 40') (RG)
6. Rubber – Gliricidia: Rubber spacing (8 'x 60') (RG)
7. Gliricidia – Pepper (8'x 8')
8. Gliricidia only (3' x 3')

At the end of year 2019 Rs.3.6 M has been spent for 102 farmers to establish of different fuelwood growing models (Table 16).

The project was in progress (Figs. 13, 14 and 15).

Table 16. *Expenditure for different activities of the project as at 31st December 2019*

Item	Expenditure (Rs.)
Farmer payments	2,989,750.00
Awareness program expenses	223,242.00
Project launching day - expenses	8,695.00
Project launching day land preparation - expenses	45,000.00
Exposure visit expenses	72,270.00
Transport expenses	46,995.00
Technical assistant payments	300,000.00
Total	3,685,952.00

Fig. 13. K.G.A.G. Ishara Lilan - Ittapana range (Gliricidia – Pepper land)

Fig. 14. D R W Athale - Polgahawela range (Gliricidia - Pepper land)

Fig. 15. M P Maddumage - Colombo range (Gliricidia – Pepper land)

RUBBER TECHNOLOGY AND DEVELOPMENT

Dilhara Edirisinghe

DETAILED REVIEW

Staff

Dr (Mrs) D G Edirisinghe, Head of the Department and Mr W D M Sampath, Research Officer were on duty throughout the year. Mrs U Aloka Weerasinghe, Research Officer assumed duties on 22.08.2019.

Mr S L G Ranjith, Experimental Officer retired from the Institute on 16.08.2019.

Mrs Priyanthi Perera, Experimental Officer and Mr D G M J Abeywardena, Miss Gayathri Bhagyawedha, Mr K I D P Perera and Miss Ishani Jayaratne Technical Officers were on duty throughout the year.

Mr Nadun Tillekeratne, Mrs Nushara Nanayakkara and Miss Madhushani Gunawardena, Technical Officers assumed duties on 21.08.2019, 21.08.2019 and 02.09.2019, respectively.

Miss S M D Shashee Rekha De Alwis Wijerathne, Management Assistant was also on duty throughout the year.

Research students

Postgraduate students

- Mr Ishara Wijesinghe, a MSc (Polymer Science and Technology) student from the University of Sri Jayewardenapura completed his research project on "Development of an oil resistant NR/NBR blend compound filled with silica extracted from rice husk ash (RHA silica)" under the supervision of Dr (Mrs) D G Edirisinghe.

Undergraduate students

- Miss Isuri D Perera, BSc student from the University of Jayawardenapura completed her third year research project on "Effect of waste polyethylene on properties of methyl salicylate treated natural rubber/low density polyethylene/waste polyethylene composites" under the supervision of Mr W D M Sampath.

- Mr P D Sandaruwan, BSc (Chemistry Special) student of the Sabaragamuwa University of Sri Lanka conducted his research project on "Effect of an *Artocarpus heterophyllus* latex as a coupling agent on paint waste-filled natural rubber/low-

density polyethylene/waste polyethylene composite" under the supervision of Mr W D M Sampath.

- Miss W P P T Wickramaachchi, BSc (Palm and Latex Technology and Value Addition) student from the Uva Wellassa University conducted her research on "Comparison of properties of dry rubber based cellular compounds with different blowing agents" under the supervision of Mr W D M Sampath and Mrs A U Weerasinghe.

- Miss Isuri D Perera, BSc (Hons., Applied Science) student from University of Sri Jayewardenepura conducted her final year research project on "Development of transparency in non-toxic natural rubber teething ring" under the supervision of Dr (Mrs) D G Edirisinghe.

Seminars/Training/Conferences/Workshops/Meetings attended

Officer/s	Subject/ Theme	Organization
DG Edirisinghe, WDM Sampath & UA Weerasinghe	Scientific Committee Meetings	Rubber Research Institute of Sri Lanka (RRISL)
DG Edirisinghe	Sectoral Committee Meeting on "Chemical & Polymer Technology"	Sri Lanka Standards Institute (SLSI)
	Undergraduate Research Symposium, as a panel member	Chemical & Process Engineering Dept., University of Moratuwa
	Inauguration of start-up engine	Sri Lanka Institute of Nano Technology (SLINTEC)
	Meetings in connection with "Shilpa Sena" - An Exposition for Technology Revolution	Ministry of Science, Technology & Research and Ministry of Plantation Industries (MPI)
	Meeting for inventors at Sri Lanka Foundation Institute	Sri Lanka Inventors Commission
	Chairmen and Directors Forum in regard to 7th Symposium on Plantation Crop Research as Secretary, Symposium Coordinating Committee	RRISL
	Meeting with industrialists in regard to revising the SLS standards on rubber	SLSI
	Meeting in regard to "Short term strategies to improve the rubber production in the country"	MPI
	Lecture on "Personality development"	RRISL

Officer/s	Subject/ Theme	Organization
WDM Sampath	Awareness seminar on the program to establish 2000 new exporters, Rathnapura	Export Development Board (EDB)
	Demonstration of Particle Size Analyzer, Hilton, Colombo.	Hemsons International (Pvt.) Ltd.
	Effective research proposal writing	National Science Foundation (NSF)
	Award ceremony of Leadership and Capacity Building Training Programme, Golden Rose Hotel, Boralasgamuwa	Ministry of Industry and Commerce
	Annual Awards Ceremony of NIPM, BMICH, Colombo 7	National Institute of Plantation Management (NIPM)
	Demonstration of conductivity meter, The Open University of Sri Lanka	ITI
UA Weerasinghe	GC-MS and ICP-MS instrumentation	SLSI and Industrial Technology Institute (ITI)
KIDP Perera	Workshop on "Tyre compounding and tyre technology for Sri Lankan tyre manufacturing industry", Taj Samudra Hotel, Colombo	EDB in collaboration with PRISL and Sri Lanka Association of Manufacturers and Exporters of Rubber Products (SLAMERP)
	Workshop on "The technology on creaming latex processes and rubber products", Thailand	International Rubber Research & Development Board (IRRDB)
SLG Ranjith	"Regional Entrepreneur Forum" on the national program to establish 2000 new exporters, Kegalle	EDB
WDM Sampath & UA Weerasinghe	Seminar on "EPDM Technology"	The Plastics & Rubber Institute of Sri Lanka (PRISL)
	Workshop on " Mechanism of monitoring and evaluation of research projects"	Council for Agricultural Research Policy (CARP)
DG Edirisinghe, WDM Sampath, UA Weerasinghe, Priyanthi Perera, SGP Bhagyawedha & KIDP Perera	7th Symposium on Plantation Crop Research, Marino Beach Hotel, Colpetty	Plantation Crop Research Institutes (RRI, TRI, CRI & SRI)
Ishani Jayaratne	Advanced rubber testing training program, Thailand	Ministry of Industry and Commerce

Lectures/Seminars/Conferences/Training/Workshops/Exhibitions conducted

Officer/s	Subject/Theme	Beneficiary/Client
DG Edirisinghe	Latex technology	Students of the Diploma Course in Polymer Technology - PRISL
	Manufacture of rubberized-coir	Students of the Higher Diploma Course in Polymer Technology - PRISL
	Latex technology	MSc Students (Polymer Science & Technology) - University of Sri Jayewardenepura
	Basic principles in rubber product manufacture	National Diploma in Plantation Crop Technology (NVQ Level 5) - NIPM
	Field visit to MODA Apparatus Housing unit, Dept. of Chemical & Process Engineering, University of Moratuwa to evaluate progress of its construction	National Science Foundation (NSF) of Sri Lanka
WDM Sampath	Compounding ingredients (Dry rubber)	Students of the Certificate Course in Rubber Technology - PRISL
	Value addition to raw rubber	Induction Course for Planter Trainees - NIPM
	Rubber products manufacture as a cottage industry	Diploma in Plantation Management and Technology - NIPM
	Lecture on “Value added products from NR latex” for NR latex manufacturers in Rambukkana	Divisional Secretariat, Rabukkana.
KIDP Perera	Compound formulations and processing techniques	Students of the Certificate Course in Plastics Technology – PRISL
WDM Sampath, SLG Ranjith KIDP Perera	“Innovate Sri Lanka” , Innovation & Invention Exhibition	University of Sri Jayewardenepura
WDM Sampath, UA Weerasinghe KIDP Perera	Workshop on “Rubber based products manufacture” in Yatiyantota	Yatiyantota Vidatha Centre
WDM Sampath, DGMJ Abeywardena KIDP Perera	Mini Technology Exhibition in Rathnapura	EDB

Officer/s	Subject/Theme	Beneficiary/Client
SLG Ranjith DGMJ Abeywardena KIDP Perera	Mini Technology Exhibition in Kegalle	EDB
Staff of the department	Field training on "Value addition to rubber products"	Undergraduate students of Faculty of Agriculture, Rajarata University
	Field training on "Rubber product manufacture"	Undergraduate students of Palm & Latex Technology and Value Addition – Uva Wellassa University
	Workshop on "Rubber based products manufacture" at RRISL, Ratmalana for members of the Kalutara district Thurusaviya Fund	Thurusaviya Fund
	Workshop on "Rubber based products manufacture" at RRISL, Ratmalana for members of Yatiyantota, Vidatha Centre	Divisional Secretariat, Yatiyantota
	Practical demonstration on "Rubber based products manufacture" at RRISL, Ratmalana	BSc (Agri. Sp.) undergraduates of the Department of Plantation Management, Wayamba University of Sri Lanka

Industrial visits

The following institutes/industries/factories were visited during the year for development/trouble shooting work.

Officer	Industry/Organization
DG Edirisinghe and KIDP Perera	D Samson Industries (PU Plant), Karandeniya and Samson PVC, Baddegama
DG Edirisinghe, SLG Ranjith KIDP Perera	DSL Lanka (Pvt.) Ltd., FTZ, Biyagama
DG Edirisinghe	Richard Pieris Natural Foams, FTZ, Biyagama
KIDP Perera	Ceylon Rubber Products International (Pvt.) Ltd.
SLG Ranjith	Ceyflex Rubber Factory, Horana

LABORATORY INVESTIGATIONS

Dry rubber technology

Development of novel recycling processes for latex/dry rubber based compound/ product waste

Reclaiming of NR glove waste using different environmental friendly reclaiming agents

Mechanical reclaiming of NR glove waste using different environmental friendly reclaiming agents was carried out with the aim of incorporating the reclaim into safety shoe soles at the request of Welington Rubbers (Pvt.) Ltd. Properties of rubber compounds containing reclaimed rubber were evaluated and compared. Incorporation of reclaim rubber produced out of sole trimmed rubber waste gave excellent results on processing and finished product and 25% cost reduction from the material cost was achieved (D G Edirisinghe and K I D P Perera).

Development of rubber composites with waste materials for different applications

Recycling of rigid polyurethane (rPU) foam waste

This project was initiated at the request of D. Samson Industries, Galle. rPU foam waste was mechanically modified using a two-roll mill at a temperature closer to ambient temperature. The modified rPU foam waste samples were characterized by measuring plasticity and Mooney viscosity and Fourier Transform Infra-red (FTIR) spectroscopy.

Composites of 70:30 virgin NBR and mechanically modified rPU foam waste were prepared according to the ASTM oil seal formulation. Initial characterization of NBR/PU composites was done using FTIR spectroscopy. Cure characteristics, Mooney viscosity, hardness, rebound resilience, compression set, tensile properties, tear strength, abrasion resistance, ageing properties, percentage swelling and crosslink density of the blend composites were determined according to the relevant ISO standards (D G Edirisinghe, K I D P Perera and L Karunanayake - Dean, Faculty of Applied Science, University of Sri Jayewardenepura, Sri Lanka).

Modified nitrile rubber (NBR) glove waste incorporated concrete cubes

It is worthwhile to use rubber-concrete composites in practice as these would be environmentally beneficial, commercially competitive and supportive for a more sustainable society. However incompatibility of rubber with concrete materials restrict the application of rubber-concrete composites, especially in structural engineering applications. Although many researchers have tried to increase the strength of rubber-concrete, more studies are still needed to significantly improve the performance of rubber concrete.

NBR glove waste was recycled mechano-chemically using an environmental friendly amino compound. Mechano-chemically reclaimed NBR glove waste was characterized by measuring plasticity and Mooney viscosity. A series of concrete

mixtures was prepared according to an experimental design based on the proportion of materials (sand, cement and rubber aggregate) used. The sand (fine aggregate) in concrete was replaced upto 20% by reclaimed NBR glove waste at 4% intervals and five concrete mixtures were produced. A concrete mixture without reclaimed NBR glove waste was also produced and it was designated as the Control.

Thereafter, moulds (15 cm x 15 cm x 15 cm) were filled with these concrete mixtures in three equal layers, each of which was compacted using the vibrating table to remove as much air as possible. Vibration was continued for 30 s to ensure a smooth and even surface film.

Polythene sheeting was placed over the concrete cubes after casting to prevent moisture loss. After 24 h at the ambient laboratory temperature, the concreate cubes were carefully removed from the moulds, labelled with their IDs. The cubes were then transferred to a water tank for curing. Finally dry, wet and bulk densities, compressive strength and water absorption of the cubes were determined according to the ISO standards. Results showed a decrease in bulk, wet and dry densities as well as compressive strength with the increase of reclaimed NBR glove waste loading. However, about 63% of compressive strength of the Control was retained when 8% of sand was replaced with reclaimed rubber (D G Edirisinghe, K I D P Perera and Y U I Senarathna (BSc Quantity Surveying) undergraduate student, Birmingham School of Built Environment, UK).

Methyl salicylate treated NR/low density polyethylene (LDPE)/waste polyethylene (wPE) composites

Used polythene sheets, which are considered as waste of PE (wPE) are a major threat to the environment and hence recycling of these is a way to reduce environmental pollution. A series of 20 pphp (parts per hundred parts of polymer) calcium carbonate filled 70:30 NR: LDPE/wPE composites were prepared by replacing LDPE with wPE from 0 (control) to 25phpp at 5 phpp intervals and using methyl salicylate (0.5 pphp) as the coupling agent. Physico-mechanical properties were evaluated and fourier transform infrared (FTIR) analyses of the composites were conducted. Water absorption capacity of the composites was also studied.

Figure 1 shows crystalline behaviour for composites with 0 phpp and 5 phpp loading of wPE and semi-crystalline behavior for the other composites. The composite prepared with wPE loading of 20 phpp shows the highest elongation (Fig. 4). According to the Figure 2, composite prepared with wPE loading of 20 phpp shows the highest hardness and it is even higher than that without wPE. In addition, highest stress is shown by the former composite, which implies that it has the highest crystallinity compared to other composites. The reason for the highest tensile strength of the composite prepared with 20 phpp loading of wPE (Fig. 3) could be attributed to greater inter molecular interaction and hence greater interfacial adhesion between the two polymer phases. Tear strength results (Fig. 5) also show an increasing trend in

interfacial adhesion between the two polymer phases when the amount of wPE is increased.

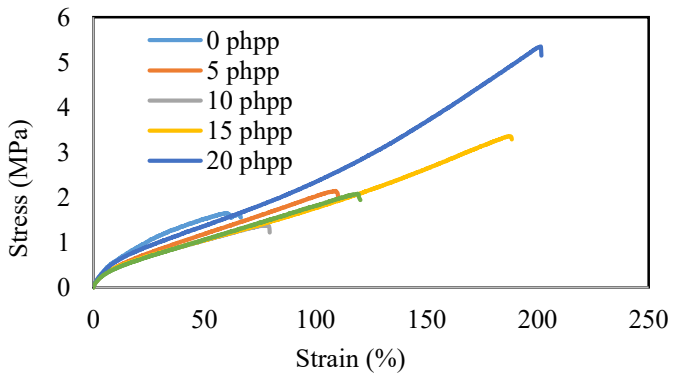


Fig. 1. Stress – strain curves of NR/LDPE/wPE composites

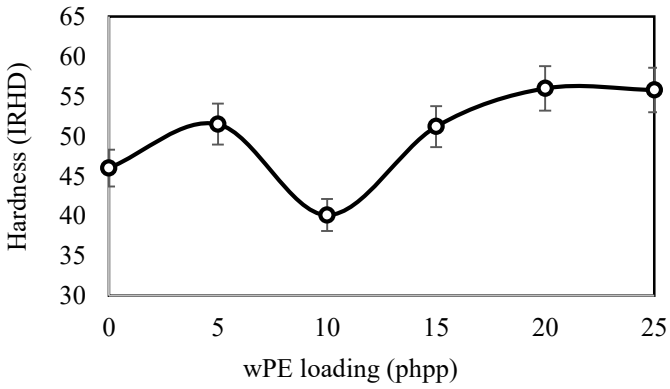


Fig. 2. Hardness of NR/LDPE/wPE composites

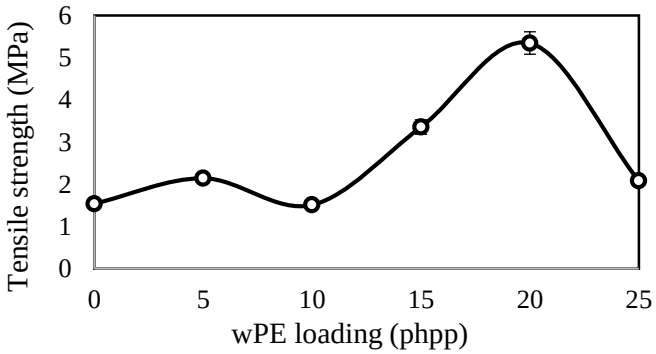


Fig. 3. Tensile strength of NR/LDPE/wPE composites

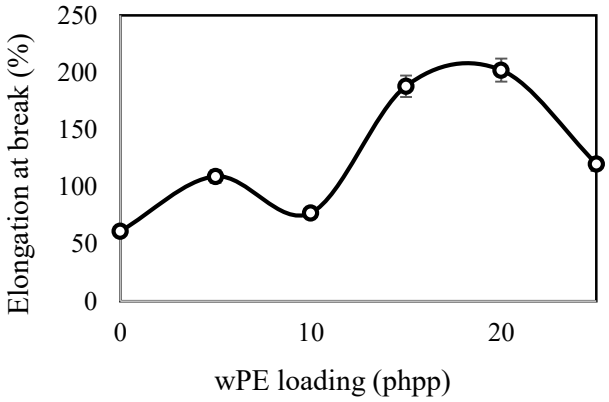


Fig. 4. Elongation at break of NR/LDPE/wPE composites

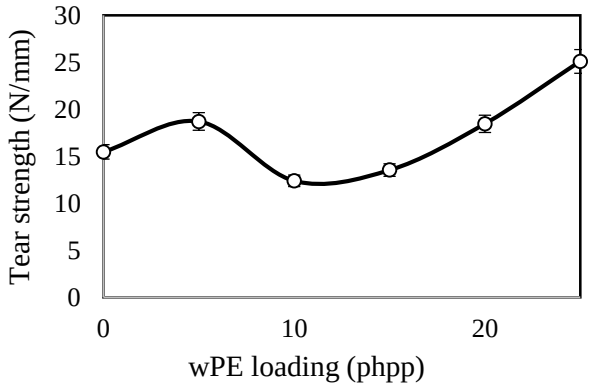


Fig. 5. Tear strength of NR/LDPE/wPE composites

Water absorption of all the composites (Fig. 6) is less than 0.35% and the composite with 10 phpp wPE shows the highest. Presence of unreacted organic methyl salicylate could be the reason for the latter observation. Water absorption decreases initially upto the increase of 5 phpp wPE and a further decline is shown from 10 phpp to 20phpp wPE. The lowest water absorption shown at 20 phpp loading of wPE confirms greater interfacial adhesion between NR and LDPE phases at this wPE loading.

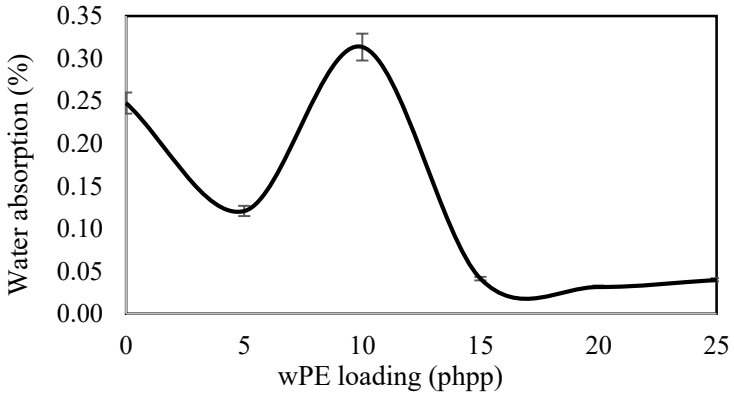


Fig. 6. Water absorption of NR/LDPE/wPE

Figure 7 presents the FTIR spectra of the composites prepared with different loadings of wPE. The composite prepared with 20 phpp wPE exhibits a peak assignment at 1378 cm^{-1}. This could be assigned to –C–O–H in-plane bending vibrations. Hence, formation of above bonds proves that the composite with 20 phpp wPE loading has achieved greater interaction between NR, LDPE, and other ingredients. This would also support increased tensile strength and tear strength obtained for the composite prepared with 20 phpp wPE.

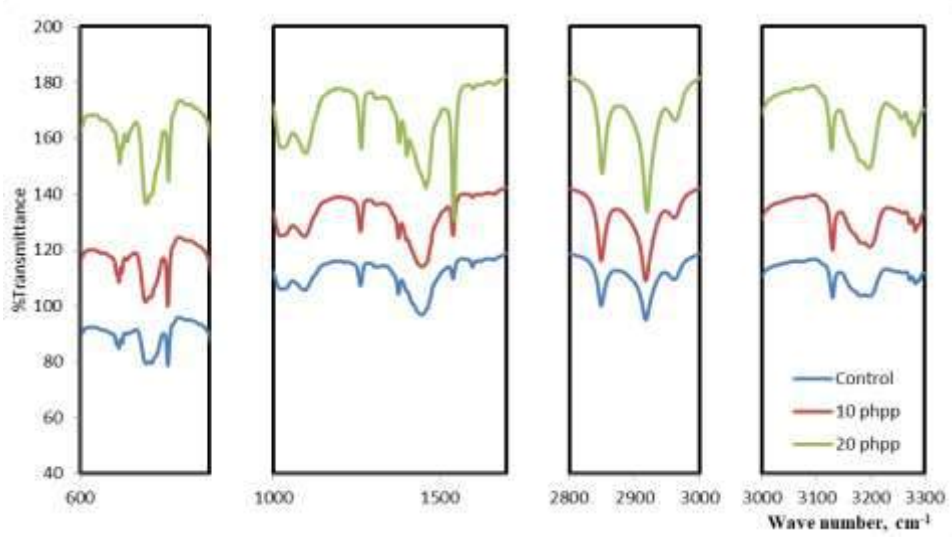


Fig. 7. FTIR spectra of gels of the Control and composites with wPE for different regions

The composite prepared with 20phpp loading of wPE shows remarkable physico-mechanical properties in term of hardness, tensile strength, tear strength and elongation at break. Therefore, it is identified as the optimum loading of wPE for 70/30 NR/LDPE composites. The composite with wPE loading of 20 phpp showed the lowest water absorption capacity. Hence, this composite would be suitable to produce water resistant products such as roofing sheets, flow tiles, *etc*. (W D M Sampath, D G Edirisinghe, V G M J Abhayawardhana and I D Perera - BSc undergraduate student, Faculty of Applied Science, University of Sri Jayewardenepura, Sri Lanka).

Artocarpus heterophyllus *(Jackfruit) latex treated NR/LDPE/wPE composites*

Artocarpus heterophyllus Latex (AHL) is an aqueous emulsion containing many ingredients such as lipids, rubbers, resins, sugars, proteins including proteolytic enzymes. In this study, AHL was used as a natural coupling agent to enhance performance of NR/LDPE/wPE composites. A series of 30:60:10 NR: LDPE: wPE composites was prepared by varying the AHL loading from 0 to 2.5 pphp at 0.5 pphp intervals. 20 pphp of calcium carbonate was also incorporated into every blend composition. Physico-mechanical properties of the composites were evaluated and Fourier Transform Infrared (FTIR) analyses of the composites were conducted. Water absorption capacity, percentage swelling and gel content of the composites were also studied.

All graphs in Figure 8 show a semi-crystalline behavior. Figure 9 shows a marked increase of tensile strength with the increase of AHL from 0.5 pphp to 1.5 pphp and the composite with 1.5 pphp shows the highest tensile strength. However, tensile strength has gradually decreased from 1.5 pphp to 2.5 pphp loading as AHL may react as a plasticizer at high loadings. According to Figure 11, the composite prepared with AHL loading of 1.5 pphp shows the highest hardness value and it reflects a high crosslink density. Tear strength results (Fig. 12) indicate that more than 1.5 pphp AHL would not significantly affect tear performance of NR/LDPE/wPE composites.

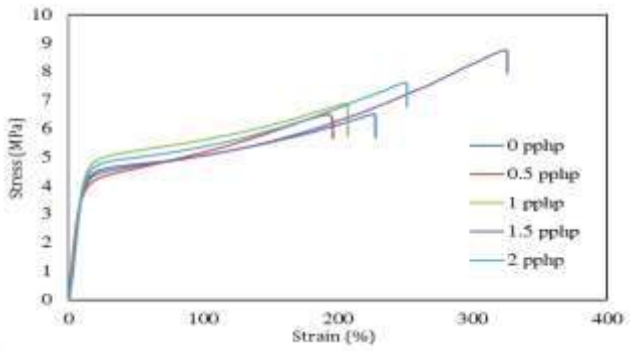


Fig. 8. Stress-strain curves of NR/LDPE/wPE composites

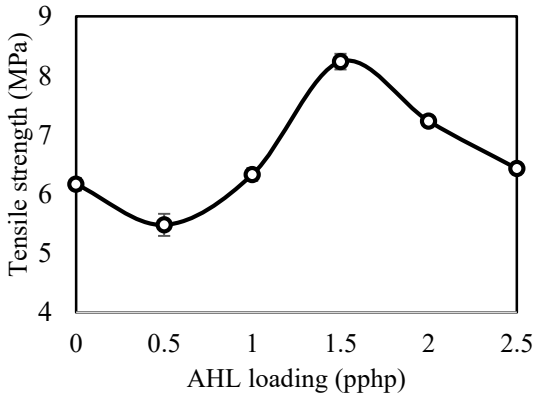


Fig. 9. Tensile strength of NR/LDPE/wPE composites

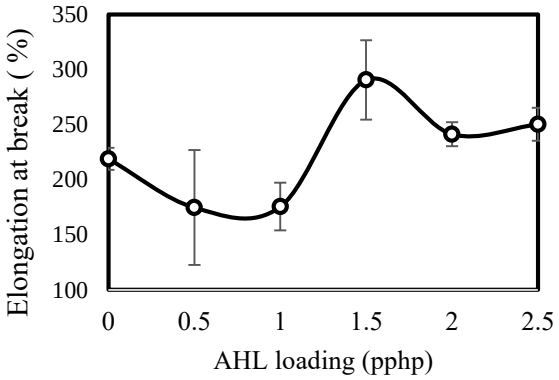


Fig. 10. Elongation at break of NR/LDPE/wPE composites

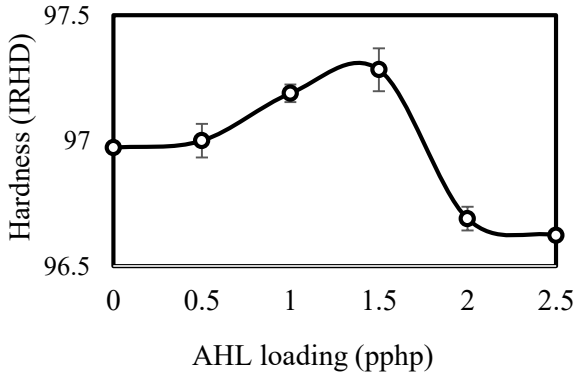


Fig. 11. Hardness of NR/LDPE/wPE composites

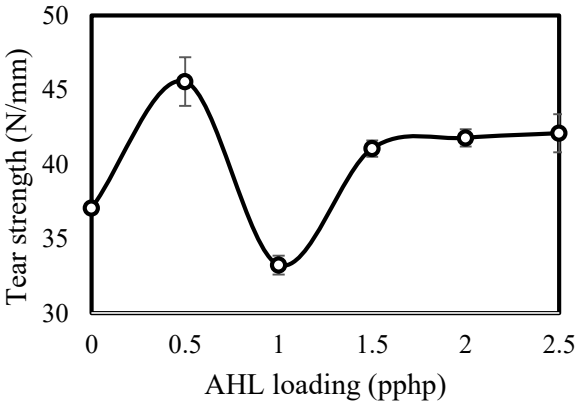


Fig. 12. Tear strength of NR/LDPE/wPE composites

Water absorption of all the composites is less than 0.35% (Fig. 13) and this can be attributed to the organic nature of NR and LDPE polymers, which have a very low reactivity with inorganic water molecules. The highest water absorption indicated by the composite prepared with 2 pphp AHL could be due to the presence of high amount of polar phenolic and alcoholic substances. The lowest water absorption at 0.5 pphp AHL loading confirms good adhesion between NR and LDPE phases of the composite.

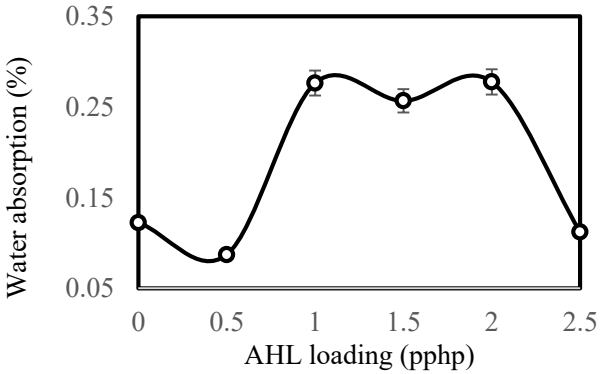


Fig. 13. Water absorption of NR/LDPE/wPE composites

The composite prepared with 1.5 pphp AHL shows the lowest swelling value (Fig. 14) compared to the other counterparts. It is interesting to note that percentage swelling of all AHL loaded composites is lower than that prepared without AHL indicating better adhesion between NR, LDPE, wPE and $CaCO_3$ of the former

composites. Further, the composite prepared with 1.5 pphp AHL has recorded the highest gel content (Fig. 15) and it is markedly higher than that prepared without AHL.

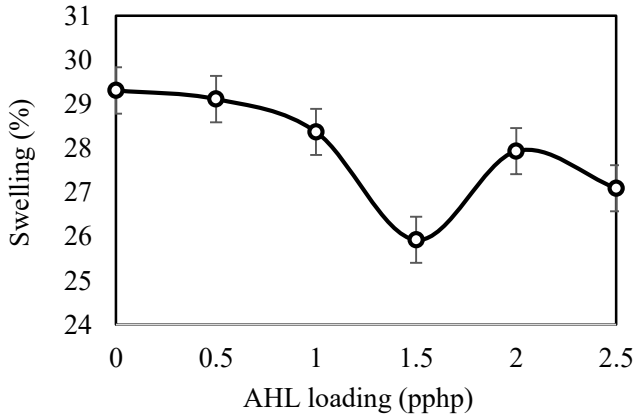


Fig. 14. Percentage swelling of NR/LDPE/wPE composites

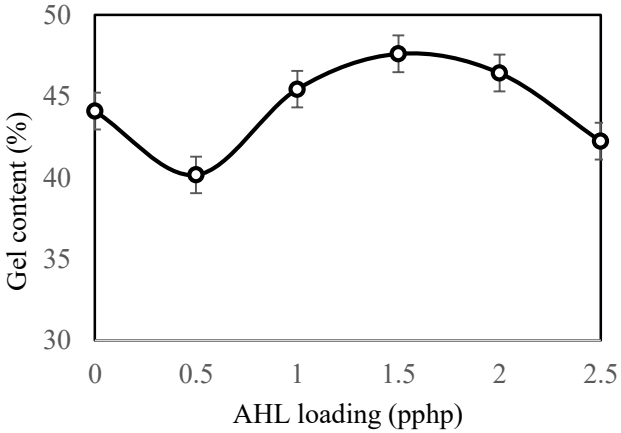


Fig. 15. Gel content of NR/LDPE/wPE composites

The FTIR spectra (Fig. 16) of the composite prepared with 2.5 pphp AHL exhibits a peak assignment at 1264 cm^{-1}. This could be assigned to C(O)–O stretching vibrations and -OH in-plane vibrations or amide. Therefore, these OH and C(O)-O groups support to react with $CaCO_3$ developing compatibility between polymer (NR, LDPE) and filler ($CaCO_3$). The spectra of all composites show a peak at 2917 cm^{-1} indicating the presence of a symmetric CH_3 group. Formation of the above bonds

proves the presence of interactions between NR, LDPE, and other ingredients in the composite prepared with 1.5 pphp AHL. Further, this composite indicates a peak assignment at 1441 cm^{-1} and could be assigned to C=O stretching vibration. Presence of C=O bond would support to form interactions with $CaCO_3$ and AHL.

