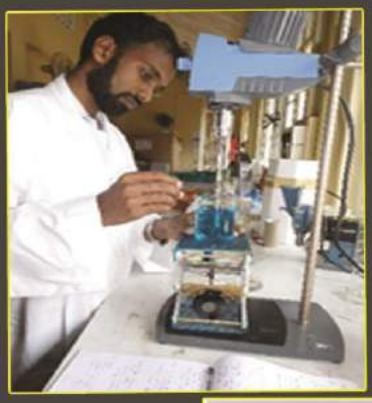
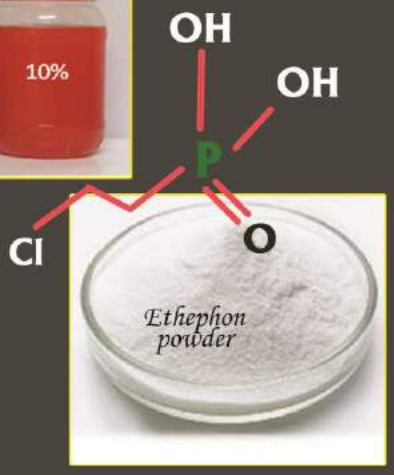
RUBBER RESEARCH INSTITUTE OF SRI LANKA





Annual Review 2020

Cover Story

Locally developed ethephon formulation to cater the needs of rubber plantation industry in Sri Lanka

Stimulation based low intensity harvesting (LIH) systems have been accepted as a modern tool to overcome the issues such as high cost of production, dearth of skilled harvesters and lower economic lifespan of trees in rubber plantations.

In LIH, ethephon (2-chloroethylphosphonic acid) is used as a latex stimulant. Ethephon generates ethylene which is a kind of plant hormone that affects the biochemical and physiological status of the tree resulting in high yields. However, for long term sustainability ethephon is to be applied on rubber trees in judicious manner only to compensate the yield loss due to lowering the tapping intensity. Although commercial grades of high purity ethephon is available in the market, it cannot be directly applied to the tree and should be formulated to make it user friendly in applying on trees with desired characteristics.

At present, total requirement of ethephon in Sri Lankan rubber industry is met by direct imports of formulated ethephon produced elsewhere. Due to high cost in importation, erratic supply to the market and the need of stimulant with different concentrations of ethephon to suit with LIH systems recommended in Sri Lanka, a necessity arouse to formulate ethephon based yield stimulant locally. Research carried out by the Department of Biochemistry and Physiology of RRISL has been able to develop cost effective water based and oil based ethephon formulations for Sri Lankan rubber growers at low costs.

Funds were received from National Science Foundation of Sri Lanka to execute this research and development work under the grant No. RG/2017/AG/01.

Rubber Research Institute of Sri Lanka

Annual Review - 2020

1st January 2020 to 31st December 2020

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

Prof (Mrs) Sudheera M W Ranwala, Chairperson, Rubber Research Board
Mr K V D C Wimalasiri, Director (Development), Ministry of Plantations
Ms Darshani De Silva, Director, National Planning Department, Ministry of Finance
Dr L M K Tillekeratne, Representative of Colombo Rubber Traders Association
Mr Anusha Perera, Plantation Consultant, Balangoda Plantations PLC
Mr Justin Senevirathne, Director, Lalan Rubbers (Pvt) Ltd
Mr Udara Premathilake, Director Plantations (Rubber), Kelani Valley Plantations PLC
Dr Kanchana Silva, Director, Thurusaviya Fund
Prof Gamini Senanayake, Chairman, Sri Lanka Council for Agricultural Research Policy

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Mr S S Poholiyadda, Chairman, Planters' Association of Ceylon (up to 21.08.2020)
Mr Bhathiya Bulumulla, Chairman, Planters' Association of Ceylon (w.e.f. 16.10.2020)

In attendance

Dr V H L Rodrigo, Additional Director, Rubber Research Institute
Mr Susantha Dissanayake, Senior Administrative Officer, RRI

STANDING COMMITTEES

Estates Committee

Prof (Mrs) Sudheera Ranwala, Chairperson, RRB (Chairman of the Committee) (from 2020.01.30)
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Dr (Mrs) P Seneviratne, Deputy Director - Research (Biology), Rubber Research Institute
Dr Susantha Siriwardena, Deputy Director - Research (Technology), Rubber Research Institute
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Mr Jagath Hettiarachchi, Senior Manager, Paiyagala Estate, (Nominated member)
Mr P A Lukshaman, Senior Manager Estates, Rubber Research Institute
Mr B S S Hewage, Senior Accountant, Rubber Research Institute

Audit and Management Committee

Ms Darshani De Silva, Director, National Planning Department, Ministry of Finance (Chairman of the Committee)
Mr K V D C Wimalasiri, Director (Development), Ministry of Plantations
Mr J M Mangalatissa, Director General, Rubber Development Department
Ms Nilani Jayasiri, Audit Superintendent, Auditor General's Department

In attendance

Dr V H L Rodrigo, Additional Director, Rubber Research Institute
Mr B S S Hewage, Senior Accountant, Rubber Research Institute
Ms M S I Senadheera, Internal Auditor, Rubber Research Board
Mr Susantha Dissanayake, Senior Administrative Officer

Scientific Committee

Members of RRISL

Prof Sudheera Ranwala, Chairperson, Rubber Research Board
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
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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 (up to 20.08.2020)
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
Mrs N P Surani Karunaratne, Research Officer, Biochemistry & Physiology Dept., RRI
Miss P G N Ishani, Research Officer, Agricultural Economics Unit, RRI
Mr Yashoda Somaratne, Research Officer, Polymer Chemistry Dept., RRI
Mr Y C Yohan Sudusinghe, Research Officer, Raw Rubber Process Development & Chemical Engineering Dept., RRI (up to 01.10.2020)
Mr P A Lukshaman, Senior Manager (Estate), RRI

Members representing the Industry and other Institutions

Mr K V D C Wimalasiri, Director (Development), Ministry of Plantation Industries,
Mrs W K Chathurangi, Assistant Director (Development), Ministry of Plantation Industries
Mr Deumith Rohana, Director (Development), Rubber Development Department, No.465, Ganahena, Bathtaramulla
Dr K de Silva, Director, Thurusaviya Fund, No 74, Kaduwela Road, Battaramulla
Dr P Dharmasena, Director, National Institute of Plantation Management, M D H Jayawardane Mawatha, Athurugiriya
Mr Manoj Udugampola CEO, Agalawatte Plantations PLC, FLC Tower, No 19, Dudley Senanayake Mw, Colombo 8
Mr A C Bertus, General Manager, Agalawatte Plantations PLC, FLC Tower, No 19, Dudley Senanayake Mw, Colombo 8
Mr S Dissanayake, DGM, Agalawatte Plantations PLC, Pambegama Estate, Parakaduwa
Mr L H S Chaminda, Superintendent, Agalawatte Plantations PLC, Peenkanda Estate, Nivithigala
Mr K M A S Wijeratne, Superintendent, Agalawatte Plantations PLC, Tiriwanaketiya Estate, Mahagama
Mr K Fernando, Superintendent, Agalawatte Plantations PLC, Culloden Estate, Neboda
Mr D Wekunagoda, Superintendent, Agalawatte Plantations PLC, Doloswala 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
Mr B L L Prematilake, Superintendent, Balangoda Plantations PLC, Mahawala Estate, Rathnapura

Mr R A Alahakoon, Superintendent, Balangoda Plantations PLC, Galatura Estate, Kiriella

Mr B Bulumulla, CEO, Elpitiya Plantations PLC, Level 09, Aitken Spence Tower 1, Vauxhall Street, Colombo 2

Mr A G Geeth Kumara, General Manager, Elpitiya Plantations PLC, Elpitiya Estate, Talgaswala

Mr Eranda, Asst. Manager, Elpitiya Plantations PLC, Talgaswala Estate, Talgaswala

Mr Chanaka Wimalasena, Asst. Manager, Elpitiya Plantations PLC, Bentota Estate, Elpitiya

Mr R B S Douglas, Senior Manager, Elpitiya Plantations PLC, Elpitiya Estate, Elpitiya

Mr N M S B Nawaratne, Manager, Elpitiya Plantations PLC, Gulugahakande Estate, Wanduramba

Mr U A Karunanayake, Manager, Elpitiya Plantations PLC, Devithurai Estate, Ethkandura

Mr Dasun Werasinghe, Senior Asst., Manager, Elpitiya Plantations PLC, Deviturai Estate, Ethkandura

Mr L M Amarathunga, Superintendent, Pusselawa Plantations PLC, Salawa Estate,

Mr S A Eriyagama, CEO, Kegalle Plantations PLC, 310 High Level Rd, Navinna, Maharagama

Mr S A A P Jayathilake, Superintendent, Kegalle Plantations PLC, Pallegama Estate, Niyadurupola

Mr S D Munasinghe, Superintendent, Kegalle Plantations PLC, Eadella Estate, Polgahawela

Mr B M J A Moonamalle, Superintendent, Kegalle Plantations PLC, Atale Estate, Atale

Mr H Madiwaka, Superintendent, Hapugastenna Plantations PLC, Bibile Estate Bibile

Mr Sanjeewa, Deputy Manager, Horana Plantations PLC, Hilstream Estate, Bulathsinhala

Mr M Kariyapperuma, Director, Horana Plantations PLC, No 400, Deans Road, Colombo 10

Mr Gamini N Ratnayake, DGM, Horana Plantations PLC, Neuchatel Estate, Neboda

Mr N Wijenayake, Manager, Horana Plantations PLC, Halwatura Estate, Ingiriya

Mr Sajith Gunbawardane, Manager, Horana Plantations PLC, Frocester Estate, Govinna

Mr N B Seneviratne, Director Low Country, Kotagala Plantations PLC, Regional Office, Colombo 01

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

Mr Priyanthe Ratnayake, Manager, Kotagala Plantations PLC, Gikiyanakande Estate, Neboda
Mr G L T Swarajith, Manager, Kotagala Plantations PLC, Eduragala Estate, Ingiriya
Mr A M A I Abesinghe, Manager, Arappalakande Estate, Thebuwana
Mr U Amarasekara, Deputy Manager, Kotagala Plantations, Vogan Estate, Matugama
Mr N Wijeratne, Manager, Kotagala Plantations PLC, Hedigalle Estate, Baduraliya
Mr C Amaratunga, RGM, Kahawatte Plantations PLC, Regional Office, Pelmadulla Estate, Kahawatta
Mr S Hewagama, DM, Kahawatte Plantations PLC, Hunuwala Estate, Opanayake
Mr Wajira Hewage, Manager, Kahawatte Plantations PLC, Opatha Estate, Kahawatte
Mr L Perera, Manger, Kahawatte Plantations PLC, Pelmadulla Estate, Kahawatte
Mr Mahesh Bandara, Asst. Manager, Kahawatte Plantations PLC, Poranuwa Estate, Kahawatte
Mr M R Jayawansha, Asst. Manager, Kahawatte, Plantations PLC, Houpe 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 D Samarasinghe, Senior Manager, Kelani Valley Plantations PLC, Edarapola Estate, Bulathkohupitiya
Mr R L Obeysekare, Kelani Valley 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 M Wijedasa, Asst. Manager, Kelani Valley Plantation PLC,
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 R Ranasinghe, Superintendent, Namunukula Plantations PLC, Eladuwa Estate, Matugama
Mr Kushan Karunathilake, Superintendent, Namunukula Plantations PLC, Citrus Estate, Poddala
Mr G S U De Silva, Superintendent, Namunukula Plantations PLC, Miriswatte Estate, Welipenna
Mr P P A Peris, General Manager, Lalan Rubbers (Pvt.) Ltd, 54, Kirulapana Avenue, Colombo 6
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 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 Kingsly, Deputy Manager, Watawala Plantations PLC, Nakiyadeniya Estate, Nakiyadeniya
Mr Asanga Ekanayake, Senior Asst. Manager, Watawala Plantations PLC, Homadola Estate, Udugama
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 Gaya Nakandala, Consultant, Hokandara North
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

Prof (Mrs) Sudheera Ranwala, Chairperson, Rubber Research Board
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	- Prof (Mrs) Sudheera M W Ranwala
Acting Secretary	- Mrs Padma Balasooriya, Personal Assistant to the Chairman (up to 13.03.2020)
	- Mrs J A H Sandhya, Stenographer (Cover up duties of the Secretary) (w.e.f. 13.03.2020)

Management Assistants - Mrs H N Kanchana (up to 19.06.2020)
- S M D S R D A Wijerathne (w.e.f. 23.06.2020)

Lawyers
Attorney General
Attorney General's Department
(Government Institutions)
P O Box 502
Colombo 12

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
No.306/72,
Agalawatta

Contact details:

Head Office and Laboratories
Dartonfield, Agalawatta

Telephones:	
Director	034 - 2248457
Additional Director	034 - 2248458
Deputy Director Research (Biology)	034 - 2295610
Senior Accountant	034 - 2295586
General	034 - 2247426
	034 - 2247383
	034 - 2295540
	034 - 2248459
Fax:	034 - 2247427
e-mail	*dirrri@sltnet.lk*
Website	www.rrisl.lk

Board Office and Rubber Chemistry & Technology Laboratories
Telewela Road, Ratmalana

Telephones:	
Chairman	011 - 2635019
Fax	011 - 2633353
Admin Dept. Telephone/Fax	011 - 2635142
Director	011 - 2633351
Fax	011 - 2633351
Deputy Director Research (Technology)	011 - 2633352

General	011 - 2635851 011 - 2635852
Fax:	011 - 2605171
e-mail	*dirrub@sltnet.lk,* *rubberreseach@gmail.com*

Sub stations

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

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

Polgahawela - Substation, Polgahawela
Telephone: 037 - 2244120

Monaragala - Substation, Monaragala
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	Miss P V A Anushka, BSc Agric. (SL) (up to Aug.)
	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)
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)
Experimental Officers	Mrs R K Samarasekera
	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 U Dissanayake, HND, 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)
	H D H C Arunasiri, HND (Kundasale)
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), M AETM (SL)
Technical Officers	Miss A H M N R Abeyrathna, BSc (SL)
(Research & Development)	D A N Mallikaarachchi, BSc (SL)
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), MPhil (SL)
	L A T S Liyanaarachchi, BSc Agric. (SL)
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)	C G 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 Agric. (SL)
	B M K Rangana, BSc (SL)
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)
Management Assistant (Clerical)	Mrs H A Manoji Erandika
Advisory Services	*(at Telewela Road, Ratmalana)*
Head of Department	D M A P Dissanayake, BSc Agric. (SL) PhD (Aberdeen) (upto December)
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 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 Agric. (SL) Mrs K K I Jayasundera, BSc Agric. (SL) D S Dissanayake, BSc Agric. (SL) K D K L Siriwardena, BSc Agric. (SL) Mrs G R Tennakoon, BSc Agric. (SL) Miss R R N D Thara, BSc Agric. (SL) (up to February) P V S Madubashana, BSc Agric. (SL) M N P de Silva, BSc Agric (SL) E W S Ruwan Kumara, BSc (SL) S M A Samarakoon, Dip. Agric. (Kundasale)
Management Assistants (Clerical)	Mrs J N R Jayasinghe Mrs S M Kaluarachchi (up to June) R G A S Dharmaratne T R C Silva (up to August) P Sachini Ishara