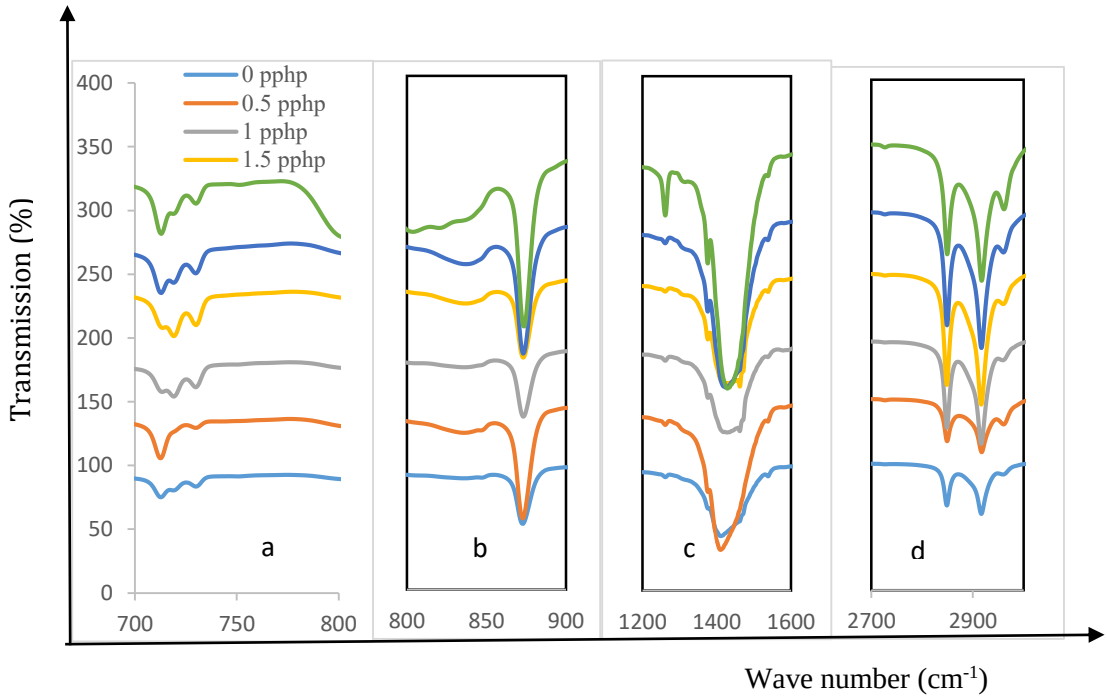


Fig. 16. FTIR spectra of different regions of gels of the composites prepared with AHL
a) 700 to 800 cm^{-1} b) 800 to 900 cm^{-1} c) 1200 – 1600 cm^{-1} d) 2700- 3000 cm^{-1}

Incorporation of 1.5 pphp AHL into NR /LDPE/wPE composites improves most of the properties in terms of tensile strength, elongation at break, swelling properties and gel content. Water absorption also increases with the increase of AHL loading up to 2 pphp and decreases above this loading. Further, composite prepared with AHL loading of 1.5 pphp showed the lowest solvent absorption, hence it reflects better solvent resistance compared to the other counterparts. Results in overall indicate that the composite with 1.5 pphp loading of AHL is the best in terms of properties (W D M Sampath, D G Edirisinghe, Y C Y Sudusingha and P D Sandaruwan – BSc (Chemistry Special) undergraduate student, Sabaragamuwa University, Sri Lanka).

Development of rubber composites with coconut husk fibre for special applications

This research was conducted in collaboration with the Coconut Research Institute of Sri Lanka. Coconut husk fibre (coir) was used as a partial replacement for carbon black with the aim of developing NR based boots with novel property combinations. Two series of NR composites were prepared by partially replacing carbon black with two different sizes of coir, *i.e.* 0-0.5mm and 0.5-1.0mm in length. Coir loading was varied from 0 phr to 50 phr at 10 phr intervals (Table 1). Physico-mechanical and ageing properties of coir filled composites were evaluated according to ISO standards.

Table 1. *Coir: Carbon black ratios of the rubber composites*

Treatment	**1**	**2**	**3**	**4**	**5**	**6**
Coir	0	10	20	30	40	50
Carbon Black	50	40	30	20	10	0

Physico-mechanical properties of NR composites

Physico-mechanical properties of carbon black filled natural rubber composites at different coir (0-0.5mm in length) loadings are shown in Table 2. The hardness of all composites was in the range of 59 to 60 IRHD. Therefore, there are no significant differences in hardness among the Control (without coir) and the other treatments. The resilience of the Control is significantly different to that of the other treatments. However, there is no significant difference between the treatments 2 to 6. Generally, heat build-up reduces with the increase of resilience. Hence, the composites prepared with coir indicate low heat build-up. The tensile strength, modulus at 100% elongation and tear strength of the treatments containing coir are significantly low compared to those of the Control. Therefore, the interaction of coir with natural rubber is low compared to that of carbon black with natural rubber. Elongation at break significantly increases from treatment 3 to treatment 6 and indicate better elastic behavior compared to the Control and treatment 2. According to Table 3, the composite prepared without coir shows better ageing properties in terms of modulus and strength properties as it contains only carbon black, which is known to be a reinforcing material. However, elongation at break of coir filled composites is better than that of Control, after ageing. The composite prepared with 10 phr loading of coir is close to the Control in terms of physico-mechanical and ageing properties.

Table 2. *Physico-mechanical properties of NR composites (0-0.5mm particle size of coir)*

Property	Treatment					
	1	**2**	**3**	**4**	**5**	**6**
Hardness (IRHD)	60±1[a]	59±1[a]	59±0.4[a]	60±1[a]	60±0.4[a]	60±0.2[a]
Resilience (%)	65±0.4[a]	69±1[b]	70±1[b]	68±1[b]	70±1[b]	70±0[b]
Tensile strength (MPa)	27±2[a]	19±1[b]	13±1[c]	10±1[d]	9±1[d]	8±1[d]
Mod at 100% (MPa)	7.2±0.4[a]	4.1±0.2[b]	2.5±0.8[c]	1.1±0.1[d]	1.3±0.1[d]	1.1±0.1[d]
Mod at 300% (MPa)	-	-	-	10±0.7[a]	8±0.9[b]	5.90±1.1[c]
Elongation at break (%)	296	284	282	308	312	340
Tear strength (N/mm)	74±5[a]	47. ±4[b]	32±2[c]	27±2[d]	24±1[d].	23±2[d]

Table 3. *Ageing properties of NR composites (0-0.5mm particle size of coir)*

Property	Treatment					
	1	**2**	**3**	**4**	**5**	**6**
Tensile strength (MPa)	8.4±1.3[a]	6.6±0.4[a]	4.9±0.4[b]	3.3±0.6[c]	2.1±0.3[d]	1.3±0.3[e]
Modulus at 100% (MPa)	8.1±0.6[a]	6.0±0.7[b]	2.4±0.5[c]	1.9±0.2[c]	1.4±0.1[d]	0.9±0.1[e]
Modulus at 300% (MPa)	-	-	-	-	-	-
Elongation at break (%)	88	103	158	178	163	172
Tear strength (N/mm)	37.3±3.8[a]	27.2±4.7[b]	26.5±2.8[b]	22.8±1.8[b]	23.3±1.5[b]	16.9±3.6[c]

Physico-mechanical properties of NR composite (0.5-1mm length coir)

Physico-mechanical properties of carbon black filled natural rubber composites at different coir (0.5-1 mm in length) loadings are shown in Table 4. According to Table 4, hardness and resilience of coir-rubber composites have notably increased with the increase of coir fibre loading and also they are somewhat higher compared to those of the composite prepared with 0-0.5mm length coir. However, tensile strength of the composites prepared with 0.5–1 mm length coir has markedly decreased with the increase of coir loading. This is probably due to the presence of coir larger in size distributed in the natural rubber composite, which easily acts as stress raisers. Modulus at 100% elongation and tear strength also decrease with the increase of coir loading. However, composites prepared with coir show an improvement in elongation at break compared to the Control. According to Table 5, ageing properties gradually decrease with the increase of coir loading. Further, composites prepared with

0.5-1 mm length coir show better ageing properties in terms of modulus and strength than those prepared with 0-0.5 mm length coir.

Table 4. *Physico-mechanical properties of NR composite (0.5-1mm particle size of coir)*

Property	Treatment					
	1	**2**	**3**	**4**	**5**	**6**
Hardness (IRHD)	58 ± 0^{a}	59 ± 0^{b}	60 ± 16^{c}	61 ± 0^{d}	62 ± 0^{e}	65 ± 0^{f}
Resilience (%)	65 ± 1^{a}	66 ± 1^{a}	69 ± 1^{b}	70 ± 1^{b}	72 ± 1^{c}	76 ± 1^{d}
Tensile strength (MPa)	27 ± 1.2^{a}	12.7 ± 1.1^{b}	10.7 ± 1.2^{b}	8.6 ± 0.8^{c}	6.9 ± 0.8^{c}	5.6 ± 0.8^{d}
Mod at 100% (MPa)	5.8 ± 0.1^{a}	2.6 ± 0.1^{b}	3.1 ± 0.2^{c}	2.57 ± 0.7^{b}	1.4 ± 0.2^{c}	1.0 ± 0.1^{d}
Elongation at break (%)	200	250	232	225	250	260
Tear strength (N/mm)	66 ± 10^{a}	54 ± 2^{b}	44 ± 5^{c}	32 ± 3^{d}	24 ± 3^{e}	19 ± 1^{e}

Table 5. *Ageing properties of NR composite (0.5-1mm particle size of coir)*

Property	Treatment					
	1	**2**	**3**	**4**	**5**	**6**
Tensile strength (MPa)	18.1 ± 3.5^{a}	11 ± 0.0^{b}	9.8 ± 0.2^{c}	8.4 ± 0.1^{d}	6.7 ± 0^{e}	5.1 ± 0.3^{f}
Mod at 100% (MPa)	6.1 ± 2.5^{a}	7.1 ± 0^{a}	5.5 ± 0.2^{c}	4.5 ± 0.1^{b}	3.2 ± 0.1^{c}	2.1 ± 0.0^{d}
Elongation at break (%)	175	146	158	159	155	161
Tear strength (N/mm)	56 ± 3^{a}	47 ± 3^{b}	43 ± 2^{b}	31 ± 4^{c}	22 ± 2^{d}	19 ± 2^{d}

(D G Edirisinghe, W D M Sampath, J A K M Fernando, Research Officer (Chemical Engineer) Department of Coconut Processing Research Division, Coconut Research Institute, Gayathri Bhagyawedha and Ishani Jayaratne)

Development of cellular rubber products with latex/dry rubber for special applications

Development of cellular rubber products with dry natural rubber

Three series of dry natural rubber based cellular compounds were prepared by using three types of blowing agents namely $NaHCO_3$, DNPT and isopropanol by varying the loading from 2 phr to 10 phr at 2 phr intervals. The compound prepared with 6 phr loading of DNPT was considered as the Control. Mechanical, morphological and water absorption properties were evaluated according to ISO and ASTM standards.

Mechanical properties of dry rubber based cellular compounds

The tensile strength of cellular compounds is presented in Figure 17, where a high tensile strength can be observed at low blowing agent loadings. The major reason for this can be the free space generated during the decomposition process, which reduces the strength of the compound due to the collapse of micro voids as the blowing agent loading increases. Elongation at break results provide information regarding the elasticity of the compound and it can be seen from Figure 18 that isopropanol blowing agent shows a fluctuating trend, while other two blowing agents show a decreasing trend. In contrast, $NaHCO_3$ indicates remarkable results at 2 phr loading and this is evident with the morphology at 2 phr as well where larger cell size for $NaHCO_3$ can be seen compared to other two blowing agents. This cell size with lower density enables the compound to elongate at its optimum level at this loading. The compression set results show a decreasing trend with the increase of blowing agent loading (Fig. 19). As the blowing agent loading increases, the number of cells in the compound increase by increasing the amount of micro voids. This allows the compound to store more gas within the structure and improve compression set. According to the results presented in Figure 20, the relative density decreases with the increase of blowing agent loading. This can be attributed to the higher free volume generated with the increase of blowing agent loading and among the three blowing agents the one with open cellular structure generates the highest amount of free volume, leading to the lowest relative density.

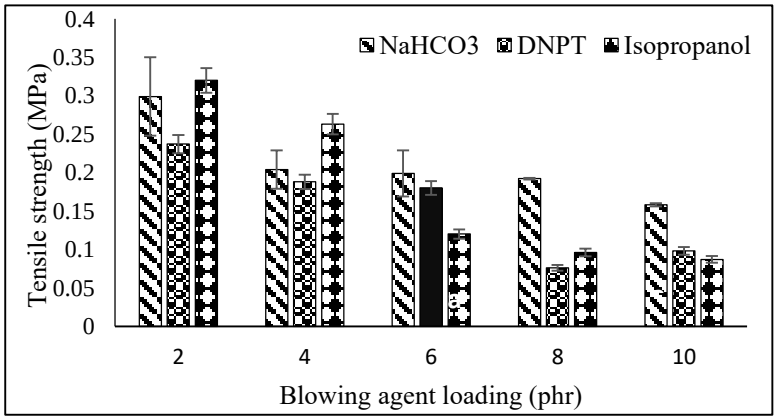


Fig. 17. Tensile strength of dry natural rubber based cellular compounds

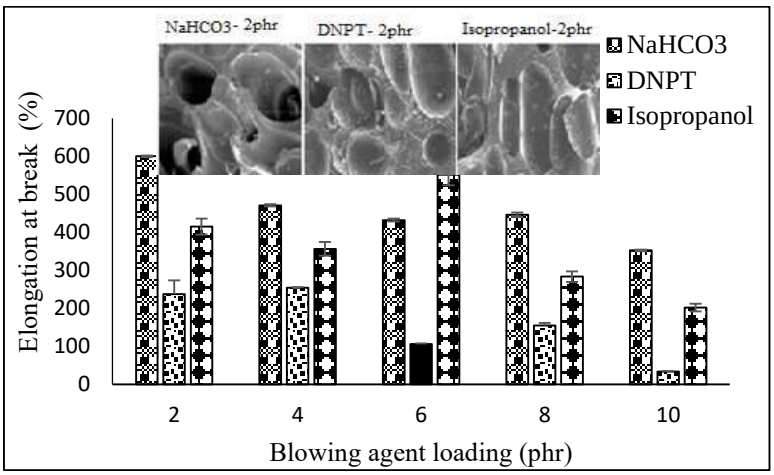


Fig. 18. Elongation at break of dry natural rubber based cellular compounds

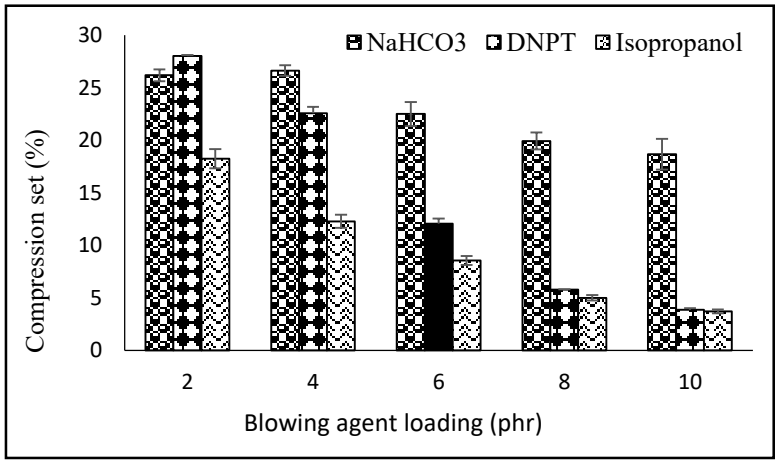


Fig. 19. Compression set of dry natural rubber based cellular compounds

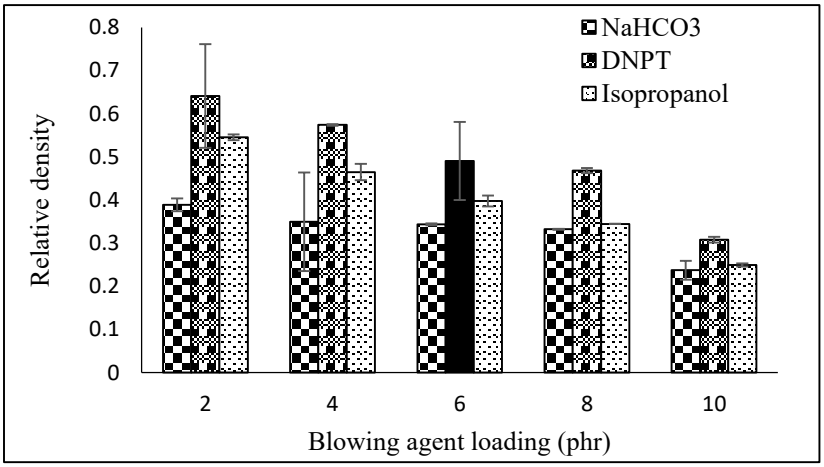


Fig. 20. Relative density of dry natural rubber based cellular compounds

Water absorption of dry natural rubber based cellular compounds

Figure 21 represents water absorption results which indicate an increasing trend with increasing blowing agent loading. These results are in-line with the obtained relative density results, where high water absorption can be seen with the compounds having a high amount of free volume generated with a higher blowing agent loading.

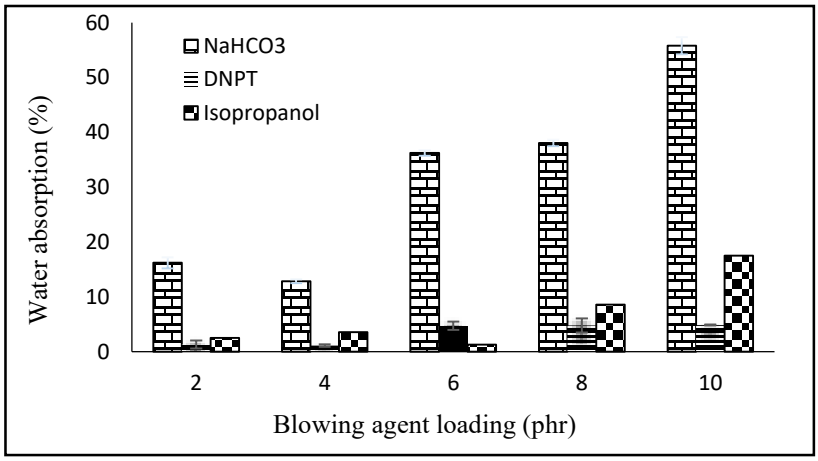


Fig. 21. Water absorption of dry natural rubber based cellular compounds

Morphology of dry natural rubber based cellular compounds

$NaHCO_3$ is an inorganic type blowing agent and it is mostly used to produce open cell foams or sponges, whereas the DNPT and isopropanol are organic type blowing agents and these are mostly used to produce closed-cell foams or microcellular rubber. Cellular compounds shown in Figure 22 (A), (C) and (E) produced using $NaHCO_3$ indicate an open cell structure. Further, the compound prepared with 10 phr loading of blowing agent shows the largest voids compared to the other two loadings namely 2 phr and 6 phr. Hence, the number of voids decrease with increasing blowing agent loading. This was evident with the lowest water absorption results obtained for DNPT incorporated compounds due to the closed-cell structure and low porosity (Fig. 24). Further more the compound prepared with isopropanol shows large voids and indicates closed-cell structure. Isopropanol incorporated composite has the lowest compression set and hence it would be suitable to produce soft sponge for makeup activities and cushioning applications.

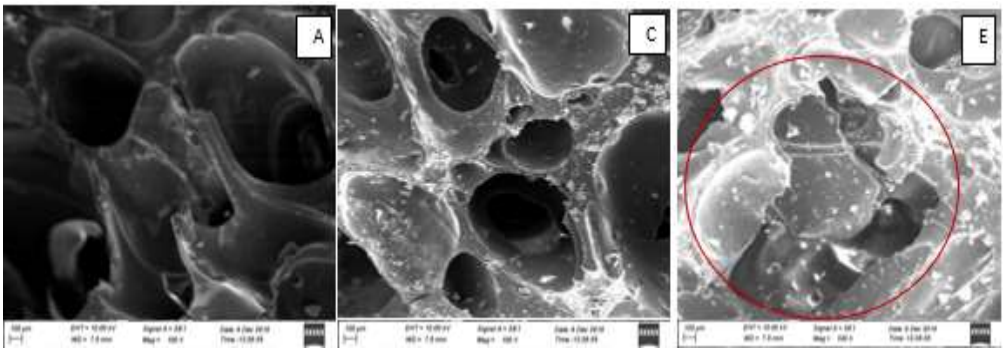


Fig. 22. SEM images of the fractured surface of cellular rubber compound prepared with $NaHCO_3$ loading of (A) 2 phr (C) 6 phr (E) 10 phr

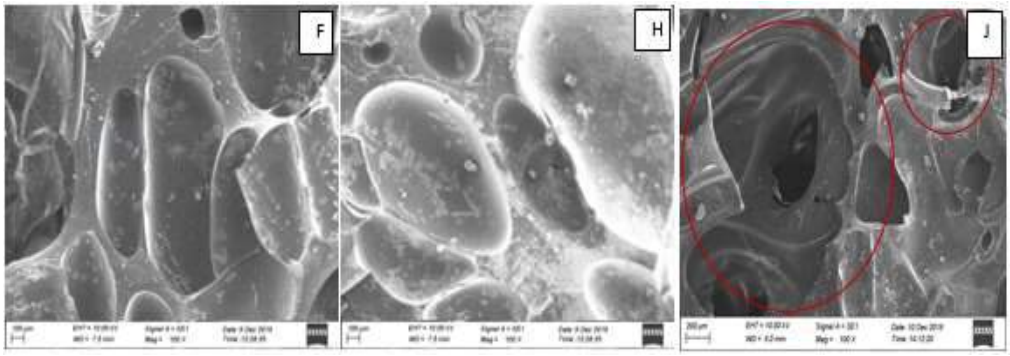


Fig. 23. SEM images of the fractured surface of cellular rubber compound prepared with isopropanol loading of F) 2 phr (H) 6 phr (J) 10 phr

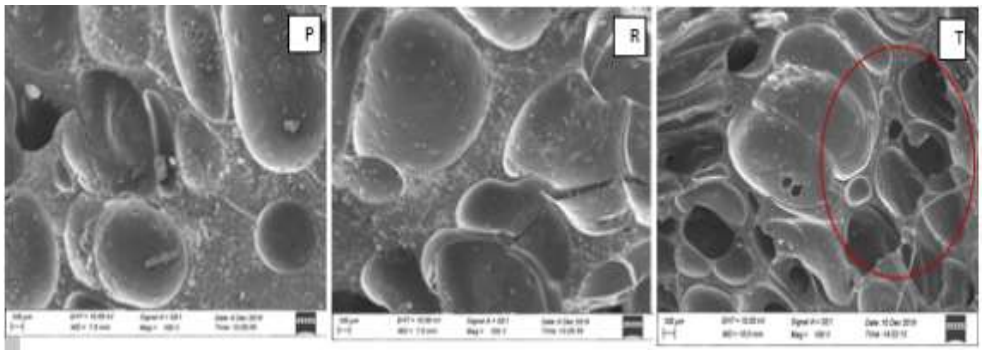


Fig. 24. SEM images of the fractured surface of cellular rubber compound prepared with DNPT loading of (P) 2 phr (R) 6 phr (T) 10 phr

It is evident from the above results that the optimal loading of blowing agent differs from one to another according to the desired property. However the trend in variation of free volume, compression set, tensile strength and elongation at break with the increase in blowing agent loading is common to all the blowing agents. Low loadings of blowing agents are preferred for improved tensile strength and elongation at break, while high loadings are preferred for compression set and water absorption properties (W D M Sampath, U A Weerasinghe and W P P T Wickramaarachchi – BSc (Palm & Latex Technology) undergraduate student, Uva Wellassa University, Sri Lanka).

Industrial extension

The following properties were tested and test reports were issued to the companies at their request.

Hardness of s ole crepe	**Physico-mechanical properties of rubber compounds**	**Physico-mechanical properties of rubber/polymer products**
• Atale Estate, Kegalle Plantations	• Eastern Merchants Plc.	• Lalan Rubbers (Pvt.) Ltd.
• Elston Estate, Pussellawa Plantations Ltd.	• Samson Reclaim Rubbers Ltd.	• DSL Lanka (Pvt.) Ltd.
• M/S Kelani Valley Plantations Plc.	• Polymer Products Impex (Pvt.) Ltd.	• Plant Science Dept., RRISL
• Panawatte Estate, Kelani Valley Plantations Plc.	• Textrip (Pvt.) Ltd.	• Quality Latex Products (Pvt.) Ltd.

Hardness of sole crepe	Physico-mechanical properties of rubber compounds	Physico-mechanical properties of rubber/polymer products
• Elpitiya Plantations, Plc.	• Dharmasiri Tyre House (Pvt.) Ltd.	• Samson Rubber Industries (Pvt.) Ltd.
• Dewalakanda Estate, Kelani Valley Plantations Plc.	• Faga Tyres (Pvt.) Ltd.	• Screenline Holdings (Pvt.) Ltd.
• Siriwansa Estate, Pussellawa Plantations Ltd.	• Ceytra (Pvt.) Ltd.	• Lalan Printing & Packaging
	• Global Rubber Industries (Pvt.) Ltd.	• Samson Rubber Products (Pvt.) Ltd.
	• Clinco Rubber Mouldings (Pvt.) Ltd.	• Road Development Authority
	• Marangoni Industrial Tyres Lanka (Pvt.) Ltd.	• Unicorn Tyre Retreading (Pvt.) Ltd.
	• Bombuwala Rubber Mills (Pvt.) Ltd.	
	• DSL Lanka (Pvt.) Ltd.	
	• Unicorn Tyre Retreading (Pvt.) Ltd.	

Development of Rubber Compounds/Products

The following rubber compound/product developments were conducted on request.

Development	Client
NR based compound for a bath mat	D. Samson International PLC
NR based formulation to produce protective caps for bicycles	R.A.P. Engineering Solutions (Pvt.) Ltd.
NR latex based can sealant	Industrial Development Board
Non-toxic, transparent, light coloured NR based teething ring	DSL Lanka (Pvt.) Ltd.
NR/ethylene-propylene-diene rubber (EPDM) blend compound for an automobile application	Entrepreneur
NR based bridge bearing compound	Supreme Plantation Engineers
NR latex based non-toxic adhesive	DSL Lanka (Pvt.) Ltd.
NR based compound for floating toys	Green Rubber Toy Company

Development	Client
NR or MG rubber (methyl methacrylate grafted rubber)/neoprene rubber (CR) based adhesive	Ceylon Vet Chem (Pvt.) Ltd., Kurunegala
NR based tyre patch compound	Tyre House, Hambantota Samson Rubber Industries, Mahara
NR based adhesive for a water-proof fabric	Vet Chem (Pvt.) Ltd., Kurunegala
Virgin NR/reclaimed toy waste blend compound	Green Rubber Toy Company

POLYMER CHEMISTRY

Y R Somarathna

DETAILED REVIEW

Staff

Mr Y R Somarathna, Research Officer was covering up the duties of the Head of Department of Polymer Chemistry Department throughout the year. Mrs I H K Samarasinghe, Research Officer was on study leave throughout the year. 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.

Foreign visits

- Singapore National University, Singapore - To present a paper entitled 'Application of nano-scale zinc oxide (ZnO) and tetramethylthiuram disulphide (TMTD) as an effective preservative system for concentrated natural rubber latex' in the International Conference on Science and Technology.

Research students

- Mr L M A Nuwan, a BSc (Palm and Latex Technology) undergraduate student from Uva Wellassa University of Sri Lanka conducted his final year research project entitled 'Study of waste-mica filled NR composites and their properties' under the supervision of Mr Y R Somarathna.

Awards

- The BEST PAPER award in the 'rubber sector' was received to Mrs I H K Samarasinghe at the 7th Symposium on Plantation Crop Research 2019 held at Colombo, Sri Lanka for the paper titled "Effect of Nitrosamine Safe Diisopropyl Xanthogen Polysulfide Accelerator on Cure and Static Mechanical Properties of Natural Rubber Compounds″

- Merit award for the best research project in 'Processing Technology' sector was received to Mr L M A Nuwan, a BSc (Palm and Latex Technology) undergraduate student from Uva Wellassa University of Sri Lanka for the project entitled 'Study of waste-mica filled NR composites and their properties' at the Academic Sessions organized by Uva Wellassa University of Sri Lanka.

Lectures/Seminars/Training/Workshops/Conferences conducted

Officer/s	Subject/Theme	Beneficiary/Client
Staff of the department	Practical sessions on Rubber Technology and Polymer Characterization	MSc students (Polymer Science and Technology), University of Sri Jayawardenapura
YR Somarathna	Rubber Wood Treatment	Students of Advance Certificate Course in Plantation Management, National Institute of Plantation Management
	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
Staff of the Department	Field training Program on Polymer Technology	Undergraduate students of Palm & Latex Technology and Value Addition, Uva Wellassa University of Sri Lanka
YR Somarathna Nirmala Jayawardena	Adhesive Manufacturing Workshop	Small and medium scale entrepreneurs

Lectures/Seminars/Training/Workshops/Conferences attended

Officer/s	Subject/Theme	Organization
YR Somarathna	International Conference in Science and Technology	Singapore National University, Singapore
	Scientific Committee Meetings	Rubber Research Institute of Sri Lanka
	Workshop on Advanced Instrumentation (GCMS)	Techno Instruments (Pvt) Ltd
	Workshop on Effective Proposal Writing	National Science Foundation of Sri Lanka
	Workshop on Project Proposal Writing and Submission	National Planning Department of Sri Lanka
	Two day Workshop on Tyre Compounding	Plastic Rubber Institute of Sri Lanka
	Workshop on Writing an Impactful Research Article	Postgraduate Institute of Agriculture, University of Peradeniya
YR Somarathna IHK Samarasinghe Nirmala Jayawardena & H MH Dhanukamalee	7th Symposium on Plantation Crop Research 2019	Crop Research Institutes of Sri Lanka (RRI, TRI, CRI and SRI)

LABORATORY INVESTIGATIONS

Development of property correlations for nitrosamine safe binary accelerator systems in sulfur vulcanized natural rubber

Behavior of Nitrosamine Safe Diisopropyl Xanthogen Polysulfide Accelerator (DIXP) in Natural Rubber Compounds: Cure and Physico- Mechanical Properties

Influence of DIXP accelerator on cure characteristics of natural rubber (NR) compounds were evaluated and compared with those of the control compounds prepared with TBBS. Figure 1 illustrates the variation of Maximum torque (S′ max) and delta cure [(maximum–minimum) torque] of DIXP and TBBS accelerated compounds. S′ max generally corresponds with stiffness and shear modulus of vulcanized rubber and indicates the state of cross linking. As the concentration of both DIXP and TBBS increases, it could be seen that S′ max value also increases indicating an increase in the stiffness of the compounds. Also Figure 1 shows that S′ max values observed for the compounds prepared with DIXP is low compared to that of the compounds prepared with TBBS. Delta cure of the DIXP accelerated compounds is also lower than that of the compounds prepared with TBBS accelerator indicating a higher cross link density for the TBBS accelerated vulcanizates.

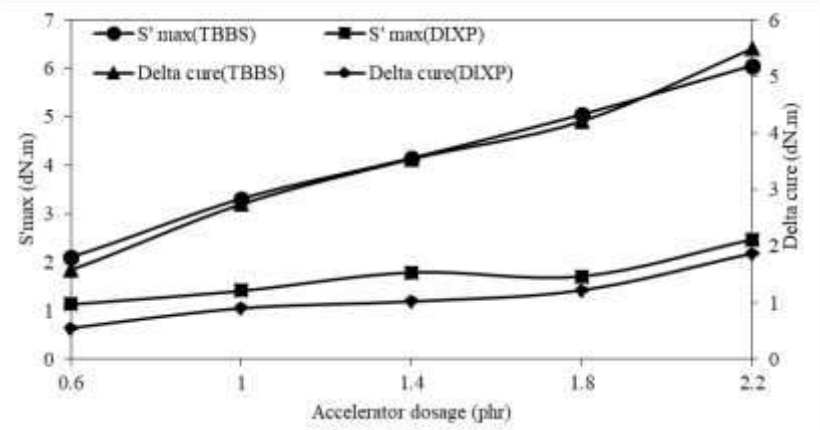


Fig. 1. Variation of S′ max and delta cure of DIXP and TBBS accelerated compounds

The stress–strain curves of the NR vulcanizates prepared with DIXP and TBBS are shown in Figures 2 and 3, respectively. The typical stress-strain curve of an elastomer is shown by the vulcanizate prepared with 2.2 phr of DIXP and those of the other three vulcanizates prepared with lower dosages of the accelerator show a much lower value for stress at break (Fig. 2). On the other hand, vulcanizates prepared with TBBS show a progressive increase in stress at break with the increase in the dosage of the accelerator.

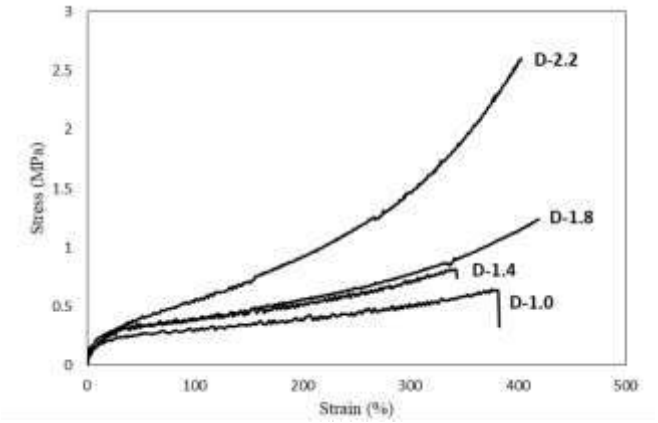


Fig. 2. Stress–strain curves of NR vulcanizates prepared with different DIXP dosages

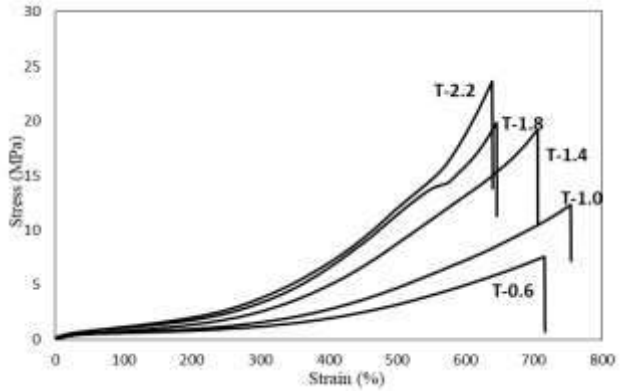


Fig. 3. Stress–strain curves of NR vulcanizates prepared with different TBBS dosages

Figure 4 illustrates the variation of elongation at break of the vulcanizates prepared with two accelerators. DIXP accelerated vulcanizates show lower values for elongation at break compared to those of the vulcanizate prepared with TBBS at the same dosage. Elongation at break is expected to reduce with the increase of accelerator dosage due to the increase in crosslink density, which decrease mobility of elastomer chains. However, there is no decrease in elongation at break with the increase of accelerator dosage, especially in the case of the series of vulcanizates prepared with DIXP. Elongation at break of vulcanizates prepared with DIXP has increased with the increase of accelerator dosage while TBBS accelerated systems has showed the expected reduction.

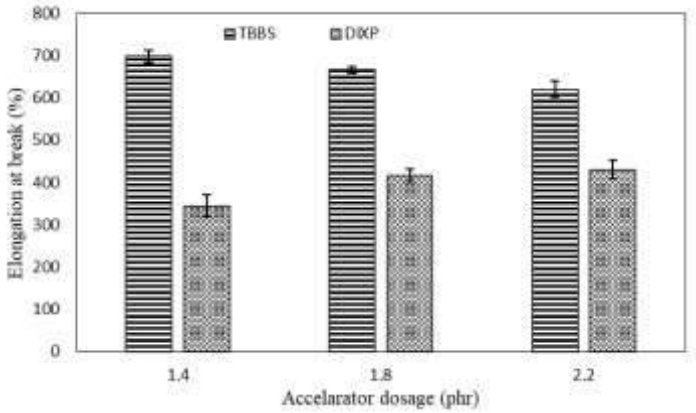


Fig. 4. Elongation at break of the vulcanizates prepared with DIXP and TBBS

In Figure 5, modulus at 300% elongations (M_{300}) increase in both the series of vulcanizates with increasing concentration of accelerators confirming the increase in crosslink density as indicated by the delta cure values in Figure 1. However vulcanizates prepared with DIXP show lower value for M_{300} compared to those of the vulcanizate prepared with TBBS at the same dosage.

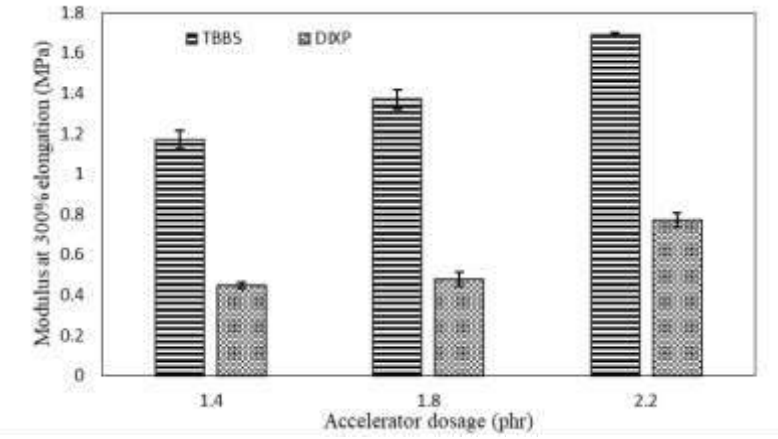


Fig. 5. M_{300} of the vulcanizates prepared with DIXP and TBBS

Figure 6 shows the variation of hardness of the vulcanizates prepared with the two accelerators at different dosages. In general, hardness is a measure of stiffness of a vulcanizate and it is directly proportional to modulus at 100% elongation. However, the variation of hardness of the vulcanizates is in agreement with that of S′ max in

Figure 1. Further it was observed lower values for hardness of DIXP accelerated vulcanizates in comparison to TBBS accelerated vulcanizates at the same loading.

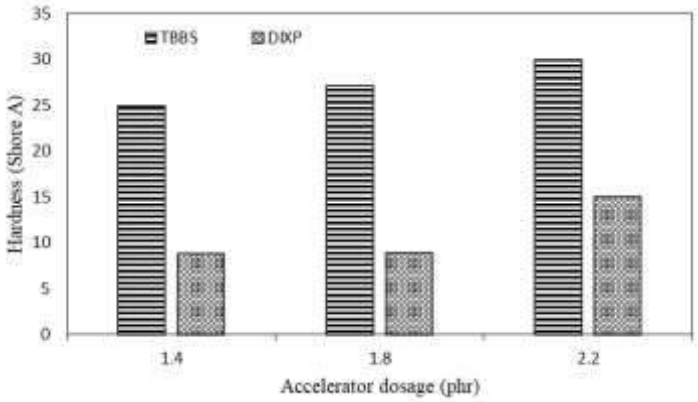


Fig. 6. Hardness of the vulcanizates prepared with DIXP and TBBS

DIXP is a nitrogen free accelerator and may be used as an alternate for nitrosamine generating traditional accelerators. Nevertheless, results reveal that most of the cure and physico-mechanical properties of NR compounds prepared with this accelerator are inferior to those of the compounds prepared with the commonly used nitrosamine safe accelerator TBBS. Therefore, it could be concluded that DIXP alone cannot be used in efficient vulcanization of NR compounds (I H K Samarasinghe, D G Edirisinghe, S Walpalage and S M Egodage - Senior Lecturers, Dept. of Chemical and Process Engineering, University of Moratuwa).

In-situ filler incorporated natural rubber latex

A novel method was developed to *in-situ* incorporation of filler particles in centrifuged natural rubber latex as a value addition step to both natural rubber and locally available dolomite. The mechanical properties of *in-situ* filler incorporated latex films and those of *ex-situ* filler incorporated latex films with different filler loadings were evaluated and compared. Further development of the novel method was continued throughout the year (Y R Somarathna, I H K Samarasinghe, S Siriwardena and D V D Mallikaarachchi).

Study of waste-mica filled NR and carbon black filled NR composites, and their properties

The fillers play a major role in rubber compounding as cost reducers and property enhancers. Carbon black (CB) is on the top of the list of most consumed fillers in tyre industry due to its excellent ability of improving physio-mechanical properties

of rubber compounds. However, due to growing environmental concerns and legislation on rubber products, the usage of CB in rubber compounding is limited owing to its affinity towards environmental pollution, high energy consumption, and depletion of non-removable resources by being a petroleum derived filler. In this study, waste mica collected at dust blowers during mica crushing is used as a potential silica filler for natural rubber. The major objectives of this study is to add value to waste mica through the enhancement of physio-mechanical properties of waste-mica filled NR composites and to compare those properties with the CB-filled NR compounds.

Firstly, the waste-mica (WM) powder was characterized using XRD and SEM, in order to study the crystal structure and surface morphology of mica, respectively. The nine compounded samples including the Control (gum compound), WM/NR and CB/NR composites were prepared according to the formula shown in Table 1. The rheological, physio-mechanical (tensile, hardness, abrasion resistance and rebound resilience), thermal (TGA) and dynamic mechanical properties (DMA) of NR composites were measured and compared.

Table 1. *Formulation of control and NR/Filler composites*

Sample Name	**Amount added/phr**								
	Control	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**
Natural Rubber	100	100	100	100	100	100	100	100	100
ZnO	5	5	5	5	5	5	5	5	5
Stearic acid	2	2	2	2	2	2	2	2	2
IPPD	1	1	1	1	1	1	1	1	1
TBBS	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Sulfur	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Waste-Mica	0	15	30	45	60	0	0	0	0
Carbon Black	0	0	0	0	0	15	30	45	60
Si-69	0	1.2	2.4	3.6	4.8	0	0	0	0

XRD confirmed the presence of silicon as SiO_2, which is about 89% w/w. SEM images of WM confirmed the flake-like crystal structure with less than 2 μm thickness (Fig. 7).

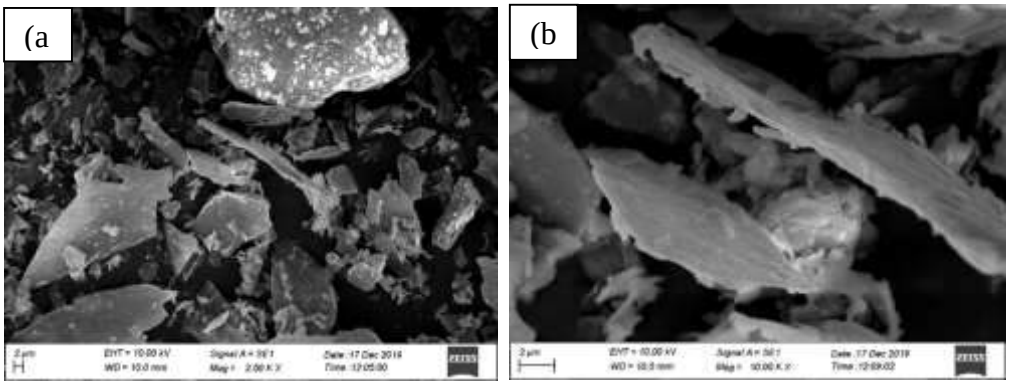


Fig. 7. SEM images of waste-mica with the magnifications of (a) x 2500 and x 50,000

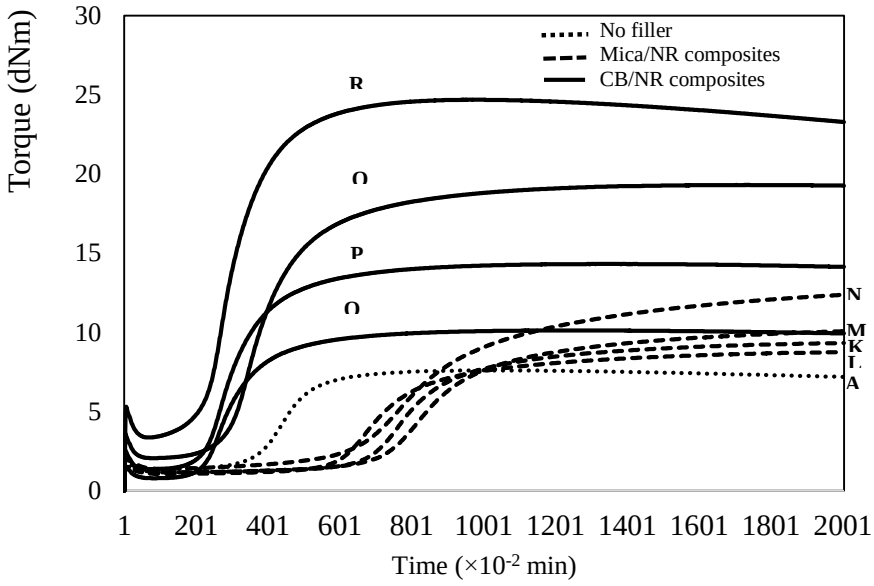


Fig. 8. Rheographs of Control, WM/NR and CB/NR samples

According to rheological data of the samples (Fig. 8), it was observed that both cure time (t_{90}) and scorch safety (ts_2) increases rapidly when increasing WM content in WM/NR composites. CB/NR composites had low ts2 values when compared to those of WM/NR. Further, both minimum torque (M_L) and maximum torque (M_H) increase rapidly when increasing the CB amount in CB/NR composites.

Tensile, abrasion volume loss, hardness and rebound resilience of samples are shown in Figure 9. Tensile strength decrease when increasing both WM and CB content

in NR/filler composites (Fig. 9a). The highest tensile strengths were observed in the lowest filler contents (K and O samples) among all WM/NR and CB/NR composites. Tensile values of WM/NR are lesser than that of the CB/NR composites with similar filler loadings. Abrasion volume losses of WM/NR composites were high in all filler loadings when compared to that of CB/NR composites (Fig. 9b). Hardness values of CB/NR composites were higher than that of WM/NR compounds in all the cases (Fig. 9c). However, in both cases, hardness increases with increasing filler loading. The highest rebound resilience was observed in the gum sample (Fig. 9d). In all other samples, the rebound resilience is gradually decreased with the increment of filler loading. However, WM/NR composites showed high rebound resilience when compared to the corresponding filler loading of CB/NR compounds.

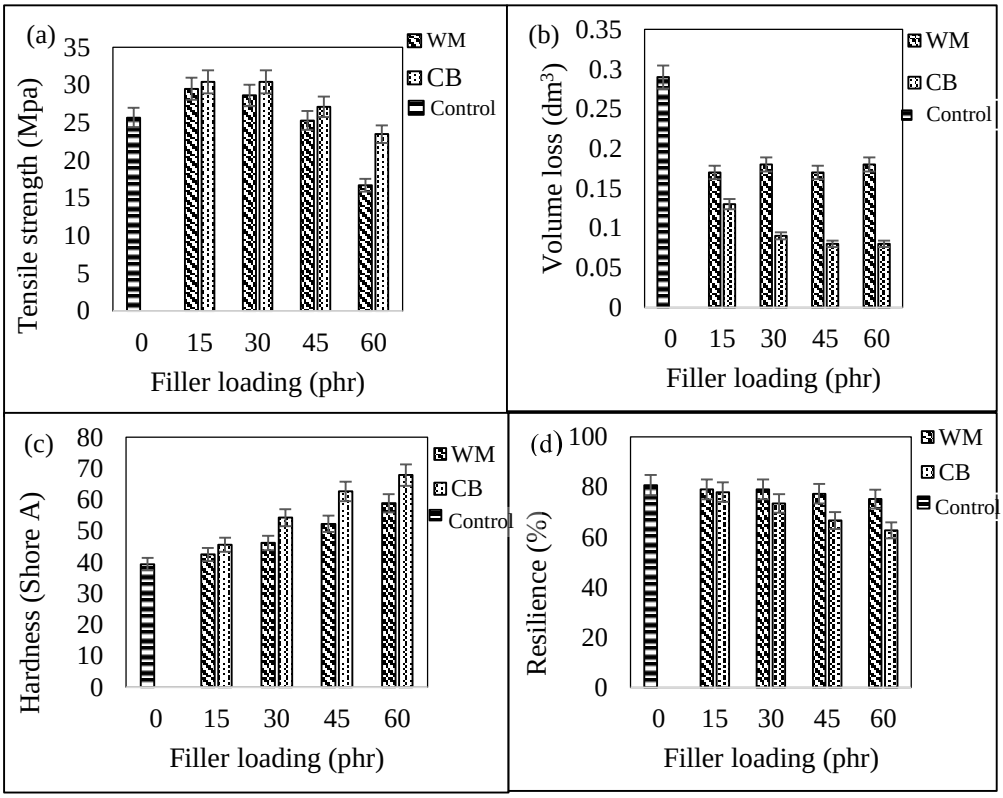


Fig. 9. Behavior of physio-mechanical properties including (a) tensile strength, (b) abrasion volume loss, (c) hardness, and (d) rebound resilience with different filler loadings

The thermograms of the composites obtained from TGA confirmed that there is no change of thermal stability due to addition of fillers. Further, according to the DMA data, the highest glass transition temperature (Tg) is obtained in the control compound, whereas all the other NR/filler composites had the Tg values in the range of 43-46 °C (Y R Somarathna, Nirmala Jayawardena, H M H Dhanukamalee, P S V Rupasinghe, H L T Tharaka, L M A Nuwan - Undergraduate Student of Uwa Wellassa University of Sri Lanka).

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
- Ceylon Electricity Board
- Samson Rubber Industries (Pvt) Ltd.
- Textrip (Pvt) Ltd.
- Polymer Products Impex (Private) Ltd.
- 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
- INOVA Environmental Services (Pvt) Ltd.
- ATG Lanka (Pvt) Ltd.
- University of Ruhuna
- University of Sri Jayewardenepura
- University of Colombo
- University of Peradeniya

RAW RUBBER AND CHEMICAL ANALYSIS

A P Attanayake

DETAILED REVIEW

Staff

Dr (Mrs) A P Attanayake, Senior Research Officer was the in charge officer of overall activities of the department throughout the year. Mr A M K S P Adhikari, Research Officer was on duty until end of March 2019. He was granted study leave for a period of three years commencing from 04th April 2019 to carry out his post graduate studies at University Putra Malaysia, Malaysia.

Mrs H V K Gamage, Experimental Officer retired with effect from 04th January 2019 after providing an outstanding 38 years of service to the Institute.

Mr L P P Vitharana, Experimental Officer retired with effect from 12th April 2019 after providing an outstanding 37 years of service to the Institute.

Mrs C Lokuge and Miss M Wijesekera, Experimental Officers were on duty throughout the year. Miss S P Wijewardana, Miss N C Y Kithmini, Miss M U D S Weerasinghe, Mr H D M S Wijewardana, Mr K A S T Koswatta Technical Officers was on duty throughout the year. Ms N S Siriwardana and G M Udayangani joined to the department as Technical Officers with effect from July 18th and August 22nd respectively. Management Assistant Miss W D D Samanmali was on duty throughout the year.

Research students

- Miss T M S Ariyaratne, BSc student from faculty of Palm & Latex Technology, Uva Wellassa University, completed her final year research project on "Comparative study of physical properties of PB 86 clone and RRIC 121 clone; genotype of *Hevea brasiliensis*" under the supervision of Dr (Mrs) Anusha Attanayake.

- Miss A U H Abeysinghe, BSc student from Faculty of Applied Sciences, University of Sri Jayewardenapura, completed her final year research project on "Use of surface energy to evaluate adhesion of bituminous based rainguard sealants to substrates" under the supervision of Dr (Mrs) Anusha Attanayake.

Seminars/Training Programmes/Workshops/Exhibitions conducted

Officer/s	Subject	Benificiary/Client
AP Attanayake CS Lokuge	One week training on raw rubber analysis	D S K Latex Rubber, Horana
Staff of the department	Latex & Raw Rubber Analysis	Undergraduate students from University of Uva Wellassa
Staff of the department	Latex testing	KRIM Gunathileka, Open University of Sri Lanka
Staff of the department	Latex Testing	MADD Kumara, University of Sri Jayewardenapura

Lectures/Seminars/Workshops/Meetings attended

Officer/s	Subject	Organization
AP Attanayake	Technology update Programme	Dartonfield, RRISL
	Research Meeting	Dartonfield, RRISL
	Progress Review Meeting	Dartonfield, RRISL
	HOD Meeting	Dartonfield, RRISL
	Board of Survey Workshop	Dartonfield, RRISL
	Crop Symposium	Marino Beach Hotel
	Workshop on ISO 17025	Plastic & Rubber Institute, Rajagiriya

LABORATORY INVESTIGATIONS

Study on raw rubber and rheological properties of RRISL 203 clone

The objective of this study was to study the raw rubber and rheological properties of this clone in order to evaluate the suitability for the production of advanced rubber products. Un-fractioned-unbleached crepe rubber manufactured using latex from this clone was collected from three crepe rubber factories in three different areas in Sri Lanka. RRIC 121, which is the most popular clone in Sri Lanka was selected as the control. Studies carried out on raw rubber properties of these rubbers revealed that, above clone recorded the highest Plasticity number as well as the highest Mooney viscosity among the other clones available in Sri Lanka.

Table 1. *Summary of raw rubber properties (with the coefficient of variation in parentheses)*

Property	RRIC 121	RRISL 203
Initial Plasticity Number (P^o)	49.2 (3.94)	66.82 (9.30)
Plasticity Retention Index (PRI)	64.25 (6.44)	52.02 (9.92)
Mooney Viscosity [MU] ML(1+4) @100°C	87.70 (4.12)	110.61 (13.14)
Exponent a [log MU/log (s)	-0.272	-0.224
Elastic energy retention exponent (a+1)	0.728	0.776
Stress Relaxation time (seconds)	18.56 (0.72)	26.18 (1.72)
Gel Content % (w/w)	10.54 (3.45)	34.62 (19.57)

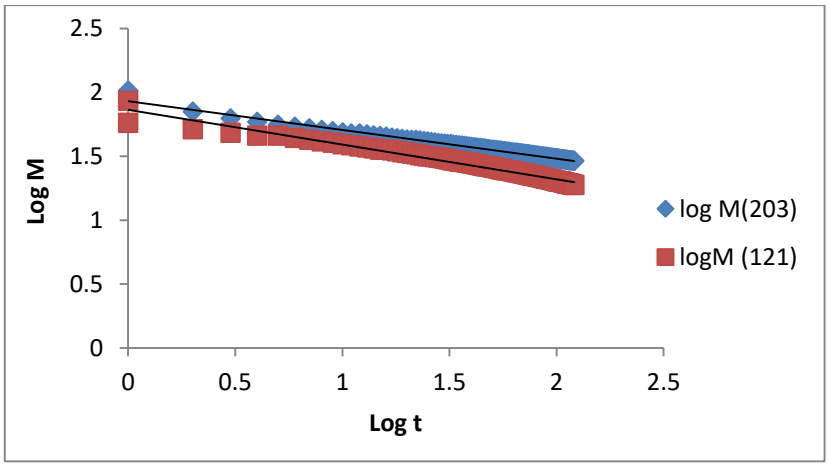


Fig. 1. Relaxation data on a log t versus log M values for RRIC 121 clone and RRISL 203 clones

According to Figure 1, RRISL 203 clone showed significantly higher stress relaxation time when compared with RRIC 121 clone.

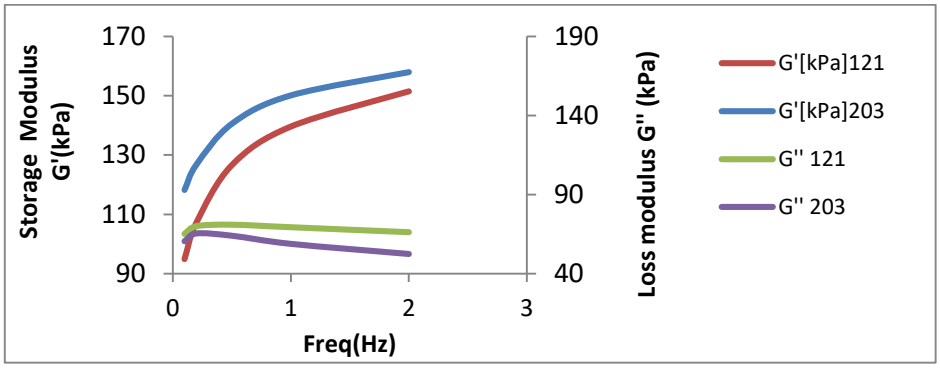


Fig. 2. Variation of storage modulus and loss modules under frequency sweep

Results of frequency sweep test are clearly showed that the rheological behavior of RRISL 203 clone is significantly different from RRIC 121 clone (Fig. 2). Trend of storage modulus (G') of RRISL 203 clone is relatively higher than RRIC 121 clone, which indicate that RRISL 203 clone has relatively higher molecular weight than the control sample. Low viscous modulus (G") at higher frequency in RRISL 203 clone indicates that clone possesses lower fraction of polymer with low molecular weight and broader molecular weight distribution.

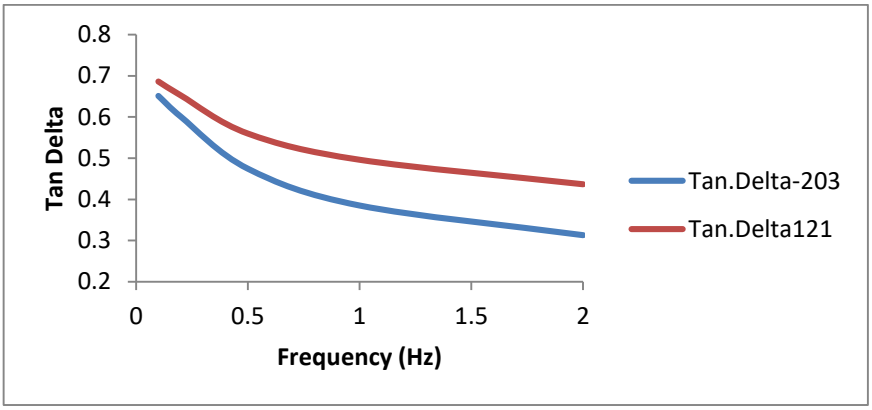


Fig. 3. Variation of Tan Delta values under frequency sweep

Tan delta is a good indicator of the molecular weight and molecular weight distribution of polymer. According to the overlay plot of tan delta values (Fig. 3), it is clearly showed that lower frequency tan delta values are slightly different. Above results showed that lower molecular fraction of the RRISL 203 clone and RRIC 121

clones are slightly different However, higher frequency tan delta values are significantly different for two clones studied. Large change in tan delta values indicates that RRISL 203 clone is a linear polymer with low chain branching with respect to RRIC 121 clone (A P Attanayake and M U D S Weerasinghe).

Comparative study of physical properties of PB 86 clone and RRIC 121 clone genotype of *Hevea brasiliensis*

Unfractioned unbleached crepe rubber was prepared for both RRIC 121 clone and PB 86 clone and their raw rubber properties showed by the Table 2.

Table 2. *Results of raw properties of UFUB crape rubber sample*

Property	Specification	PB 86	RRIC 121
Acetone content	3.00 (max)	1.87^{b}	3.45^{a}
Volatile matter% (w/w)	0.5% (max)	0.34^{b}	0.38^{a}
Ash content% (w/w)	0.20 (max)	0.085^{a}	0.080^{b}
P0 (Wallace units)	30 (min)	53.5^{a}	48.5^{b}
PRI (Wallace units)	60 (min)	61.68^{a}	54.64^{b}
Nitrogen content% (w/w)	0.35 (max)	0.28^{a}	0.32^{a}
Mooney viscosity	75-85	77.51^{a}	75.56^{b}
Colour	1 - 1.5 (unit)	1^{b}	1.5^{a}
Polymer content	93-96	98.39^{b}	98.77^{a}

Note: Means that do not share same letter in grouping are significantly different

Table 3. *Curing characteristics of the compounds*

Compound	PB 86 - A	RRIC 121 - A
Maximum Torque :ML (dNm)	1.10^{a}	0.77^{b}
Minimum Torque : MH (dNm)	6.03^{a}	5.67^{b}
MH-ML (dNm)	4.93^{a}	4.90^{b}
Scorch time : Ts_2 (Minutes)	2.46^{a}	2.55^{a}
Cure time : Tc_{90} (Minutes)	4.96^{a}	4.97^{a}
Cure rate index : CRI	20.22^{a}	20.35^{a}

(Note: Values that do not share a same letter are significantly different with respect to the particular property)

Table 3, shows curing characteristics of the rubber gum compounds made out of PB 86 and RRIC 121 clone. The highest (MH) and the lowest minimum torque (ML) have been recorded in the PB 86 rubber compound. The information of the processability of the particular rubber compounds can be described by the minimum

torque value. It relates to the initial viscosity of the compound. The minimum torque value has a relationship with stiffness and cross link density of compounded rubber. The maximum torque (MH) of compounds can be used to interpret the elastic modulus of vulcanizates. Further, the torque difference (MH-ML) can be correlated to the cross linking density of rubber vulcanizate. Crosslink density of PB 86 clone is significantly higher than RRIC 121 clone. Clone type has not significant influence on scorch time, the optimum cure time and the CRI. PB 86 clone shows relatively higher tensile strength (Fig. 4), Elongation at break (Fig. 5), Tear strength (Fig. 6) and rebound resilience value (Fig. 9). Further above clone shows low compression set value (Fig. 8) and low hardness value (Fig. 7).

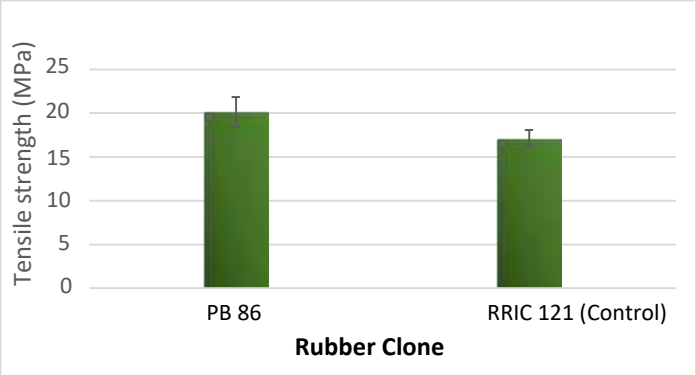


Fig. 4. Tensile strengths of the gum vulcanizate

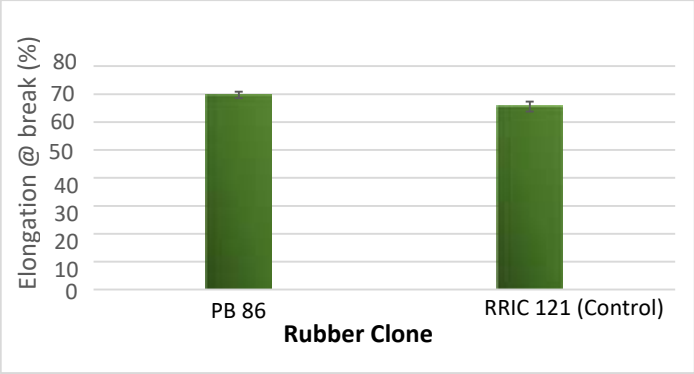


Fig. 5. Elongation at break of the gum vulcanizate

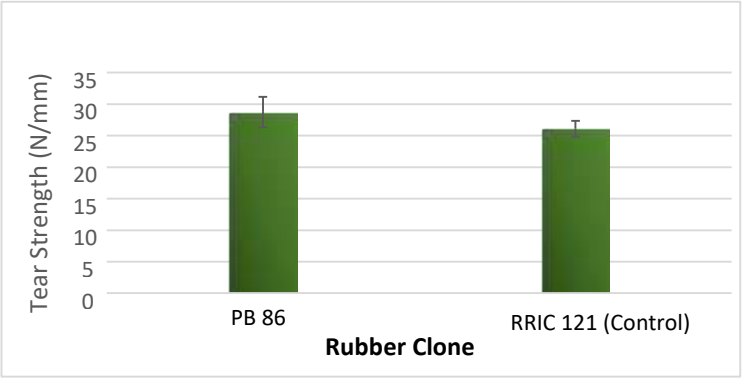


Fig. 6. Tear strengths of the gum vulcanizate

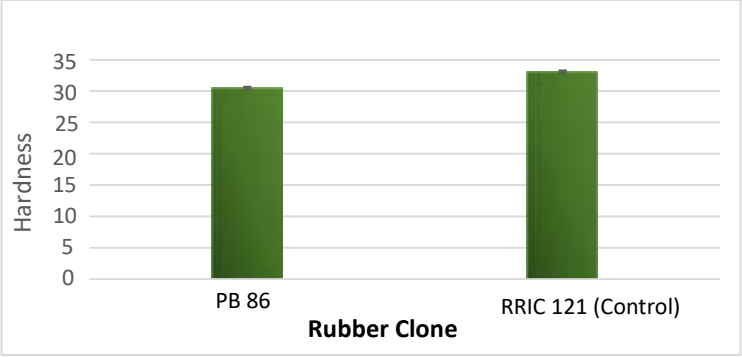


Fig. 7. Hardness of the gum vulcanizate

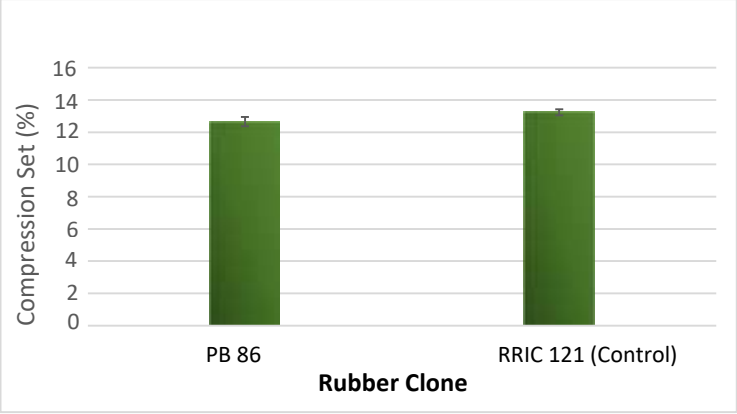


Fig. 8. Compression set of the samples

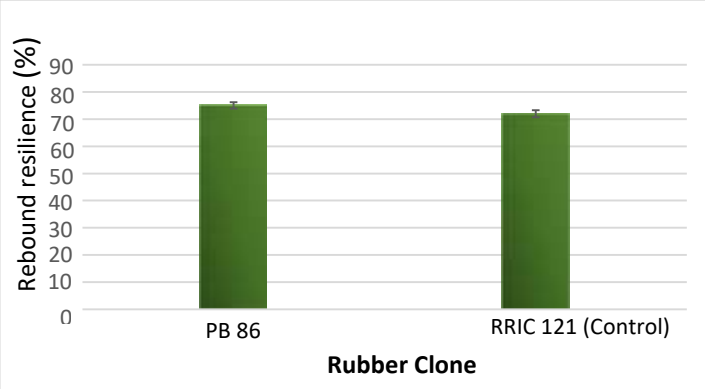


Fig. 9. Rebound resilience of samples

(A P Attanayake, N S Siriwardana and T M S Ariyaratne)

Use of surface energy to evaluate adhesion of bituminous based rainguard sealants to substrates

This research was conducted at the Rubber Research Institute of Ratmalana in collaboration with the Road Development Authority (RDA). The objective of the study was to solve the issues faced by the rubber planters in Sri Lanka regarding rain guard sealant. The rain guard sealant is often prone to developing cracks in service, leaving the rubber bark open to air thus contaminating the latex with rain water. The composition of a rain guard sealant consists of bitumen, styrene-butadiene copolymer and filler. The high variation of bitumen sources, resources processes, polymer content and filler type significantly affects the chemical composition of a sealant and consequently its rheological properties. Apart from these factors various environmental conditions are encountered through the lifetime of a sealant. This along with factors such as time, temperature, aging, moisture, physical hardening, contamination, storage hardening, and degradation of surrounding material, microbial action, and trapped moisture and air bubbles during installation make it even more challenging to predict sealant performance in the field. While this study is not aiming to simulate field conditions, it attempts to develop laboratory test methods capable of measuring parameters that correlate with field performance. Having such tests, one can select sealants that have high potential of appropriate field performance. In addition, the opportunity to further study the effects of different field conditions is available by establishing a standard test method to assess sealant performance. In order to find a solution to this matter, the rubber research institute ventured on a research to establish sealant specifications by evaluating the existing sealants in the market by comparing

the adhesiveness of the sealants. Adhesive failure in which the sealant de bonds from the crack walls is the most common sealant failure mode.

The resistance against separation of two materials that are adhered together for a period of time at a specific temperature is defined as adhesion. In order to improve adhesive bonds and predict failures the adhesion phenomenon has been studied both from physical and chemical points of view. Adhesion is also an important parameter in many practical engineering applications such as crack sealing. One of the main causes of adhesion failures is fracture. A fracture at the interface can be an irreversible entropy-creating process, through which a substantial amount of energy is dissipated. Energy dissipation is related to the ability of the interface to transfer stress, and also to the adhesive's plastic and viscoelastic deformation properties. Five samples of rain guard sealant collected from different plantation companies in Sri Lanka, among them some of the sealant were imported products and some produced locally.