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)
Experimental Officer	Mrs G M Priyanthi Perera, BSc (SL), MSc (SL)
Technical Officers	V G M J Abeywardena, NDT
(Research & Development)	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)
	Mrs E N N Nanayakkara, BSc (SL)
	A H R W M N Gunawardena, BSc (SL)
Management Assistant (Clerical)	Miss S M D S R de A Wijeratne (upto June)

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)
Technical Officers (Research &	Mrs H M H Dhanukamalee, BSc (SL)
Development)	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
Technical Officers	Miss S P Wijewardena, BSc (SL) (upto June)
(Research & Development)	Miss N C Y Kithmini, BSc (SL)
	Miss M U D S Weerasinghe, BSc (SL)
	H D M S Wijewardena, BSc (SL)
	K A S T Koswatta, BSc (SL)
	Mrs. N S Siriwardena, BSc (SL), MSc (SL)
	Miss G M Udayakumari, BSc (SL)
Management Assistant (Clerical)	Miss W D D Samanmali

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

Research Officer	Y C Y Sudusinghe, BSc (SL) (up to October)

Experimental Officers	Mrs U M S Priyanka, BSc (SL), MSc (SL)
	Mrs V C Rohanadeepa
	A K D W Prasad
Technical Officers	R D Illeperuma, BSc (SL)
(Research & Development)	Miss P K N N Sandamali, BSc (SL)
	WA S Bandara, BSc (SL)
Management Assistants (Clerical)	Mrs H A Janani Lakshika, BA (SL)
	Mrs P D S Dilhani

Sections/Units

Biometry Section	*(at Dartonfield, Agalawatta)*
Principal Research Officer	Mrs B W Wijesuriya, BSc Agric (SL), MPhil (SL), PhD (SL)
Research Officer	A M R W S D Ratnayake, BSc (SL)
Experimental Officer	O V Abeyawardene, Dip. Agric. (Kundasale)
Technical Officer (Research & Development)	Mrs M I N Silva, BSc (SL) (up to October)
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	P M M Jayatilleke, NDT (Agric.)
(Research & Development)	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), MSSc (SL)
Library Assistant & Assistant Publication Officer	Mrs R M Amaratunga, Intermediate; Lib. Sci. Doc. & Info. (SLLA)
Experimental Officer	Miss D M C Wijesekara, Dip. Rubber Tech (PRI)
Library Assistant & Publication Assistant (Ratmalana)	Mrs D N C Amarathunga
Management Assistant (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
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
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 Tilakeratne

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 K D K P Ranaweera
	Mrs M S W H Kumari, BSc (SL)
	U Samantha Munindradasa, BA (SL) (up to Sept.)

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, (upto October)
	Mrs G P Kukulewithana
Management Assistants (Clerical)	Mrs C Dissanayake
	A K D A Wickremasinghe, (up to November)
	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), MBA (SL)
	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)
Field Officer (Nivitigalakele)	B M Siriwardena
Management Assistants (Clerical)	H D D Achinda
	M A N Sachith Pawinda
	T D Harsha

* Full pay study leave

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 the administrative and financial functions of the institute are given.

Rubber industry of Sri Lanka

Rubber production and consumption

The rubber industry in the country was severely affected by the lockdown situation of COVID during the months of March to June. Average monthly production of rubber came down to 6,141 tonnes with 1.3% month on the decrease. This decline was 12% compared to the values (3,400 tonnes) recorded for the corresponding period in 2019. The production of most of the rubber product industries got halted or interrupted during this period. However, with special permission given to the rubber estates and product manufacturers to work amidst the lockdown situation and some level of increase in demand for rubber products, the situation improved. With that, the natural rubber (NR) production of the country in the year 2020 was recorded as 78,204 tonnes showing about a 4.6% increase from the previous year value. Total NR consumption in the country has been maintained at 111,000 tonnes (just a 1.7% decline against the previous year) despite the slowdown in the world economy with a negative growth rate.

Rubber extent

The total extent of rubber lands in the country at the end of 2020 has been recorded as 138.3 thousand hectares with about 75-80% under tapping. Accordingly, there has been a slight increase in rubber extent from the previous year.

NR exports and imports

Sri Lanka has exported around 15,766 tonnes of natural raw rubber in the year 2020, particularly in form of crepe (44%) and Sheet (27%) rubber indicating a 21% increase from the values of 2019 based on total raw rubber export quantity. Moderate recovery of raw rubber prices at the international market and reduction in raw rubber local consumption would have attributed to this improvement.

Rubber manufacturing sector

Earnings through raw rubber exports were Rs.5.6 billion in the year 2020 against Rs.4.3 billion in the year 2019. Export earnings from finished products were recorded as Rs.145 billion in 2020, showing a reduction of about 5.8% against the previous year. Export earnings from semi-processed rubber have been reported as Rs.0.53 billion in the year 2020, while it was Rs.0.7 billion in the year 2019. Accordingly, total export earnings from the rubber industry remained at Rs.151 billion (US$ 816 million) showing a 5.6% reduction from the previous year.

Global rubber industry review

Natural rubber supply

Total world NR production decreased to 12,782 thousand tonnes in 2020 from 13,841 thousand tonnes recorded for the year 2019 (7.6% decrease) according to ANRPC statistics. This was mainly due to the Covid-19 impacts in the major markets in the Asia Pacific region during the mid of the year.

NR average yield

Yield per hectare has declined in ANRPC member countries including Sri Lanka except for Cambodia in 2020. The expansion in the mature area reflects the large scale planting undertaken during the period from the year 2005 to 2012. The average yield of Sri Lanka has been estimated as 642 kg/ha/year in the year 2020 while it was 658 kg/ha/year in the year 2019.

Global NR demand

Total NR demand was estimated as 12,827 thousand tonnes in 2020 showing a 6.3% decline from the previous year with a reduction of the supply-demand gap.

World NR price movement

Despite the declining trend prevailed in most of the key markets starting from the year 2011 to 2018, prices experienced a slight increase for the period of 2019 to 2020. Global rubber prices were slightly higher throughout the year 2020 except for the first quarter. In Sri Lanka, the annual average RSS 3 price in 2020 was US$ 1.86 per kg which was remained at the same value in the year 2019. The average price of RSS 3 was recorded as US$ 1.74 in Bangkok against the previous year average value of US$ 1.66. Average Indian RSS 4 has decreased to US$1.82 from US$ 1.89 per kg against the previous year. According to the predictions of ANPRC countries, global natural rubber prices are likely to improve due to the global economic recovery and higher demand from the major consumers in the world.

Research and development focus

Amidst the COVID pandemic, a new leaf disease named ‘Pestalotiopsis’ began spreading in the rubber lands in wet regions of the country; hence emphasis was given to develop the control measures and to apply them in the field with the

assistance of the Rubber Development Department, Thurusaviya and Regional Plantation Companies. Also, rubber growers were assisted with the control of White Root Disease. Unsatisfactory level of rubber price, high cost of production, lack of skilled workers for rubber cultivation, low productivity in rubber lands and the associated decline in rubber production in the country were the other focuses of the research and development (R&D) activities. In view of increasing the land productivity with regular tapping, the application of low frequency harvesting systems which reduce the cost of production whilst increasing the harvesters' income and tree lifespan, was promoted along with other good agricultural practices. Ethephon formulations were developed locally for this purpose. 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, the focus on clone development was multifaceted in the directions of high yielding, disease tolerance, timber production and drought resistance. In view of increasing the land extent under rubber, attention was given to expand the rubber cultivation in nontraditional areas. Also, the institute focused on developing a carbon trading project for the voluntary carbon market with rubber cultivated in Ampara and Monaragala districts. In addition, developing new avenues for value addition and processing raw rubber in a healthy and environmentally friendly manner were of high priority. Research on developing new rubber compounds for product manufacturing industries, a new approach for manufacturing low protein centrifuged latex, natural-based additives in rubber product manufacture and use of safer chemicals in raw rubber manufacture continued. Technology transfer programmes were mainly conducted more strategically.

Whilst continuing with activities in the Finite Element Analyses and Simulation Centre managed as a private-public partnership, purchase of key instruments to establish a tyre testing facility at the institute was attended.

Obstacles for research

Despite adequate funds allocated to the institute, the issue of not having a sufficient number of qualified senior scientists continued. Unattractive remuneration packages in operation for such high calibre positions has resulted in leaving those to the greener pastures, particular to local Universities. A proposal to build up a University by combining all Plantation Crop Research Institutes is in negotiation. This requires immediate attention of policymakers as the country expects a faster rate of development in the rubber industry.

Administrative and financial functions

Although the progress of R&D activities was affected during the lockdown period, the general performance in physical and financial aspects was at a satisfactory level by end of the year. Training programmes provided to employees were limited to

15 within the country. No events were recorded on foreign travel but there were several local and international programmes were attended on the digital platform.

Appreciations

For effective conduct in R&D, the guidance and directions together with financial support and patronages given by the Rubber Research Board and the Ministry are appreciated. The 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 Agricultural 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 2020.

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

Mrs P V A Anushka, Research Officer resigned from duties with effect from 21st August.

Research students

Following students are supervised by Dr (Mrs) S P Withanage.

- L G S Lasara, a student from the Faculty of Agricultural Sciences, Sabaragamuwa University carried out her final year research project on "Precise selection of superior genotypes at the early stage of 2014 hybridized progeny of rubber (*Hevea brasiliensis*)".
- T P G M D Nanayakkara, a student from the Faculty of Agricultural Sciences, Sabaragamuwa University carried out his final year research project on "Screening of the year 2000 hp trail four for selection of multipurpose rubber clones (*Hevea brasiliensis*)".
- W V N S Bandara, student from the Faculty of Agricultural Sciences, Sabaragamuwa University carried out his final year research project on "Screening of the year 2000 HP trail (five) for selection of multipurpose rubber clones (*Hevea brasiliensis*)".
- H W Arunodi Madahasi, a student from the Faculty of Graduate Studies, University of Kelaniya carried out her MSc research project on "Precise selection of high yielding *Hevea brasiliensis* genotypes at the early stage of evaluation".
- B P D M Bandara, student from the Faculty of Agriculture and Plantation Management, Wayamba University carried out her final year research project on "In-silico characterization of ref gene from *Hevea brasiliensis* and identification of high and low rubber yielding trees for ref gene expression studies".
- M F F Mifdha, a student from the Faculty of Agriculture and Plantation Management, Wayamba University carried out her final year research project on "Characterization of selected *Hevea* genotypes from the 1995 Hand Pollination Progeny.*"*

Training students

Following students are supervised by Dr (Mrs) S P Withanage.

- C A Jayalath and M F F Fahma, students from the University of Sri Jayawardenapura completed their one - month In-plant training programme.
- S K M N D Prematihilake, a student from the University of Jaffna completed her one-month In-plant training programme.
- M A M Chathuranga and R V M Silva, students from School of Agriculture, Labuduwa completed their six months In-plant training programme.

Meetings/Seminars and Workshops attended

Officer/s	Subject/Theme	Date	Organization
KK Liyanage	Bid Evaluation Workshop	30th -31st January	Colombo
SP Withanage KK Liyanage TTD Dahanayake	Technology Update	12th February	RRISL, Dartonfield
SP Withanage KK Liyanage TTD Dahanayake	Scientific Committee Meeting	14th February	RRISL, Ratmalana
SP Withanage	Meeting on conducting training sessions - Component 02- Implementation of the National Biosafety Frame wok in accordance with Cartagena Protocol on Biosafety	31st August	Ministry of Mahaweli Development & Environment and NSF - Virtual
SP Withanage	Training program on Guidelines on contained use of genetically modified organisms and Institutional Biosafety	22nd-24th September	Ministry of Mahaweli Development & Environment and NSF - Virtual
SP Withanage	Technical training on the safety assessment of food derived from GM plants in Sri Lanka	6th-8th October	Ministry of Mahaweli Development & Environment and NSF - Virtual
SP Withanage	Technical Sessions on Testing of genetically modified mosquitoes	12th-14th October	Ministry of Mahaweli Development & Environment and NSF - Virtual
SP Withanage	Technical sessions on the Conduct of confined field trials of genetically modified Plants in Sri Lanka	20th-22nd October	Ministry of Mahaweli Development & Environment and NSF - Virtual

Officer/s	Subject/Theme	Date	Organization
SP Withanage	Technical sessions on the Environment Risk Assessment of genetically modified organisms	27th- 29th October	Ministry of Mahaweli Development & Environment and NSF - Virtual
SP Withanage	Technical sessions on the Environment Risk Assessment of genetically modified organisms	3rd November	Ministry of Mahaweli Development & Environment and NSF - Virtual
SP Withanage	Webinar on Emerging technologies –Trends opportunities, challenges, and issues	15th & 23rd December	NSF- Virtual

Hand pollination programme

The annual hand pollination programme was done at Neuchatle estate and fifty-five new genotypes were raised. Five promising clones were used as female parents whereas four clones were used as male parents to develop genetically diverse high yielding vigorous genotypes. Details of new genotypes and crosses made are given in Table 1.

Table 1. *Details of parentage and the number of genotypes obtained in the 2020 hand pollination programme*

Cross	No. of genotypes obtained
RRISL 203 x RRISL 2006	30
RRISL 205 x RRISL 2006	08
RRISL 2005 x RRISL 208	01
RRISL 203 x RRISL 2005	03
RRISL 201 x RRISL 2006	07
RRISL 2006 x RRISL 205	03
RRISL 2006 x RRISL 208	03
Total	**55**

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

Developing the *Hevea* Breeding Garden

RRIC 100, RRIC 130, RRISL Centennial 3 and PB 86 clones were introduced into the breeding garden at Neuchatel estate. The agronomic practices were continued and selected trees were trained by pruning and bending branches towards the ground for easy and safe access to flower inflorescences for future breeding programmes (S P Withanage, K K Liyanage, T M S K Gunasekara and B W A N Baddewithana).

Multilateral clone exchange programme

A Memorandum of understanding was signed in 2015 by the fifteen member countries of the International Rubber Research and Development Board (IRRDB) to exchange materials under the multilateral clone exchange programme. Objectives are to promote international cooperation and capacity building in the IRRDB member countries for the betterment of the natural rubber industry and to evaluate the performance of all the exchanged clones in different agro-climatic conditions in the member countries. The multiplication process continued and plants were prepared to establish two trials at Galewatta, Dartonfield estate. Two Indian clones RRII 430 and RRII 414 were bud grafted at Sapumalkanda nursery, Lalan Rubber (Pvt.) Ltd. The average first-year girth of foreign clones established at the Neuchattle estate was given in Table 2.