Table 4. *Results obtained (averaged) for contact angle measurements for each probe liquid with the sealant as the substrate*

Sealant Type	Contact angle for water	Contact angle for glycerol	Contact angle for formamide
LA	92.6	98.2	68.35
PA	87.45	93.15	66.45
PU	97.75	101.15	68.65
CL	104.5	112.85	67.8
DA	113.45	131.85	73.25

Table 4 shows the contact angle results obtained for each sealant as the substrate. Water, glycerol and formamide are used as the respective liquids. When analyzing the contact angles with water for the series of sealants we can see that the DA sample shows the highest hydrophobicity while the PA sample shows the highest hydrophilic nature. Although these values are only useful in determining the surface tension values of the sealants (Table 5) and surface energy component (Table 6), it is hard to predict about the sealant adhesiveness through these data alone. In order to get an idea about the sealant adhesiveness further data such as contact angle of each sealant on a glass slide as the substrate was carried out.

Table 5. *Calculated surface tension (γ_s) values obtained for each sealant*

Type of sealant	γ_s^{LW}	γ_s^+	γ_s^-	γ_{total}
LA	151.29	40.19	3.44	174.80
PA	127.91	28.51	5.90	153.85
PU	169.26	47.61	1.23	184.57
CL	299.63	113.84	0.05	304.71
DA	24.30	15.21	25	63.3

Table 6. *Surface Energy (γ_l) components of probe liquids at 20° C, m J/m^2*

Probe liquid	γ_l	γ_l^{LW}	γ_l^+	γ_l^-
Water	72.8	21.8	25.5	25.5
Glycerol	64	34	3.92	57.4
Formamide	58	39	2.28	39.6

Table 7. *Contact angle (°) between different sealants and glass*

Type of sealant	Contact angle with a glass slide
LA	126.73
PA	121.12
PU	131.51
CL	113.78
DA	103.34

The above data mentioned in the Table 7 shows different contact angles of different sealants on glass surfaces. Accordingly, the PU sample shows the highest contact angle with glass. This gives the idea that the PU sample could be having the lowest adhesion with the substrate. But as work of adhesion depends both on the surface tension and contact angle formed with a specific substrate we could only arrive at` such conclusion by calculating the work of adhesion.

Table 8. *Table of work of adhesion (J/m^{-2}) values for each sealant*

Type of sealant	Work of adhesion (J/m^{-2})
LA	70.26
PA	74.33
PU	62.24
CL	181.84
DA	46.69

The work of adhesion values for each sealant is depicted in the Table 8. Accordingly, the CL sample shows the highest work of adhesion and the DA sample

shows the lowest work of adhesion. Work of adhesion is a parameter which gives an idea about the degree of adhesion of a sealant towards a particular surface. In other words, it gives a quantifiable data about the difficulty to peel off a sealant from a specific substrate. The above data shows that the DA sample is the easiest to peel off and the CL sample is the hardest to peel off (Fig. 9).

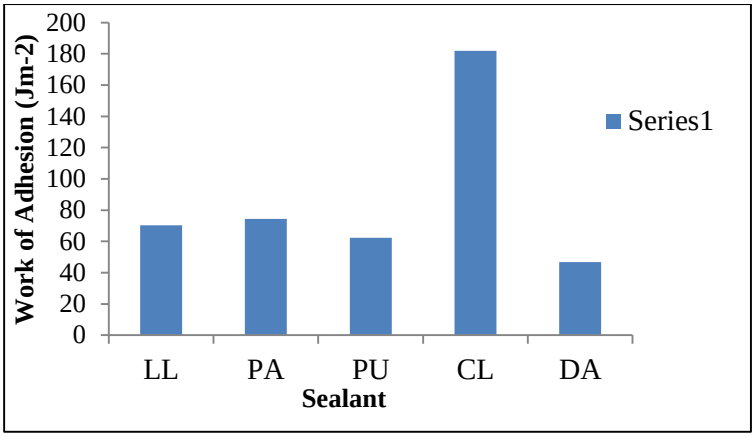


Fig. 9. Work of adhesion of type of sealant

Table 9. *Softening point values and penetration values*

Type of sealant	Softening point value	Penetration value
PA	55.7	246
LA	62.5	212
PU	58.5	212
CL	56.7	170
DA	54.7	133

The conclusion of this project is that the rain guard sealant obtained from CL provides the best work of adhesion and that obtained from DA provides the lowest adhesion. However, when considering the softening point values and penetration values (Table 9), it provides the highest softening point value is depicted by PU. It suggest that PU requires more temperature to soften. On the other hand the lowest penetration value is again depicted by PU which shows that it is the stiffest sealant. Further studies will be carried out in order to find correlation between work of adhesion and other bitumen quality parameters (A P Attanayake, Supun Tharaka and A A U H Abeysinghe).

Quality analysis of latex, raw rubber and rubber processing chemicals
RR & CA/2019/01

Testing and certification services were provided to all the sectors in the rubber industry as given below:

Service	No. of samples
Miscellaneous analysis	
Raw rubber test	2009
Latex sample test	1015
Chemical samples	29
Gloves sample	01
Polythene samples	22
Testing certificates	350

RAW RUBBER PROCESS DEVELOPMENT AND CHEMICAL ENGINEERING

Y C Y Sudusingha

DETAILED REVIEW

Staff

Mr Y C Y Sudusingha, a Research Officer covered up the duties of the Head of the Raw Rubber Process Development & Chemical Engineering Department throughout the year. Messrs U M S Priyanka, V C Rohanadeepa, A K D Warnajith, Experimental Officers and Messrs R D Illeperuma, W A S Bandara and P K N N Sandamali, Technical Officers were on duty throughout the year. Mrs Chandrika Nalini, an Experimental Officer retired on 28th October 2019 and Mr W U R de Silva, a Technical Officer resigned with effect from 31st July 2019. Mrs H A Janani Lakshika, Management Assistant was on duty throughout the year.

Research students

- Ms P M G Hansani, BSc student from Uva Wellassa University of Sri Lanka, completed her research project titled "Preparation and characterization of deproteinized crepe rubber using a serin type proteolytic enzyme" under the supervision of Mr Yohan Sudusingha
- Ms P M G Hansani, BSc student from Uva Wellassa University of Sri Lanka, completed her research project titled "A Novel Process to Manufacture Low Protein Centrifuged Latex" under the supervision of Mr Yohan Sudusingha
- Mr M A D D Kumara, BSc Special in Polymer Science student from Sri Jayawardenapura University of Sri Lanka, completed his final year research project titled "Novel preservative system for Natural Rubber Latex" under the supervision of Mr Yohan Sudusingha and Dr Susantha Siriwardena
- Ms M G Romaine Sanju, BSc Special in Physics student from Sri Jayawardenapura University of Sri Lanka, completed her final year research project titled "Development of Multi-Functional Carbon Nanotubes (CNT) Incorporated Natural Rubber (NR) Cellular Compounds" under the supervision of Mr Yohan Sudusingha and Dr Susantha Siriwardena
- Ms G D Saduni, BSc Special in Chemistry student of Rajarata University and Messrs R K D T T Alwis, H M C S B Herath and D G T R Bandara BSc (Eng) students from Peradeniya University of Sri Lanka, completed their industrial training at Raw Rubber Process Development and Chemical Engineering Dept.

Seminars/Training programs/Workshops/Conferences/Meetings attended

Officer/s	Subject	Organization
YCY Sudusingha	Workshop on Calibration and Uncertainty	Sri Lanka Accreditation Board
YCY Sudusingha UMS Priyanka VC Rohanadeepa AKD Warnajith RD Illeperuma PKNN Sandamali	7th Crop Symposium	Crop Institutes of Sri Lanka
UMS Priyanka VC Rohanadeepa AKD Warnajith RD Illeperuma PKNN Sandamali WAS Bandara	"SRI LANKA LAB EXPO" Exhibition and Conference on all laboratory related technologies and products	Sri Lanka Exposition and Convocation Centre

Seminars/Training programs/Workshops/Exhibitions conducted

Officer/s	Subject	Organization
YCY Sudusingha	Raw rubber processing and waste water treatment technologies. Drying techniques used in raw rubber manufacturing processes	National Institute of Plantation
YCY Sudusingha AKD Warnajith	Certificate course in Rubber and Plastic technology	Plastic and Rubber Institute
	RSS manufacturing Process	Thurusaviya Program
YCY Sudusingha AKD Warnajith UMS Priyanka	Workshops on Latex Preservation (Eight Programs)	Dipped Products Private Limited
	Training Program on raw rubber processing for Development Officers	Rubber Development Department
YCY Sudusingha AKD Warnajith RD Illeperuma UMS Priyanka	Training Program on raw rubber processing for undergraduates	Faculty of Technology of University of Sri Jayawardenapura
AKD Warnajith UMS Priyanka	Field training program on "Crepe Rubber Manufacture" for Planter Trainees	National Institute of Plantation Management
AKD Warnajith VC Rohanadeepa	Training Program on "Raw Rubber Processing and Practices" for undergraduates	Faculty of Animal Science and Export Agriculture of University of Uva Wellassa

Officer/s	Subject	Organization
AKD Warnajith	Training Program on "Raw Rubber Processing" for Diploma holders	Angunakolapalessa Agriculture School and Karapincha Agriculture School
	Training Program on "Raw Rubber Processing" for Msc Students	University of Kelaniya
	Training Program on RSS Manufacturing for Smallholders (Six Programmers)	Thurusaviya Trust Fund
RD Illeperuma PKNN Sandamali WAS Bandara	Laboratory Training on Waste Water Testing for planter trainees	National Institute of Plantation Management
Staff of the Department	Workshop on "RSS Grading"	RSS manufactures
	Seminar on "How to control VFA at the field level"	Field latex suppliers of Glenross Centrifuged Factory
	Training program on "Raw Rubber Processing" for Rubber Development Officers	National Plantation Institute Rubber Development Department

Advisory visits

Services provided

Services provided	No. of factories/visits
Process and quality improvements	08 (15)
Waste water treatment	05 (6)
Waste water sample collection for testing	41 (42)
Plans issued for construction of new SS drying systems with Capacity less than 100kg	25
Miscellaneous advisory and troubleshooting	12 (12)
Tank Calibration	13 (11)

Waste water analysis

Collection of waste water samples from raw rubber processing and allied industries and analysis of waste water were carried out throughout the year.

Sample tested and certificates issued

Sample tested	No. of Samples/ Certificates
Waste water - rubber related	73/60
Waste water - Non rubber related	17/15
Processing water	5/2
Miscellaneous Sample (Metal ions, ZnO, *etc*.)	2/2
Analysis of Extractable proteins	15/07
No of "certificates of epidemic prevention" issued for sole crepe	50

Miscellaneous

Technical assistance given to Thurusaviya annual programs was continued by extending the services of resource personnel and technical expert panels for evaluating quotations, issuing smoke house plans, inspection of construction and operational activities of sheet rubber processing centers and single day smoke drying units.

LABORATORY AND FIELD INVESTIGATIONS

A novel process to manufacture low protein centrifuged latex

An experiment was conducted to develop to manufacture centrifuged latex with reduced protein levels following an environmentally friendly hybrid route by combining fractionation and creaming processes. Firstly, preserved NR field latex was fractionated at four different Dry Rubber Contents (DRC): 15%, 18%, 21% and 24%. Subsequently, all fractionated field latex were diluted to bring down the DRC at 10%. They were creamed up to 30% DRC using sodium alginate at 20 phr concentration. Creamed latex obtained was then subjected to centrifugation process. Fractionated Creamed Centrifuged Latex (FCCL) samples were compounded according to a basic formula to form latex films and cured in a drying oven at 120 ^{0}C for 20 minutes. Latex properties and their film properties were studied according to the standard test procedures and compared with Single Centrifuged Latex (SCL) and Double Centrifuged Latex (DCL). The FCCL sample fractionated at 15% DRC (15% FCCL) showed the lowest nitrogen content while other samples follow the order of 18% FCCL< 21% FCCL < 24% FCCL<DCL<SCL. According to the one way ANOVA analysis, there was a significant difference in latex properties (TSC, DRC, NRC, TN) in novel method and conventional method at 95% confidence level. Also, 15% FCCL exhibited the lowest VFA development over the all other samples including SCL and DCL due to the lower amount of non – rubber contents (NRC). Moreover, it showed similar MST development with all other samples. However, films prepared using FCCL and DCL have higher swelling indices and lower tensile strength and water adsorption as most of the protein may have removed during the process. In conclusion,

the process of manufacturing centrifuged latex using creamed and fractionated at 15% DRC is more suitable to manufacture of low protein centrifuged latex for sensitive advanced applications than currently available methods such as double centrifugation.

Table 1. *Results of centrifuged latex properties*

Sample	TSC (%w/w) ISO 124:2014	DRC (%w/w) ISO 126:2005	NRC (%w/w) TSC - DRC	TN (%w/w) ISO 1656:2014
DCL	58.8533^{b}	57.6533^{b}	1.2^{bc}	0.1676^{b}
SCL	61.1567^{a}	58.610^{a}	2.547^{a}	0.2697^{a}
15% FCCL	57.803^{e}	56.600^{c}	1.143^{c}	0.1263^{c}
18% FCCL	58.3233^{d}	57.02^{bc}	1.303^{bc}	0.1461^{bc}
21% FCCL	58.4067^{cd}	56.95^{c}	1.4567^{bc}	0.1520^{bc}
24% FCCL	58.6633^{bcd}	57.1533^{bc}	1.5100^{bc}	0.1579^{b}

Table 2. *Film properties*

Sample	Water adsorption (w/w %)	Swelling Index	Tensile strength (Mpa)	Modulus @ 100 (Mpa)	Tensile strain @ break (%)
SCL	14.1	3.7	19.1	0.64	529
DCL	9.6	3.9	18.6	1.14	750
15% FCCL	8.6	4.2	15.3	0.62	903
18% FCCL	8.9	3.7	15.6	0.58	572
21% FCCL	9.4	4.6	14.5	0.64	501
24% FCCL	9.4	6.7	15.1	0.63	728

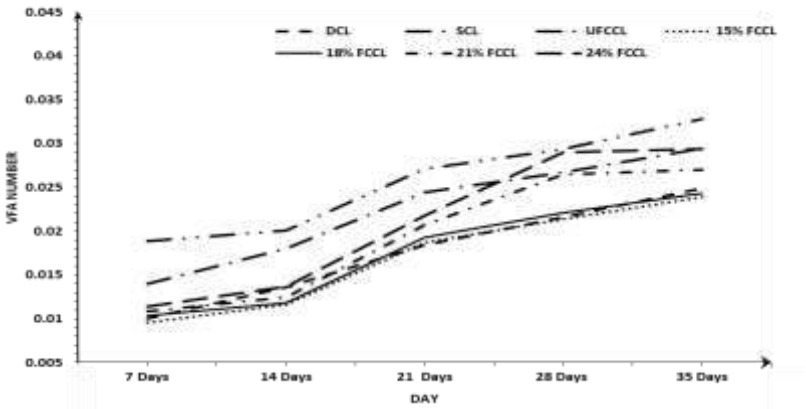


Fig. 1. VFA development of centrifuged latex
(Y C Y Sudusingha, P K N N Sadamalee and Ruvinda Illeperuma)

A novel curing process for thin latex films

In the manufacturing process of vulcanized latex films, pre-preparation of number of separate dispersions to incorporate various vulcanizing ingredients into latex is a must. Improvement of the efficiency of this process could positively affect the curing rates and resource use, hence the productivity. A new procedure for incorporation of vulcanizing ingredients into latex was tested in an attempt to shorten the total production time of the compounds without affecting the product performance. In the novel process, a single dispersion of all curing ingredients (accelerator, activator and sulphur) was first prepared maintaining their relevant ratios. This dispersion of curing agents mix was later added to latex compound and thin vulcanized latex films were prepared. Their counterpart latex films were also prepared following the conventional compounding process (separate addition of dispersions of the ingredients). It was found that new ingredients incorporation procedure could be used to incorporate curing agents to latex without affecting the quality of compounded latex and the quality of vulcanized latex films. The reduction of maturation and curing periods of latex compounds were found when the novel procedure is adopted. In terms of mechanical properties, the novel method led to a slight improvement in properties of the vulcanized films when compared to the conventionally prepared ones. It was found that dispersion mix with highest possible total solid content matured at ambient temperature (28 ^{0}C) offers the optimum performance. The dispersion mix stored above the ambient temperature yielded vulcanized films with poor mechanical properties with prolongs drying periods. It was also found that storage period of dispersion mix at ambient temperature did not show any impact on the vulcanized film properties (S Siriwardena, U M S Priyanka, A K D Warnajith, V C Rohanadeepa and P K N N Sadamalee).

Preparation of polypropylene and skim natural rubber thermoplastic natural rubber

Processing conditions for unvulcanised and dynamically vulcanized polypropylene and skim rubber blends were established in the previous year. A series of these blends (Table 3) was prepared in an internal mixer following the established processing conditions.

Table 3. *Composition of polypropylene and natural rubber blends*

	PP-Skim Natural Rubber series					**PP-Standard Lanka Rubber series**				
PP	30	40	50	60	70	30	40	50	60	70
SNR	70	60	50	40	30	-	-	-	-	-
SLR	-	-	-	-	-	70	60	50	40	30

Tensile properties of the blends

Stress-strain curves of both PP/SLR and PP/SNR blends are presented in Figures 2 and 3, respectively. All curves have shown the behaviour of typical Thermoplastic Elastomers (TPEs) with relatively high initial modulus, less defined yield stress. It was shown that the replacement of SLR with SNR has no effect on the EB values of the PP/NR blends.

The results show that dynamic vulcanization of the rubber phase and the increase of the plastic phase in the blend cause to increase the tensile strength irrespective of the rubber. Tensile values extracted for dynamically vulcanized blends are presented in Figure 4. When the rubber phase becomes smaller, the effect of crosslink formation may not be sufficient to offer a significant difference in tensile strength as PP phase predominates over in the properties of the blends.

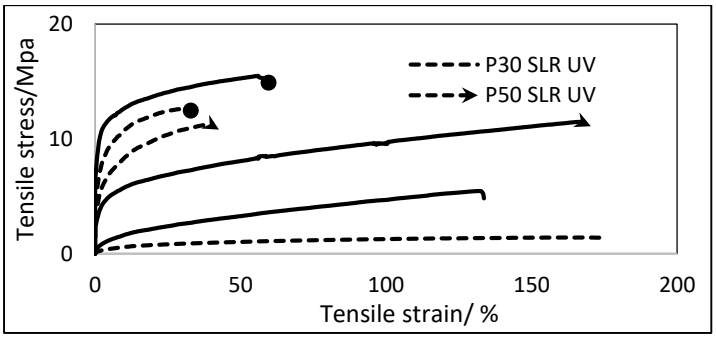


Fig. 2. Stress-strain curves of the PP/SLR all blends types at different blend ratios

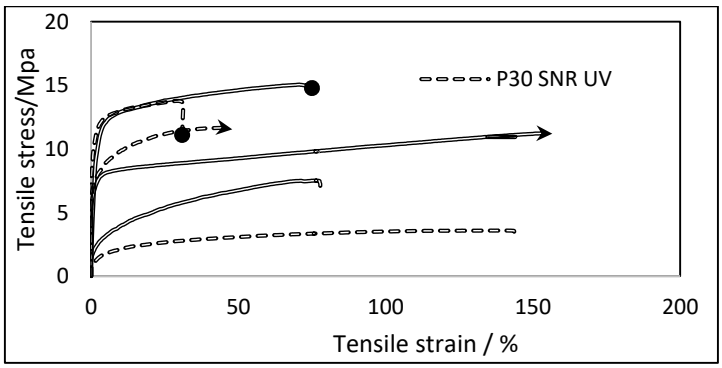


Fig. 3. Stress-strain curves of the PP/SNR all blends types at different blend ratios

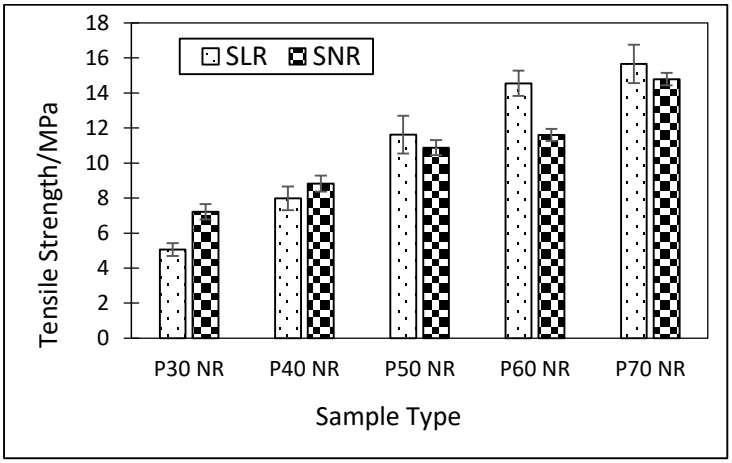


Fig. 4. Effects of blend ratio on tensile strength of PP/NR dynamically vulcanized blends

Hardness of the blends

For both types of blends, SNR incorporated blend shows high values, particularly in rubber dominant blends. With the increase of PP content, it became the continuous phase and the effect of rubber phase on hardness diminishes. However, there was an increasing trend in the hardness values as the SNR percentage in the blend increased.

Melt Flow Index (MFI) of the blends

It can be clearly seen that both PP/SNR-DV and PP/SLR-DV blends have significantly lower MFI values than their UV counterparts because the viscosities of blend materials have increased after vulcanization (Figs. 5 and 6). It was not possible to get a measurable value for P40 SLR-DV and P50 SLR-DV blends according to the method followed because those blends have high viscosities. MFI has also increased with the increase of plastic content of PP/NR blends showing better processability of PP rich blends. However, it is interesting to note that there is no significant difference of viscosities between both PP/SLR and PP/SNR blends as assessed by MFI value. Comparison of the MFI values shows that the viscosities of PP/SNR DV blends were lesser than those of PP/SLR-DV blends.

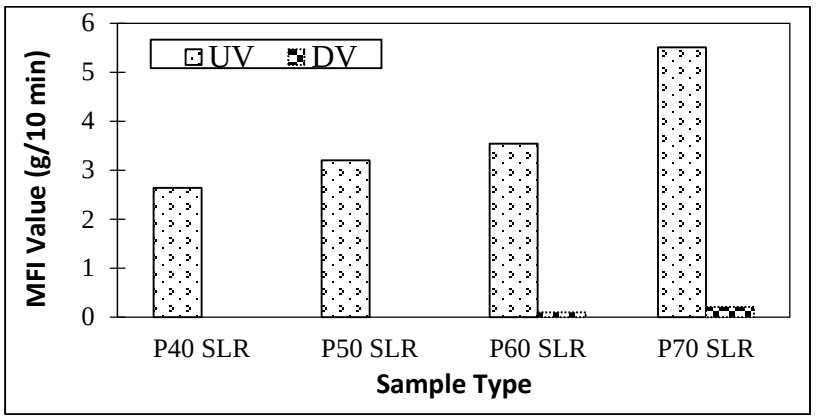


Fig. 5. The MFI results of PP/SLR blends

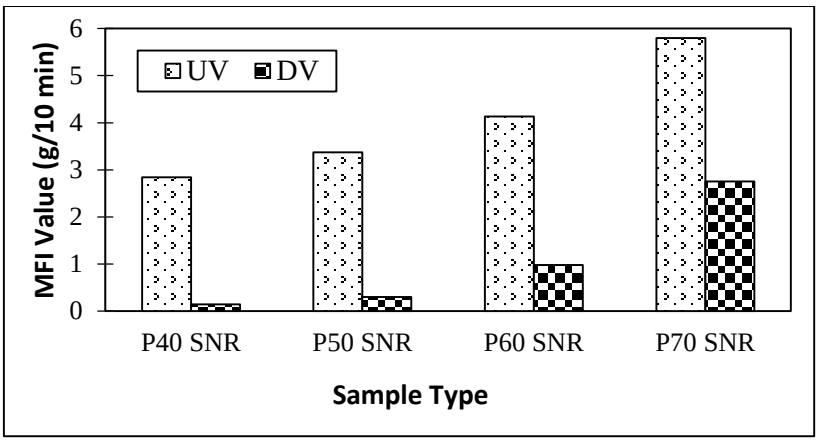


Fig. 6. The MFI results of PP/SNR blends

Aged tensile properties

Thermo-oxidative ageing properties

For this study, DV blends of P40 SNR, P50 SNR and P60 SNR blends were chosen. Figure 7 shows the effects of blend ratio on the ageing properties of dynamically vulcanized PP/SNR blends. It could be seen that all PP/SNR blends have small decrements of tensile strength after ageing. It could be observed that the aged tensile strength is increased with increase in the plastic content in the blend.

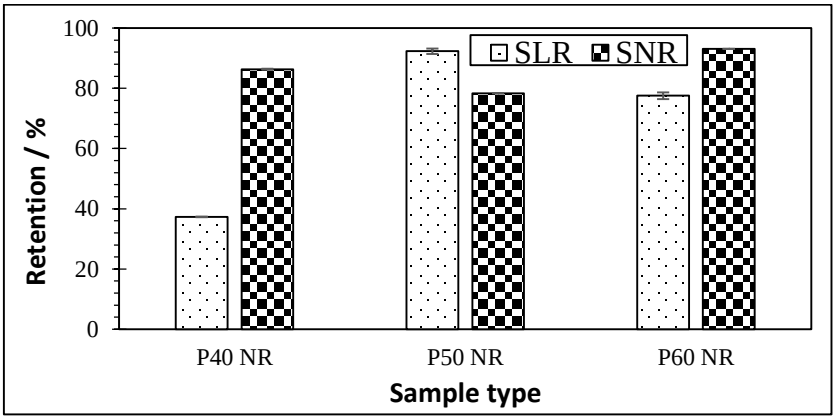


Fig. 7. Effects of blend ratio on ageing properties of PP/NR dynamically vulcanized blends

Thermogravimetric Analysis (TGA) of blends

Decomposition of PP starts at the temperature of 300 ^{0}C and ends around 360 ^{0}C with a steep decline in the graph of PP, which is lower than NR types where SNR and SLR decomposition initiate at 352 ^{0}C and 342 ^{0}C, respectively (Fig. 8). Slight weight loss, before polymer degradation, was observed in SNR due to higher volatile matter content than in SLR. A higher weight loss percentage during main polymer decomposition was reported by SLR than that by SNR as SLR contains a greater amount of cis1,4 polyisoprene than low-quality SNR. However, there is no evidence of degradation of polymers before their processing temperature (200 ^{0}C). PP decomposition temperature has been increased with the addition of NR as shown in Figures 9 and 10. Further, the vulcanization of NR phase has no significant effect on thermal stability and onset degradation temperature of the blends. It is noticeable from Figure 10 that the onset decomposition temperature was reduced with the decrease of the SNR percentage in the blend. Moreover, PP30 SNR and P50 SNR blends have similar thermal degradation pattern, while PP70 SNR blends which contain higher plastic contents shows lower weight loss during the polymer decomposition.

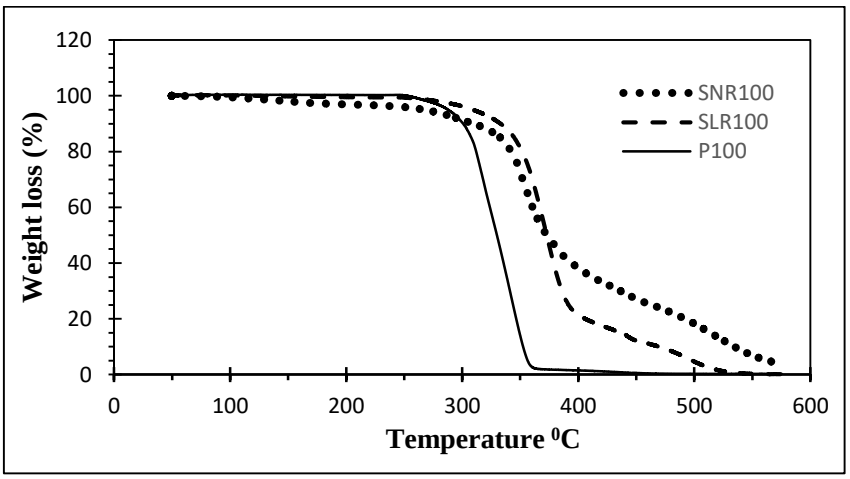


Fig. 8. Thermal gravimetric analysis of polymers; SNR, SLR and PP

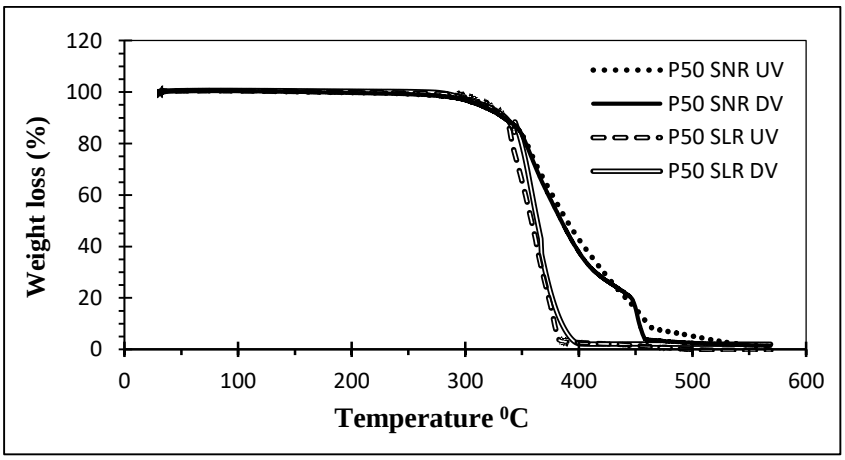


Fig. 9. Thermal gravimetric analysis of unvulcanized and dynamically vulcanized samples of PP50 NR blends

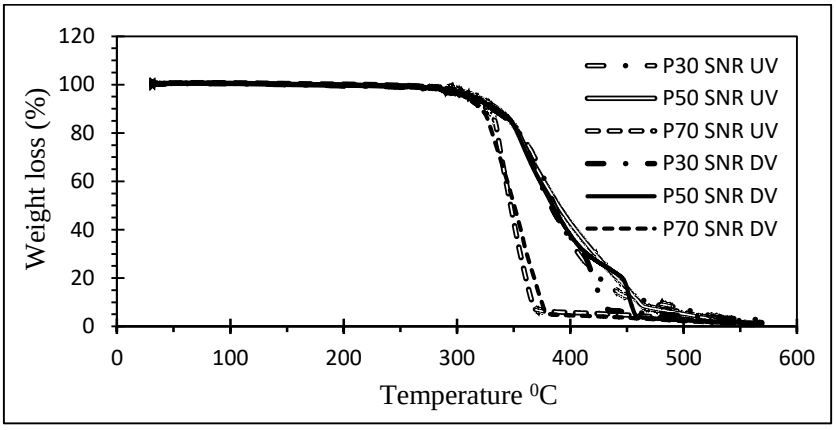


Fig. 10. Thermal gravimetric analysis of unvulcanized and dynamically vulcanized samples of PP30 SNR, PP50 SNR and PP70 NR blends

Effect of sulphur concentration

In this study, the sulfur concentration was varied from 0 phr to 1 phr 0.25 intervals. Cross-link density of each PP/NR blend is different from one to each other as they have different sulphur to rubber ratio. It was found that there is no significant difference between the tensile strength of P50 SNR and P50 SLR blends (Fig. 11). Among the sulphur concentrations studied, optimum sulphur concentration could be considered as 0.25 phr when the variation of tensile strength values is closely studied.

Long-term processability

Long-term processability of dynamically vulcanized blends was studied using a Moving die rheometer. Two 50/50 PP/SNR and PP/SLR samples were used as representative samples of the blend series. The samples were subjected to shear in Moving Die Rheometer at 180 ^{0}C for an extended period. The toque was measured. At the commencement, both samples registered very high torque as they were in cold state initially. Once the PP phase gets melted, the viscosity of the blend obviously becomes very low. It could be seen that both blends SLR and SNR show no reduction in MDR torque ensuring the long-term possibility of rubber without any effect on its long-term processability (Fig. 12).

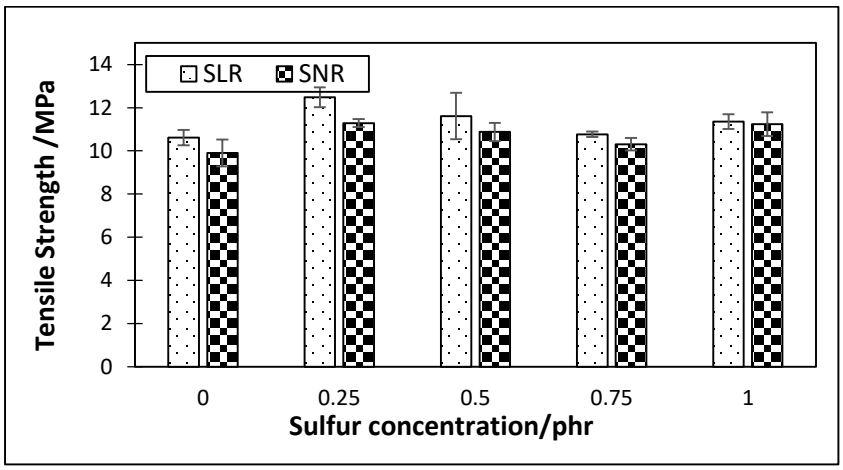


Fig. 11. The effects of sulfur concentration on tensile strength of PP/NR DV blends

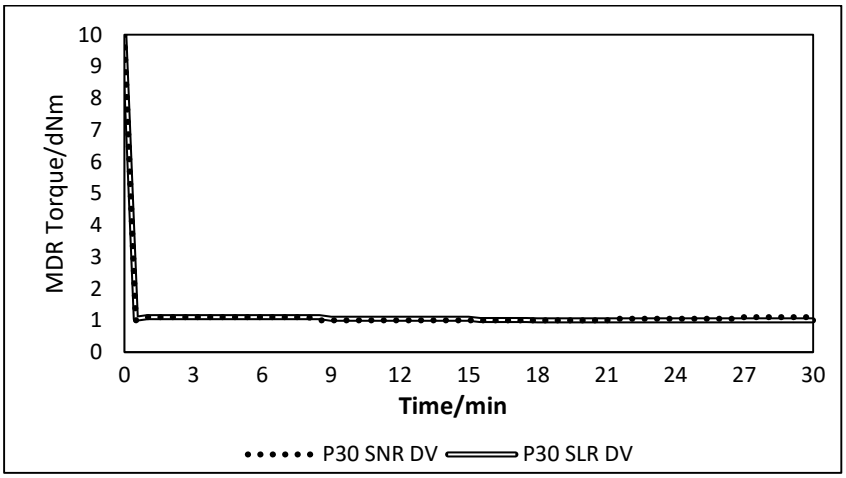


Fig. 12. Torque development of dynamically vulcanized P30 SNR and P30 SLR blends

Impact strength

Impact strength of SLR and SNR incorporated samples was studied in the range of 50 to 90 PP percentages in the blend varying the PP content at 10% increment. Effect of dynamic vulcanization was also studied. It was very clear that dynamic vulcanization has a marked effect on improving the impact strength. It is also shown that SNR has a similar effect on impact strength similar to the SLR.

Extractable protein content

Leachable protein contents of PP/SLR:50/50 and PP/SNR:50:50 blends are given in Table 4. Results have not shown any regular trend. However, it is obvious that the leachable protein contents are below the specified limits except for PP50/SLR blend.

Table 4. *Extractable Protein content of PP/SLR:50/50 and PP/SNR:50:50 blends*

Sample		Absorption
P50 SLR	UV	ND
	S= 0	51.15
	S= 0.25	18.37
	S= 0.5	ND
	S= 0.75	9.62
	S= 1.0	2.63
P50 SNR	UV	ND
	S= 0	22.21
	S= 0.25	20.44
	S= 0.5	2.63
	S= 0.75	15.15
	S= 1.0	ND

*ND= Not Detectable

(D S Wijewardena, S Siriwardena, Y C Y Sudusingha and D G Edirisingha)

Development of mobile applications for Sri Lankan rubber industry

A mobile application was developed to improve the efficiency of the technology transfer and troubleshooting activities especially for the small and medium rubber and rubber product manufacturers through providing effective knowledge dissemination & promoting technologies while letting access to updated information & active communication.

The application consist of,

1. All the basic calculations required for raw rubber processing
2. RSS defects identifier
3. Single day Smoked dryer designs
4. Communication network with audio caller option, Facebook and YouTube
5. RRISL recommendations and other information such as advisory circulars

Raw rubber manufacturers, entrepreneurs and other interested parties such as researchers and students will be the beneficiaries of this App and it will bring the a

basic knowledge of rubber plantation and technology at one's fingertip. Also, it might help to attract the young generation to the industry.

This is a mobile application in which XML, JAVA have been employed as the frontend and firebase as the background. Android Studio 3.2 was used for the App development platform while Firebase was used for authentication.

Main menu which is considered the main module of the app leads to the calculations of the particular raw rubber type, details about rubber products and communication network. A screenshot of the main menu is given in Figure 13.

Fig. 13. Main menu of the App

Dry rubber content, required amounts of dilution water and other chemicals such as formic acid, sodium sulphite, bleaching agent, Diammonium Hydrogen Phosphate (DAHP) *etc*. can be easily calculated by just feeding latex volume and Metrolac reading. Anybody who does not have basic knowledge on raw rubber manufacturing processes can effortlessly calculate above quantities without any error using this feature. Interfaces of calculation menu for preservation (Fig. 14a) Ribbed Smoke Sheet (RSS) (Fig. 14b), crepe (Fig. 14c), and DAHP addition (Fig. 14d) are also shown below.

Fig. 14a. Preservation type

Fig. **14b**. Calculations of RSS

Another important feature of the App is communication network which consists of audio caller option, Facebook and YouTube and allows the user to contact RRISL officials to get information, training and technical support.

This App also contains details about required equipment, process flow charts, required raw materials and formulations of four different products: balloons and bands, cast products, rubberized coir mattresses.

Fig. 14c. Calculations of crepe

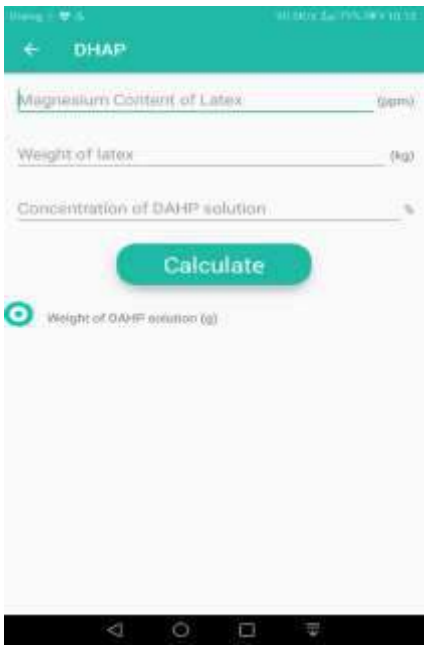


Fig. 14d. Calculation of DAHP

The navigator drawer (Fig. 15) of the application has all recommendations and advisory circulars issued by Rubber Research Institute of Sri Lanka. Other than that, it consists of SS dryer designer where users have the option to get SS dryer designed just by typping their daily crop. Also, it contains RSS defect identifier in the navigation menu (Fig. 15). In this feature, users identify more than 10 different defects on RSS sheets by themselves by the way of comparing title on the screen and defect on the sheet (Fig. 16) and once the defect is identified it would give the possible causes and remediation actions relevant to the defect (Y C Y Sudusingha, W U R De Silva and S Siriwardena).

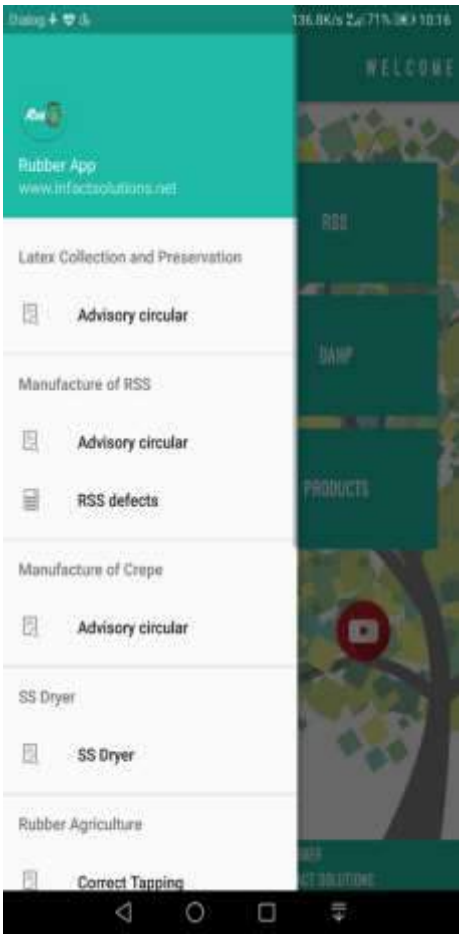


Fig. 15. Navigation Menu

Fig. 16. RSS defect identifier

Development of reinforced carbon nanotube incorporated cellular (close –cell) natural rubber composites

Development of reinforced Natural Rubber (NR) cellular structures without compromising its lightweight has become an important requirement in cellular material applications. Therefore, this study is aimed to evaluate the potential of Multiwall Carbon Nanotubes (MWCNT) as a reinforcement filler in developing lightweight NR based closed-cell structures with improved strength. Two series of Cellular Natural Rubber Composites (CNRCs) were prepared using two types of filler namely Carbon Black-N330 (CB) and MWCNT. Each series of the composites was prepared using dry mixing and filler-latex Masterbatch (MB) techniques. MWCNT loading was varied from 0 (control) to 4 phr at 1 phr intervals when the composites prepared using dry

mixing technique. However, only 2 phr MWCNT incorporated CNRC was prepared using the other method. CB incorporated composites were prepared using both techniques varying CB loading from 5 to 20 with 5 phr intervals. Azodiamide was added as a blowing agent at 4 phr loading to all samples during compounding on the two-roll mill. Curing characteristics of rubber compounds were determined using a Rubber Processing Analyzer at 160 ^{0}C. The one-step foaming method was employed to foam CNRCs at 160 ^{0}C for 30 minutes in an electrically heated hydraulic press without applying pressure. Physico-mechanical properties such as Tensile Strength, Tear Strength, Compression Set and Water Absorption of vulcanized CNRCs were tested according to the standard procedures. Minimum and maximum torque values of the compounds increased with the filler loading for all candidate composites. It was also found that these values of MWCNT/CNRCs at low filler loading were comparable with CB/CNRCs counterparts with higher filler loading. This is due to the ability of MWCNT making more stronger filler-NR interactions caused by their higher aspect ratio and reduced cell size with thicker cell walls. Moreover, CNRCs, where MWCNT was incorporated in dry form, showed higher curing rate indices than the corresponding CB filled compounds. MWCNT/CNRC (2 phr loading) formed through filler-latex masterbatch showed the inferior properties than all the other candidate filled samples. However, MWCNT/CNRC with 4 phr filler loading prepared by following the dry method exhibited improved tensile and tear properties compared to the Control. The same composite showed comparable properties to both 15 and 20 phr CB/CNRCs prepared following latex MB and dry mixing techniques, respectively. For all CNRCs produced, compression set values and water absorption values remained below 23% and 4.52%, respectively. When overall properties were considered, it was found that samples prepared using dry mixing method exhibited improved properties than the filler-latex MB counterparts probably due to the formation of larger MWCNT agglomerations as evidence by the SEM. In sum, it was found that use of MWCNT could produce CNRCs having comparable properties to the CB reinforced CNRCs, with an approximate weight reduction of 75% in terms of the filler loading (Y C Y Sudusingha, S Siriwardena, U M S Priyanka and Ruvinda Illeperuma).

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	Industrial training on adaptive research	Undergraduate students of Ruhuna University
	Training on adaptive research	Postgraduate students of Peradeniya University
	Training on rubber cultivation in non traditional areas	Undergraduate students of Jaffna University
	Training on agronomic practices of rubber cultivation in non traditional areas and carbon trading with rubber	Officers of the Rubber Development Department Field Animators of the STaRR Project Officers of Thurusaviya Fund

Seminars/Training/Workshops/Meetings/Conferences attended

Officer/s	Subject/Theme	Organization
ES Munasinghe	Workshop on Carbon Footprint Calculation	Green Building Council of Sri Lanka
	Workshop on Carbon Crediting System	Climate Change Secretariat of Sri Lanka
	Workshop on Current Status of Agronomy Research	Sri Lanka Council for Agricultural Research Policy
	Workshop on Registering Carbon Credits	Carbon Consulting Company
	Workshop on Forestry for Low Carbon Future	Sri Lanka Council for Agricultural Research Policy
	Progress Review Meeting on Rubber Cultivation in Eastern and Uva Provinces	Ministry of Plantation Industries

Officer/s	Subject/Theme	Organization
ES Munasinghe	Project Implementing & Monitoring Committee Meeting on Carbon Trading	RRISL
BMDC Balasooriya	Workshop on Scientific Approach and Research Methodology for Agriculture	Sri Lanka Council for Agricultural Research Policy
ES Munasinghe & BMDC Balasooriya	Research Committee Meeting	RRISL
	Scientific Committee Meeting	RRISL
	7th Symposium on Plantation Crop Research	Plantation Crop Research Institutes

Field visits

Experimental - 103
Advisory - 5
Other - 5

FIELD INVESTIGATIONS

Expansion of rubber cultivation to non traditional areas (ARU/01)

- ***Assessments on the socioeconomic impact of rubber cultivation in the Eastern province***

  The study was conducted to quantify the impact of rubber cultivation on the peasant community in the Eastern province through the assessments on major livelihood capital assets. Padiyathalawa Divisional Secretaries Division of Ampara District, where rubber was initially introduced to the Eastern Province was considered for the study. Major livelihood capital assets; human, natural, physical, financial and social capital prevailed with rubber farmers were compared with non-rubber farmers in the area.

  There was no demographic difference reported from two farmer groups considered. The majority of farmers were in the age group of 40-60 years and their families consisted of an average of four members. Though they had educated up to secondary level, none of them had experience in doing other occupation except farming. Further, they all were enriched with their own family labour. The average land extent owned by a farmer was 2 ha and many of those lands were located within 1 km distance from the home. Non-rubber farmers fully utilize their lands for subsistence farming whilst rubber farmers used only *ca.* 20% of that for the same.

  The total household income of a rubber farmer was significantly ($t=-5.40$, $p<0.05$) higher than that of a non-rubber farmer, securing a higher level of financial capital.

The annual income of a rubber cultivating household ranged from LKR 100,000 to LKR 555,000 with an average of LKR 280,000, the income from rubber has accounted for 60% to the total. However, the average income of a non-rubber household has limited to LKR 155,000 and varied within the range of LKR 71,000 to 300,000.

The total average annual household expenditure of a rubber growing family (LKR 81,717) was significantly higher ($t=-3.22$, $p<0.05$) than that of a non-rubber growing family (LKR 56,503) indicating improvements in human capital. Among the components of expenditure, greater portions have been deserved in cultivating crops and food for a household in both types of households. In percentage apportion, expenditure on the food of both groups was more or less similar with a 34% share to the total. Rubber farmers have assigned significantly higher proportion (each 5%) of their expenditure for children's education ($t=-3.43$, $p<0.05$) and family health care ($t=-3.15$, $p<0.05$) than non-rubber farmers.

Rubber associated developments such as basic infrastructure facilities of houses, convenience in the dwelling, facilities to strengthen social connectivity and improvement in farming were significantly higher in rubber growers than that of non-rubber growers.

Rubber farmers have significantly higher capacity over non-rubber farmers in lending money to neighbouring farmers. Interaction with relatives and friends and involvement in religious activities have increased significantly with the rubber cultivation. Also, they contributed a significantly high amount for charity work and spent much time on community participation representing a higher level of social capital.

Rubber cultivation has not so far influenced the Natural capital since all farmers had equal opportunities in accessing water sources and lands with fertile soils (E S Munasinghe, V H L Rodrigo, P M M Jayathilake and N M Piyasena).

- ***Assessments on yield potential and seasonal variation of rubber yield in the Eastern province***

  In order to identify the yield potential and seasonal variation of yield at smallholder conditions, daily yield records of seven mature rubber fields in Padiyathalawa and Mahaoya Divisional Secretariat areas have been monitored throughout the year.

  The highest yield per tree per tapping was observed in March whilst the lowest in November (Fig. 1). The average annual latex yield was recorded as 1,800 kg/ha at the early stage of harvesting (Panel B) and the average number of tapping days was 128 per tree per year.

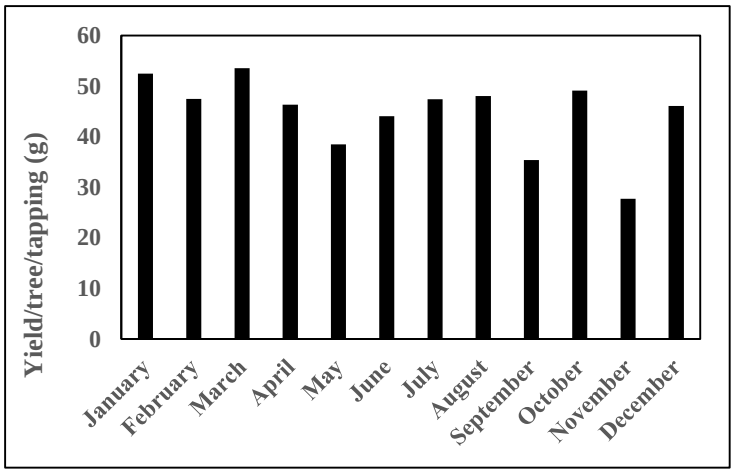


Fig. 1. Seasonal yield variation under smallholder conditions of Eastern province

(E S Munasinghe, V H L Rodrigo, P M M Jayathilake and N M Piyasena)

- ***Incorporation of crop residues as a moisture conservation method***
  This study was conducted to assess the effectiveness of incorporating crop residues as a moisture conservation method in the Intermediate zone of the country. The experiment was laid out in mature (15 years old) rubber fields in Padiyathalawa with three replicates, each having *ca.* 300 trees of clone RRIC 121. The experiment comprised two spatial systems of placing pits for filling crop residues, *i.e.* 1) one pit per tree placing at the centre of interrow and 2) one pit per two trees placing at the centre of interrow allowing maximum distance to rubber trees. Pits were made with the dimensions of 120 x 60 x 60 cm and filled with crop reduces available in the area. Moisture content (percentage Volumetric Water Content -VWC%) of surface soils (0-15 cm) of experimental sites were measured during two consecutive dry periods prevailed after six and twelve months from the establishment (the site had no rains above 0.03 mm for 43 and 39 days before the measurements, respectively). The results revealed that the spatial system of one pit per tree (T1) showed significantly ($p<0.05$) higher value than those of one pit per two trees (T2) and the fields having no pits (T3 - control) (Fig. 2).

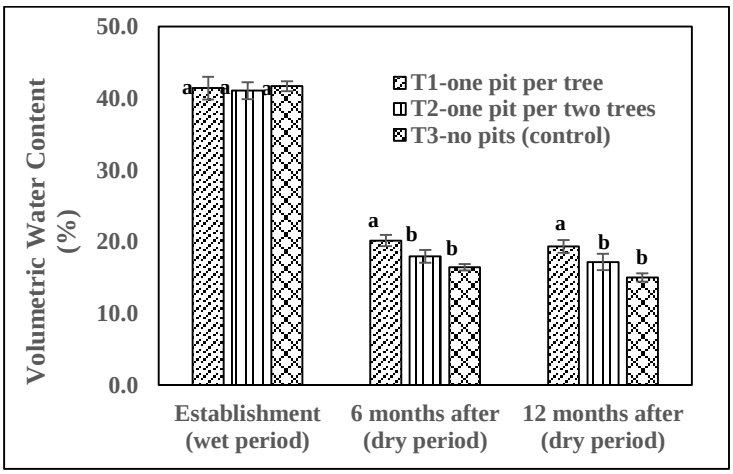


Fig. 2. Percentage Volumetric Water Content (VWC%) of surface soils of fields having two spatial systems of pits filled with crop residues (T1- one pit per tree, T2- one pit per two trees) and fields with no pits (T3 - control)

The average girth increment of rubber trees was monitored throughout 18 months from the establishment of the experiment. Trees in both spatial systems of pits filled with crop residues, T1 and T2 showed higher girth increment rates than that of T3. Of those girth increment rate was highest in T1 (Fig. 3).

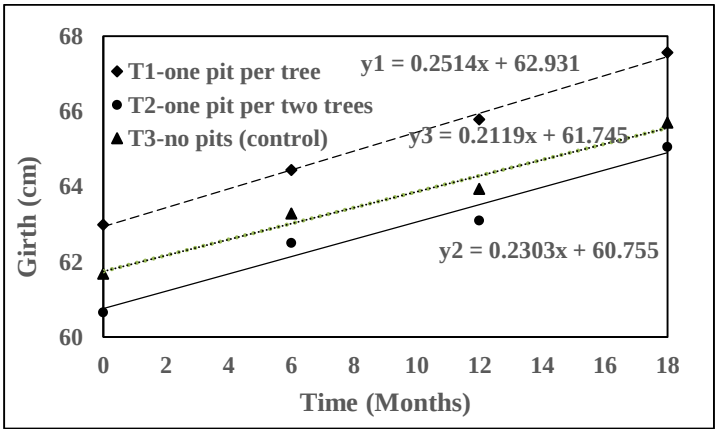


Fig. 3. Average girth increment of rubber trees in two spatial systems of pits filled with crop residues (T1- one pit per tree, T2- one pit per two trees) and fields with no pits (T3 - control)

Percentage Dry Rubber Content (DRC%) of latex harvested from T1 showed significantly ($p<0.05$) higher value than those of T2 and T3 at the first dry period prevailed after six months of the establishment. However, during the second dry period (after 12 months of the establishment), both spatial systems reported significantly higher DRC% than that of T3 whilst T1 with the highest value (Fig. 4a). Nevertheless, this effect has not been reflected from the yield per tree since differences shown in g/t/t were not significant (Fig. 4b) (E S Munasinghe, V H L Rodrigo, P M M Jayathilake and N M Piyasena).

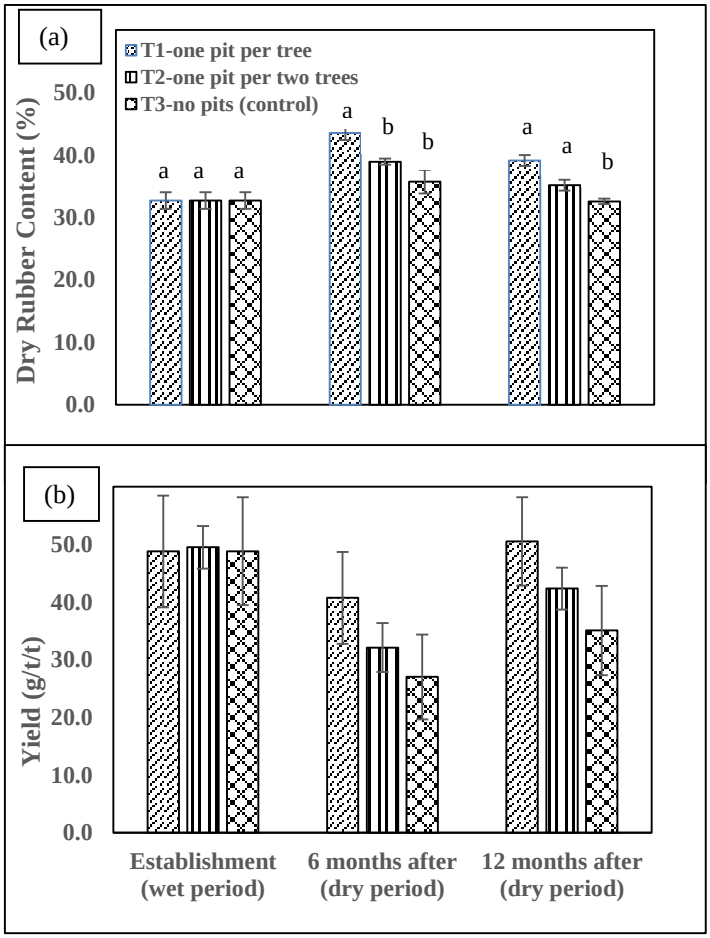


Fig. 4. (a) Percentage Dry Rubber Content (DRC%) and (b) Yield of rubber trees of two spatial systems of pits filled with crop residues (T1- one pit per tree, T2- one pit per two trees and fields with no pits (T3 - control)

- ***Improving the protocols available to cultivate rubber in Dry Zone***
  Latex harvesting was inaugurated in the firstly planted smallholder rubber field in Vavuniya District with the participation of government officials of the Ministry of Plantation Industries, Rubber Development Department, Thurusaviya Fund, local authorities and villagers in the area. Simultaneously, a processing center was established to facilitate the manufacturing of ribbed smoked sheets at the same location (Fig. 5).

Fig. 5. Commencement of tapping and establishment of the processing centre at Vavuniya

With the aim of improving suitable protocols available to cultivate rubber in the Dry zone, farmer participatory adaptive research trials were established in Northern and North Central provinces of the country.

Growth performance (in terms of girth and height) of rubber plants of sites in Kilinochchi and Anuradhapura was assessed (Table 1).

Table 1. *Growth of rubber plants in Dry zone*

Sites	Year of planting	Site code	Land extent	Clone	Mean girth (cm)	Mean height (cm)
Kilinochchi	2017	2017/K1	½ Ac	RRISL 203	8.06±0.26	301.8±3.67
	2017	2017/K2	½ Ac	RRISL 203	10.25±0.31	351.0±3.52
	2017	2017/K3	½ Ac	RRIC 121	8.97±0.32	368.5±8.97
Anuradhapura	2017	2017/A1	2 Ac	RRISL 203	9.60±0.14	310.6±3.67
			2 Ac	RRIC 121	10.40±0.13	376.7±3.52

Feasibility of cultivating rubber in Galenbindunuwewa and Kahatagasdigiliya Divisional Secretaries divisions of Anuradhapura district of North-Central Province was assessed through conducting SWOT analyses. Accordingly, Strengths,

Weaknesses, Opportunities and Threats for rubber cultivation in the area were identified (Table 2). Thereafter four farmer participatory adaptive research plots were established in the area.

Table 2. *Summary of SWOT analysis conducted in Galenbindunuwewa and Kahatagasdigiliya Divisional Secretaries divisions of Anuradhapura district*

	Rank	**% Farmer**
Strengths;		
Enthusiasm & interest	1	39
Water availability	2	17
Land availability	3	10
Weaknesses;		
Initial capital	1	22
Land ownership	2	13
Animal damages	3	12
Lack of water	3	12
Opportunities;		
Land ownership	1	22
Knowledge on new crop	2	19
Cultivate bare lands	3	13
loan facilities for intercrops	4	7
Comfortable environment	5	6
Threats;		
Drought	1	43
Wild animal damages	2	7
Diseases	3	6

(E S Munasinghe, V H L Rodrigo, P M M Jayathilake and N M Piyasena)

- ***Water requirement to 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 at Thalawa, Anuradhapura. The experiment consists of two factors, watering interval (4, 5 and 6 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 but with two different clones, *i.e.* RRIC 121 and RRISL 203. Each treatment plot contained 8 trees and only the preliminary data were collected (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 initiated to identify the research, development and extension needs of the smallholder rubber farmers in Sri Lanka. It was planned to carry out the study in four major traditional rubber growing districts: Kegalle, Gampaha, Kurunegala and Kandy. Pre-tested semi-structured questionnaire survey was planned for the data collection and stratified random sampling technique was used for the sample selection. The sample size is 1200 rubber smallholders. The study is in progress.

  According to the results, it was found that the percentage use of flatlands for rubber cultivation in Kegalle, Kurunegala and Kandy was respectively 12%, 20% and 6%. About 9% and 3% if rubber lands in Kegalle and Kurunegala were observed as sloppy lands while there were no sloppy lands cultivated with rubber found in Kandy district. The rest of the rubber lands in the study area were moderately sloppy lands. Based on the partial data set, the adoption rates of a few major agronomic practices in three rubber growing areas were computed and reported in Table 3.

Table 3. *Adoption rates of few major agronomic practices in three rubber growing areas*

Agronomic practice	Adoption rate		
	Kegalle	**Kurunegala**	**Kandy**
Fertilizer application	75%	88%	100%
Weed management	94%	96%	100%
Application of rainguard	7%	7%	18%
Usage of new tapping knife	35%	26%	45%
Adoption of correct time of planting	90%	76%	100%

(B M D C Balasooriya, P Seneviratna and N M Piyasena)

- ***On-farm behavior of smallholder rubber farmers in traditional rubber growing areas***

  This study was started with the objective of identifying 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 wet and intermediate zones of the country. Farmer fields were selected in both districts for the data collection on yield, the number of tapping days and market details. The study is in progress. So far data collection has been done for 25 fields in Kegalle and 20 fields in Kurunegala.

Based on the partial data set, the on-farm productivity and tapping days for the period of last six months in 2019 are presented in Figure 6 and 7 respectively. The yield per hectare in Kegalle district can be observed lower than that of in Kurunegala district which is mainly due to the higher number of tapping days reported in Kurunegala. During the last six months of the year, the lowest productivity is reported in October in both districts where the lowest number of tapping days are recorded. The highest yields are respectively reported in July and December in Kegalle and Kurunegala. On average, the total yield reported during last six month of the year in Kegalle is 527.4±109.9 Kg/ha while that of in Kurunegala is 594.7±126.6 Kg/ha (B M D C Balasooriya, P Seneviratna and N M Piyasena).

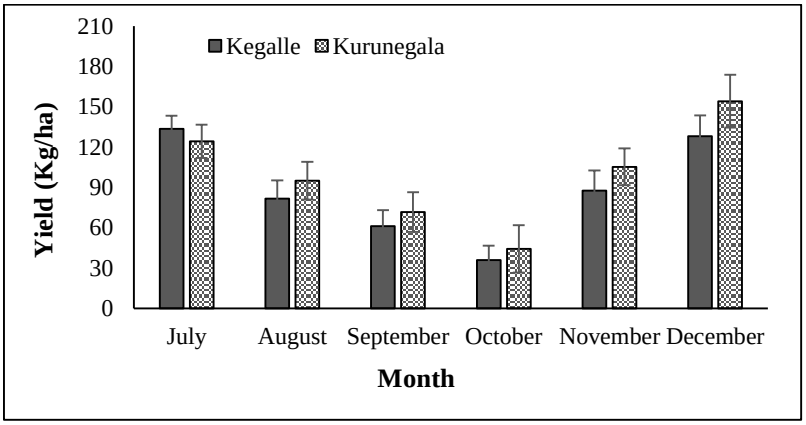


Fig. 6. Seasonal yield variation during last six months of the year

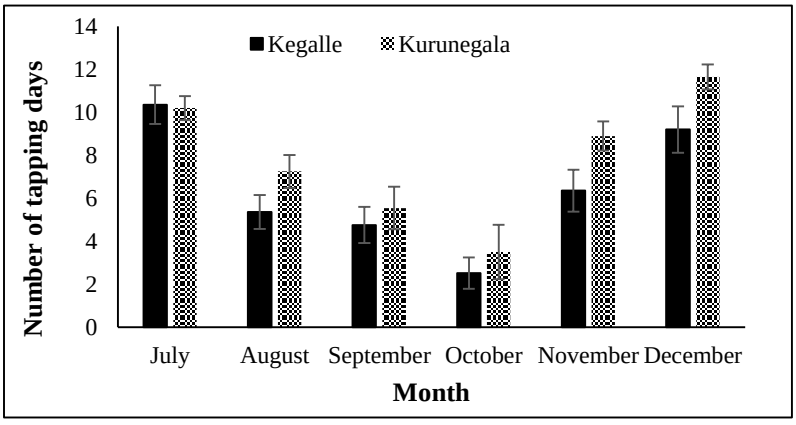


Fig. 7. Variation in number of tapping days during last six months of the year

- ***Adaptability of new mammalian pest repellent under smallholder conditions***
  This trial was started with the collaboration of Plant Pathology and Microbiology Department to identify the suitable application frequency of newly introduced mammalian pest repellent. Four sites were selected for repellent application against porcupine and wild boar damages. Sixty trees were selected for the treatment in each field and the same number of trees kept as the control (without applying the repellent). Damages were recorded in treated and untreated plots (Table 4).

Table 4. *Percentage of mammalian pest damaged trees in research fields*

Field	Planting year	Clone	Damage %					
			Treated			Not treated		
			After 6 Months	After 12 Months	After 24 Months	After 6 Months	After 12 Months	After 24 Months
Smallholder field 1	2015	RRISL 203	0%	8%	5%	5%	10%	4%
Smallholder field 2	2014	RRIC 121	0%	17%	8%	10%	12%	10%
Smallholder field 3	2012	RRIC 121	0%	33%	15%	13%	35%	18%
Polgahawela sub-station field	2012	RRIC 121	0%	8%	10%	5%	8%	10%

According to the results, the application frequency of six months is suitable for the intermediate zone. Considering the rainfall pattern in the area, January and July can be identified as the most suitable months for the application of repellent for maximum results.

Another three smallholder fields were selected to study whether wild boar and porcupine attacks would be reduced when the tapping is done. At the commencement of tapping the damage incidences of these fields were about 70%. According to the results, mammalian pest damages have become very low during tapping. During the first year of tapping, in one field there were no damages at all and in the other two fields, it was only 1% and 6%. During the second year of tapping no damages were recorded in all three fields. This may be due to increased human activities reported in respective fields with the commencement of tapping (B M D C Balasooriya and N M Piyasena with the collaboration of Plant Pathology and Microbiology Department).

- ***Bee keeping in rubber plantations***
  A study was commenced to identify the current status of beekeeping in rubber plantations and identify suitable protocols to promote rubber bee keeping system. Kegalle district was selected as the study site and pre- tested semi-structured questionnaire survey was planned to collect the cross-sectional data in rubber smallholdings. Data collection on details of rubber cultivation, demographic details of the rubber farmers, details on bee keeping and data on willingness to accept bee keeping by rubber farmers were in progress (B M D C Balasooriya, E S Munsinghe, N M Piyasena and P M M Jayathilake).

Developing a project to approach the voluntary carbon market with the rubber cultivation in Eastern and Uva Provinces for 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 new rubber cultivations in Uva and Eastern provinces. An extent of 3,000 ha scheduled to be planted under the Smallholder Tea and Rubber Revitalization (STaRR) Project and 2,500 ha of that extent are expected to be used for carbon trading. In order to get VCS, preparation of Project Description Document (PDD) was commenced in collaboration with Carbon Consulting Company. Identification of GPS locations of new rubber smallholdings (planted from 2016 to 2018) in Moneragala and Ampara districts were done in collaboration with STaRR Project. Estimation of Carbon Footprint of rubber related organizations was commenced (V H L Rodrigo and E S Munasinghe).

BIOMETRY

Wasana Wijesuriya

DETAILED REVIEW

Staff

Dr (Mrs) Wasana Wijesuriya, Principal Research Officer and Experimental Officer, Mr Vidura Abeywardene were on duty throughout the reporting year. There were two new recruitments to the Biometry section during this year. Mr Dilhan Rathnayaka joined the Biometry section as a Research Officer with effect from 02nd September 2019 and Mrs I N S Silva assumed duties as a Technical Officer on the 22nd August 2019 and were on duty throughout. Mrs S N Munasinghe, Management Assistant attached to the Biometry section was also on duty throughout.

Seminars/Training/Workshops addressed/conducted

Mrs Wasana Wijesuriya and Mr Dilhan Rathnayaka conducted the following training programmes organized by RRISL.