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

Country	Clone	Average girth (cm)
Thailand	RRIT 251	6.61
	RRIT 3904	8.02
	RRIT 3604	4.95
	RRIT 226	6.53
	RRIT 408	6.63
India	RRII 414	7.52
	RRII 417	7.13
	RRII 422	7.76
	RRII 429	6.69
	RRII 430	6.03
Myanmar	ARCPC 2/4	7.39
	ARCPC 6/22	7.75

(S P Withanage, K K Liyanage, 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 2014 hand pollinated progeny was subjected to repeated evaluation. The progeny was characterized with yield parameters such as girth, latex yield, and bark thickness. The girth was measured in individual genotype at the height of 45 cm from the ground level and tapping was done at the same height. Around 158 accessions at mother plant nursery belong to this progeny were subjected to preliminary studies with yield and growth parameters and selected twenty genotypes for further analysis with Physiological and biochemical parameters. Five genotypes as 2014 HP-11, 2014HP-21, 2014HP-42, 2014HP-65 and 2014HP-78 showed (Table 3) outstanding characters. Results clearly showed that the early selection procedure can be strengthened by

taking more yield parameters. Further, their correlation will be helpful to develop yield indexes in the future.

Table 3. *Girth (cm) average bark thickness (mm) yield (g/t/t) and DRC % of the best performing genotypes from five years old 2014 hand pollinated progeny (seedlings) established in mother plant nursery at Nivitigalakele in 2015*

Genotype number	Girth (cm)	Average bark thickness (mm)	Average yield (g/t/t)	DRC %
2014HP11	56.50	9.00	173	21.43
2014HP21	53.00	9.33	104.6	13.67
2014HP42	53.50	7.00	164.7	20.82
2014HP65	48.00	5.17	61.2	20.68
2014HP78	51.50	5.33	104.6	10.07

(S P Withanage, A K Gamage, B W A N Baddewithana and T M S K Gunasekara and Collaborate with Biochemistry and Physiology Department).

Evaluation of the 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 4.

Table 4. *Details of Small Scale Clone Trials*

HP year	Site	Planting season	Current status
2000	Dalkeith IV & V	June 2003	10th year of tapping
	Elston VIII & IX	July 2003	10th year of tapping
2002	Pallegoda I	July 2007	7th year of tapping
2002	Eladuwa II	May 2009	6th year of tapping
2004	Eladuwa Trial I	July 2009	6thyear of tapping
2007	Kuruwita Substation (seedlings)	July 2009	5th year of tapping
1995	Yatadola	July 2011	5thyear of tapping
2005	Monaragala	Nov 2014	Immature
	Galewatta	May 2016	Immature
2008	Eladuwa	Nov 2016	Immature
2010	Eladuwa	Nov 2016	Immature
2011	Eladuwa	Oct 2018	Immature

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

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 trial 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. Latex yield was analyzed using the secondary data collected from the year 2011 up to 2019, bark thickness at the height of 150 cm from the bud union in 2015, branching height, clear bole volume, annual girth from the secondary data of 2019. Clustering was done using the above five parameters according to their performances. Among these parameters, the relationship between average latex yield with girth and bark thickness and clear bole volume with height and girth were evaluated. Cluster analysis, Duncan's Multiple Range Test, analysis of variance, and Pearson correlation coefficient tests were done by using Statistical Analysis Software version 9.1. For trial IV, clones selected for the latex-timber purpose are included in these clusters. Among all the clusters, cluster four performed with the best average latex yield of 55.35 g/t/t, the girth of 107.56 cm, bark thickness of 8.95 mm, and clear bole volume of 0.68 m^3. Genotypes 2000HP- 568, 2000HP 585, 2000HP 638 and 2000HP 945 were the best latex-timber clones that belong to cluster four. Evident from results that there is a strong correlation between average latex yield with bark thickness and girth with Correlation coefficient 0.69 and 0.71 respectively. For Trial V, the best latex-timber clones were in cluster 04 and it obtained with genotypes 2000 HP 203, 2000 HP 207 and 2000 HP 208 The best timber-latex clones were ins cluster 03 and it included genotypes 2000 HP 333, 2000 HP 334 and 2000 HP 1158 genotypes. All selected genotypes were arranged to establish at bud wood nursery and data collection was terminated (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 the 13^{th} year was grouped using Duncan's multiple range test and the topmost promising HP entries at Kuruwita Substation are given in Table 5. Top-ranked HP entries in Kuruwita Substation had yielded from 46.30 g/t/t to 68.79 g/t/t.

Evaluation of 2002 HP clones

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

Twelfth -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 5. *Mean yield and girth of the best performing HP entries of the 2001 HP progeny planted in 2006 in Kuruwita Sub-station*

Kuruwita Sub-station		Kuruwita Sub-station	
Clone	**Yield (g/t/t)**	**Clone**	**Mean girth (cm)**
RRISL-203	68.79[a]	2001HP-220	74.88[a]
2001 HP-164	61.00[ab]	RRIC 121	71.10[ab]
2001 HP- 183	50.00[ab]	2001HP-185	69.21[abc]
2001 HP-220	47.33[ab]	2001HP-179	65.94[abcd]
RRIC 121	46.30[ab]	2001HP-205	65.05[abcd]

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

Clone	Mean girth (cm)
2002-18	75.3[a]
RRISL 203	74.42[ab]
2002-14	73.22[abc]
2002-96	73[abc]
2002-17	71.23[abcd]
2002-11	70.57[abcd]
2002-24	68.2[abcde]
2002-69	67.44[abcdef]
2002-86	66.77[bcdefg]
2002-71	66.67[bcdefg]

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

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

Thirteen genotypes from 2002 hand pollination progeny were planted with two control clones, RRIC 121 and RRISL 203. Randomized Complete Block Design was used with four replicates per genotype. The replicate size was six. The eleventh-year girth was taken at the height of 150 cm from the bud union and mean girth values are shown in Table 7. Although fourth-year yield data collection was started, only a few test tapings were possible.

Table 7. *Mean girth at eleventh-year of best performing HP entries and control clones selected from the 2002 HP progeny planted in 2009 at Eladuwa*

Clone	Mean girth (cm)	Clone	Mean girth (cm)
HP 138	83.88[a]	RRIC 121	67.05[bc]
HP 66	73.45[b]	HP 9	61.73[cd]
HP 93	71.13[b]	HP 19	60.19[cd]
HP 30	69.72[b]	HP 62	58.03[ed]
HP 139	67.65[bc]	RRISL 203	56.09[edf]

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

Evaluation of 2004 HP clones

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

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

The tenth-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 of 10th year of the best performing HP-entries selected from the 2004 HP- progeny planted at Eladuwa estate. Mean values with the same letter are not significantly different*

Clone	Mean girth (cm)
HP - 107	65.21^{a}
HP - 347	65.18^{a}
RRIC - 121	62.76^{ab}
HP - 456	62.5^{ab}
HP - 228	61.83^{abc}

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

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

Twelfth-year girth data were collected for the seedling progeny and family means are given in Table 9. Family RC 130 x GP 1-2 recorded the highest girth. Fourth-year tapping data were collected from the above progeny and family means are given in Table 10. Family RC 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)
RC 130 x GP1-2	70.00^{a}
RC 130 x GP21-163	69.70^{a}
RC 130 x GP22-137	69.28^{a}
PB 260 x IAN 45-710	64.12^{a}
IAN 45-710 x PB 260	63.37^{a}
RC 130 x GP10-154	62.75^{a}
45-717 x PB 260	56.50^{a}
PB260 x 45-717	55.00^{a}
RC 130 x GP44-24	53.83^{a}

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

Clone	Yield (g/t/t)
RC 130 x GP44-24	47.4[a]
RC 130 x GP22-137	43.6[a]
PB 260 x IAN 45-710	40.3[a]
IAN 45-710 x PB260	39.0[a]
RC 130 x GP21-163	37.0[a]
RC 130 x GP10-154	22.0[a]
RC 130 x GP1-2	21.9[a]
PB 260 x 45-717	19.4[a]

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

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

Thirty-five genotypes from 2005 hand pollination progeny which 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. The sixth-year girth was measured and progeny-wise comparison made against the control clones (Table 11). Trees are to be prepared for next year pollination programme with the objectives of developing pseudo hybrids and pure lines concerning clones RRIC 100 and 103.

Table 11. *Sixth-year average girth (cm)*

Progeny	Average girth (cm)
Progeny 1	24.11
Progeny 2	18.90
Progeny 3	20.17
PB 86	23.61
RRIC 100	24.19
RRIC 52	25.00
RRIC 103	29.25
RRISL 201	22.58

(S P Withanage, K K Liyanage, T T D Dahanayake and N S Jayasinghe)

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

Sixteen genotypes selected from 2010 HP progeny were planted in Eladuwa estate in Complete Randomized Block Design with control clones, RRIC 121 and RRISL 2001. All agronomical practices such as weeding, removing offshoots, *etc.* were done according to RRISL recommendations. The fourth-year girth was taken

and the mean girth values of the best performing six genotypes are given in Table 12 with the control clones.

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

Clone	Girth (cm)
HP - 38	27.92[a]
HP - 4	25.66[ab]
HP - 25	25.43[abc]
HP - 22	25.06[abc]
HP - 35	24.53[abc]
RRISL 2001	20.6[f]

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

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

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

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

Clone	Girth (cm)
HP - 276	17.20[a]
HP - 302	17.13[a]
HP - 42	16.30[ab]
HP - 41	16.30[ab]
HP - 297	16.27[ab]
RRIC - 121	16.20[abc]

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

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

Annual girth measurements were taken from all the trials. Table 14a (registered clones) and 14b (unregistered clones) show the planting sites, year of planting, and girth measurements at 150 cm for the year under review and the previous two years.

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

Clone	Site	Year of planting	Mean girth (cm)		
			2018	2019	2020
RRISL 201	Dammeria B	2010	46.1	56.2	51.07
	Eladuwa	2009	56.9	58.9	60.84
RRISL 203	Monaragala	2009	50.0	51.4	53.59
	Eladuwa	2009	57.1	59.4	61.80
	Wewassa	2011	52.1	53.0	57.33
	Lagos	2011	56.4	58.3	58.67
	Muwankanda	2010	49.0	51.7	NT
	Dammeria B	2010	40.2	40.7	41.5
	Kamburupitiya (University)	2011	61.6	63.9	68.37
RRISL 208	Dartonfield	1994	78.6	78.7	NT
	Lagos	2013	48.7	51.2	53.97
	Moralioya	2010	56.7	58.5	60.56
	Dammeria B	2010	NT	NT	
	Eladuwa	2009	56.6	58.7	70.5
RRISL 210	Payagala	2006	67.1	NT	NT
RRISL 211	Dartonfield	1994	78.9	NT	NT
RRISL 216	Dartonfield	1994	82.7	84.7	NT
RRISL 219	Dartonfield	1994	90.0	93.0	NT
	Kuruwita	2008	52.5	54.8	55.5
RRISL 2000	Kuruwita	2005	71.3	73.5	74.56
RRISL 2001	Dammeria B	2010	55.7	56.2	58.76
	Muwankanda	2010	55.0	NT	NT
	Dammeria B (Hanipe Dev.)	2011	55.7	56.2	58.76
	Wewassa	2011	46.8	47.2	52.45
	Lagos	2013	49.5	51.5	53.65
RRISL 2003	Lagos	2013	51.1	52.7	55.62
RRISL 2006	Lagos	2013	42.1	45.8	50.66
	Monaragala	2009	57.4	59.4	63.83
	Eladuwa	2009	57.5	59.6	62.33
	Moralioya	2010	59.3	61.6	63.0
RRISL 2100	Monaragala	2009	57.0	58.1	61.07
	Edalla	2010	54.0	56.0	57.84
	Kuruwita	2011	50.8	52.3	53.55
RRISL Centennial 3	Kuruwita	2009	58.0	60.5	61.76
	Monaragala*	2009	53.2	54.6	58.42
	Eladuwa	2010	64.2	66.0	
	We-oya	2010	57.4	59.7	62.46
	Edalla	2010	59.8	62.4	64.51
	Kuruwita	2011	56.5	58.4	59.84
	Siriniwasa	2011	58.8	61.8	63.37
	Lagos	2013	55.8	55.3	56.67

Clone	Site	Year of planting	Mean girth (cm)		
			2018	2019	2020
RRISL Centennial 4	Kuruwita	2007	57.6	58.3	59.07
	Eladuwa	2009	54.8	56.3	57.13
	Monaragala	2009	56.0	57.1	59.55
	Lagos	2011	58.6	60.4	61.73
RRISL Centennial 5	Eladuwa	2009	57.9	59.4	61.61
	Kuruwita	2007	62.5	64.3	65.3

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

Clone	Site	Year of planting	Girth in cm		
			2018	2019	2020
86-10	Kuruwita	2009	50.4	51.9	53.00
86-87	Kuruwita	2009	53.5	55.0	55.75
87-235	Kuruwita	2008	53.8	56.1	57.31
95-55	Lagos	2013	56.1	56.0 (150 cm)	57.92
RRIC 100 seedlings	Kuruwita	2005	71.0	72.2	74.98

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

Estate/RRISL collaborative clone trials (ECT's)

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

Table 15. *Yield (g/t/t) values of evaluating clones are given for the year*

Clone	Tapping system	Site	Year of planting	Average yield (g/t/t)	Year of tapping
RRISL 208	S2 d2	Galewatta	1995	54.61	20th
RRISL 211	S2 d2	Galewatta	1995	85.30	20th
RRISL 211	S2 d3	Galewatta	1995	67.57	20th
RRISL 216	S2 d2	Galewatta	1995	29.79	20th
RRISL 219	S2 d2	Galewatta	1995	29.31	20th
RRISL 203	S2 d2	Dmmaria B	2010	24.26	2nd
RRISL 2001	S2 d2	Dmmaria B	2010	22.74	2nd
RRISL 203	S2 d2	Lagos	2011	48.45	3rd
Centennial 4	S2 d2	Lagos	2011	45.61	3rd
Centennial 3	S2 d2	We-Oya	2010	38.17	3rd
RRISL 2006	S2 d2	Eladuwa	2009	49.97	4th
RRISL 208				40.10	
RRISL 201				26.21	

Clone	Tapping system	Site	Year of planting	Average yield (g/t/t)	Year of tapping
RRISL 203	S2 d2	Eladuwa	2009	33.65	
Centennial 3				35.85	
Centennial 4				36.11	
Centennial 5				35.37	
Centennial 4	S2 d2	Kuruwita	2007	34.34	5th
Centennial 5	S2 d2	Kuruwita	2007	28.18	5th
RRISL 2000		Kuruwita	2005	3.58	8th
RRISL 219	S2 d3	Kuruwita	2008	58.92	4th
Centennial 3	S2 d3	Siriniwasa	2011	43.35	2nd
RRISL 208	S2 d3	Moralioya	2010		3rd
RRISL 2006	S2 d3	Moralioya	2010		3rd

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

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 the 1995 hybridization programme where non-Wickham clone GPS 1 was used as the male parent, were characterized. Annual girth was taken and yield data collection were done twice a month, plot-wise. The trial was taken to further study with bark anatomy analysis for precise selection. It was observed that a number of latex vessel rings, the density of latex vessels, bark thickness, and chlorophyll content had a high positive correlation with yield. The girth was found to be the lowest correlation to the yield. Out of the studied genotypes, 95HP55 performed exceptionally high in yield. It also showed higher outstanding mean values in other characters except for girth and immature girth increment. 95HP1 also performed better than the control clone in its yield, girth, chlorophyll content, and bark anatomical characters (Fig. 1). Accordingly, 95HP55, 95HP1 and 95HP41 are found to be more promising, hence suitable for future breeding and selection programs.

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

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

Testing of promising clones for sub-optimal conditions

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

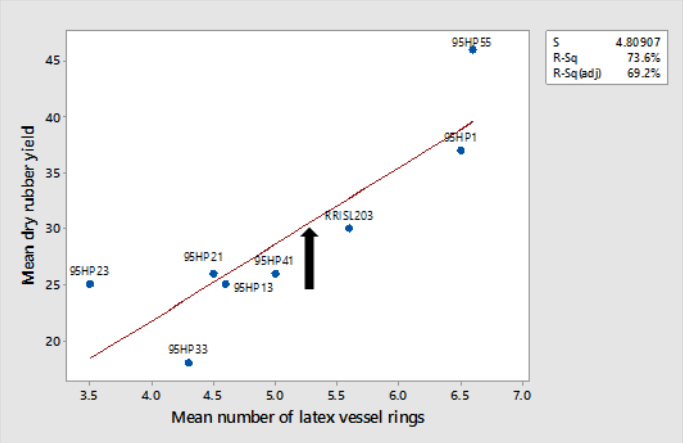

Fig. 1. Variation of mean dry rubber yield with the mean number of latex vessel rings. Black arrow: best-fitted line (A strong positive correlation of 73.6% resulted between mean dry rubber yield with the mean number of latex rings and the regression equation was mean dry rubber yield = -5.541 + 6.831 mean number of latex rings)
(S P Withanage and A K Gamage)

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

Seven experimental plots were established at Padiyathalawa/Mahaoya areas in the Eastern Province. Their control (reference) plot was established at Bandaragama, which belongs to traditional rubber growing regions. Details of these trials are given in Table 16.

Table 16. *Details of smallholder/RRI collaborative trials at Eastern Province and the Eighth year mean girth data*

Trial	Smallholder & Location	Agro-climatic Region	75% expectancy-value of Annual Rainfall (mm)	Clones planted	Mean girth (cm)
SRT-EP 12/1	SM Wirawardana Marawa Padiyathalawa	IL2	> 1600	RRISL 2001 RRISL 203 RRISL 2005 RRISL 2006	NT
SRT-EP 12/2	Indrani Kusumalatha Marawa Padiyathalawa	IL2	>1600	RRISL 203 RRIC 121 RRISL 2001 RRISL 2006	59.4 56.5 58.0 53.0

Trial	Smallholder & Location	Agro-climatic Region	75% expectancy-value of Annual Rainfall (mm)	Clones planted	Mean girth (cm)
SRT-EP 12/3	AM Sumanawathi Helakomana Padiyathalawa	IL2	> 1600	RRISL 203 RRIC 100 RRISL 2005 RRISL 208	NT
SRT-EP12/4	HM Wimalasena Kudaharasgala Mahaoya	IL2	> 1600	RRISL 208 RRISL 2005 RRIC 100 RRISL 203	53.0 53.8 50.5 46.65
SRT-WP 12/8	Ranjith Thambawita Bandaragama Panadura (Kalutara district - Control Trial)	WL 1a	>3300	RRISL 208 RRISL CEN 3 RRISL 2001 95HP - 55 RRISL 203 RRIC 100 RRISL211 RRISL 2005	60.0 62.04 62.37 66.4 59.9 62.0 58.17 61.32

NT – Not taken

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

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

Planting

Five experimental plots were established in Ampara area in the Eastern Province. However, two trials were terminated due to poor support received from the smallholders (Table 17).

Table 17. *Details of smallholder/RRI collaborative clone trials planted in 2013 in the Eastern Province and the seventh year mean girth data*

Trial	Smallholder & Location	Agro-climatic Region	75% expectancy-value of Annual Rainfall (mm)	Clones planted (No. of trees)	Mean girth (cm)
SRT-EP 13/1	HM Jayarathna 17-1 C, Lathugala Warankatagoda	DL2a	> 1300	RRIC 121 (210)	45.51

Trial	Smallholder & Location	Agro-climatic Region	75% expectancy-value of Annual Rainfall (mm)	Clones planted (No. of trees)	Mean girth (cm)
SRT-EP 13/4	HM Saman Kumara 17/1 B, Lathugala Warankatagoda	DL2a	> 1300	RRISL 203 (210)	47.37
SRT-EP 13/5	M Chandrani Ranasingha 51 B - 2, Lathugala Warankatagoda	DL2a	> 1300	RRISL 203 (210)	45.64

(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 18 with their sixth year mean girth.

Table 18. *Details of smallholder/RRI collaborative clone trials planted in 2014 in the Eastern Province*

Trial	Smallholder & Location	Agro-climatic Region	75% expectancy-value of Annual Rainfall (mm)	Clones planted	Mean girth (cm)
SRT-EP 14/1	G Senevirathne Mahaoya	IL2	>1600	RRIC 121	NT
SRT-EP 14/2	M Senevirathne Mahaoya	IL2	> 1600	RRISL 2001	NT
SRT-EP 14/3	AM Jayasekara Mahaoya	IL2	>1600	RRISL 2006	NT
SRT-EP 14/4	TM Amarasena Mahaoya	IL2	>1600	RRISL 2005	NT

NT – Not taken

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

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

Four experimental sites were established in Bibile area in collaboration with the World Vision Organization. Girth data were taken and given in Table 18. One

trial was established in Kataragama. Girth data in the third year was taken and details are given in Table 19.

Table 19. *Details of smallholder/RRI collaborative clone trials planted in 2015 in Uva Province and third-year mean girth data*

Trial	Smallholder & Location	Agro-climatic Region	75% expectancy-value of Annual Rainfall (mm)	Clones & the number of plants	Mean girth (cm)
Bibile (Collaborate with World Vision)					
SRT-UP 15/1-WV	HM Punchibanda Ilukpathana	IL1c	>1300	RRISL 2001(215)	27.39
SRT-UP 15/2-WV	AM Karunawathie Ilukpathana	IL1c	>1300	RRISL 2001(215)	21.9
SRT-UP 15/3-WV	HMW Wijekumara Kudumirisketiya Ilukpathana	IL1c	>1300	RRISL 2001(430)	29.18

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 2016 in Uva Province and fourth year mean girth data*

Trial	Smallholder and Location	Agro-climatic Region	75% expectancy-value of Annual Rainfall (mm)	Clones & the number of plants	Mean girth (cm)
Kataragama					
SRT-UP 15/5	GK Chaminda Diyawaragmmana Junction, Sella Rd Kataragama	DL 5	>650	RRISL2001 RRISL 203 (215)	22.82 23.72

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

Table 21. *Details of smallholder/RRI collaborative clone trials planted in 2015 in North Central Province*

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

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

PLANT SCIENCE

N M C Nayanakantha

DETAILED REVIEW

Staff

Dr N M C Nayanakantha, Head of the Department, Mr T U K Silva, Senior Research Officer and Mr M N de Alwis, 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, Mrs W K S W Watawala, Miss H Subasinghe, Mr D Priyadarshana, Mrs N Udayakumari, Mr H G H C Arunasiri and Miss W M D Wickramakumari Technical Officers, Mrs D E Jayawardena and Mrs P D A H M A de Almeida, Management Assistants were on duty throughout the year. Dr (Mrs) D S A Nakandala, Research Officer, was on no-pay leave from 8th December, 2020 to undertake an assignment as Senior Resilient Agriculture Specialist of the World Bank Project titled "Climate Adaptation and Resilience Project for South Asia" in Thailand.

Dr (Mrs) D S A Nakandala was awarded her PhD in Irrigation and Water Management with effect from 1st of January, 2018, and the Viva-voce examination was held on 22nd July 2020 at the University of Ruhuna, Sri Lanka.

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

Officers involved	Subject/Theme	Number of programmes	Beneficiary/Client
MN de Alwis	Nursery Management	01	Agriculture students
	Bud grafting Training Programme	01	Elpitiya Plantation Ltd.
MN de Alwis LN de Zoysa	Bud grafting Training Programme	03	Rubber Development Department
PKW Karunatilaka	Tapping	25	Plantation Companies (Managers, Asst. Managers, Field Officers), Smallholders, University students and Agriculture Diploma students

Seminars/Conferences/Meetings/Workshops attended

Officer	Subject	Organization
NMC Nayanakantha	Meeting on Nursery Management	Ministry of Plantation Industries
	Meeting on 13 years education and new subject on Plantation Crop Research	National Institute of Education (NIE), Maharagama
	Progress Review Meetings	Ministry of Plantation Industries
	TEC Meetings for Purchase of Rubber Plants for STaRR Project	Office of the STaRR Project, Battaramulla
TUK Silva	International Symposium on Agriculture and Extension	Faculty of Agriculture, University of Ruhuna
DSA Nakandala	International Symposium on Multi-Hazard Early Warning and Climate Change	Disaster Management Centre, Sri Lanka
NMC Nayanakantha TUK Silva DSA Nakandala MN Alwis	Scientific Committee Meeting	Rubber Research Institute of Sri Lanka

Services

Testing the quality of polythene

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

Supplying of marking plates

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

Issuing authentic budwood

About 700 meters of budwood were issued to Departments of RRISL and for rubber 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 12, 13 & 14 (N M C Nayanakantha, M N de Alwis, L N de Zoysa and R Handapangoda).

Visits

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

LABORATORY INVESTIGATIONS

Tissue culture

No lab work was done during the 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 pattern of different clones at Galewatta were made and the wintering was recorded to be irregular and earlier (starting from December) due to the occurrence of *Pestalotioptis* leaf disease (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

Data were not collected during the period and data gathered so far are being analyzed (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

A seed priming experiment was established at the nursery site of the Plant Science Department in 2019 in order to improve germination dynamics of rubber seeds with chemical priming. 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% $ZnSO_4$				

Seeds were sown in germination beds filled with sand according to a Randomized Complete Block Design (RCBD) with three blocks. Effects of priming treatments on germination of rubber seeds were recorded in the Annual Review for 2019. Germinated seeds were transplanted in polybags according to an RCBD design. Growth data of seedlings (*i.e.;* stem diameter and height, number of leaves and leaf chlorophyll content) were recorded after one, two and three months of transplanting (Table 1). Root growth, leaf area and dry matter analysis were done after three months of transplanting (Table 2).

Table 1. *Effect of priming treatments on stem diameter, stem height, number of leaves and leaf chlorophyll content of seedlings after 1, 2 and 3 months of transplanting*

Treatment		**Stem diameter (mm)**	**Shoot height (cm)**	**No. of leaves**	**Leaf chlorophyll content (SPAD value)**
T1	1 month	4.1±0.2^{a}	24.1±1.4^{a}	2.6±0.2^{a}	60.0±5.3^{a}
	2 month	5.4±0.2^{ab}	42.3±1.8^{a}	5.4±0.3^{a}	-
	3 month	6.0±0.2^{a}	52.3±2.8^{a}	7.1±0.7^{a}	67.9±4.3^{a}
T2	1 month	4.1±0.2^{a}	22.9±1.4^{a}	2.6±0.2^{a}	52.5±6.9^{a}
	2 months	5.2±0.2^{ab}	40.2±3.2^{a}	4.7±0.5^{a}	-
	3 months	5.9±0.4^{a}	48.2±3.9^{a}	6.4±0.9^{a}	64.9±8.5^{b}
T3	1 month	4.1±0.2^{a}	25.3±1.3^{a}	2.8±0.2^{a}	60.3±3.7^{a}
	2 months	5.2±0.2^{ab}	41.9±2.4^{a}	5.0±0.4^{a}	-
	3 months	6.2±0.4^{a}	52.9±3.4^{a}	6.7±1.0^{a}	55.2±7.4^{b}
T4	1 month	4.0±0.2^{a}	24.5±1.3^{a}	2.8±0.2^{a}	57.1±7.6^{a}
	2 months	5.1±0.2^{ab}	40.1±3.1^{a}	4.9±0.4^{a}	-
	3 months	6.0±0.3^{a}	49.9±3.7^{a}	6.5±0.9^{a}	59.8±4.2^{ab}
T5	1 month	4.1±0.2^{a}	24.7±1.4^{a}	2.9±0.2^{a}	59.9±3^{a}
	2 months	5.3±0.2^{ab}	41.5±2.6^{a}	4.7±0.5^{a}	-
	3 months	6.3±0.3^{a}	52.0±3.5^{a}	6.3±0.9^{a}	56.0±6.7^{b}
T6	1 month	4.2±0.2^{a}	24.0±1.7^{a}	2.9±0.2^{a}	53.9±8.7^{a}
	2 months	5.5±0.2^{ab}	42.9±2.8^{a}	4.9±0.5^{a}	-
	3 months	6.0±0.3^{a}	50.4±3.8^{a}	5.8±0.9^{a}	60.7±4.5^{ab}
T7	1 month	4.1±0.2^{a}	24.5±1.6^{a}	2.7±0.2^{a}	48.2±8.7^{a}
	2 months	5.2±0.2^{ab}	43.4±2.9^{a}	4.9±0.4^{a}	-
	3 months	5.8±0.3^{a}	52.2±3.3^{a}	6.2±0.9^{a}	56.7±2.3^{b}

Table 2. *Effect of seed priming on length of taproot, leaf area, dry weight of roots (tap root & lateral roots) and dry weight of shoots of seedlings after three months of transplanting*

Treatment	Tap root length (cm)	Leaf area (cm^2)	Dry weight (g)	
			Roots	Shoots
T1	40.9±3.3[a]	629.5±144.4[a]	2.5±0.3[a]	5.8±0.7[a]
T2	44.1±2.8[a]	501.9±111.3[a]	2.3±0.3[a]	4.7±0.6[a]
T3	38.9±2.6[a]	521.6±124.5[a]	2.4±0.4[a]	5.4±1.0[a]
T4	39.2±3.1[a]	546.4±122.8[a]	2.4±0.2[a]	5.2±0.6[a]
T5	40.9±3.3[a]	604.9±144.2[a]	2.6±0.3[a]	5.9±0.6[a]
T6	43.2±3.4[a]	458.9±100.4[a]	3.3±0.4[a]	4.9±0.5[a]
T7	40.1±1.9[a]	480.9± 99.8[a]	2.5±0.3[a]	5.6±0.7[a]

No significant differences (P>0.05) were recorded for morphological attributes of rubber seedlings among priming treatments (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)

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

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

An experiment was commenced to study the effect of the height of the germination bed on the growth and root attributes of rubber seedlings. Germination beds were prepared with river sand at different heights as shown below. Fresh rubber seeds were sown in germination beds according to a Randomized Complete Block Design.