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/Meetings/Workshops attended

Officer	Subject/Theme	Organization
W Wijesuriya	Research Coordination Committee Meetings of the project "Assessment of Spatial Impacts of Climate Change on the Plantation Sector in Sri Lanka"	National Science Foundation (NSF)
	Review Meetings of the project on "Introduction and Establishment of New Fuelwood Growing Models in Selected Lands of Smallholder Rubber Farmers"	FAO/RRISL
	Training Workshop on Monitoring and Evaluation of Research Projects	SLCARP
	National Priority setting on Agronomy Research	SLCARP
	Central Scientific Committee Meetings	RRISL

Officer	Subject/Theme	Organization
W Wijesuriya	Stakeholder Meeting for Curriculum Development on BSc (Plantation Management) External Degree	Wayamba University of Sri Lanka
D Rathnayaka	Experiences during the 2019 Southwest monsoon season (May to September 2019)	Department of Meteorology, Colombo
	Workshop on the Use of bio-engineering Methods to Mitigate Landslides	SLCARP
W Wijesuriya D Rathnayaka	7th Symposium on Plantation crops, Colombo, Sri Lanka	RRISL, CRI, TRI and SRI

Seminars/Conferences/Workshops/Meetings/Training sessions addressed

Mrs Wasana Wijesuriya addressed the following Seminars/Conferences/ Workshops/ Meetings.

Subject/Theme	Organization
Liaison Officer's report for 2018/19 for the Socio-economic specialist group of IRRDB	Meeting of Chairmen and Directors of IRRDB, Myanmar
Forecasting of Rubber Prices in the Sri Lankan market using Multiple Temporal Aggregation (MTA)	IRC 2019, International Rubber Conference of IRRDB, Myanmar
SLCARP 1st half-yearly progress of research action plan 2019 - RRISL	SLCARP, Colombo
Workshop on the Current Status of Agronomy Research	Agronomy Research Priority Setting Committee, SLCARP, Colombo

Research students

The following students are registered for postgraduate studies under the supervision of Dr (Mrs) Wasana Wijesuriya.

- Mr M W H Gayan - Completed his MSc on 25th July 2019 on "Suitability of different drought indices under Sri Lankan conditions based on statistical considerations and practical use" at the Faculty of Agriculture, University of Ruhuna
- Mr L A T S Liyanaarachchi - Continued working for his MPhil on "Indicator based identification, forecasting and mapping of droughts in Sri Lanka" at the Wayamba University

The following are the undergraduate students who conducted their research under the guidance of Dr (Mrs) Wasana Wijesuriya.

- Ms N Sivanathan from Wayamba University continued her studies on "Forecasting drought incidence in Sri Lanka: Application of ARIMA and Exponential smoothing models"
- Ms O V K Maduwanthi of the University of Sri Jayawardenepura studied the "Factors affecting employees' job satisfaction in the Rubber Research Institute"

RESEARCH AND DEVELOPMENT

The Biometry section focuses 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 familiarize the statistical techniques among the researchers and to encourage proper use of these methods.

Application of novel forecasting of rubber prices in the Sri Lankan market

During this year, a novel statistical method was introduced for forecasting rubber prices. A comparison was made to compare this method with SARIMA and ETS methods. This study attempted to forecast two types of rubber in the Sri Lankan market; namely, Latex Crepe Grade 1 (LC-1) and Ribbed Smoked Sheet Grade 1 (RSS-1). The combined forecasts for prices of LC-1 and RSS-1 are depicted in Figures 1a and 1b. A series length of 222 (January 2000 to June 2018) was considered for estimation of the model and the forecast horizon was July 2018 to June 2019 in both cases. Hence, the x-axis of the Forecast in Figures 4a and 4b represent time points in months commencing from January 2000 and in Level, Trend and Season the x-axis indicates months of the year.

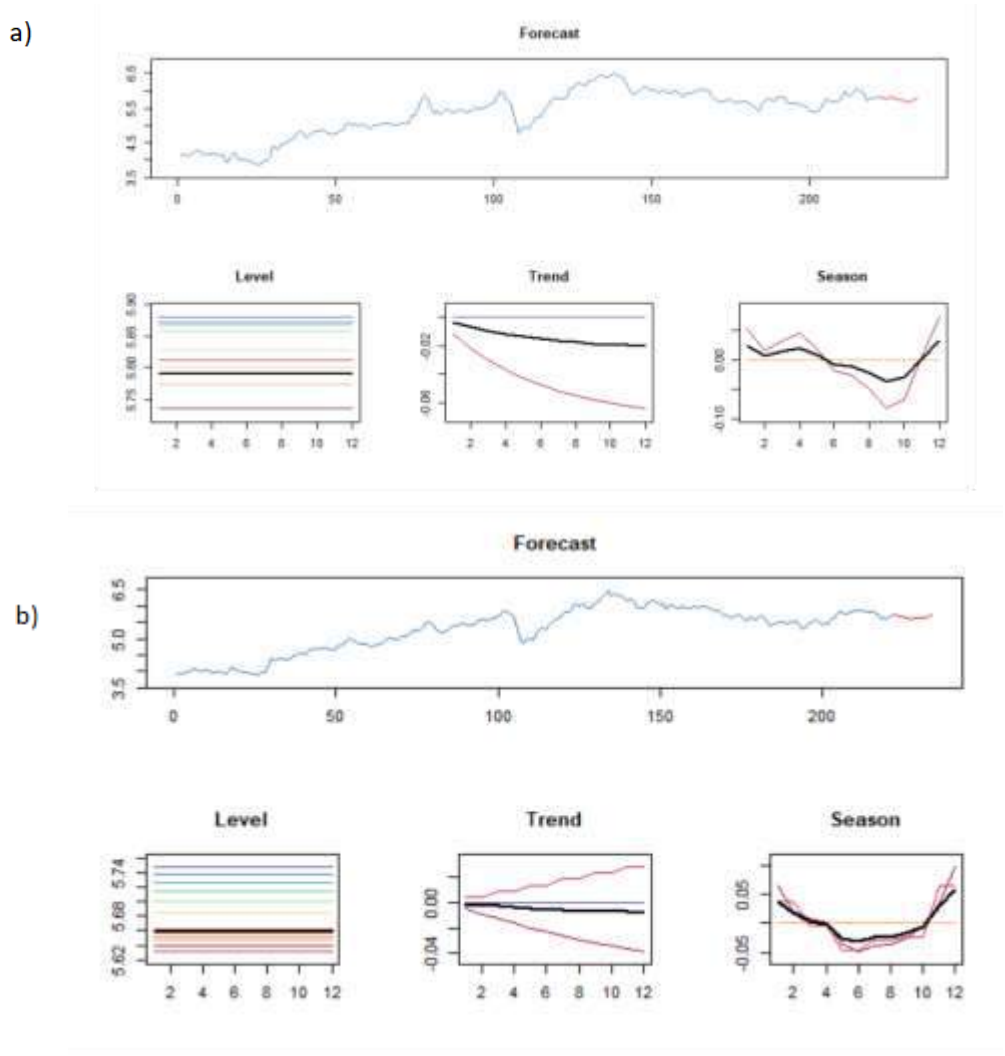


Fig. 1. Forecasts of prices of LC-1 and RSS-1 from July 2018 to June 2019 (beyond the vertical line in the forecast plot) together with level, trend and seasonal components (the dark line indicates the median) **Note**: y-axis– Natural log values of rubber prices in Forecast, Trend component for Level, Seasonal index for Season

The actual and forecast values of LC-1 and RSS-1 prices by Seasonal ARIMA, Holt-Winters exponential smoothing and Multiple Aggregation Prediction Algorithm (MAPA) are listed against the forecast horizon (July 2018 to June 2019) in Tables 1 and 2, respectively. The metric used to measure the forecast efficiency of the three

models considered in this study, Mean Absolute Percentage Error (MAPE) is listed against three different forecast periods; namely, 3, 6 and 12 months. It was observed that the forecast efficiency of RSS-1 is generally better than that of LC-1 for all the forecast horizons tested in this study (Table 3). MAPA method outperforms the other two conventional methods. It is also evident that MAPA can be used for forecasts ahead of one year with considerable accuracy.

These combined forecasts were compared with forecasts from the Holt-Winters exponential smoothing (ETS) method and seasonal ARIMA (SARIMA) available in the FORECAST package in R employing Mean Absolute Percentage Error (MAPE). Across the forecast horizons, the combined forecasts through MTA were found to be efficient than ETS and SARIMA, especially for six and 12-months. Forecasting with MTA therefore can be suggested for practical use on forecasting of rubber prices as combining multiple temporal aggregation levels leads to more accurate forecasts. The forecasts and forecast efficiency of LC-1 and RSS-1 prices are given in Tables 1 to 3.

Table 1. *The actual and forecast values of LC-1 prices by Seasonal ARIMA, Holt-Winters exponential smoothing and Multiple Aggregation Prediction Algorithm (MAPA)*

Month - Year	Actual Price (Rs/kg)	Forecasts of LC-1 prices (Rs/kg)		
		SARIMA	ETS	MAPA
Jul-18	336.86	334.73	345.19	335.29
Aug-18	332.00	327.64	318.57	321.18
Sep-18	300.50	329.93	314.64	317.67
Oct-18	279.67	336.07	315.51	316.71
Nov-18	265.86	337.55	307.60	305.21
Dec-18	261.00	339.66	304.26	296.49
Jan-19	228.06	341.40	307.12	295.75
Feb-19	227.75	334.76	307.34	293.83
Mar-19	253.79	335.96	309.39	289.17
Apr-19	262.83	337.33	298.32	292.66
May-19	270.14	350.83	317.60	316.08
Jun-19	325.50	358.61	338.36	331.62

Table 2. *The actual and forecast values of RSS-1 prices by Seasonal ARIMA, Holt Winters exponential smoothing and Multiple Aggregation Prediction Algorithm (MAPA)*

Month - Year	Actual price (Rs/kg)	Forecasts of RSS-1 prices (Rs/kg)		
		SARIMA	ETS	MAPA
Jul-18	300.00	301.03	310.75	301.87
Aug-18	281.44	290.87	298.57	291.78
Sep-18	259.10	291.43	297.97	287.15
Oct-18	263.21	289.59	294.71	285.15
Nov-18	262.75	282.35	287.15	275.89
Dec-18	274.50	286.30	288.59	272.87
Jan-19	252.30	287.39	293.24	275.06
Feb-19	247.67	288.88	294.42	275.06
Mar-19	267.17	285.44	289.74	277.00
Apr-19	265.15	292.77	291.49	280.90
May-19	275.41	299.24	302.17	291.78
Jun-19	316.52	310.00	321.82	304.60

Table 3. *The forecast efficiency of Seasonal ARIMA, Holt Winters exponential smoothing and Multiple Aggregation Prediction Algorithm (MAPA) as explained by Mean Absolute Percentage Error (MAPE) for prices of LC-1 and RSS-1*

LC-1 Prices

Forecast period (months)	MAPE values (%) for forecasts using different models		
	SARIMA	ETS	MAPA
3	3.91	3.74	3.14
6	14.84	9.39	6.51
12	23.87	15.24	9.83

RSS-1 Prices

Forecast period (months)	MAPE values (%) for forecasts using different models		
	SARIMA	ETS	MAPA
3	5.39	8.22	3.04
6	6.33	8.50	4.84
12	8.04	9.66	5.71

(W Wijesuriya, J K S Sankalpa and P G N Ishani)

Factors affecting employees' job satisfaction in the Rubber Research Institute

Job satisfaction is vital for employees to perform their duties effectively and efficiently. Persons with a higher level of job satisfaction, perform their duties effectively than the employees who have less job satisfaction or high job dissatisfaction. The purpose of this study was to assess the satisfaction level of the employees and identify the factors that affect employee job satisfaction. Working environment, salary, job security, training and development, and relationship with co-workers are the key influential factors identified through past literature.

This was quantitative research that used the deductive approach and the survey strategy. The closed-ended questionnaire with a five-point Likert scale was used in the primary data collection method and company reports, websites, research articles were the secondary data sources. The questionnaire was structured based on two sections, *viz.* section one aimed at demographic information of the respondents and section two addressed the perceived factors influencing the employee job satisfaction. The selected sample size was 100. This sample represented research staff, administrative staff and extension staff of the Rubber Research Institute of Sri Lanka (RRISL).

The result of this study confirmed that there was no significant relationship between the levels of job satisfaction based on those demographic factors. Overall job satisfaction of employees of RRISL is 3.62 with a standard deviation of 0.918 and therefore can be interpreted as moderately satisfied. The results indicated that work environment, salary, training and development, relationship with co-workers have a significant impact on employees' level of job satisfaction whereas job security of the institute has no significant impact on the employees' level of job satisfaction (W Wijesuriya, P G N Ishani and O V K Maduwanthi (Research Student).

This study is in progress to employ Structural Equation Modeling (SEM) as an analytical approach that simultaneously combines factor analysis and linear regression models for theory testing.

Improving the knowledge base on climate, climate change & variability for better decision making in rubber growing areas (BM 02)

Maintenance and establishment of meteorological & agro-meteorological stations (BM/02/a)

Maintenance and data recording is being done in the meteorological stations owned by RRISL by visiting and inspecting of 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. The data and information pertaining to these stations are explained in the Meteorological Summary of this report (W Wijesuriya, D Rathnayaka, O V Abeywardene and I N S Silva).

Maintenance of databases on meteorological data in rubber growing areas (BM/02/b)

The database with daily meteorological data collected at Dartonfield meteorological station was properly maintained. Reports were prepared from this daily database and sent to the Department of Meteorology. Rainfall records received at the Dartonfield Station are sent to National Building and Research Organization (NBRO) for issuing warnings on landslides. 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.

A database is maintained on rainfall experienced in rubber growing areas of Sri Lanka. Monthly rainfall values experienced in rubber growing areas is given in Table 4 (W Wijesuriya, D Rathnayaka and V Abeywardene and I N S Silva).

Analysis of data to identify changes in patterns and trends in rainfall, identification of drought impacts and spatial analysis of droughts (BM/02/b)

Forecasting of Drought Indices - Application of ARIMA and Exponential smoothing models

This study indicates that the SPI is a valuable tool for quantifying drought at different scales and is able to detect different levels of severities. Further, this study investigated the ability of ARIMA/SARIMA and Exponential smoothing models to forecast drought conditions. The best fit models found in Table 5 can be used for predicting SPI time series of multiple time scales to detect the drought severity of 30 weather stations in Sri Lanka which is useful information for the local administration and water resource planners to take safety measures considering the severity of droughts well in advance. Moreover, forecast from these can be used for spatial interpolations and produce GIS maps (surface plots) which can better visualize the spatial distribution of different droughts in the near future (W Wijesuriya, H M L K Herath (Wayamba University) and N Sivanathan - Research Student).

Table 5. *Best fit models for SPI 1 and SPI 3 for different sites*

Station	SPI 1	SPI 3
Wet Zone		
Agalawatta	ARIMA(1,0,0)(1,0,1)$_{12}$	ARIMA(0,0,3)(1,0,0)$_{12}$
Ambepussa	ARIMA(3,0,0)	ARIMA(2,0,2)(1,0,1)$_{12}$
Colombo	N,N	ARIMA(2,0,3)
Galle	ARIMA(1,0,0)	A,N,N
Gampaha	N,N	ARIMA(2,0,3)
Katugastota	N,N	ARIMA(0,0,3)
Katunaayaka	N,N	ARIMA(0,0,2)
Kegalle	N,N	ARIMA(1,0,3)
Matara	Ad,N	ARIMA(4,1,1)(2,0,1)$_{12}$
Nuwaraeliya	N,N	ARIMA(1,0,2)
Pasyala	N,N	ARIMA(3,1,3)(2,0,0)$_{12}$
Ratmalana	N,N	ARIMA(2,0,2)(1,0,0)$_{12}$
Ratnalana	ARIMA(2,1,2)(2,0,0)$_{12}$	ARIMA(3,1,3)(1,0,1)$_{12}$
Intermediate Zone		
Badulla	N,N	ARIMA(0,0,3)
Bandirippuwa	ARIMA(1,0,1)	ARIMA(2,0,3)
Kurunegala	N,N	ARIMA(0,0,3)(1,0,1)$_{12}$
Matale	N,N	ARIMA(0,0,2)
Moneragala	N,N	ARIMA(1,0,2)(1,0,0)$_{12}$
Dry Zone		
Wellawaya	N,N	ARIMA(0,1,3)
Akkarayankulam	ARIMA(2,0,0)(1,0,0)$_{12}$	ARIMA(1,0,2)(2,0,2)$_{12}$
Ampara	ARIMA(3,0,1)	ARIMA(1,0,2)(1,0,0)$_{12}$
Anuradhapura	N,N	ARIMA(0,0,3)(1,0,0)$_{12}$
Batticaloa	N,N	ARIMA(2,0,2)(1,0,0)$_{12}$
Hambantota	ARIMA(1,0,0)(1,0,0)$_{12}$	ARIMA(3,0,2)(0,0,1)$_{12}$
Iranamadu	ARIMA(1,0,0)(1,0,0)$_{12}$	ARIMA(1,0,3)(1,0,0)$_{12}$
Jaffna	ARIMA(1,0,1)(2,0,0)$_{12}$	ARIMA(1,0,2)(2,0,0)$_{12}$
Okkampitiya	Ad,N	ARIMA(0,0,2)
Puttalam	ARIMA(2,0,0)(1,0,0)$_{12}$	ARIMA(1,0,2)(2,0,0)$_{12}$
Trincomalee	Ad,N	ARIMA(0,0,2)(1,0,0)$_{12}$
Vavuniya	ARIMA(3,1,2) (1,0,0)$_{12}$	ARIMA(4,1,2)(0,0,2)$_{12}$

NN – No trend, no seasonality Ad,N – Additive trend, no seasonality

The occurrence of extreme events in rubber growing areas

The occurrence of extreme rainfall and temperature events are important indicators of climate change. This study attempts to identify the trends in the occurrence of extreme rainfall events employing the Standard Precipitation Index (SPI) together with other popular indices. Extreme weather events have become a common and important phenomenon in the study of climate change. According to

Intergovernmental Panel on Climate Change (IPCC), 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.

In this study, 35 years (1983-2017) of rainfall data will be used to analyze extreme events of rainfall in selected stations, representing wet, intermediate and also areas where rubber cultivation is recently introduced. The selected sites which represent 13 districts are; Agalawatte (WL1a), Badulla (IM1a), Colombo (WL1a), Galle (WL2a), Gampaha (WL2b), Hambantota (IL1b), Katugastota (WM2b), Kurunegala (IL1a), Matale (WM3b), Matara (WL1a), Moneragala (IL1c), Nuwara Eliya (WU3), Ratnapura (WL1a) and Kegalle (WL 2a).

SPI values were generated for the above-mentioned studies so far and this study is in progress (Dilhan Rathnayaka and W Wijesuriya).

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 main objective of this project is to introduce a synergistic and strategic approach to establish fuelwood species in smallholder rubber lands which assure 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 of socio-economic surveys and constructing indices for the combined benefit and monetary advantage. The details of activities conducted during the year under review 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 on the Plantation Sector of Sri Lanka. Several discussion rounds were undertaken between the team members on

deciding the sampling methods. Data collection through questionnaire surveys and focused group interviews is in progress.

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 (Dr Mrs Wasana Wijesuriya and Ms Dammika Balasooriya represent the research team of this project).

Involvements in IRRDB activities

Dr Wasana Wijesuriya continued to assist IRRDB in attending to the duties of the Liaison Officer of the Socioeconomic Specialist Group during 2019. In response to the call for funding by IRRDB for 2020, a proposal was submitted to conduct a Workshop on "Understanding Fundamentals in GIS and Geospatial Applications" and a Conference on "GIS for Better Decision Making". This will be scheduled to be held in Sri Lanka in September 2020. The objective of this workshop is to develop the capacity of Socio-economists in employing GIS in the discipline of socioeconomics. This proposal was selected for funding in 2020 at the IRRDB Directors'' meeting in Myanmar in October 2019.

Table 4. *Monthly rainfall in rubber growing areas in 2019*

Month	*Location*										
	Hanwella	***Ratnapura***	***Agalawatte***	***Galle***	***Kekanadura***	***Nittambuwa***	***Kurunegala***	***Moneragala***	***Uhana***	***Matale***	***Badulla***
	WL 1a	**WL 1a**	**WL 1a**	**WL 2a**	**IL 1a**	**WL 3**	**IL 1a**	**IL 1c**	**DL 2a**	**WM 3b**	**IM 1a**
January	4.1	37.5	117.8	27.7	42.3	0.7	0.0	28.1	107.5	2.0	64.2
February	319.6	306.0	176.9	120.7	2.7	118.6	85.3	198.1	205.1	17.2	166.5
March	159.5	123.8	118.4	148.2	125.7	66.7	32.7	6.5	0.0	36.4	10.1
April	316.9	225.1	289.0	88.4	192.1	365	145.5	305.3	31.8	153.9	42.3
May	115.5	99.3	457.7	269.8	257.7	111	0.9	47.7	0.0	0.2	90.0
June	299.5	397.2	409.9	179.2	184.7	293.9	156.4	15.2	19.6	82.6	29.3
July	82.5	224.0	136.2	124.5	93.7	112.1	96.2	27.3	66.1	59.4	111.6
August	476.6	642.1	566.4	426.0	249.7	311.3	137.1	13.7	65.3	116.3	53.4
September	768.0	469.9	771.7	603.7	560.7	511.1	157.3	291.7	149.0	109.7	219.5
October	621.1	598.6	541.5	604.3	354.4	745.6	479.8	342.6	191.0	269.4	362.0
November	552.2	348.9	480.7	309.4	245.3	431.4	322.1	371.3	464.5	69.8	268.2
December	313.7	200.4	279.5	135.3	120.8	225.3	156.1	464.8	662.2	308.8	372.8
Total rainfall (mm)	**4029.2**	**3672.8**	**4345.7**	**3037.2**	**2429.8**	**3292.7**	**1769.4**	**2112.3**	**1962.1**	**1225.7**	**1789.9**
No. of rainy days	**170**	**221**	**212**	**192**	**137**	**179**	**138**	**124**	**84**	**123**	**156**

AGRICULTURAL ECONOMICS

J K S Sankalpa

DETAILED REVIEW

Staff

Mr J K S Sankalpa and Miss P G N Ishani, Research Officers (Agricultural Economists) were on duty throughout the year.

Seminars/Conferences/Meetings/Workshops attended

Office	Activity	Organisation
JKS Sankalpa	Scientific Committee Meeting	Rubber Research Institute of Sri Lanka
	Plantation Crop Research Symposium-2019	Plantation Crop Research Institutes
PGN Ishani	Scientific Committee Meeting	Rubber Research Institute of Sri Lanka
	Monsoon Forum	Department of Meteorology
	Workshop on INFORM database management	SLCARP
	Scientific Committee Meeting	Rubber Research Institute of Sri Lanka

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 94 during this year. All

these were updated and recorded in a database. 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 RSS 3 are given in Figure 1(a) and 1(b), respectively. The highest average price of RSS 1 was Rs.325, recorded in December. Yearly average prices of all grades of RSS were higher than that of the previous year (2018). Higher prices compared to the previous year were recorded starting from mid of the year 2019. Average RSS 1 price difference against the previous year was around Rs.7. Yearly average RSS1 price has increased by 2% when compared to 2018. This was mainly due to lower supply prevailed at the international market.

(a) (b)

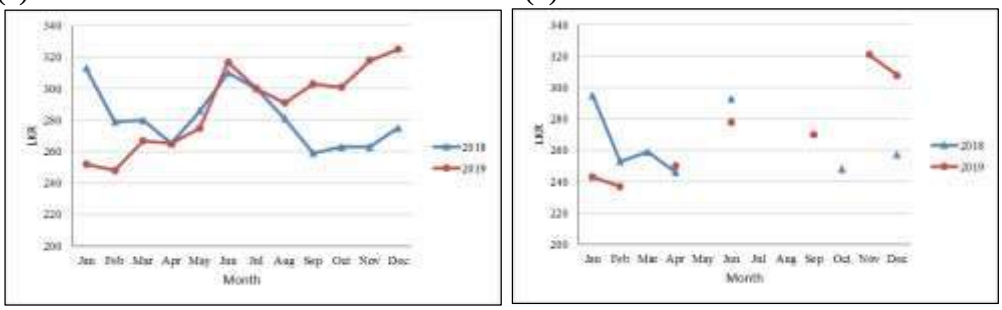


Fig. 1. The monthly average prices of RSS 1 (a) and RSS 3 (b) in 2018 and 2019

Prices of Latex Crepe (LC)

Prices of Latex Crepe 1X for 2018 and 2019 are shown in Figure 2. LC1X prices have remarkably increased during the latter part of 2019. The gap between the LC prices was high at the beginning of the year and prices were low until August of the year. The average LC1X price ranged from Rs.230 (February) to Rs.370 (December) during 2019. The average price of LC1X was Rs.303 which was a 7% reduction compared to the previous year.

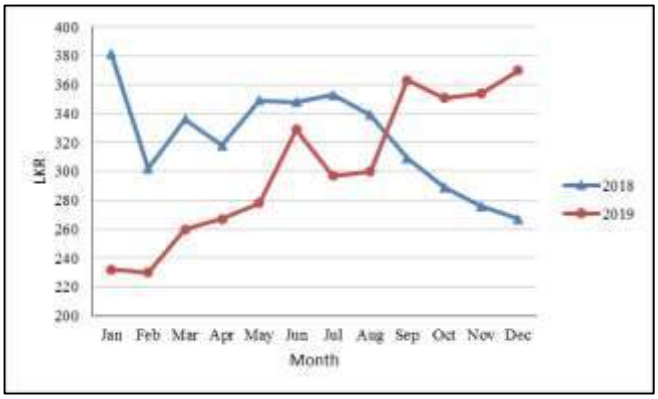


Fig. 2. The monthly average of nominal LC1X price in years 2018 and 2019

RESEARCH

The following studies were conducted in 2019.

Trend analysis of rubber industry (AE/01)

Analysis of the competitiveness of rubber products international trade in Sri Lanka

Although the value of rubber export earnings is a decent figure compared to Sri Lankan external trade, it is not a considerable share in the global rubber industry. Hence, specific innovations are necessary for increasing market share and the competitiveness of Sri Lankan rubber trade in the world market. Having focused on the significance of the international rubber trade in Sri Lanka, it is worth to examine the way forward of rubber products trade and competitiveness of Sri Lankan rubber trade. Changing the export share of a country in the world market is a simple indicator to measure the export performance of any country. However, it does not indicate that its international competitiveness and it may have an increasing or decreasing trend. The trade competitiveness of a country depends on several factors, namely the target market, commodity composition and overall position of the international trade.

No prominent studies have been reported in the literature that focuses on analysing the competitiveness of rubber products of Sri Lanka in the world market. Although the research focused on analysing of the export growth performance of the country during the past, no studies were conducted to measure the competitiveness of rubber products categories. Therefore, non-availability of international trade indicators of rubber exports may generate incapability of proper decision making. Making the correct decision at the time of its required is also a crucial factor in international trade and delayed response to the market changes may have drastic losses from international trade. Therefore, this study focuses on the competitiveness of rubber products trade in

the international market using the Constant Market Share (CMS) model. Competitiveness of product categories was analyzed using the Constant Market Share (CMS) model, which decomposes the export growth into its composition.

Rubber products export data issued by the Sri Lanka Custom was used in this study. Also, the World Integrated Trade Solutions (WITS) and Trade Map (International Trade 'Centre's trade statistics for international business development). The data cover a period of 20 years (1999 to 2018). Four finished rubber products with the largest share in the total value of rubber and rubber products export earnings of Sri Lanka at the disaggregated level was selected for the analysis. The selection of major importing countries was done in the two-step process. First, the average import value of countries for the sample period was computed. Then the first five countries were selected after ranking these countries based on the average import values. The four-digit harmonised classification system (HS) was used to classify the four finished rubber products.

Sustainability analysis of rubber-based farming systems (AE/03)

A farm typology of smallholder rubber-based intercropping farmers in non-traditional areas in Sri Lanka

Factor Analysis of Mixed data method was used in the previous year to analyse socio-economic characteristics of farm households who have rubber-based intercropping practices. However, a clear boundary wasn't observed and interpretation of results was quite tricky. To address this issue, AEU has revised this study using Cluster Analysis (CA) followed by Principal Component Analysis (PCA) of mixed data. This new method of analysis demarcated rubber-based intercropping practices in non-traditional rubber growing areas in Sri Lanka.

This study attempts to categorise the adoption of food crops intercropped in immature rubber lands in the Moneragala district, Sri Lanka using the socio-economic characteristics of farm households. The results indicate six predominant rubber intercropping types and their socio-economic characteristics. Six groups disassociate from each other due to significant differences among the variables including food crop or dairy cattle use in rubber lands, credit access, market access, non-farm income, farm extent, investment in rubber intercropping, use of machines in cultivation, household size and age of rubber trees. The highest number of farmers are in group one. Group one is characterised by banana cultivation, while group two represents rubber-cocoa farming, small land extent and relatively good access to the market. Farmers in group three are passionfruit-practised farmers in the rubber lands and they make a high investment in rubber intercropping. Non-farm income earnings and rubber-pepper practice characterises in group four. Group five mainly disassociates from other groups due to lower machine usage, low investment, comparatively large households, rubber-based groundnut and rubber-based dairy cattle farming. Group six represents rubber with maize farmers and they have a relatively large farm extent, access to credit

services and immature rubber trees. The highest number of farmers represents in group one (45%) followed by group six (15%), group two (14%), group four (13%), group five (7%) and group three (6%) respectively.

Table 2 shows the groups of farmers and the significance of their socio-economic characteristics. When there is a more distinct variable value among groups (clusters), the p-value is lower. In our farm typology classification, the characteristics for differentiating the clusters are discussed. Investment in rubber-based food crop cultivation, non-farm income earnings, use of machines in farming, household size, age of rubber trees, access to credit services, access to market and rubber-based farmland extent were significant in differentiating clusters. All farm types explored during this study were significant in the identification of clusters and were included in the separate groups, except for groundnut and dairy cattle. Both groundnut and dairy cattle were included in the same group. The income per ha of land, other agricultural income, education and age of farm household head, participation in the societies were not significant characteristics in differentiating clusters.

Cluster analysis results reveal that income from rubber-based food crops has a non-significant variation. A few household variables, including household age, the farming experience of household head and education of household head, are not significant characteristics in differentiating clusters. Farmers with proper education possess the ability to manage technologies. The average number of years of schooling in all groups is 8-9 years. A Farmer's social participation is important on various fronts in rubber intercropping such as knowledge sharing on intercrops, establishing volunteer groups in basic infrastructure development and formulating of a micro-credit scheme etc. Farmers who participate in the discussion group have higher technology adoption and farm profit improvements. Socio-economic characteristics based farm typology classification conveys many advantages and can be used to identify the present status of food crops intercropped in immature rubber lands. Agricultural extension workers and policymakers can use the findings of this study to address socio-economic development issues of immature rubber-food crops intercropping farmers in non-traditional areas.

Use of GIS in rubber plantation management (AE/03)

AEU has been involved in many collaborative research activities with the Biometry section and it was in progress to develop yield and field maps including management information for the Polgahawela substation. AEU has involved in further collaborative works with the Advisory Services Department in the project titled "Introduction and Establishment of New Fuelwood Growing Models in Selected Lands of Smallholder Rubber Farmers". AEU has involved in GIS mapping of new fuel wood growing models around the country. These databases are helpful in the decision-making process of efficient extension planning.

Updating databases on the rubber industry, analysis on rubber end products manufacturing sector and other economic evaluations (AE/04)

Agricultural Economics unit has conducted several studies to analyse the rubber international trade and rubber price that prevailed in the international and local markets. The aim was to present the current status at the local and international markets and thereby to assist the stakeholders in taking suitable measures to improve the gains from the rubber industry. Fig. 3 (a) shows the raw rubber exports and imports of Sri Lanka from 2016 to 2019.

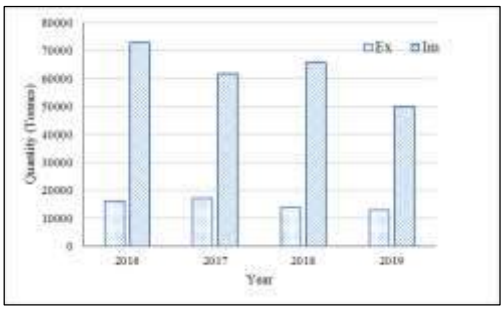


Fig. 3 (a). Raw rubber exports and imports

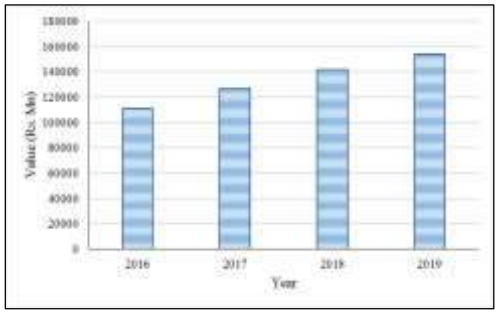


Fig. 3 (b). Earnings from End products and Semi-processed products

Fig. 3 (b) shows the earnings from rubber end products from 2016 to 2019. Quantity of raw rubber export has decreased by 7% in the year 2019 against the previous year. The average export quantity was in a declining trend for the period of 2016-2019. Earnings from rubber finished and semi-processed products have increased by 9%, year on year from 2018 to 2019. Earnings from finished and semi-processed were recorded as Rs. 154 billion in the year 2019 while, it was Rs.142 billion in the year 2018. Earnings from this sector were in an increasing trend and it was about 12% growth for the period of 2016 to 2019.

Analysis of technical efficiency of rubber smallholder farmers (AE/05/b)

This study was started in the year 2018 and completed in 2019. The attempt was to examine the relationship between efficiency and poverty. Also, it has been focused on analysing the effect of farmer's characteristics on poverty levels among the smallholder rubber farmers in Kegalle District, Sri Lanka.

Data were collected from 195 smallholder rubber farms in Kegalle district through a questionnaire survey. Cobb-Douglas Stochastic Frontier Analysis (SFA) was employed to determine the Technical Efficiency (TE) of the farmers and the poverty gap index was calculated to measure the depth of poverty in the sample. Correlation analyses were conducted to analyse the relationship between poverty and technical

efficiency. Generalised Linear Model (GLM) was employed to determine the farm and farmer characteristics affecting poverty.

The estimated mean technical efficiency of smallholder rubber farmers in Kegalle district was 63%, implying that the dry rubber production could be increased further by 37% through better use of existing resources and technology. Correlation analysis indicated that TE has a significant negative correlation (r=-0.147, P=0.04) with poverty, indicating that improving TE will help to eradicate poverty. Results of the GLM model indicated that years of education of the farmer and the farm size has a strong negative influence on poverty while family size and age of the farmer has a positive association with poverty. Hence, policymakers should give more consideration to these factors in poverty alleviation programmes.

Descriptive statistics of variables used in the Stochastic Frontier Model are presented in Table 3. The majority of the farmers in the sample (42%) have studied up to ordinary level, while 27% of the farmers have primary education, 26% studied up to advanced level, and about 6% of the sample farmers had higher education qualification. The majority of the farmers (87%) have adopted the knowledge gathered from extension services. The owner of the land manages more than 90% of the rubber lands. While the family members harvest 44 % of the farmlands, 56% of harvesting is done through hired labour. The mean experience level of farmers in the sample is 20 years which ranged from 7 to 40 years. Estimates of the production function are depicted in Table 4. High standard deviation was recorded for the average yield harvested by farmers.

Table 3. *Descriptive statistics of variables used in the stochastic frontier model*

Variable	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Variables used in production function				
Dry Rubber yield (kg/year)	1048.05	671.46	150	3500
Labour (Man Days/year)	144.37	41.48	68	314
Fertilizer (kg/year)	119.06	146.29	1	641
Land Area (ha)	0.86	0.51	0.20	2.02
Chemicals (L/year)	41.52	343.49	1	3901
Variables used in the inefficiency model				
Labor Involvement from Family (Number)	4	1.44	1	5
Experience (Years)	20.31	8.01	7	40

Table 4. *Maximum Likelihood Estimation of the Cobb-Douglas Stochastic Production Frontier*

Variable	Coefficient	Std. Err	t
Ln (labour)	0.731	0.104	7.025***
Ln (Fertilizer)	-0.014	0.012	-1.117
Ln (Land Area)	0.333	0.054	6.171***
Ln (Chemical)	-0.056	0.132	-0.424
Constant	4.473	1.154	3.876

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

The results of the General Leanier Model (GLM) model is presented in Table 5. This GLM model has a reasonable model fit with a R^2 value of 33%. Results of the GLM indicate that years of education of the farmer and farm size has a significant negative relationship with the poverty gap index. Hence, the increasing farm size and improving the education level of the farmer helps to reduce the poverty level of farmers. Further family size and age of the farmer has a significant positive association with the poverty gap index. Hence increasing family size and age of the farmer tends to increase the poverty level of farmers. However, gender, experience and dependency ratio do not have a significant relationship with the poverty gap index. According to the results of correlation analysis, there is significant negative (r=0.1478, P=0.0402) relationship between technical efficiency and poverty gap. Thus, there exists an inverse relationship between poverty and technical efficiency.

Table 5. *Results of the GLM model for the relationship between poverty and technical efficiency*

Variable	Coefficient	Std. Error	z	P>|z|
Gender	0.071	0.169	0.420	0.672
Dependency ratio	-0.046	0.059	-0.780	0.434
Education	-0.171	0.069	-2.470	0.013**
Family size	0.387	0.071	5.450	0.000***
Age	0.101	0.058	1.740	0.082*
Farm size	-0.206	0.078	-2.630	0.009***
Experience	-0.105	0.080	-1.310	0.191
Constant	-0.056	0.155	-0.360	0.718

Table 1. *Monthly Auction Prices of Rubber in year 2019*

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	252	249	243	239	.	232	228	216	212	208	203	200	203	199	188
Feb	248	241	237	233	230	230	228	220	217	215	211	211	212	209	.
Mar	267	271	.	241	.	260	254	247	243	231	228	225	222	216	205
Apr	265	255	250	239	237	267	263	247	242	235	225	221	221	216	203
May	275	268	.	257	245	278	270	260	256	253	244	233	231	226	224
Jun	317	314	278	295	283	329	326	318	313	289	280	263	242	237	238
Jul	300	286	.	.	.	297	297	282	274	271	255	248	239	229	219
Aug	291	290	.	.	.	300	298	283	275	257	247	243	238	237	220
Sep	303	281	270	254	.	363	356	303	279	263	252	248	247	245	225
Oct	301	295	.	.	.	351	346	326	320	270	262	258	253	249	230
Nov	318	325	321	0	268	354	352	334	325	272	266	259	259	254	.
Dec	325	318	308	310	.	370	369	353	329	277	271	268	267	261	253
2018 Average	288	283	272	230	253	303	299	282	274	253	245	240	236	231	220

Table 2. *The variable representation in six clusters (C) and p-value of group mean comparison*

	C1	C2	C3	C4	C5	C6	
	N=93	*N*=30	*N*=12	*N*=27	*N*=15	*N*=31	*P-value*
	Banana	*Market access, Small farm extent, Cocoa*	*High investment, Passionfruit*	*Non-farm income, Pepper*	*Low investment, Low machines use, Large household size, Groundnut, Dairy cattle*	*Immature rubber, Access to credit, Large farm extent Maize*	
Economic factors							
Income per ha (US$) (intercrops)	1885 (2811)	2600 (2344)	1127 (844)	1315 (1015)	1457 (1047)	1800 (1837)	0.267
Non-farm income	11 (12%)	0	1 (8%)	8 (30%)	0	1 (3%)	0.004
Other farm income other than rubber intercrops	12 (13%)	8 (27%)	1 (8%)	3 (11%)	2 (13%)	8 (26%)	0.307
Investment per ha (US$)	217 (219)	149 (107)	328 (256)	179 (154)	123 (130)	259 (184)	0.02
Use of machinery	13 (14%)	13 (43%)	4 (33%)	7 (26%)	5 (3%)	13 (42%)	0.003
Household specific factors							
Education (years)	9 (2)	9 (2)	9 (3)	8 (2)	8 (2)	9 (2)	0.58
Household size	4 (1)	4 (1)	4 (1)	4 (1)	5 (1)	3 (1)	0.003
Age of household head	50 (13)	47 (10)	51 (6)	48 (12)	47 (13)	43 (11)	0.186
Society involvement	72 (77%)	29 (97%)	10 (83%)	22 (81%)	13 (87%)	28 (90%)	0.151
Rubber intercropping land extent	0.67 (0.32)	0.53 (0.23)	0.74 (0.37)	0.62 (0.27)	0.64 (0.46)	0.86 (0.55)	0.014
Age of rubber trees	5 (1)	5 (1)	5 (1)	5 (1)	4 (1)	3 (1)	0.001

	C1	C2	C3	C4	C5	C6	
	N=93	*N*=30	*N*=12	*N*=27	*N*=15	*N*=31	*P-value*
	Banana	*Market access, Small farm extent, Cocoa*	*High investment, Passionfruit*	*Non-farm income, Pepper*	*Low investment, Low machines use, Large household size, Groundnut, Dairy cattle*	*Immature rubber, Access to credit, Large farm extent Maize*	
Rubber-based Intercropping practice							
Banana	92 (99%)	0	0	1 (4%)	0	0	< 0.001
Pepper	0	0	0	22 (81%)	0	0	< 0.001
Cocoa	1 (1%)	30 (100%)	0	0	0	0	< 0.001
Groundnut	0	0	0	1 (4%)	9 (60%)	0	< 0.001
Maize	0	0	0	3 (11%)	0	31 (100%)	< 0.001
Passionfruit	0	0	12 (100%)	0	0	0	< 0.001
Dairy cattle	0	0	0	0	6 (40%)	0	< 0.001
Infrastructure							
Access to credit	21 (23%)	4 (13%)	3 (25%)	6 (22%)	2 (13%)	16 (52%)	0.015
Access to market (km)	8 (4%)	6 (4%)	7 (3%)	9 (5%)	8 (4%)	15 (6%)	< 0.001

LIBRARY AND PUBLICATION

N C D Wijesekara

DETAILED REVIEW

Mrs N C D Wijesekara, Librarian & Publication Officer, Mrs R M Amaratunga, Library Assistant & Assistant Publication Officer, Mrs D N C Amaratunga, Library Assistant & Publication Assistant (Rathmalana Library), Mr P M Prema Jayantha, Management Assistant and two Library Attendants were on duty throughout year.

Publications

The following RRISL regular publications were published during the year.

- RRISL Journal Vol. 96 (2016)
- RRISL Annual Review 2017
- Proceedings of the Seventh Symposium on Plantation Crop Research Vol. 1 (2019)
- Proceedings of the Seventh Symposium on Plantation Crop Research Vol. 2 (2019)

Advisory Circulars (Sinhala & English)

- ක්‍රේප් රබර් නිෂ්පාදනය
- බද්ධ අතු තවාන් පාලනය
- සුදුමුල් රෝග පාලනය
- අච්චු භාවිතයෙන් භාණ්ඩ නිෂ්පාදනය
- පාංශු සංරක්ෂණය
- ක්‍රේප් රබර් නිෂ්පාදනය
- රබර් කිරි ආශ්‍රිතව බැලුන් නිෂ්පාදනය
- ක්ෂේත්‍ර සංස්ථාපනය හා අපරිණත වගා නඩත්තුව
- රබර් සඳහා පොහොර
- රබර් කිරි ආශ්‍රිත කොහු මෙට්ට නිෂ්පාදනය
- Manufacture of Rubber Smoked Sheet
- Management of White Rood Disease
- Soil Conservation
- RSS Manufacture
- Bud wood Nursery management
- Manufacture of Latex Crepe Rubber

List of books purchased during the year

No	Title	Publisher	Year of the publication
01	Sustainable Agriculture and Sustainability	Springer	2011
02	Scientific Writing and Communication in Agriculture and Natural Resources	Springer	2013
03	Environmental and Material Flow Cost Accounting	Springer	2009
04	The Triumph of the Fungi A Rotten History	Oxford	2007
05	Pathogenic Root – Infecting Fungi	Cambridge University Press	2011
06	Phoma Identification Manual	CABI Publishing	2004
07	Plant Pathologist's Pocket book	CABI Publishing	1998
08	Selecting Statistical Techniques for Social Science Data : A Guide for SAS Users	SAS Institute Inc.	1998
09	Science policy and politics of modern agricultural system : global context to local dynamics of sustainable agriculture		2014
10	Beneficial microorganisms in agriculture aquaculture and other areas	Springer	2015
11	Agricultural statistical data analysis using stata	CRC Press – New York	2013
12	Statistical Information on Plantation Crops - 2017	Ministry of Plantation Industries	2017
13	Objectives, Functions & Economic Data	Central Bank of Sri Lanka	2019
14	Sri Lanka socio economic data - 2019	Central Bank of Sri Lanka	2019
15	පුරාණයෙන් රුපියලට	ශ්‍රී ලංකා මහ බැංකුව	2013
16	අරමුණු කාර්යයන් සහ සංවිධානය	ශ්‍රී ලංකා මහ බැංකුව	2019
17	Economic and social statics of Sri Lanka	Central Bank of Sri Lanka	2019
18	සිංහල ඉංග්‍රිසි ශබ්දකෝෂය	බුද්ධදාස හේවගේ ඉගෙනුම් මධ්‍යස්ථානය - රාජගිරි මාවත, පිටිගල, බොරළුහේන	2019
19	රණමඟ ඔස්සේ නන්දිකඩාල්-කොටි සංවිධානයේ සත්‍ය කතාව	මේජර් ජනරාල් කමල් ගුණරත්න	2019
20	අයි.එස්.අයි.එස්. හිම රාත්‍රිය	සරසවි ප්‍රකාශකයෝ, නුගේගොඩ	2015
21	Atlas of Sri Lanka	Vijitha Yapa Publication	2019

DARTONFIELD GROUP

P A Lukshaman

DETAILED REVIEW

Mr P A Lukshaman Senior Estate Manager, Mr Dinesh Achinda, Mr T D Harsha and Mr M N S Pavinda Management Assistants, Mr B M Siriwardena Field Officer and Mr K A Sarath Kumara, Mr Jagath Nakandala, and Mr N L D Premechandra 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	07
Total	**15**

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	23.16	121.10	33.76	178.02
Immature area	13.19	37.96	9.18	60.33
Cinnamon under power line	0.80	-	-	0.80
State land take in	0.27	-	-	0.27
Nurseries	7.27	2.62	2.00	11.89
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	7.02	3.04	12.20
Roads	2.92	6.86	0.36	10.14
Building	16.92	5.43	7.79	30.14
Play Ground	1.00	-	-	1.00
Proposed replanting area	-	-	12.69	12.69
Proposed Cinnamon Ns.	0.20	-	-	0.20
Streams	-	-	2.17	2.17
Grand total	**74.49**	**184.15**	**73.24**	**331.88**

Rainfall

The annual rainfall recorded for the year was 4,389.7 mm with 204 wet days.

Table 2. *Annual rainfall and wet days of the group for last five years*

	2015	2016	2017	2018	2019
Rainfall (mm)	4,014.5	2,682.1	4,068.1	3,773.3	4389.7
Wet days	210	181	188	195	204

Crop

A total crop for 150,416 kg have been harvested against the estimated crop of 197,295 kg (76%) which is a decrease of 46,879kg

Table 3. *The crop and YPH (kg) of the Dartonfield group from 2015 to 2019*

Hect.	2015		2016		2017		2018		2019	
	181.28		181.28		176.05		178.02		178.02	
Division	Crop	YPH	Crop	YPH	Crop	YPH	Crop	YPH	Crop	YPH
Dartonfield	26,878	834	23,635	734	19,124	649	19,477	841	15,683	677
Gallewatta	109,247	901	123,207	1,016	106,531	938	119,458	986	104,699	865
N'kele	25,545	919	29,294	1,053	35,800	1,086	39,600	1,173	300,34	890
Group total	161,670	892	176,136	972	161,455	917	178,535	1,003	150,416	845
Group estimate	200,688	1,107	197,474	1,089	185,606	1,054	193,037	1,084	197,295	1,108

Tappers productivity

The average IPT during the last five years are given in Table 4.

Table 4. *The average IPT (kg) of Dartonfield group from 2015 to 2019*

	2015	2016	2017	2018	2019
Dartonfield	5.6	5.7	6.4	7.1	6.7
Gallewatte	7.2	7.9	7.6	7.9	7.1
Nivitigalakele	7.2	7.3	8.4	8.7	7.8
Group average	**6.9**	**7.4**	**7.6**	**8.0**	**7.2**

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*

	2015	2016	2017	2018	2019
Normal tapping	204	258	224	222	201
Late tapping	12	07	02	6	19
Cash/Double tapping	(23)	(29)	(18)	(25)	(21)
No tapping	70	39	69	52	80
Rain guard tapping	79	62	69	85	65
Slight rain	-	-	01	-	-
Total no of tapping days	295	327	296	313	285

Rain guards

Total areas of 178.02 hectares were rain guarded during the year and an additional crop of 26292 kg was harvested which amounts to 17% of total crop harvested. Additional tapping days done with rain guards during the year were 46, 76 and 71 for Dartonfield, Galewaththa and Nivithigalakele respectively. Profit generated due to rain guarding was Rs.365,984.64 and profit per hectare was Rs.2,055.86.

Table 6. *Additional income generated by fixing of rain guards (Rs/kg)*

	Dartonfield Division	Gallewatta Division	Nivithigalakale Division	Total
Area (ha)	23.16	121.10	33.76	178.02
No. of rainguards fitted	5,350	40,047	8,715	53,712
Additional crop (kg)	2,181	17,089	7,022	26,292
Rainguard cost per kg.	92.81	82.41	96.41	87.01
Tapping cost per kg.	139.94	139.94	139.94	139.94
C.O.M. Rs/kg	35.35	35.35	35.35	35.35
Total cost Rs/kg	268.10	257.70	271.70	262.30
N.S.A. Rs./kg	276.22	276.22	276.22	276.22
Additional profit Rs./kg	8.12	18.52	4.52	13.92
Additional profit from rainguards (Rs.)	17,709.72	316,488.28	31,379.44	365,984.64
(Additional profit per hectare (Rs.)	764.67	2,613.45	940.15	2,055.86

Total profit and profitability per hectare

The total loss and loss per hectare were Rs.8,226,251.04 and Rs.46,209.70 for the year under review.

Table 7. *Comparative statement of the revenue profit per kg and profit per hectare*

	Years				
	2015	**2016**	**2017**	**2018**	**2019**
Mature area (ha)	181.28	181.28	176.05	178.02	178.02
Total profit/(loss) (Rs.)	(2,475,167.70)	(1,107,895.44)	6,207,944.75	(2,319,169.65)	(8,226.251.04)
Profit/(loss) per ha. (Rs.)	(13,653.84)	(6,111.52)	35,262.40	(13,027.58)	(46,209.70)

Cost of production and productivity

Table 8. *Labour rates and break down of cost of production from 2015 to 2019 (Rs /Kg)*

	2015	**2016**	**2017**	**2018**	**2019**
1. Labour wages	687.50	687.50 up to Sept. & 805 from Oct.	805	805	805.00 up to Jan. & 855.00 from Feb.
2. Cost of production	270.57	241.13	280.55	268.43	330.91
2.1 Tapping	113.94	116.46	122.77	115.63	139.94
2.2 Manufacture	36.43	32.35	34.47	33.08	35.35
2.3 General charges	103.07	74.43	97.29	98.10	124.18
2.4 Mature/area upkeep	17.13	17.89	26.02	21.62	31.44
3. N.S.A.	255.26	234.84	319.00	255.44	276.22
4. Profit/(loss) per kg	(15.31)	(6.29)	38.45	(12.99)	(54.69)

Manufacture

Out of the latex crop of 150,416 kg harvested, 118,601 kg has been graded as RSS No. 01 which is 91%. Details are given in Table 9. Latex crape No.1 percentages are shown below quantities, that given to the research purposes.

Table 9. *Summary of grades manufactured during the year*

Grade	**Quantity (kg.)**	**Percentage %**
Latex crepe No.1	461	17
Latex crepe No.2	-	-
Latex crepe No.3	-	-
Latex crepe No 4	2,200	83
Total	**2,661**	**100**
RSS No.01	118,601	91
RSS No.02	300	-
RSS No.03	10,600	08
RSS No.04/05	2,425	01
Total	**131,926**	**100**

Grade	Quantity (kg.)	Percentage %
Scrap crepe No. 1	14,939	96
Scrap crepe No.2	595	03
Scrap crepe No.3/4	295	01
Total	**15,829**	**100**
Grand total	**150,416**	**-**

Different types of rubber manufactured, percentage of grades received for pale crepe and RSS are shown in Figures 1(a) and (b).

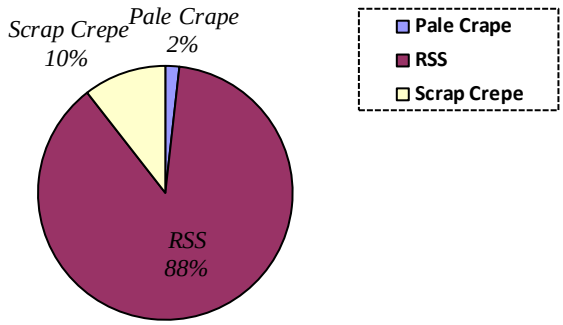


Fig. 1(a). Percentage of different types of rubber manufactured

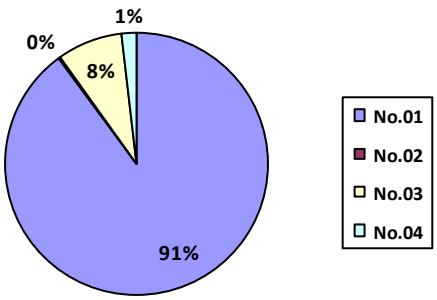


Fig. 1(b). Percentage of grade of RSS manufacture

Table 10. *Best auction prices received in the year 2019 by the Dartonfield Estate Group*

Date	Category	Quantity sold (kg)	Price at auction (LKR/kg)
2 January	RSS 1	3375	260
31 January	RSS 1	1325	250
28 February	RSS 1	8775	252
14 March	RSS 1	3975	270
26 March	RSS 1	3925	262
9 April	RSS 1	2425	275
14 May	RSS 1	3650	275
22 May	RSS 1	2075	275
28 May	RSS 1	1725	275
18 June	RSS 1	4950	330
25 July	RSS 1	3825	300
20 August	RSS 1	3500	285
27 August	RSS 1	3100	300
23 October	RSS 1	1025	312
29 October	RSS 1	800	315
5 November	RSS 1	1275	319
17 December	RSS 1	1700	325
31 December	RSS 1	1950	325

Dartonfield Estate Group has received the best Auction prices of sheet rubber category one (RSS 1) for 18 times during the year 2019 (Table 1). The highest best price received for the RSS 1 was LKR 325 in December 2019 and higher prices have been enhanced by the favourable market condition prevailed during the latter part of the year.

KURUWITA SUB - STATION

P A Lukshaman

DETAILED REVIEW

Staff

Mr P A Lukshman Senior Manager (Estate) attended to the duties of the Estate Manager. Mr D S Jayasinghe, Mr K D P Senarathne, Management Assistants, Mr D D A Jayathunga Field Officer, K K S Dinesh and Mrs E P S L Erawwala Field Supervisors were on duty throughout the year.

The estate cadre stood as follows at the end of the year.

Intermediate Staff	- 01
Assistant Staff	- 03
Minor Staff	- 02

Hectarage

A summary of the hectarage is given in Table 1.

Table 1. *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 72,308 kg was harvested during the year, recording a decrease of 8,840 kg on previous year's crop.

The actual yield per hectare (YPH) was 911.1 kg. which is a decrease of 113.9 kg when comparing with previous year's crop.

The yield 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				
	2015	**2016**	**2017**	**2018**	**2019**
Estimated	1,378.65	1,339.54	1,318.57	1320.61	1271.00
Actual	1,367.32	1,383.17	1,086.67	1025.11	911.10

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	121.1
February	61.1
March	67.7
April	53.8
May	85.7
June	63.3
July	89.7
August	66.4
September	48.0
October	69.7
November	99.1
December	85.5

Tapper productivity

The average intake per tapper at the end of the year was 7.4 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				
	2015	**2016**	**2017**	**2018**	**2019**
Intake per tapper	8.9	9.1	9.0	8.6	7.4

Rainfall

The annual rainfall recorded during the year was 4,560.8 mm with 244 wet days (Table 5).

Table 5. *Annual rainfall figures and the number of wet days of the estate for the past 5 years*

	Year				
	2015	**2016**	**2017**	**2018**	**2019**
Rainfall (mm)	4,002.14	3,342.80	4,768.40	4560.8	3976.8
Wet days	251	222	246	244	226

Tapping days

There were 321 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				
	2015	**2016**	**2017**	**2018**	**2019**
01.Total tapping days	**348**	**352**	**321**	**324**	**323**
1.1 Normal	174	260	203	232	250
1.2 Late	32	08	00	00	11
1.3 Rain Interference	02	-	40	00	00
1.4 Rainguarded Tapping	140	84	78	92	62
02. Recovery Tapping	(08)	-	-	-	-
03.No tapping	17	14	44	41	42

When compared with the last year there was an increase in normal tapping days from 232 to 250 days during the year.

Rainguard

Due to the use of rainguards an additional 62 tapping days were recorded during the year. This contributed to 17% of the total crop yielding an additional profit of Rs.642,594.65.

An analysis of the use of rainguards for the years 2016, 2017, 2018 & 2019 are given in Table 7.

Table 7. *An analysis of the use of rainguards (Rs./kg)*

	Year			
	2016	**2017**	**2018**	**2019**
Hectarage (ha.)	73.41	63.46	64.96	70.25
No. of rainguards fitted	22,262	19,904	22758	23212
Additional tapping days	84	78	92	62
No. of kilos harvested	20,454	18,710	18419	12113
Rainguard cost per (kg.)	43.41	39.20	49.76	82.55

	Year			
	2016	**2017**	**2018**	**2019**
Tapping cost (Rs./kg.)	89.65	99.08	105.14	127.94
Total cost (Rs./kg.)	133.06	138.28	154.90	210.49
N.S.A (Rs./kg.)	217.11	294.18	244.89	263.54
Additional Profit (Rs./kg.)	84.05	155.90	89.99	53.05
Additional profit from rainguards (Rs.)	1,719,158.70	2,916,889.00	1,657,525.81	642,594.65
Additional profit per hectare (Rs.)	23,418.59	45,964.21	25516.10	9,147.25

Total profit and profitability per hectare

The total Loss and Loss per hectare were Rs.5,363,084.36 and Rs.67,579.19 respectively for the year 2019.

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				
	2015	**2016**	**2017**	**2018**	**2019**
Mature extent (ha.)	73.26	75.66	77.66	79.16	79.36
Total profit (Rs.)	1,667,830.50	3,959,993.84	3,727,550.47	(2,908,957.77)	(5,363,084.36)
Profit per hectare (Rs.)	22,765.91	52,339.33	47,998.33	(36,747.82)	(67,579.19)

Cost of production and profitability

The cost of production has increased by Rs.58.35 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 break down of the cost of production from 2015 to 2019 (Rs./kg.)*

	Year				
	2015	**2016**	**2017**	**2018**	**2019**
Labour rate	687.50	Jan. - Nov. 687.50 From December 805.00	805.00	Jan.-Oct. 805.00 From Nov 855.00	855.00
Cost of production	191.21	179.27	250.01	279.36	337.71
Tapping cost	87.77	89.65	99.08	108.80	134.74
Manufacturing	22.14	21.49	32.65	36.33	33.11
General chargers	64.72	54.48	92.38	97.16	135.40
Field & cultivation cost	16.58	13.65	25.90	37.07	34.47
N.S.A	207.86	217.11	294.18	244.89	263.54
Profit per kg.	16.65	37.84	44.17	(34.47)	(74.17)

POLGAHAWELA SUB STATUION

P A Lukshaman

DETAILED REVIEW

Mr P A Lukshaman, Senior Estate Manager overlooked the activities of the Sub Station and Mr Nuwan Disanayake, Management Assistant were on duty throughout the year.

Crop

Total crops of 15,678 kg have been harvested against the estimated crop of 18,253 kg which is a decrease of 2,575 kg. The total crop, YPH and IPT for 2015, 2016, 2017, 2018 and 2019 are in given in Table 1.

Table 1. *Total crop (kg) and YPH (kg) and IPT (kg) for the years of 2015,2016, 2017, 2018 and 2019*

Year	Hectare	Crop (kg)	YPH (kg)	IPT (kg)
2015	10.75	12,206	1,136	9.2
2016	11.75	13,753	1,170	10.1
2017	11.75	7,661	652	9.6
2018	11.75	14,710	1,070	10.7
2019	17.75	15,678	883	9.4

Rainfall

The annual rainfall recorded for the year was 2,170.0 mm with 139 wet days.

Table 2. *Annual rainfall and wet days of the estate for last four years*

	2015	2016	2017	2018	2019
Rainfall (mm)	2,817.01	1,947.07	1,974.8	2,683.7	2,170.0
Wet days	162	109	164	153	139

Tapping days

Annual breakdown of tapping days and No tapping days are given in Table 3.

Table 3. *Annual tapping days no tapping days*

	2015	2016	2017	2018	2019
Tapping days	291	246	223	292	312
No tapping days	74	119	142	73	53

Meteorological Summary

Dartonfield Station

Wasana Wijesuriya

Average annual rainfall of 4,088 mm was observed in the Dartonfield Meteorological Station located in the Agro-Ecological Region, WL_{1a} during the last 20 years. Out of the 20 years since 2000, total rainfall of less than 3,000 mm has been recorded only during 2016 which was 2,966 mm. In 2000, the total rainfall slightly exceeded 3,000 mm (Fig. 1). The rainfall recorded in 2019 was 4,346 mm, which accounted for an increase of 9%, compared to the previous year. The annual rainfall in 2019 was observed above average for Dartonfield. The average annual rainfall is marked as a straight line in Fig. 1.

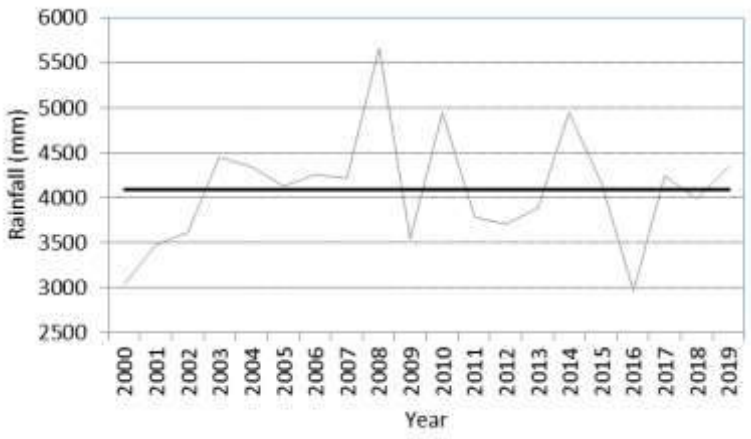


Fig. 1. Variation in annual rainfall at Dartonfield from 2000 to 2019

As indicated in Fig. 2, the rainfall distribution at Dartonfield during this year departed from the usual bimodal rainfall pattern. Above-average monthly rainfall values were observed in August, September and November while below-average values were recorded in March, April, May and July. The rest of the months, *viz.* January, February, June, October and December were very close to the long-term average. The minimum monthly rainfall of 118 mm was recorded in January and March whilst the maximum monthly rainfall of 772 mm was recorded in September.

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 (2,342 mm) during 2019. This rainfall amount contributed 54% to the total rainfall,

which is, comparatively higher than the long-term average contribution (48%). Rainfall during IM2 (October & November) in 2019 brought 1,023 mm whilst IM1 (March & April) recorded a low rainfall of 407 mm. During the North East season (December 2019 to February 2020), 528 mm of rain was recorded, which is comparatively lower (12%) than the long-term average contribution (14%) of this season.

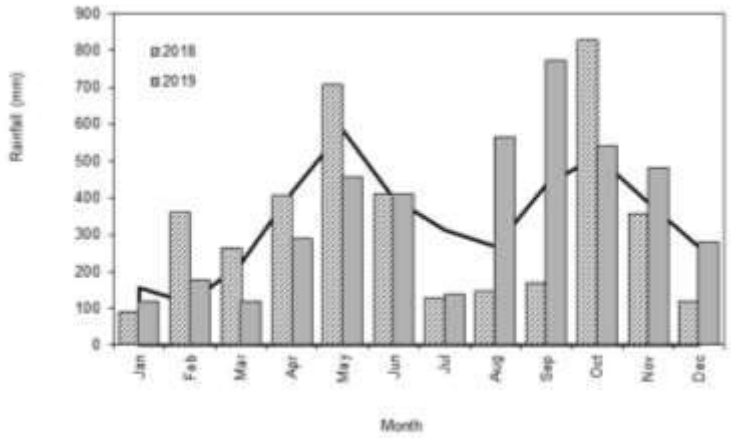


Fig. 2. Distribution of monthly rainfall in 2018 and 2019 at Dartonfield (The line graph indicates the long-term average)

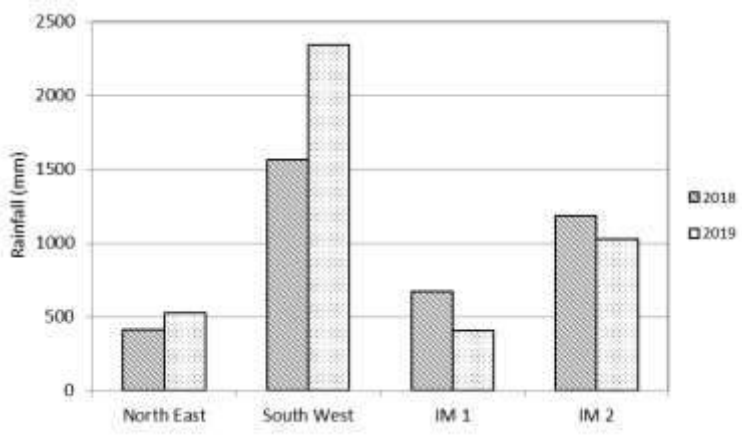


Fig. 3. Seasonal distribution of rainfall at Dartonfield in 2018 and 2019

The distribution of weekly rainfall is depicted in Fig. 4. Ten dry weeks (weeks having a total rainfall less than 10 mm) were observed during this year. The highest weekly rainfall of 282.3 mm was observed in the 38th standard week, in the month of September (17th to 23rd of September).

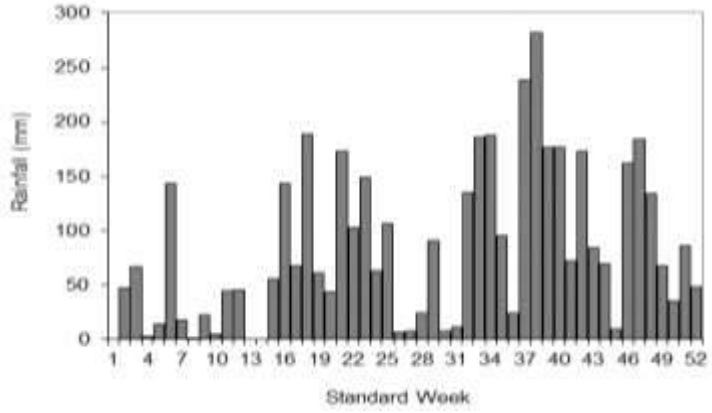


Fig. 4. Weekly variation in rainfall in 2019

There were 5 rainfall events that exceeded the hazardous limits for landslides (100 mm of rainfall during a day) reported during the year under review. The amount of rainfall and number of rainy days under low, moderate and high rainfall categories are listed in Table 1. The observed total number of rainy days of the year was 223, which is close to the long-term average of 220 days. A dry spell lasted over a month or more can have adverse impacts on rubber plantations. There were only 6 dry spells greater than or equal to 7 days; the longest being 16 days, from 24th March to 8th April. The details of the dry spells are given in the table below.

Details of dry spells at Dartonfield

Dry spell No.	Period	No. of days
1	1st - 9th January	09
2	17th - 25th January	09
3	27th January - 2nd February	07
4	16th - 24th February	09
5	24th March - 08th April	16
6	4th - 10th May	07

Rainfall at RRISL substations

There are three substations maintained by RRISL in Kuruwita (WL_{1a}), Narampola (IL_{1a} bordering WL_{2b}), Moneragala (IL_{1c}) and Nivithigalakele (WL_{1a}). The annual rainfall totals of 3,628 mm, 2,195 mm, 2210 mm and 4,115 mm were recorded, respectively, in Kuruwita, Narampola, Moneragala and Nivithigalakele stations during 2019. The details of rainfall in these stations are given in Tables 2 to 5.