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

Seedlings were uprooted from germination beds when two leaves were completely emerged and in copper brown to light green stage. Length of taproot was recorded at the time of transplanting in polybags (Table 3).

Table 3. *Shoot and root attributes (mean values) of seedlings at the time of transplanting*

Treatment	Tap root length (cm)
T1	5.8±0.31
T2	7.7±0.32
T3	7.6±0.60
T4	7.7±0.79

Growth data of seedlings were recorded after two months of transplanting in polybags (Table 4).

Table 4. *Effect of the height of germination bed on seedling attributes after two months of transplanting into polybags*

	Shoot Length (cm)	Stem diameter (mm)	No. of leaves	Length of taproot (cm)	Dry weight of shoot (g)	Dry weight of tap root (g)	Dry weight of secondary roots (g)
T1	36.8±1.25	4.0±0.15	4.1±0.26	29.0±2.26	1.6±0.18	0.5±0.10	0.3±0.05
T2	37.6±1.83	4.0±0.17	4.3±0.29	32.4±2.30	1.9±0.24	0.5±0.06	0.3±0.04
T3	33.3±1.75	3.9±0.14	3.6±0.30	33.6±1.69	1.5±0.10	0.5±0.02	0.3±0.03
T4	40.7±2.55	4.2±0.14	4.9±0.44	29.9±2.93	1.9±0.28	0.5±0.10	0.4±0.09

(N M C Nayanakantha and U N Udayakumari)

Effect of polybag size and colour on growth of seedlings

This experiment was commenced at Egaloya RDD Nursery in 2018 to investigate the effect of the sizes of polybags and colour of polybags on the growth of young budded rubber plants under nursery conditions. Details of the experiment and results were discussed in Annual Reviews for 2018 and 2019. Nursery-grown plants were field planted, according to the RCBD design, in order to investigate their growth performances under field conditions. About 500 young budded plants (two-whorled) were established at Dapiligoda of Dartonfield Estate in 2020. The stem diameter of plants were recorded at basal level (about 5 cm from the ground) (Table 5 & 6).

Table 5. *Effect of size of polybags on the growth of plants after one month of field establishment*

Treatment	Stem diameter (mm)
T1 (5"x13")	9.3±0.36
T2 (5"x15")	11.0±0.37
T3 (6"x13")	10.1±0.30
T4 (6"x15")	12.2±0.42

Table 6. *Effect of colour of polybags on the growth of plants after one month of field establishment*

Treatments	Stem diameter (mm)
Black (Control)	9.7±0.23
Transparent	10.5±0.31

Growth of plants was satisfactory irrespective of treatments (N M C Nayanakantha, M N de Alwis, R Handapangoda, E U M De Z Dissanayaka and U N Udayakumari).

Nursery techniques

Effect of seed quantity on growth and bud grafting performance of rubber (NT/SQ/2020/Mon)

An experiment was commenced to see the effect of seed quantity on germination and the quality of planting material. This study was conducted at Moneragala Substation in 2020 with different quantities of seeds as treatments *viz.*, T1: two-folds (recommended), T2: three-folds, T3: four-folds and T4: five-folds of rootstock plants to be established in a nursery according to the RCBD design. Normally it takes more than two weeks to start germination in nurseries in Moneragala. Therefore, germinated seeds were removed from the seedbeds after two weeks of sowing at different rounds as shown in Table 7.

Table 7. *Different treatments of seed quantities*

Treatment	Seed quantity	Rounds of germinated seeds removed
T1 (control)	Two folds	3
T2	Three folds	2
T3	Four folds	1
T4	Five folds	1

Germinated seeds were transplanted into polybags (7”x18” size) filled with soil mixed with compost (100 g/bag) and HERP (50 g/bag). Growth attributes (stem

diameter, leaf chlorophyll content and dry matter content) of seedlings were assessed four months after transplanting (Tables 8 & 9).

Table 8. *Effect of seed quantity on growth attributes of rubber seedlings after 4 months of transplanting*

Treatment	Stem diameter (mm)	Diameter increment (mm)	Leaf chlorophyll content (SPAD value)	Dead plant %
T1	5.8 ± 0.08	1.4 ± 0.05	40.4 ± 2.54	17.2
T2	5.7 ± 0.08	1.5 ± 0.05	40.8 ± 1.79	26.0
T3	6.7 ± 0.06	1.7 ± 0.05	41.4 ± 1.83	1.3
T4	6.9 ± 0.06	1.8 ± 0.04	43.0 ± 1.90	0.0

Table 9. *Effect of seed quantity on the dry weight of shoots and roots of rubber seedlings after four months of transplanting into poly bags*

Treatment	Dry weight of shoot (g)	Dry weight of root (g)
T1	12.6 ± 2.04	4.3 ± 0.65
T2	13.1 ± 3.19	4.8 ± 0.97
T3	18.7 ± 3.21	6.3 ± 1.52
T4	18.6 ± 2.73	6.9 ± 0.77

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

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

A new experiment was commenced at Moneragala Substation to assess the effect of row arrangement of rootstock nurseries on the production of quality planting materials. Treatments were as follows;

T1 (Control) : Single row
T2 : Two rows
T3 : Three rows
T4 : Four rows

Polybagged plants were arranged in a nursery according to the Randomized Complete Block Design. Polybags were kept at the nursery site in five blocks. In a block, there were four row-wise treatments and each had 50 plants per row. Each treatment was separated by a guard row on either side of the treatments. The space between two rows was 45 cm.

The stem diameter of plants was recorded after four months of transplanting. Ten plants from each treatment were uprooted to assess the dry matter content of shoot and roots (Table 10). Soil moisture content in polybagged plants was recorded

by using Theta-probe equipment. Moisture measurements were recorded diurnally in each. Theta probe was inserted into soils in the polybag up to 10 cm depth and moisture percentage in volume basis was recorded by using a moisture meter that connected to the theta probe (Table 11).

Table 10. *Effect of number of rows on morphological attributes of rubber seedlings after four months of transplanting into polybags*

Treatment	Stem diameter (mm)	Leaf chlorophyll content (SPAD value)	Dead plant %
T1	5.6±0.12	37.1±0 .64	10.0
T2	6.5±0.10	41.1±1.65	5.4
T3	6.5±0.07	42.0±1.30	0.6
T4	6.5±0.07	43.0±0.94	1.9

Table 11. *Average soil moisture content (v/v%) of different treatments after four months of transplanting into polybags*

Treatment	Soil moisture content at different time interval (v/v/%)		
	8.00 a.m.	12.00 noon	4.00 p.m.
T1	18.0±0.50	14.3±0.54	12.9±0.45
T2	18.0±0.67	14.8±0.59	12.9±0.70
T3	17.1±0.66	14.0±0.78	11.1±0.78
T4	16.5±1.03	13.1±0.84	11.1±0.91

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

Irrigation systems for rubber nurseries and immature plants

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

A porous tube micro-irrigation system was installed at two immature rubber clearings in Moneragala with the onset of North-East monsoon rain in November, 2020. The main objective of this study was to minimize the drought stress of immature rubber plants while enhancing the growth performance and establishment rate under dry climatic conditions. Three types of porous irrigation systems were installed as shown below. About 120 porous tube micro-irrigation units were installed at the field according to a Randomized Complete Block Design with six replications before establishing rubber plants in the field.

T1 : One porous tube unit at 14” depth from the surface of the soil
T2 : One porous tube unit at 24” depth from the surface of the soil
T3 ; Two porous tube units at 14” and 24” depths from the surface of the soil
T4 : Manual watering (Control)
(D S A Nakandala, M N de Alwis and P K W Karunatilaka)

Budwood nurseries

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

Old budwood nursery at Dolahena was uprooted and new mother bush plants belonged to 32 clones were established with the onset of South-West monsoon rain in May 2020. Budwood nurseries in Dartonfield, Olikanda and Gallewatta were maintained throughout the year. Weeding, manuring, pollarding and application of fungicide were done at regular intervals (N M C Nayanakantha, P Seneviratne and R Handapangoda).

Budwood nursery for clone identification purposes (2010/DF)

This overaged bud wood nursery was to uproot but could not be uprooted due to some restrictions of Covid 19 pandemic situation (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 12,13 & 14.

Table 12. *Details of RPC nurseries established in 2020*

Regional Plantation Company	No. of estates having nurseries	No. of nurseries for the RPCs	No. of plants established in 2020	No. of plants certified as Y.B. in 2020
Kegalle	5	7	46,500	32,900
Kotagala	1	1	11,800	2,000
Pussellawa	4	4	-	24,000
JEDB	1	1	3,000	1,600
Hapugasthenne	1	1	-	13,000
Elpitiya	1	1	17,500	4,500
Malwattavalley	3	3		24,200
Lalan	1	1		90,000
Total	**17**	**19**	**78,800**	**192,200**

Table13. *Details of government nurseries established in August 2019, January 2020 and August 2020*

Name of the nursery	Season	No. of plants established	No. of plants certified
Egaloya	2019 Aug.	225,900	65,000
	2020 Jan.	10,740	5,000
	2020 Aug.	300,000	-

Name of the nursery	Season	No. of plants established	No. of plants certified
Gurugoda	2019 Aug.	168,700	77,000
	2020 Jan.	9,910	5,500
	2020 Aug.	300,000	-
Karapincha	2019 Aug.	91,000	25,000
	2020 Jan.	18,000	
	2020 Aug.	120,000	
Meerigama	2019 Aug.	-	
	2020 Jan.	16,000	
	2020 Aug.	147,000	
Welikadamulla	2019 Aug.	251,000	
	2020 Jan.	40,320	
	2020 Aug.	290,000	
Middeniya	2019 Aug.	75,800	32,000
	2020 Jan.	5,000	
	2020 Aug.	118,000	
Moneragala	2019 Aug.	261,930	158,000
	2020 Jan.	86,090	
	2020 Aug.	450,000	
Padiyathalawa	2019 Aug.	92,880	25,000
	2020 Jan.	-	
	2020 Aug.	110,000	
	2020 Jan.	186,060	-
	2020 Aug.	183,500	
Grand Total		**3,557,830**	**322,500**

Table 14. *Details of private nurseries established in 2020*

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Region	No. of nurseries	No. of plants established	No. of plants certified
Kegalle	6	-	34,200
Ratnapura	2	75,000	-
Total	8	75,000	34,200

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

Inspection of budwood nurseries

All budwood nurseries belong to Rubber Development Department (RDD) were inspected and instructions were given to uproot over aged budwood nurseries. Clonal composition in budwood nurseries was identified and recorded (N M C Nayanakantha, M N de Alwis and D L N de Zoysa).

Discarding of weak plants in rubber nurseries

Discarding of weak budded plants and seedling plants (unsuccessful) in nurseries belonged to RDD was initiated but could not be continued as planned due to restrictions imposed after Covid 19 pandemic (N M C Nayanakantha, M N de Alwis and D L N de Zoysa).

Planting techniques

Stumped budding experiment (SB/2016/Moneragala)

A stumped budding experiment was established at Moneragala Substation in November 2016. Regular maintenance, including manuring and circle weeding, was done throughout the year. The annual girth of three types of plants (*i.e.* whole plant with root bole and stumped budded plant) and normal plants was recorded (Table 15).

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

Treatment	Girth (cm)	Girth increment (cm)
Whole plants with root boles	18.3±1.27	4.6±0.45
Stumped budded plants	16.8±1.28	3.4±0.59
Normal plants	28.0±0.48	7.4±0.15

The girth of the normal plants was shown to be satisfactory as compared to stumped budded plants. Almost all root bole plants survived but about 50% of stumped budded plants died and were replaced with new plants during the past three years due to their poor growth (N M C Nayanakantha, D S A Nakandala, M N de Alwis and D L N de Zoysa).

Performances of clones PB 86 and RRIC 100 (2013)

Young budded plants of clones PB 86 and RRIC 100 were established at Gallewatta Division of Dartonfield Group in 2013 to compare the growth and yield performances of two clones. Weeding, manuring, and other agronomic practices were done as per recommendations of RRISL. Girth data are shown in Table 16. Tapping could not be commenced due to the poor girth of clone PB 86.

Table 16. *Mean girth of two clones in 2020*

Clone	Girth (cm)
PB 86	45.1±1.13
RRIC 100	61.7±1.05

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

Northern Province planting

Kilinochchi (PT/2015/Kilinochchi)

Data were not recorded due to COVID19 pandemic condition (N M C Nayanakantha, M N de Alwis and D L N de Zoysa).

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

This experiment was commenced in Kekirawa, Anuaradhapura in order to study the establishment rate and growth of rubber under sub-optimal climatic conditions prevailing in drier areas. The main objective of this experiment was to compare the growth attributes of different root bole plants produced under varied potting media (Table 17). The control treatment was selected as two-whirled young budding plants and plants were arranged in the Randomized Complete Block Design.

Table 17. *Composition of the media used to prepare root bole plants*

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

Morphological attributes of plants *viz.* basal girth and girth at 120 cm, leaf area, number of leaves and dead plants were recorded one year after field establishment. General maintenance and fertilizer application were done according to the RRISL recommendation (Table 18).

Table 18. *Effect of root bole media on morphological attributes of rubber plants after one year of field establishment*

Treatment	Basal girth (cm)	Girth at 120 cm height	No. of leaves	Leaf area	Dead plant %
Control	6.6 ± 0.16	4.2 ± 0.14	50± 2.70	211.7±13.3	16
T1	6.9 ± 0.19	4.9 ± 0.15	54 ± 2.77	137.9± 28.3	12
T2	7.3± 0.26	5.0 ± 0.22	58 ± 3.19	142.2± 25.5	10
T3	7.9 ± 0.21	5.2 ± 0.17	59 ± 2.47	227.1± 16.7	2
T4	7.6 ± 0.23	5.1 ± 0.18	65± 2.31	179.1± 27.0	14
T5	6.9 ± 0.22	4.7 ± 0.15	51 ± 3.02	196.8± 18.9	18

According to the results, root bole plants with 50% (T3) and 75% (T4) coir pith mixtures recorded a higher basal girth when compared to the other treatments (M N de Alwis, D S A Nakandala, 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)

This experiment was terminated and the data gathered so far are being analyzed (T U K Silva, V H L Rodrigo and H Subasinghe).

Low density trial at Gallewatta and Nivithigalakele - 2012

Two field experiments on low density were established at Galewatta and Nivithigalakele Divisions of Dartonfield Group in 2012. Two different spacing systems (*i.e.* 16'x16' and 14'x15') and two clones (*i.e.* RRISL 203 and RRISL 2001) were used as treatments and sub treatments. The mean girth of trees for each experiment was recorded (Tables 19 and 20). A test tapping was done at Gallewatta and yield data were recorded in terms of girth and g/t/t (Table 19). A test tapping was done at D/2 and D/3 frequencies for the experiment at Nivithigalakele (Table 20).