Table 2. *Monthly variation of rainfall and rainy days in 2019 - 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	24.4	6	3	3	0
February	213.8	10	3	6	1
March	102.7	8	1	7	0
April	55.2	18	5	11	2
May	106.8	14	3	11	0
June	472.9	24	5	16	3
July	219.8	18	7	10	1
August	582.2	31	7	21	3
September	506.6	27	6	19	2
October	616.1	27	2	22	3
November	529.4	27	10	11	6
December	198.5	18	5	13	0
Total	**3,628.4**	**228**	**57**	**150**	**21**

*A rainy day is defined as a day with a rainfall ≥ 0.3 mm

Table 3. *Monthly variation of rainfall and rainy days in 2019 - 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	37.4	5	1	4	0
February	158.4	8	0	8	0
March	77.2	6	0	6	0
April	235.4	14	4	9	1
May	373.0	16	2	11	3
June	411.1	22	2	19	1
July	139.3	12	3	9	0
August	574.0	23	1	20	2
September	692.8	25	2	19	4
October	556.6	20	0	18	2
November	603.2	22	0	18	4
December	257.0	13	2	10	1
Total	**4,115.4**	**186**	**17**	**151**	**18**

*A rainy day is defined as a day with a rainfall ≥ 0.3 mm

Table 4. *Monthly variation of rainfall and rainy days in 2019 - Narampola, Polgahawela*

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	0.0		0	0	0
February	189.3	5	0	4	1
March	65.5	5	0	5	0
April	280.4	12	2	10	0
May	60.7	2	1	0	1
June	196.8	16	3	12	1
July	148.9	12	3	9	0
August	214.5	18	2	16	0
September	265.1	23	8	14	1
October	451.6	24	2	20	2
November	197.7	11	1	9	1
December	120.7	11	2	9	0
Total	**2,195.2**	**139**	**24**	**108**	**7**

*A rainy day is defined as a day with a rainfall ≥ 0.3 mm

Table 5. *Monthly variation of rainfall and rainy days in 2019 - Kumbukkana, 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	22.4	4	2	2	0
February	163.0	5	0	4	1
March	5.0	2	1	1	0
April	248.2	9	1	6	2
May	48.0	2	0	2	0
June	24.2	2	0	2	0
July	50.6	4	1	3	0
August	29.2	1	0	1	0
September	258.4	11	0	9	2
October	399.0	20	1	17	2
November	443.8	15	0	13	2
December	518.0	15	2	9	4
Total	**2209.8**	**90**	**8**	**69**	**13**

*A rainy day is defined as a day with a rainfall ≥ 0.3 mm

Other meteorological parameters

Table 6 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 dropped below 20^0C in 5 days; 2 days each in January and November and 1 day in May.

The daily average temperature pattern was fairly steady with a mean annual temperature of 27.6 ^{0}C, which could be a favourable condition for rubber plantations. The lowest mean minimum temperature of 21.6 ^{0}C was observed in January while the highest mean maximum temperature of 33.6 ^{0}C was observed in March and April. However, any signs of adverse conditions concerning the temperature regime at Dartonfield were not reported during the year.

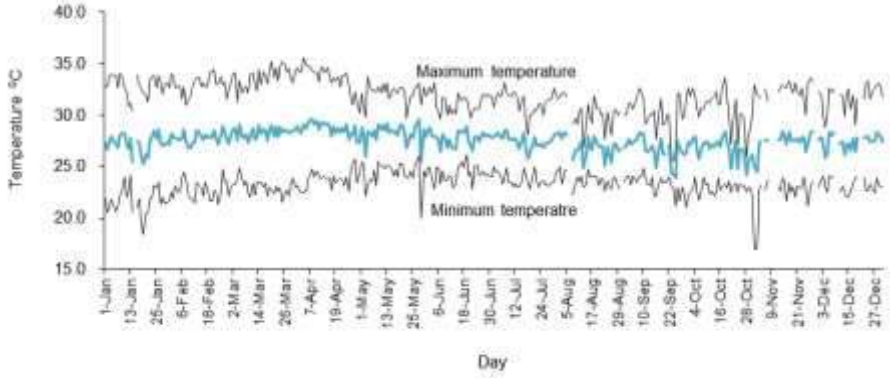


Fig. 5. *Daily minimum, maximum and average temperature distributions in 2019*

A total of 1727 bright sunshine hours was received at an average rate of 4.7 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 43% of the days, while in 26% 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 2019 was observed in the range, 60% to 99%. The mean RH values recorded at 08:30 and 15:30 were 85% and 73%, respectively.

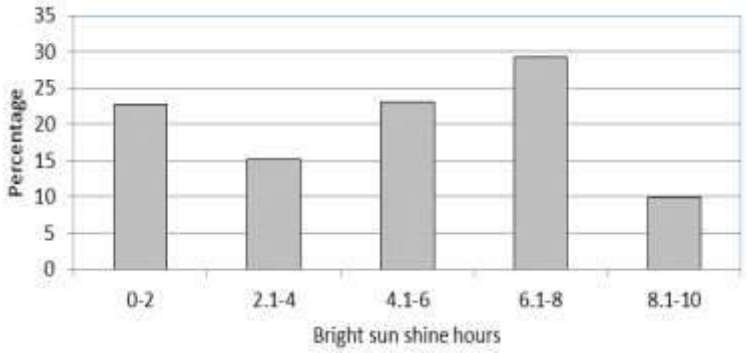


Fig. 6. Distribution of bright sunshine hours in 2019

Table 1. *Monthly variation of rainfall and rainy days at Dartonfield in 2019*

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	117.8	(156)	6	(11)	0	5	1	96.0
February	176.9	(114)	10	(09)	2	7	1	91.8
March	118.4	(222)	12	(13)	4	8	0	123.0
April	289.0	(415)	16	(18)	3	12	1	103.3
May	457.7	(584)	17	(24)	5	9	3	88.4
June	409.9	(398)	24	(23)	3	20	1	82.2
July	136.2	(313)	15	(22)	4	11	0	136.1
August	566.4	(268)	28	(20)	6	19	3	81.5
September	771.7	(436)	27	(22)	4	19	4	69.6
October	541.5	(513)	27	(23)	7	18	2	68.2
November	481.0	(387)	26	(20)	4	19	3	60.6
December	279.5	(266)	15	(15)	3	12	0	54.9
Total	4,346.0	(4,072)	223	(220)	45	159	19	1,055.6

* A rainy day is defined as a day with a rainfall ≥ 0.3 mm

** Average values for 1980-2005 are shown in parentheses

Table 6. *Variation of observed meteorological factors at Dartonfield (Latitude $6^0 32'$; Longitude 80.09 E; Altitude 65.50m) in 2019*

Month	Temperature (^{0}C)					Relative humidity (%)			Mean Wind speed (kmph^{-1})
	Mean Max	Mean Min	Mean	No of days Min Temp<20	Sun shine hours	8.30 am	No of days 8.30am>90%	3.30 pm	
January	32.8	21.6	27.2 (26.7)	2	6.3	84 (88)	4	63 (68)	1.5
February	32.9	22.7	27.8 (27.1)	-	6.4	84 (86)	5	70 (65)	1.5
March	33.6	23.0	28.3 (27.6)	-	6.7	80 (85)	4	66 (68)	1.4
April	33.6	23.8	28.7 (27.8)	-	5.7	81 (85)	3	65 (75)	1.4
May	32.1	24.4	28.3 (27.6)	1	5.5	84 (88)	4	70 (77)	1.7
June	31.2	24.3	27.8 (26.9)	-	2.6	88 (89)	11	78 (77)	1.4
July	31.3	23.8	27.6 (26.7)	-	4.4	88 (89)	13	71 (75)	1.7
August	30.1	23.7	26.9 (26.6)	-	2.8	89 (88)	2	78 (74)	1.6
September	30.0	23.2	26.6 (26.7)	-	3.4	88 (88)	7	77 (75)	1.6
October	30.6	22.9	26.8 (26.6)	-	3.2	85 (86)	7	84 (77)	1.2
November	32.3	22.4	27.4 (26.6)	2	5.6	80 (85)	3	79 (77)	1.0
December	31.7	23.2	27.5 (26.7)	-	4.4	87 (85)	7	74 (73)	1.0

** Average values for 1980-2005 are shown in parentheses

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(Bold type - Employees of Rubber Research Institute of Sri Lanka)

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Awards

Edirisinghe, D.G. (2019). Award for "Scientific Excellence" in the Rubber Sector during 2016-2018 was received at the 7th Symposium on Plantation Crop Research held at the Marino Beach Hotel, Colombo on 4th November, 2019.

Kondarage, Y.G., Pitawala, H.M.J.C., Kirushanthi, T. **Edirisinghe**, **D.,** Etampawala N. Thusitha (2019). The research titled "Ceramic waste based natural rubber composites: An exciting way for improving mechanical properties" received the SLAAS - Section D – Life & Earth Sciences – Second Prize at the SLAAS Annual Sessions held in December 2019.

Samarasinghe, I.H.K., Edirisinghe, D.G., Walpalage, S. and Egodage, S.M. (2019). Effect of Nitrosamine Safe Diisopropyl Xanthogen Polysulfide Accelerator on Cure and Static Mechanical Properties of Natural Rubber Compounds - Award for the "Best Paper" was received at the 7th Symposium on Plantation Crop Research held at the Marino Beach Hotel, Colombo on 6th November, 2019.

Sampath, W.D.M. (2019). Lead Mind Award was received from the Ministry of Industry and Commerce under the "Rubber Cluster Young Network".

GENETICS AND PLANT BREEDING

The annual hand pollination programme was not carried out this year. Hand pollination progeny of 2013 was analyzed to select best genotypes for further evaluation process. It was observed that around eight genotypes recording yield over 44 g/t/t including two out-standing genotypes which recorded over 95 g/t/t yield. Studies are continued with 2012 hand pollinated progeny to predict the genetic potential of yield with different bark anatomical traits of laticiferous using hierarchical agglomerative method. 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 have already been established at Monaragala Substation with control clones. RRIC 100, RRIC 103, RRIC 52, PB 86 and RRISL 201 were prepared for next hybridization programme with the focus on raising true (pseudo) hybrids.

The existing small scale .estate collaborative and smallholder trials established in traditional and non-traditional areas were maintained satisfactorily.

Analysis of differential expression of some key antioxidant genes between TPD affected and healthy rubber trees using semi quantitative real time PCR showed that the HbMn SOD and HbCAT genes were down regulated in TPD affected rubber trees. Quantitative real time PCR analysis showed that MAP Kinase gene was up regulated in the clone RRISL 2005 under water stress conditions and has better drought tolerance. Moderate and low level of tolerance in clones RRISL 2006 and RRISL 2100 were reported respectively. Similarly based on CAT gene up regulation, the clones RRIC 121 and RRISL 203 showed the possibility of tolerance for soil moisture stress.

Multiplication process of foreign clones is continued to conduct their adaptability trials. Preliminary evaluation process on non-Wickham germplasm is continued and selections were made for further evaluation. Routing maintenance and renewal of bud wood nurseries and breeding garden were carried out at both Neuchatle estate and Nivitigalakele Breeding premises.

PLANT SCIENCE

Priming (pretreatment) with water (hydropriming) and chemicals (urea and $ZnSO_4$) accelerated germination and increased percentage germination in rubber seeds. About 2500 plants were bud grafted with different clones to initiate new experimental trials in both dry and wet zones. Root bole plants were prepared with an improved potting mixture and planted in Galgamuwa (dry zone). Physio-chemical and growth data were recorded in plants for experiments related to alternative sowing media for river sand, alternative polybag sizes for the standard polybag size and plants treated with various chemicals and botanicals for improved germination, growth and abiotic stress tolerance. Girth data were recorded for experimental trials on planting densities and stumped buddings.

In total, 115 nursery visits were made and about 1,155,100 plants were certified. Daily latex and tea yields were recorded in Tea X Rubber intercropping trials. Growth and physiological data were recorded for Rubber X Agarwood experiment in Dartonfield, Rubber X Fruit crops trials in Moneragala and Ampara. Infilling of rubber plants were done for intercropping trials commenced in Kilinochchi, Ampara and Moneragala. In total, 48 advisory visits and 420 experimental visits were made together with 47 training programmes.

Application of antioxidants, chemicals and stimulations were done on trees at experimental trials in both intermediate and wet zone. Yield and weather data were recorded for night tapping experiments at Galewatta and Moneragala. Yield data were recorded for the experimental trials conducted on testing various chemicals and botanicals for alleviating TPD condition in rubber trees, for the clone RRISL 203 in response to D2 or D3 tapping frequencies and for winter rest experiments. Flow rates and plugging indices and bark thickness were recorded for bark management experiment. Brown bast count of rubber trees and DRC measurements were taken.

PLANT PATHOLOGY AND MICROBIOLOGY

Clonal screening programme towards the incidence of secondary leaf fall diseases, Powdery mildew and Colletotrichum leaf disease showed moderate conditions except for a few disease vulnerable sites. According to the Corynespora screening programme, there were no disease reports in new clones. However, the disease severity has increased in the clones already in use. The incidence of Phytophora disease was severe during the year. By July 2019, a new leaf fall disease was reported in Sri Lanka. The involvement of several plant pathogens was reported and Co0lletotrichum and Pestalotiopsis played the major role. The disease reached epidemic proportions devastating nearly 5000ha in the main rubber growing districts, Kalutara & Ratnapura. Further spread of the disease was controlled using two effective fungicides carbendazim and hexaconazole. The antagonistic plants effective against Rigidoporus under in vitro conditions were tested in the field. Studies on the biology of the pathogen population Phellinus noxious were undertaken due to the high incidence from non-traditional rubber growing areas. Antagonistic fungi were identified from rubber growing areas to control the white root disease biologically. Talc was identified as a less bulky medium for the formulation of a biopesticide and the effectiveness has been proven under laboratory conditions. Ten training programmes were conducted to educate the growers on the effective management of white root disease. Twelve demonstration plots were established on the management of white root disease.

SOILS AND PLANT NUTRITION

Seven research activities on improvement of soil fertility, increasing fertilizer use efficiency, soil, water and nutrient conservation, weed control and a capital project on "Modification of fertilizer recommendations system of Hevea with reference to plant, soil and field parameters" were implemented. The project entitled "Enhancing soil fertility in degraded rubber lands by combine use of agro management practices such as inorganic fertilizer, biofertilizer, cover cropping and mulching with organics" which was funded by National Research Council (NRC) was initiated. Bacterial cultures collected from Boralu series did not produce any halos on Higher Grade Eppawala Rock Phosphate (HERP) and Eppawala Rock Phosphate (ERP). "Shaka Sara" new liquid organic manure was tested for their Sri Lanka Standard (SLS) parameters and evaluated at Ekerrella estate which showing significantly higher girth in 4th year immature Hevea plants. It was concluded that the application of polythene mulch effectively controls weeds in immature rubber plantations upto two years period that tested so far. Moreover, 100% weed control was observed under the shade net for more than 30 months. Application of two types of Encapsulated Coir Bricks (ECB) gave better plant girth of immature rubber compared to the conventional type of fertilizer application at different age intervals. Application of environmentally friendly alternatives for inorganic fertilizers and compost were re-tested. Three species of the earth warms; Eudrilus, Lumbricus, and Eisenia were introduced and Eudrilus was identified as the most effective one for the decomposition of kitchen garbage. In-vitro earthworm cultures were maintained for further decomposition of organic manure. Reusable Porous Tube (RPT) showed a significantly higher plant diameter and leaf nutrient contents compared to conventional fertilizer application. R/SA based mixtures; R/SA 7:9:9:3, modified new fertilizer mixture and potassium double recommended mixture have given improved plant growth in Moneragala and Ampara districts. Two soil maps relevant to rubber growing areas in Colombo and Kurunegala districts were prepared and twenty different soil associations were identified. Soil, plant, and field parameters were collected from different soil associations representing four estates in Colombo district and one estate in Kurunegala district. Site-specific fertilizer recommendation programme provided 33 fertilizer recommendation reports for 5508 ha of mature rubber. Four land suitability reports were issued for 505.2 ha under the land selection programme. Analytical service offered 115 analytical reports including 1664 parameters based on 405 fertilizer & soil samples from outside organizations.

BIOCHEMISTRY AND PHYSIOLOGY

Technology transfer programmes for effective introduction of low intensity harvesting systems were carried out throughout the year covering the districts belonging to Kalutara, Rathnapura and Kegalle Regional Offices of Rubber Development Department. Under special capital project received, about 1,082 ha of smallholder and estate sector rubber fields were applied with S/2 d4 low intensity harvesting system. Time course variations of yield data and latex physiology parameters of rubber trees stimulated with different ethephon types were assessed in order to identify the best yield stimulant type for rubber.

Physiological and growth data were collected from experimental fields established at Vauniya, Kandakadu, Padiyathalawa and Hambegamuwa with 10 Hevea clones in order to identify the best clones for the sub-optimal climatic conditions in non-traditional rubber growing areas.

Effect of different non-rubber components on quality of raw rubber was assessed with five Hevea genotypes in view of developing a system to screen the best clones producing quality raw rubber at the early stages of the breeding and selection programme. Latex biochemical and physiological assessment of new HP progenies at Yatadola estate was done during high yielding and wintering periods on request of Genetics and Plant Breeding Department, RRISL.

Formulation of in-country water based ethephon formulation was completed under the National Science Foundation research project RG/2017/AG/01 and commercial scale testing was in progress.

ADVISORY SERVICES

The extension strategy focused on farmer participatory development of selected rubber units in each REO divisions in traditional rubber growing areas was continued and 104 rubber lands were developed as model rubber holdings. Eighteen rubber processing centers were developed as models and construction of 28 new RSS processing centers and rehabilitation of 04 substandard centers were attended. Basic data and information were collected to developed selected villages as model rubber villages and action plans were prepared. Three technology transfer centers were established at Kegalle, Rathnapura and Kalutara areas for effective technology transfer to rubber growers. Road constructions in selected area for Techno Park at Monaragala Substation was completed. Preparation of technical banners and other field works were in progress.

Under the FAO funded project titled "Introduction and Establishment of new fuelwood growing models in selected lands of smallholder rubber farmers", Rs.3.6 M has been spent for 102 farmers to establish of different fuelwood growing models.

Farmer training programmes were conducted to educate 122 smallholders and 239 estate staff (Field Officers and estate workers) on general cultivation and processing aspects of rubber. Group extension programme called "Vihidum Sathkara" was effectively conducted providing advisory and extension services for 259 small land units in traditional rubber growing areas for necessary improvements. One hundred twenty five advisory visits were carried out to solve problems in technology adoption on requests made by smallholders.

RUBBER TECHNOLOGY AND DEVELOPMENT

Mechano-chemical reclaiming of natural rubber (NR) glove waste using different environmental friendly reclaiming agents was conducted and properties of rubber compounds containing reclaimed rubber were evaluated and compared. Also, virgin NR/mechanically reclaimed latex based cast product waste blend compounds were prepared at the request of a toy company.

A series of 70:30 NR : low density polyethylene (LDPE)/wPE (polyethylene waste) compounds was prepared with methyl salicylate and properties were evaluated. Also, two series of 60:30:10 NR/LDPE/wPE composites were prepared; one with paint waste and the other with calcium carbonate as filler using a plant based compatibilizing agent and properties were compared with those containing a titanate based conventional coupling agent.

Rigid polyurethane (PU) foam waste was recycled at the request of a shoe manufacturer and a series of virgin nitrile rubber (NBR) / recycled PU (rPU) foam waste composites was prepared by varying the amount of rPU foam waste in the blend. Physico-mechanical properties of the composites were evaluated.

Three series of NR composites were prepared using three different size ranges of coconut fibres by varying the carbon black:coconut fibre ratio with the aim of developing a rubber boot compound with special properties. Physico-mechanical properties of the three series of NR composites were evaluated. This work was conducted in collaboration with the Coconut Research Institute.

Dry NR based cellular sheets were prepared with different blowing agents and properties were evaluated. Also, NR latex foam was produced successfully using creamed latex for the benefit of SMEs. NR latex foam formulation was transferred to a private company for production of ear plugs. Advice and assistance was given to a toy company to produce NR latex foam based toy animals.

NR based compound for a bath mat, NR based formulation to produce protective caps for bicycles, virgin NR/reclaimed toy waste blend compound, NR latex based can sealant, non-toxic, transparent, light coloured NR based teething ring, NR/ethylene-propylene-diene rubber (EPDM) blend compound for an automobile application, NR based bridge bearing compound, NR latex based non-toxic adhesive, NR based compound for floating toys, NR or MG rubber (methyl methacrylate grafted rubber)/neoprene rubber (CR) based adhesive, NR based tyre patch compound and NR based adhesive for a water-proof fabric were developed at the request of the industry.

Tested 107 sole crepe samples, 211 rubber compounds and 389 rubber products at the request of the rubber industry. Twenty one SMEs and four groups of students were trained at RRISL, Ratmalana on "Manufacture of NR based Products". Conducted four workshops on "Rubber based Products Manufacture" in different districts of the country organized by the Thurusaviya Trust Fund and Vidatha Centres. The staff was actively involved in arranging the RRISL/rubber sector stall at four exhibitions.

POLYMER CHEMISTRY

Research work on development of property correlations for nitrosamine safe binary accelerator systems was continued throughout the year. Laboratory trials in relation to formulate nitrosamine safe vulcanizates using binary accelerator systems were successful when compared to the performance of single accelerator systems.

A novel method was developed to in-situ incorporation of filler in natural rubber latex as a value addition step for natural rubber and locally available dolomite. The filler incorporated natural rubber has shown good physical properties when compared to ex-situ filler incorporated natural rubber films. Further development of the method was continued throughout the year.

Mica waste; a type of silica filler was value added by the development of waste-mica filled NR composites. The properties of waste-mica/NR composites with different loadings were evaluated and compared with those of carbon black/ NR composites. As per the study results, waste-mica/NR composites could be used for applications that require high thermal insulating, high rebound resilience, low thermal degradation, moderately high hardness and tensile, and low swelling properties.

More than thousand samples of polymeric materials and compounding ingredients received from industry and academia were analyzed using advanced instrumentation including, Fourier transform infrared spectrophotometer (FTIR), Differential Scanning Calorimeter (DSC), Dynamic Mechanical Analyzer (DMA) and Thermo-gravimetric Analyzer (TGA).

RAW RUBBER AND CHEMICAL ANALYSIS

The department is mainly catering to rubber industries, plantation sector as well as SME sector by providing internationally accepted testing facilities. The department offered the 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 from other 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 3076 test for natural rubber latex, dry rubber and rubber processing chemicals were tested for their quality during the year. This included 2009 dry rubber tests,1015 latex tests and 29 rubber processing chemical test. In total 350 test 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 research projects during the year.

Use of surface energy to evaluate adhesion of bituminous based rain guard sealants to substrate was identified as a successful method to select quality rain guard sealant. Dynamic properties of RRISL 203 clone was studied and above clone was identified as a good clone for a product which need good elastic properties.

The department was renovated in order to quire laboratory accreditation to meet the international standard during the first and second quarter of the year.

RAW RUBBER PROCESS DEVELOPMENT AND CHEMICAL ENGINEERING

A combined process of dilution, fractionation, creaming and centrifugation was applied to manufacture concentrated latex with reduced protein levels. Fractionated creamed centrifuged latex was compared with single centrifuged and double centrifuged latex properties. In addition, the effect of the DRC level of the fractionation process on the removal of protein was studied at various DRC levels at 15%, 18%, 21% and 24%. It was found that centrifuged latex manufactured using fractionated and creamed latex at 15% DRC level has the lowest non-rubber content and nitrogen level than the other treatments studied. Also, it has the lowest rate of VFA development. Film properties of vulcanized films made out this latex exhibited slightly lower film properties may be due to the removal of most of the non-rubbers during the concentration process. Overall, it could be suggested that the process of manufacturing centrifuged latex using creamed and fractionated latex at 15% DRC level is more effective in manufacturing low protein centrifuged latex than the currently available method of double centrifugation.

A novel curing method was studied using a single dispersion of curing ingredients including sulfur, accelerators and activator with suitable ratios in order to reduce the cost, energy, and time consumption associated with the compounding and vulcanization process. Thin latex films properties of vulcanized films prepared using this new method and the conventional compounding method where the curing ingredients are added as separate dispersions were compared. According to the results, the curing system with 50% TSC stored at room temperature with 18-30 hour compound maturation period has better film properties than the conventional system. In conclusion, this novel method might be a suitable substitute for conventional method used in latex compounding while improving film properties and curing rate.

The mechanical and rheological properties of unvulcanized and vulcanized blends of skim rubber and Poly Propylene with fillers and without fillers were prepared and tested. All blends exhibited the behaviour of typical thermoplastic elastomers. The tensile strength, ageing properties and material flow index (MFI) values were increased as increasing plastic content. According to physio-mechanical properties the optimum sulfur loading and filler loading were determined.

The first android mobile application was designed and developed to the Sri Lankan rubber industry to enhance overall performance of the rubber industry by providing effective knowledge dissemination & promoting technologies while letting access to updated information & effective communication. It contains all the calculations required for raw rubber processing, RSS defects identifier, SS dryer designing, communication network with audio caller option, Facebook and YouTube, and RRISL recommendations & other information such as advisory circulars.

An experiment was conducted to evaluate the potential of MultiWall Carbon Nanotubes (MWCNT) as reinforcement filler in developing lightweight natural rubber (NR) based closed-cell structures for improved strength. Carbon nanotubes filled cellular NR composites of dry CNT loadings of 1, 2, 3 and 4 phr were investigated and compared with that of CB/NR composites. It was found that use of MWCNT could produce CNRCs having comparable properties to the CB reinforced CNRCs, with an approximate weight reduction of 75% in terms of the filler loading.

The staff of the department continued to process routine technical assistance, analytical services and training to large scale raw rubber producers, small and medium scale sheet rubber producing and various government institutions and non-government organization.

ADAPTIVE RESEARCH

Latex harvesting in the Dry Zone of the country was inaugurated in the firstly planted smallholder rubber field in the Vavuniya District of the Northern Province with the participation of government officials of the Ministry of Plantation Industries, Rubber Development Department, Thurusaviya Fund, local authorities and villagers of the area. Simultaneously, a processing center was established to facilitate the manufacturing of ribbed smoked sheets at the same location. A study conducted to quantify the impact of rubber cultivation on the rural livelihood of the Eastern province revealed that rubber farmers have shown significant improvements in their human, financial, physical and social capital assets than those of non-rubber farmers. Feasibility of cultivating rubber in Galenbindunuwewa and Kahatagasdigiliya Divisional Secretaries divisions of Anuradhapura district of North-Central Province was assessed through SWOT analyses and four farmer participatory adaptive research plots were established in the area subsequently. Latex harvesting was commenced in the firstly established rubber field in the Moneragala sub-station of the institute. A survey conducted among smallholders in Kegalle, Kurunegala and Kandy districts have shown over 75% adoption rate to agronomic practices; fertilizer application, weed management and planting at the correct time in cultivating rubber. A survey was started to assess the willingness to accept beekeeping by rubber smallholders. GPS locations of new rubber smallholdings in Moneragala and Ampara districts were identified in collaboration with the Smallholder Tea and Rubber Revitalization (STaRR) Project with the objective of estimating potential carbon units to be fixed.

BIOMETRY

The Biometry section has been involved in research, focusing 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. The research studies carried on climatology were mainly focused on drought analysis and rainfall anomalies through different indices and studies were conducted on forecasting these indices employing different methods to compare them for accuracy. 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. The database on rainfall in rubber growing areas was updated for the reporting year. The officers of the Biometry section have been involved with multi-disciplinary studies with different departments of RRISL, Universities and other crop research institutions.

AGRICULTURAL ECONOMICS

Agricultural Economics Unit (AEU) revised the methodology applied in farm typology of rubber intercropping in non-traditional areas in Sri Lanka. Mixed data analysis was implemented to the identification of rubber-based farm typology classification. A research was completed to find out Technical efficiency (TE) of smallholder rubber farmers in Kegalle District of Sri Lanka. Also, it was further extended to analyze the relationship between TE and poverty with the intention of developing a production function for the latex harvesting and analyze the TE of each farm household. In the second stage, the Impact of TE on poverty was elaborated.

In collaboration with the Advisory Services Department of RRISL. The overall impact of the project titled "Introduction and Establishment of New Fuelwood Growing Models in Selected Lands of Smallholder Rubber Farmers" was analyzed. Also, a few spatial maps were developed for the rubber lands using GIS. AEU analysed the market behaviour of Sri Lankan rubber products to identify the competitiveness of those at the international market to provide guidelines for selecting highly profitable rubber products. Also, AEU has involved in the analyses of rubber prices and international trade statistics throughout the year.

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 processing and publishing of its regular publications. The Library and Publication Section supported by providing scientific primary as well as secondary sources, by maintaining permanent collections and providing access to all necessary materials. Our library services are, Lending, Reference, Inter-library Loan, Photocopying, Indexing Service, Content Pages Service, Current Awareness Service, Selective Dissemination of Information (SDI) Service. The prime objective of the library to provide promptly, appropriate documents to its clientele so as to gain knowledge to do research and study works efficiently.

Twenty one text books were added to the reference section of the library bringing the total collection up to 6182.

While two journals were purchased, 20 titles were received on exchange basis.

DARTONFIELD GROUP

A total crop of 150,416kg has been harvested during the year achieving 76% of the estimated crop. When comparing with the previous year, crop records a decrease of 16%. The crop harvested on wet days due to the rain guards was 26,292kg which amounts to 17% of total harvested crop.

Average Yield per Hectare (YPH) for the year was 845 kg showing a decrease of 158kg from the previous year.

The average intake per tapper recorded during the year was 7.2kg from a tapping task of 230 trees. Highest intake per tapper of 10.8kg was recorded from the 2010 field in 3rd year tapping with a tapping task of 223 trees of clone RRISL 203/2001 tapped on S/2 d4 tapping system with ethral.

The total number of normal, late, rain guard & no tapping days recorded during the year were 201,19, 65 & 80 days, respectively.

Total rainfall recorded for the year was 4,389.7mm with 204 wet days showing 616.4mm more rainfall and 09 wet days more than the values recorded in the previous year.

The Cost of Production (COP) and Net Sale Average (NSA) recorded for the year was Rs.330.91 and Rs.276.22, respectively, giving a loss of Rs.54.69 per kg and a total loss of Rs.8.2 million. Loss per hectare recorded for the year was Rs.46,209.70. Quality level of grade 1 manufactured 91% of ripped smoke sheets (RSS).

KURUWITA SUB - STATION

The mature extent of the Kuruwita Sub Station was 79.36 hectares during the year.

A total crop of 72308 kg was harvested during the year recording an decrease of 8840 kg on previous year's crop.

The actual yield per hectare (YPH) was 911.1 kg. The average intake tapper (IPT) of the estate was 7.4 kg and this is a decrease of 1.2 kg when compared with the previous year.

The total number of Normal, Rainguarded and No tapping days recorded during the year were 261, 62 and 31 respectively.

The annual rain fall recorded during the year was 3,976.8 mm with 226 wet days as against 4,560.8 with 244 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.337.71 and Rs.263.54 per kg respectively. The loss made for the year was Rs.5.3 million and the loss per hectare recorded for the year was Rs.67,579.19.

POLGAHAWELA SUB - STATION

A total crop of 15,678 kg, has been harvested providing 86% of the estimated crop of the year. This was 6% more from the value recorded in previous year.

Average yield per hectare (YPH) for the year was 883 kg. 6.0 heactare new clearing was added to the extent at the middle of the year. This resulted in a decrease of 183 kg (17%) over the last year.

The average intake per tapper during the year was 9.4 kg. The highest intake per tapper of 11.2 kg was recorded from the year 2008 clearing with a tapping task of 269 trees of clone RRIC 121 tapped on S/2d2, S/2d3 & S/2d4 systems.

The total Number of tapping days & No tapping days were 312, 53 respectively.

Total rainfall recorded for the year was 2,170.0 mm with 139 wet days. Out of the total manufactured RSS, the share of No. 01 Grade was 73%.

METEOROLOGICAL REPORT

The total annual rainfall at Dartonfield during this year was 4,346 mm, 258 mm above the long-term average and an increase of 9% compared to the previous year. The monthly rainfall distribution at Dartonfield during this year departed from the usual bimodal rainfall pattern. Above average monthly rainfall values were observed in August, September and November while below average values were recorded in March, April, May and July. The rest of the months, viz. January, February, June, October and December were very close to the long-term average. The minimum monthly rainfall of 118 mm was recorded in January and March whilst the maximum monthly rainfall of 772 mm was recorded in September.

The South West monsoon season (May - September) carried most of the rains (2,342 mm) during 2019. This rainfall amount contributed 54% to the total rainfall, which is, comparatively higher than the long-term average contribution (48%). Rainfall during IM2 (October & November) in 2019 brought 1,023 mm whilst IM1 (March & April) recorded a low rainfall of 407 mm. During the North East season (December 2019 to February 2020), 528 mm of rain was recorded, which is comparatively lower (12%) than the long-term average contribution (14%) of this season.

There were 5 rainfall events that exceeded the hazardous limits for landslides (100 mm of rainfall during a day) reported during the year under review. The observed total number of rainy days of the year was 223, which is close to the long-term average. A dry spell lasted over a month or more can have adverse impacts on rubber plantations. There were only 6 dry spells greater than or equal to 7 days; the longest being 16 days, from 24th March to 8th April.

The daily average temperature pattern was fairly steady with a mean annual temperature of 27.6^{0}C, which could be a favourable condition for rubber plantations. The lowest mean minimum temperature of 21.6^{0}C was observed in January while the highest mean maximum temperature of 33.6^{0}C was observed in March and April.

A total of 1,727 bright sunshine hours was received at an average rate of 4.7 hours/day. Bright sunshine hours exceeded 6 in 43% of the days, while in 26% of the days it was below 4 hours. The mean RH values recorded at 08:30 and 15:30 were 85% and 73%, respectively.

There are three substations maintained by RRISL in Kuruwita (WL_{1a}), Narampola (IL_{1a} bordering WL_{2b}), Moneragala (IL_{1c}) and Nivithigalakele (WL_{1a}). The annual rainfall totals of 3628 mm, 2195 mm, 2210 mm and 4115 mm were recorded, respectively, in Kuruwita, Narampola, Moneragala and Nivithigalakele stations.