Table 19. *Mean girth, girth increment and yield (g/t/t) of trees of rubber clones at different densities at Gallewatta*

Clonal density	Mean girth (cm)	Girth increment (cm)	Average g/t/t (g)
RRISL 2001 14'×15'	56.8^{a}	3.2^{a}	58.6^{b}
RRISL 203 14'×15'	56.2^{a}	3.4^{a}	62.3^{ab}
RRISL 2001 16'×16'	57.8^{a}	3.2^{a}	61.4^{ab}
RRISL 203 16'×16'	57.4^{a}	3.5^{a}	71.9^{a}

Table 20. *Mean girth, girth increment and yield (g/t/t) of trees of rubber clones at Nivithigalakele*

Clonal density	Tapping frequency	Average girth (cm)	Girth increment (cm)	Average g/t/t (g)
RRISL 2001 16'×16'	D/2	59.3[a]	2.1[a]	67.9[a]
	D/3	60.0[a]	2.3[a]	76.9[a]
RRISL 203 16'×16'	D/2	56.5[a]	2.0[a]	73.0[a]
	D/3	58.1[a]	2.0[a]	81.5[a]

(P Seneviratne and R Handapangoda)

Low density trail at Kandakadu, Polonnaruwa – 2013

A low-density experiment with the clone RRIC 121 was established at Kandakadu in Polonnaruwa District in 2013. The spacing system adopted was 16'x16' with banana as an intercrop. The annual girth of plants was not recorded due to the restrictions imposed by COVID19 pandemic. Some healthy rubber plants at the experimental site were destroyed by wild elephants on two occasions (P Seneviratne, N M C Nayanakantha, M N de Alwis and R Handapangoda).

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

A new experiment was established at Galewatta Division of the Dartonfield Group in July 2020 with the onset of South-West monsoon rains. The objective of this study was to evaluate the growth, physiological and molecular biological variations of different rubber clones *viz.*, RRISL 201, RRISL 2006, Centennial 4 and RRIC 121 under wet and dry climates. About 600 two-whorled young budded plants of each clone were established at Galewatta Division for the Wet Zone according to a Randomized Complete Block Design (RCBD) with three blocks. About 50 plants from each clone (treatment) were planted for each block. Regular maintenance including the application of fertilizer and circle weeding was done according to RRISL recommendations (N M C Nayanakantha, D S A Nakandala, M N de Alwis and D L N de Zoysa).

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

A new experiment on holing at planting, using a digger machine was commenced to minimize the cost of labor. The experiment was established at three fields of Kumarawatta estate in Moneragala District with the onset of North-East monsoon rains in 2020. The experiment design was a Randomized Complete Block design (RCBD) with three treatments and three blocks. Treatments of the experiment are given below. Each treatment consisted of 45 planting holes in each block.

T1 : Holing by using an auger mounted to a tractor
T2 : Holing by using a Back-hoe machine
T3 : Manual holing (Control)

The newly introduced tractor-mounted auger (a digger machine) was used to dig planting holes effectively and efficiently for the first time in rubber fields in Sri Lanka (N M C Nayanakantha, P K W Karunatilaka and H G H C Arunasiri).

Exploitation

Longer tapping cycles through shorter tapping cuts - Pitiakanda estate

This trial was commenced in 2009 to investigate the effect of shorter tapping cuts on the yield of rubber. A tapping block of RRIC 117 from 2003 clearing was selected. Yield measurements for the period from January to August 2020 are given in Table 21.

Table 21. *Yield measurements for the period from January to August 2020*

Treatments	Mean No. of trees	No. of tapping days per year	Latex yield (g/t/t)	Mean crop per tapping (kg)	Brown bast %
T1: S/4 d3 + 5% Ethrel (once a month)	42	67	35.6	0.50	-
T2: S/3 d3 + 2.5% Ethrel (once a month)	41	67	31.7	0.43	0.3
T3: S/2 d3 + 2.5% Ethrel (4/year)	38	67	36.8	0.38	0.5

There was no marked difference among treatments tested. The same yield could be obtained from lesser bark in T1 and T2 when compared to control T3.

A repeat trial on longer tapping cycles through shorter tapping cuts was commenced in May 2018 at Pitiyakanda estate in order to study the effect of shorter tapping cuts on the yield of rubber further. A tapping field of RRIC 121 clone planted in 2011 was selected for this experiment. Treatments and yield measurements are given in Table 22.

The same yield could be obtained from lesser bark consumption at S/4 d3 tapping (T1) with 5% Ethrel application at a rate of once a month (Table 21) (P Seneviratne, N M C Nayanakantha, R K Samarasekara,W K S W Watawala and H G H C Arunasiri).

Table 22. *Yield measurements for the period from January to August 2020*

Treatments	Average No. of trees	No. of tapping days per year	Latex yield (g/t/t)	Mean crop per tapping (kg)	Brown bast%
T1: S/4 d3 + 5%Ethrel (once a month)	27	36	45.4	1.35	0.67
T2: S/3 d3 + 2.5%Ethrel (once a month)	30	36	38.4	1.32	1.33
T3: S/2 d3 + 2.5%Ethrel (4 application/year)	29	36	55.5	1.22	1.0

Winter rest experiments

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

Yield measurements for the period from January to September 2020 are given in Table 23.

Table 23. *Yield measurements for the period from January to September 2020*

Treatments	Yield (g/t/t)		
	RRIC 100	RRIC 121	RRISL 203
T1 - Tapping without winter rest	9.8	10.5	6.9
T2 - Rested during the winter period	9.7	10.3	8.6
T3 - d6 tapping practiced only during the winter period	12.3	11.2	7.7

There was no marked difference among the treatments tested (P Seneviratne, N M C Nayanakantha, R K Samarasekara, W K S W Watawala and H G H C Arunasiri)

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

No visits were made during the period due to the COVID19 pandemic condition (P Seneviratne, N M C Nayanakantha, R K Samarasekara, W K S W Watawala and H G H C Arunasiri).

Night/Early morning tapping experiments (NT/2019)

Two experimental trials on early morning tapping were commenced at Gallewatte Division of Dartonfield Group and Moneragala in 2019. The main objective of this study was to investigate the effectiveness of early morning tapping on latex yield and related parameters.

NT/2019/Gallewatta

A rubber clearing of RRIC 121 which was established in 2006 at Gallewatte Division was selected for this study. A total number of 90 tapping trees was selected at d3 tapping with stimulation. The experiment was conducted 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.

Latex was collected from 15 trees for each block. Dry rubber content (DRC) was estimated and g/t/t was calculated. Weather data such as relative humidity, temperature and wind speed were recorded by using a pocket weather meter. The yield was calculated as mean total crop and g/t/t (Figs. 1 & 2).

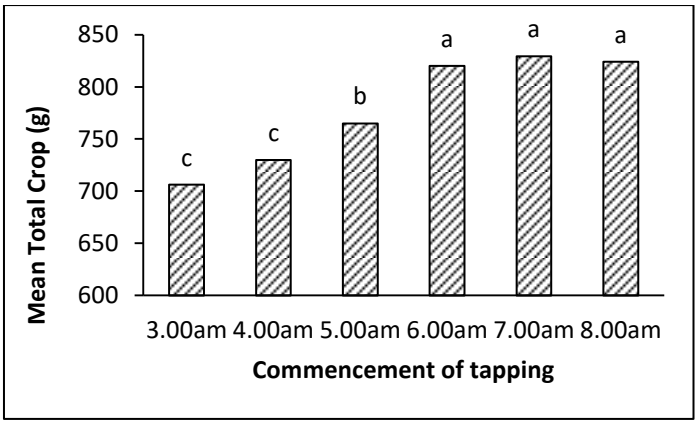


Fig. 1. Mean total crop of 15 trees/tapping at 54 tapping days

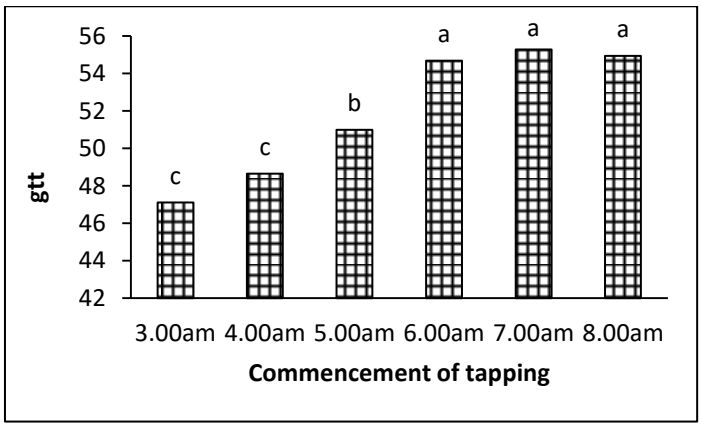


Fig. 2. Mean g/t/t of 15 trees/tapping at 54 tapping days

Results revealed that there was a significant difference in yield at 6.00 am. 7.00 am, and 8.00 am time intervals when compared with early hours such as 3.00 am, 4.00 am and 5.00 am (N M C Nayanakantha, R K Samarasekera, W Karunatilaka and W K S W Watawala).

NT/2019/Moneragala

Yield measurements were not taken due to COVID19 pandemic in the country (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 at Pitiyakanda estate. A tapping block was selected from the 2004 clearing of RRIC 121clone. Treatments were applied as shown in Table 24. Yield measurements for the period from January to August 2020 are given in Table 24.

Table 24. *Yield measurements for the period from January to* August 2020

Treatments	Yield (g/t/t)
T1: Control, S/2 d3 + 2.5%Ethrel (4/year)	17.8
T2: T1 + Moringa Leaf Extract 5% (Once a month)	24.9
T3: T1+ SNP 100 µM (once a month)	23.8
T4: T1+ Banana Leaf Extract 5% (once a month)	21.0
T5: T1+ Moringa Leaf Extract 10% (once a month)	24.5
T6: T1+ SNP 150 µM (once a month)	20.2
T7: T1+ Banana Leaf Extract 10% (once a month)	21.0

Higher g/t/t values were recorded in treatments T2 and T5 in which Moringa leaf extracts were applied at 5% and 10% concentrates respectively (Table 24) **(**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 at Padukka estate. Sixty tapping trees were selected from the 2007 clearing of RRISL 203 at Menerigama Division in Padukkka estate and two treatments were introduced as follows. The annual mean yield in terms of g/t/t from January to December 2020 for two frequencies, are shown in Table 25.

Table 25. *Effect of tapping frequency on yield of RRISL 203*

Treatments	Yield (g/t/t)
S/2 d3	17.9
S/2 d2	18.4

(N M C Nayanakantha, R K Samarasekera, W K S W Watawala and H C Arunasiri).

Impact of different bark consumption rates associated with additional days of latex harvesting on growth, yield and economical 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. 3 & 4). 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. Rainfall, number of wet days and number of tapping days were recorded throughout the year. Five tapping systems (treatments) were tested as shown below for four clones, *i.e*. RRIC 100, RRIC 102, RRIC 121 and RRIC 133.

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

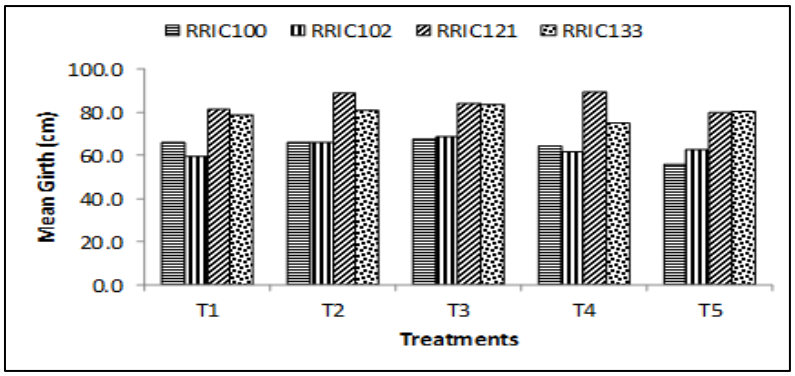


Fig. 3. Mean girth (cm) of different clones with different treatments at the end of year 2020

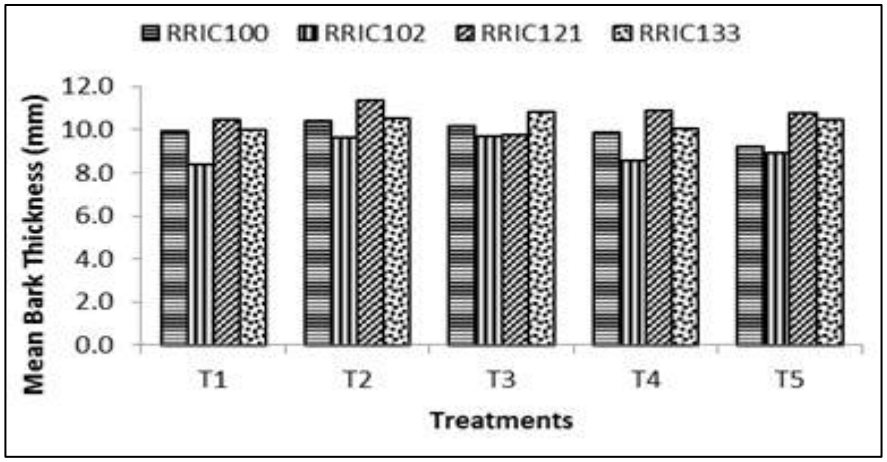


Fig. 4. Mean bark thickness (mm) of different clones with different treatments at the end of year 2020

Higher yields in terms of g/t/t were recorded in trees which were stimulated with ethephon (ET 2.5%) and tapping at d3 frequencies (Fig. 5). Out of the four clones, the highest yield per tree per tapping was recorded in RRIC 121 (Fig. 5).

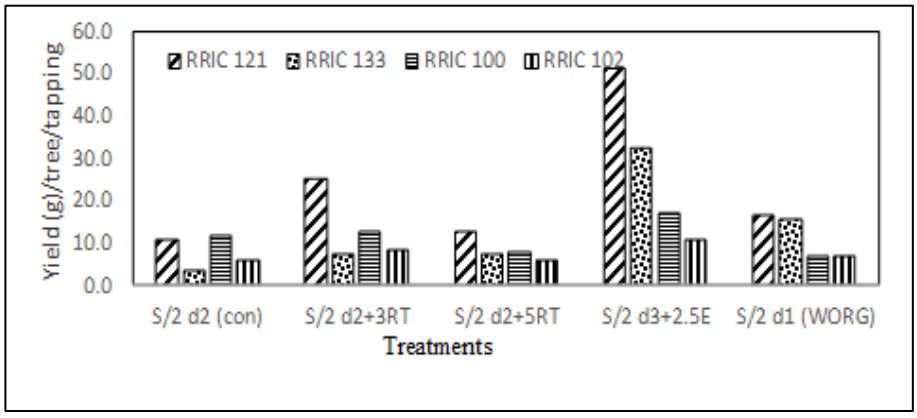


Fig. 5. Mean dry rubber yield (g) per tree per tapping in four clones with five treatments recorded from January to December 2020

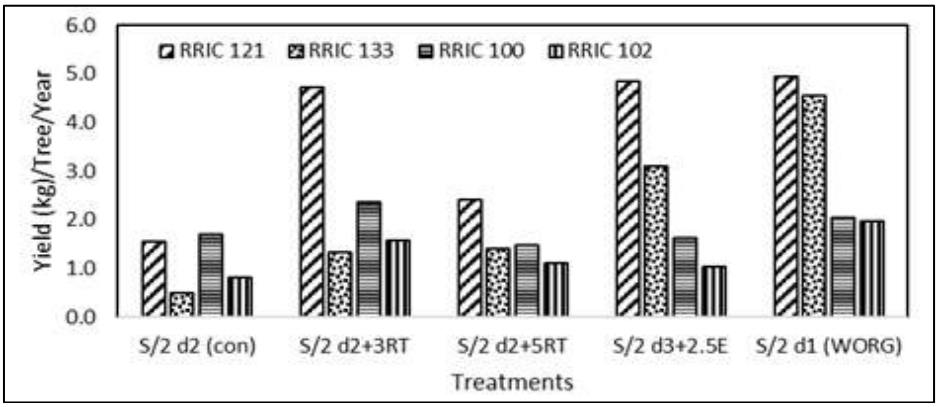


Fig. 6. Dry rubber yield (kg) per tree per annum in four clones with five treatments recorded from January to December 2020
(T U K Silva, P Seneviratne, W Senevirathna and H Subasinghe)

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

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

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

The objective of this experiment was to investigate the possibilities to increase the productivity of rubber plantations through the management of bark consumption rates. A rubber field established in 2006 with RRIC 121 clone at Sirikandura estate was selected for the study. Six tapping systems were employed as treatments (Table 26). The experiment was designed according to a Randomized Complete Block Design (RCBD) with three replications of each treatment. Growth and yield data were recorded (Table 27).

Table 26. *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)

Table 27. *Mean girth, bark thickness and yield (g) per tree per tapping (g/t/t) under different tapping systems*

Treatment	Mean girth (cm)	Mean bark thickness (mm)	Yield (g/t/t)
T1	69.8	8.0	38.8
T2	73.1	8.4	35.6
T3	72.3	7.8	23.8
T4	69.0	8.0	34.4*
			29.1*
T5	68.7	7.3	39.7
T6	70.5	7.2	34.5

* 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 rambutan trees with respect to the basal girth, tree height and canopy area was recorded (Table 28).

Table 28. *Mean basal girth (cm), tree height and canopy area of rambutan trees under different treatments*

Treatment	Mean basal girth (cm)	Tree height (m)	Canopy spread (m)
T1 (3 m×3 m) -15 m	96.7	4.0	9.6
T2 (3 m×3 m) -18 m	104.6	3.9	10.3
T3 (3.5 m×3.5 m) -15 m	92.4	4.0	8.0
T4 (3.5 m×3.5 m) -18 m	91.4	3.7	8.1

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

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

This intercropping field was established as an intercropping demonstration plot at the RRISL substation in Moneragala. The growth of rubber trees in terms of girth under different planting systems is given in Table 29.

Table 29. *The girth of rubber trees under different intercropping systems and spacing arrangements*

Intercropping system	Spacing of rubber (m)	Girth of rubber (cm)
Rubber x Pineapple	Single row system	59.9
Rubber x Banana	2.5 m x 7.75 m	58.9
Rubber x pomegranate/Guava	Single row system	56.8
Rubber* x pomegranate*/Guava*	2.5 m x 12 m	44.3
Rubber x Cinnamon	Paired row system	60.8
Rubber x Mango/Rambutan	(3 m x 3 m) – 18 m	57.4

*Planted in the year 2012

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

Special Capital Project (22-01-17)

A special capital project was granted in 2018 titled "Intercropping diverse crop plants (medicinal, fruit crops and multipurpose crops) under rubber in non-traditional areas to ensure economically and environmentally sustainable land use practice for rubber cultivation".

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

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

Four fruit crops *i.e.* orange, sour soup (Anoda), Guava and Papaya were planted under rubber with 2.5 m x 7.75 m and 2.5 m x 12.0 m spatial arrangements. Planting of both rubber and fruit crops were done as per the recommendations given by RRISL and the Department of Agriculture. The growth of rubber in terms of basal girth and height after 2 years of planting are shown in Table 30. Growth of intercrops after two years is shown in Table 31.

Table 30. *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)
2.5 m x12.0 m	Sour soup	10.1
	Orange	11.5
	Guava	9.2
	Papaya	9.1
2.5 m x 7.75 m	Sour soup	9.7
	Orange	9.4
	Guava	8.1
	Papaya	8.7

Table 31. *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)
2.5 m x 12.0 m	Sour soup	24.0	3.2
	Orange	16.9	1.7
	Guava	18.3	2.4
2.5 m x 7.75 m	Sour soup	21.1	2.9
	Orange	14.3	1.5
	Guava	21.1	2.5

(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 in Ampara District in 2018. Four fruit crops *i.e.* orange, sour soup, guava and papaya were planted under rubber with the spacing of 2.5 m x 7.75 m. However, establishment rates of fruit crops and rubber were not satisfactory due to the long dry spells that prevailed at the time of establishing rubber and fruit crops (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 in Ampara District to establish intercropping trials with short-term crops. Three short-term crops, *i.e.* thibbatu, thumbakaravila and maize were selected and established under rubber with a 2.5 m x 7.75 m spacing system (T U K Silva, N M C Nayanakantha, H Subasinghe and D Priyadarshana).

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

No visits were made during the period due to restrictions imposed by COVID19 pandemic (N M C Nayanakantha and P D Pathirana).

Intercropping Agarwood with Rubber (IC/AW/2015)

Three Agarwood species *i.e. Gyrinopswalla, Aquilaria crassna* and *Aquilaria subintegra* were established as intercrops under rubber at three different planting systems *i.e.* single row, double rows and planted under natural shade. Growth data were recorded from January to December 2020. In the double row system under full sunlight condition, the highest girth was recorded in *A. crassna* and the highest girth increment was recorded in *A. subintegra* and the lowest was recorded in *G. walla*. In single-row system under full sunlight condition, the highest girth and girth increment were recorded in *A. crassna*. Under natural shading system, the highest girth and girth increment were recorded in *A. subintegra* (Table 32).

Table 32. *Growth attributes of three Agarwood species after 63 months from field planting*

Planting system of Rubber	Agarwood species	Girth of plants (cm)	Girth increment (cm)
Double row	AC	68.9±1.7	3.1±0.3
	GW	30.5±1.2	1.4±0.1
	AS	66.4±1.7	3.3±0.3
Single row	AC	70.4±3.0	3.3±0.2
	GW	24.2±2.2	1.6±0.1
	AS	62.2±2.6	2.0±0.2
Natural shade	AC	43.0±3.4	3.4±0.5
	GW	20.5±4.4	1.3±0.3
	AS	44.2±3.5	3.9±0.7

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

Testing different cinnamon spacings under two spatial arrangements of rubber

One hectare field from the Kuruwita Substation of RRISL was selected to conduct the above trial. The objective of this experiment was to identify the best rubber x cinnamon intercropping system to optimize cinnamon yield throughout the economic lifespan of rubber. Two spatial arrangements of rubber were taken as main treatments and three spatial arrangements of cinnamon were taken as sub treatments. Details of the treatments are given in Table 33.

Table 33. *Main and sub-treatments of rubber and cinnamon*

Main treatment	Sub treatment
Rubber	Cinnamon
(I). 2.5 m x 7.75 m	(I). 0.6 m x 1.2 m
(II). 2.5 m x 12.0 m	(II). 0.9 m x 1.2 m
	(III). 1.2 m x 1.2 m

(T U K Silva, N M C Nayanakantha, P D Pathirana and D Priyadarshana)

NRC Project (Grant No. 18-088)

A research grant was awarded from the 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. One-acre farmer field was selected at Hingurana in Ampara District for the experiment and about 200 rubber plants of RRIC 121 were established in 2018. Plants were imposed with different treatments as shown in Table 34.

Table 34. *Treatments imposed on rubber plants*

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

SNP: Sodium nitroprusside, SA: Salicylic acid, MLE: Moringa leaf extract

Growth and physiological data could not be recorded as planned during the year due to restrictions imposed by COVID 19 pandemic (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. Miss A H N R Aberathne and Mr D A N Mallikaarachchi Technical Officers worked throughout the year. Mrs K A D Y Madushani Lanka, Management Assistant was on duty throughout the year. Mr P L P B Nishantha, Temporary Research Assistant under the Development Project – 23/1/15 resigned from duties with effect from 31st August 2020 and Miss K L K Shehani worked throughout the year 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
Ministry of Plantation Industries **Development Project - 23/1/15**	May 2016 - 2021	Identification of the Potential Pest and Disease Problems of Rubber in Non-Traditional Areas to Develop Improved Management Strategies	20 Rs. Mn.
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.
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.

Research students

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

Name	Duration	University	Project title
MKR Silva (PhD)	2014 - 2019	University of Colombo	A study of the Brown Root Disease of rubber and its causative fungus *Phellinus noxius*
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 Colombo	Screening of selected *Hevea brasilinsis* grown under suboptimal ecological conditions in Sri Lanka against foliar diseases 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 microflora 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 Advisory Committee	Department of Agriculture
THPS Fernando	Pesticide Sub-Committee	Department of Agriculture

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.

Field visits

Purpose	No of visits
Experimental	665
Advisory	93
Other	08
Total	**766**

Advisory visits and training programmes (PP- 08)

The staff of the department made 93 advisory visits mainly to handle complicated disease problems. The 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, S C P Wijayaratne, E A D N Nishantha, A H M N R Aberathne and D A N Mallikaarachchi).

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 Thalgaswala 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

More than fifty White root disease patches were rehabilitated in the following estates. Arappalakanda Estate, Kuruwita Sub-station (nearly 65 patches), Dartonfield estate, Padukka estate, Matuwagala estate, Divithura estate and Keeragala estate. All the infected plants were removed and infected root pieces were burnt *in situ*. Then sulphur sprinkling was carried out to make conditions unfavorable for the growth of the fungus *Rigidoporus microporus*. Later, indicator plants were established (*Gliricidia* & *Cloterlaria*) to trace out any remaining inocula. Pineapple cultivation was established at Galewatta in view of providing an additional income for the grower. The fields were generally maintained and indicator plants were examined for the detection of the disease. The experiments are 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 (23/ 01 /17) **(Table 1)**

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

District	Site	Clone & year of planting	Year of first visit	Owner and Address	Initial infected trees	No of chemical app	Recovery percentage
Kalutara	Kithulgoda	RRIC 121 2012	9/10/20	AP Kolonna Kithulgoda	30	01	100%
	Kithulgoda	RRIC 121 2011/2012	10/7/20	Saminda Bathalahena, Kithulgoda	60	01	100%
	Galpatha	RRIC 121 2014 RP	5/10/20	Dayarathne Galpatha	18	01	100%
	Yattapatha	RRISL 203 2013 RP	14/9/20	Ariyadasa Sirima Udyanaya Yattapatha	75	02	98.6%
	Bellana	RRIC 121 2005 RP 2011 RP	9/10/20	Lal Hapuarachchi Akkara 4, Panadandukanda watta	28	02	100%
	Hedigalla	RRIC 121 2010 RP	5/10/20	MD Dinusha Batagodawita, Hedigalla	75	02	100%

	Pelawatta	RRIC 121	24/1/20	Hasini Hemanthika Palawatta	28	02	100%
	Dodangoda	RRIC 121 2015 RP	20/2/20	Thudugala, Dodangoda	36	02	100%
	Dodangoda	RRISL 203 2018	30/9/20	T Chandralatha Ruwanmaga, Dodangoda	15	02	100%
	Kakillandawatta Remuna	RRIC 121 2014 RP	30/9/20	PLA Premathilake Kakillandawatta Remuna	15	02	100%
	Dodangoda	RRIC 121 2010 RP	2020	KA Vijitha Lakmal No.55, Dolalanda, Dodangoda	13	02	100%
	Horana, Uduwa	RRIC 121 RRISL 2001 2017 RP	2020	Amarasekera Haputhanthri Horana	30	02	100%
Galle	Pitigala	RRISL 203 2013 RP	20/7/20	Leelawathi Pitigala	30	02	100%

(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)

Chemical controlling to stop further spread of new leaf fall disease in rubber plantations

The preliminary investigations on the chemical controlling trials were conducted with the assistance of the stakeholders (Table 2a & b). The chemical controlling trials will be commenced from the beginning of 2021.

Table 2a. *Chemical controlling activities of new leaf disease on estates under RPCs Plantation Companies*

District	Extent (ha)	Estate	Extent (ha)	Action undertaken
Ratnapura	150	Keeragala	25	Spraying carried out
		Palmgarden	22	Spraying carried out
		Rambukkanda	35	Spraying carried out
		Galatura	Mild	Visited and instructed
		Peenkanda	20	Spraying carried out (partially)
		Kiribathgala	25	Visited and instructed
		Hapugastenna	23	Spraying carried out (partially)
		Sunderland	10	Visited and instructed
Kalutara	60	Hilstream	30	Spraying carried out
		Uskvally	15	Spraying carried out
		Mohamadi	15	Spraying carried out
		Dartonfield	Mild	Spraying carried out
		Lavent	20	Spraying carried out

District	Extent (ha)	Estate	Extent (ha)	Action undertaken
Kegalle		Urumeewala	10	Spraying carried out
		Enderapola	15	Spraying carried out
Galle		Thalgaswala	20	Spraying carried out

Table 2b. *Chemical controlling activities of new leaf disease under Small & Medium holder sectors*

District	Reported extent (ha)	Action (s) undertaken
Kalutara	200	Spraying carried out (partially)
Ratnapura	120	Spraying carried out (partially)
Kegalle	01	Visited and instructed

(T H P S Fernando, M K R Silva with all the staff of the department)

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

Data collection of the collaborative adaptability trial in Polgahawela to evaluate the chemical repellent for the smallholder conditions in the intermediate zone was temporarily discontinued due to covid-19 condition in the country (M K R Silva, B M D C Balasooriya, T H P S Fernando, B I Tennakoon-PP & MB collaboratively with Adaptive Research Unit).

Tree injection against White root disease - Vogan estate

Based on the previous results new experiments are to be carried out to confirm the observations. This operation could not be continued due to covid-19 condition in the country (T H P S Fernando and S C P Wijayaratne).

Chemical control of the Brown root disease

Screening of potential fungicides was carried out as *in vitro* trials, as pot experiments (in polybags) and as field experiments.

***In vitro* screening of the potential fungicides**

Three potential fungicides namely: tebuconazole (Folicur, 250 EW, Bayer), hexaconazole (Hayzole, 50 EC, Hayleys) and propiconazole (Propiconazole, 50 SL, Hayleys) were tested *in vitro* for their efficacy against *P. noxius* (isolate number 9) under two laboratory techniques: poisoned food technique (PFT) and soil fungicide screening test (SFST). A completely randomized design with four replicates was adopted and both tests were carried out at four fungicide concentrations. The analysis of variance of the diameter reduction values over the control at different concentrations of the three fungicides (at the SFST trial) was carried out using the

statistical software SAS ver. 9.2. Subsequently, mean separation was done with Duncan's Multiple Range Test (DMRT).

Under the PFT, with all three fungicides, the fungus could not grow at concentrations as low as 0.1ppm. Moreover, in all the treatments, the pathogen was unable to resume its growth when the inoculum disk was replaced on the growth medium in the Petri plate. Under the SFST, the three fungicides showed a significant variation in the diameter reduction of the fungus values at four concentrations of the fungicide (Table 3).

Table 3. *Effect of fungicide and concentration on* P. noxius *growth* in vitro

Fungicide	**The percentage of inhibition of the fungus over the control (cm) at different concentrations of the fungicide (ppm)***			
	0.1	0.5	1	2
Tebuconazole	33.16[a]	55.71[a]	77.66[a]	100.00[a]
Hexaconazole	22.34[b]	44.42[b]	66.97[b]	89.04[b]
Propiconazole	0.00[c]	2.34[c]	13.32[c]	33.60[c]

*Values in the same column followed by the same letters are not significantly different at DMRT at P=0.05

According to the results, all three fungicides resulted in a diameter reduction of the fungus *Phellinus noxius*. In all concentrations, the highest and lowest diameter reduction have been observed with Tebuconazole and Propiconazole, respectively and at each concentration, the diameter reduction was significantly different in three fungicide treatments. Tebuconazole showed total inhibition of the fungus at the concentration of 2 ppm.

Screening of the potential fungicides under poly bag conditions

Seedlings planted in polybags were used to determine the effect of selected fungicides: tebuconazole and hexaconazole on disease control and twenty seedlings were used for each treatment. For the inoculation of the seedlings, an artificial inoculation medium comprised of rice bran and sawdust (1:2 w/w) with 15% moisture (w/w) was prepared. Three months old rubber seedlings were artificially inoculated by incorporating 100 g of the inoculated medium into the potting medium to have contact with the collar region of each seedling. Two months after the inoculation, the respective fungicide treatment was carried out and for each pot in the treatments and a repetitive application was carried out three months after the first application. The treatments applied are summarized in Table 4.

Table 4. *Details of the treatments used in the experiment*

Treatment No	Fungicide	Fungicide/ plant (ml)	Grams of active ingredient/plant
1	Tebuconazole (Folicur, 250 EW)	2.5	0.625
2	Tebuconazole (Folicur, 250 EW)	5	1.25
3	Hexaconazole (Hayzole, 50 EC)	12.5	0.625
4	Hexaconazole (Hayzole, 50 EC)	25	1.25

Two months after the second fungicide application, a disease rank was assigned to each seedling from 0 to 3 for each tree based on the level of root and foliar symptoms. The disease level recorded as ranks were subjected to the General Linear Model analysis in order to find out the variability among the different chemical treatments.

According to the mean disease ranks of both foliar and root symptoms, the two fungicides have shown a significant variation in the effectiveness over the disease. Tebuconazole has shown a significantly lower mean disease rank over hexaconazole according to both foliar and root symptoms at the probability level 0.001 (Table 5).

Table 5. *Effect of fungicide on mean disease rank under poly bag conditions*

Fungicide	Mean disease rank	
	Foliar	Root
Tebuconazole	0.07500[a]	0.12500[a]
Hexaconazole	2.10000[b]	2.25000[b]

*Values in the same column followed by the same letters are not significantly different at DMRT at P=0.001

However, the two concentration levels of the fungicides 0.625 g of a.i./plant and 1.25 g of a.i./plant have not shown a significant variation in the effectiveness over the disease at P=0.001. Tebuconazole at the concentration of 1.25 g of a.i./plant has resulted in total inhibition of disease (according to both foliar and root symptoms). Moreover, a significant interaction effect was not observed between the fungicide and the concentration at both foliar and root mean score values.

Screening of potential fungicides under field conditions

Lower concentrations of the two fungicides: tebuconazole and hexaconazole were tested at five locations, as none of the trees under the earlier-used higher concentration treatments did exhibit disease symptoms. The new treatments used were tebuconazole (Folicur 250 EW), in 0.625 g of a.i./plant concentration, and in 1.25 g of a.i./plant concentration, hexaconazole (Hayzole 50 EC) in 0.625 g of

a.i./plant concentration and in 1.25 g of a.i./plant concentration. Three trials were carried out in four, five and six-year-old clearings at Galagedara, Sri Lanka (IL1a) while the other two were in five and six-year-old clearings at Badalkumbura (IM2b). At each site, approximately 12 to 18 trees were used per treatment. The initial infection level was assessed and a rank was assigned from 0 to 3 for each tree based on the level of foliar symptoms. Thereafter, the respective treatment was carried out and a repetitive application was carried out three months after the first application. After two months of the second fungicide application, the disease infection level of each tree was assessed and a rank was assigned for each tree. The disease level recorded as ranks was subjected to the General Linear Model analysis in order to find out the variability among the different chemical treatments.

As shown in the mean disease rank, the two fungicides and the two concentrations have shown a significant variation in the effectiveness over the disease (Table 6). Moreover, an interaction effect was observed between the fungicide and the concentration. At both concentrations, tebuconazole has shown a significantly lower mean disease ranks over hexaconazole (Table 15).

Table 6. *Effectiveness of the fungicides measured as mean disease rank*

Fungicide	**Mean disease rank at different concentration levels**	
	0.625 g of a.i./plant	**1.25 g of a.i./plant**
Tebuconazole	0.46667^{a}	0.06494^{a}
Hexaconazole	2.18667^{b}	1.35065^{b}

*Values in the same column followed by the same letters are not significantly different (α=0.001)

(M K R Silva, T H P S Fernando, B I Tennakoon and Nadeeshani Abeyrathne)

Biology of pests (23/P/02)

***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 7). The gaps of knowledge in view of improving the management strategies of white root disease were also reported (T H P S Fernando, S C P Wijayaratne and A Mallikarachchi).

Studies on the biology and molecular biology of pests

***Comparison of the morphological and physiological characters of* Rigidoporus microporus *and* Phellinus noxius**

Four *P. noxius* isolates (with significant variation of the morphological and physiological characters) were compared with four *Rigidoporus microporus* isolates. In each experiment on the comparison of morphological and physiological features of the two pathogens: growth rate on different culture media, the effect of temperature,

pH and light on the growth of the two pathogens, the relevant parameters were subjected to ANOVA and the mean separation was done with Least Significant Difference (LSD). Moreover, the growth rate variation of each pathogen with the change of the parameters: culture media, temperature and pH was also subjected to ANOVA and subsequently to the mean separation with Duncan Multiple Range Test (DMRT)/Least Significant Difference (LSD). The growth rate variation of each pathogen with the change of the light level was analyzed with the pooled t-test.

Table 7. *WRD survey concerning the spread with 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	√
Delkith estate	√	Arappolakanda estate	√
Raigam estate	√	Vogan estate	√
Rathnapura	√	Kalvariya estate	√
Elapatha (SH)	√	Maggona	√
Matuwagala estate	√		

Comparison of the growth rate and the effect of culture media on the growth

The growth of the isolates of the two pathogens was compared on four culture media; Potato dextrose agar (PDA), Czapec-dox agar (CDA), Malt extract agar (MEA) and Lima bean agar (LBA). The growth rates of the isolates of *R. microporus* and *P. noxius* on four tested growth media are shown in Table 8.

Table 8. *Mean growth rates of the isolates of* R. microporus *and* P. noxius *on different growth media*

Pathogen species	Mean growth rate on different growth media*			
	CDA	LBA	MEA	PDA
Phellinus noxius	1.6505^{a}	1.6265^{a}	1.8707^{a}	1.5020^{a}
Rigidoporus microporus	1.3822^{b}	1.3328^{b}	1.2518^{b}	1.2750^{b}

*Note: Values in the same column followed by the same letters are not significantly different at α=0.001

In all four growth media, the growth rate of *Phellinus noxius* is significantly higher than that of *Rigidoporus microporus* (P=0.001), while significant within-pathogen variations in the growth rate were observed between the different culture media by both *P. noxius and R. microporus.* In *P. noxius* the growth rate was

significantly higher on MEA than that on other media (P=0.001), while in *R. microporus*, the growth rate was significantly higher on CDA and LBA than that on two other media (P=0.05). On MEA, the studied isolates of *R. microporus* showed a growth rate ranging from 1.02 to 1.52 cm/day whereas the value ranged from 1.2 to 2.2 cm/day in *P. noxius*.

Comparison of the effect of temperature on the growth

The effect of temperature on the mycelial growth of the two pathogens was compared on MEA under dark conditions (Table 9). Inoculated Petri plates were placed at 5, 10, 15, 20, 25, 30, 35 and 40 ^{0}C under incubator conditions. Four days after the inoculation, the colony diameter was measured along two perpendicular axes and the rate of growth under each temperature was compared. Those that didn't grow even after 10 days of incubation were moved to room temperature and their ability to resume the growth was determined.

Table 9. *Mean growth rates of the isolates of* R. microporus *and* P. noxius *under different temperature regimes*

Pathogen species	**Mean growth rate under different temperature regimes***						
	5 ^{0}C	15 ^{0}C	20 ^{0}C	25 ^{0}C	30 ^{0}C	35 ^{0}C	40 ^{0}C
Phellinus noxius	NG	0.1578^a	0.7804^a	1.4320^a	1.8007^a	2.1859^a	NG
Rigidoporus microporus	NG	0.1023^b	0.4789^b	0.9125^b	1.3609^b	0.7945^b	NG

*Note: Values in the same column followed by the same letters are not significantly different at α=0.001: NG- No growth

Between 15 ^{0}C to 35 ^{0}C, with the change of temperature, the growth of the tested isolates of *P. noxius* and *R. microporus* was significantly different at all the tested temperatures (P=0.001). Moreover, significant within-pathogen variations in the growth rate were shown between the different temperature regimes by the two pathogens *P. noxius and R. microporus.* In *P. noxius,* the highest growth rate (significantly different from the others at P=0.001) was observed at the temperature 35 ^{0}C, while in *R. microporus*, the highest growth rate (significantly different from the others at P=0.001) was observed at the temperature 30 ^{0}C.

Comparison of the effect of pH on the growth

To compare the effect of pH on the growth of the two pathogens, colony growth was studied in 300 ml flasks containing 30 ml of Malt Extract broth (ME broth). After autoclaving the growth medium, by adding either 1N HCl or 1N KOH, the pH value of the broth in each set of flasks was adjusted from 3-8. Thereafter, two agar disks (9 mm diameter) cut with a sterile cork borer from the periphery of the colony of each isolate were placed into each flask and the inoculated flasks were incubated at RT under dark conditions. After 6 days of incubation, the mycelial mats

were harvested by filtering and dried at 80 ^{0}C until a constant weight has resulted. The growth rates of the tested isolates of *R. microporus* and *P. noxius* under different pH levels are shown in Table 10.

Table 10. *Mean growth rates of the isolates of* R. microporus *and* P. noxius *under different pH levels*

Pathogen species	Mean growth rate under different pH regimes*					
	3	**4**	**5**	**6**	**7**	**8**
Phellinus noxius	NG	0.3500^a	0.6500^a	0.9600^a	0.4350^a	NG
Rigidoporus microporus	NG	0.0735^b	0.1640^b	0.2330^b	0.3985^a	0.2310^b

Note: Values in the same column followed by the same letters are not significantly different at α=0.0001; NG- No growth

Though none of the isolates of *Phellinus noxius* could grow at pH levels higher than 7, in *R. microporus* a growth occurred when the pH was increased to 8. In *P. noxius* and *R. microporus*, the optimum growth was at pH 6 and 7, respectively. However, the mean growth rates of the two pathogens were significantly different at the pH level of 6, while the values are not significantly different at the pH level of 7 (P=0.0001). Moreover, significant within-pathogen variations in the growth rate were shown between the different pH levels by both *P. noxius and R. microporus.* In *P. noxius*, the growth rate was significantly different among all pH levels nevertheless the no-growth condition at the pH levels 3 and 8 (P=0.001), while in *R. microporus*, the growth rate was significantly different among all tested pH levels (P=0.0001).

Comparison of effect of light on the growth

The effect of light on the mycelial growth of the pathogen isolates was compared on MEA. Inoculated plates were incubated at RT under two light regimes: 24 h dark and normal day and light regimes. Normal day and light regime experiment was performed using a glass incubation chamber and the plates incubated under continuous dark were covered with aluminum foil and placed in an incubating chamber lined with black polythene. Four days after the inoculation, the colony diameter was measured along two perpendicular axes and the rate of growth under each light and dark regime was compared. The growth rates of the isolates of *R. microporus* and *P. noxius* under light and dark regimes are shown in Table 11.

Table 11. *Mean growth rates of the isolates of* R. microporus *and* P. noxius *under light and dark regimes*

Pathogen species	Mean growth rate under different light regimes*	
	Light	Dark
Phellinus noxius	1.5600[a]	1.8975[a]
Rigidoporus microporus	1.0700[b]	1.2518[b]

Note: Values in the same column followed by the same letters are not significantly different at α=0.0001

At both light and dark regimes, the isolates of *Phellinus noxius* has shown a significantly higher mean growth rate (P=0.0001). Anyway, both fungi grew well under dark conditions. Moreover, within-pathogen variations in the growth rate were shown between the different light levels by *P. noxius* and *R. microporus.* In *P. noxius*, the growth rate was not significantly different between the two light regimes (t=8.2; P=0.001). In *R. microporus,* the growth rate was significantly different between the two light regimes (t=6.55; P=0.001) (M K R Silva, T H P S Fernando, B I Tennakoon and Nadeeshani Abeyrathne).

Comparison of the enzyme production by the two pathogens: **Rigidoporus microporus *and* Phellinus noxius**

The abilities of the two pathogens: *R. microporus* and *P. noxius* (isolate 9 of *P. noxius* and isolate Rm 1 of *R. microporus*) on the production of pectolytic, cellulolytic enzymes and laccases along with the temporal patterns of the enzyme production were compared.

Production of pectinolyic enzymes

Among pectinolytic enzymes, the production of two enzymes namely: Pectin lyase - PL (thiobarbituric acid method) and Polygalacturonase - PG (agar plate method and the viscosity reduction method) were assayed by the two pathogens. The PL production of the two tested isolates of *R. microporus* and *P. noxius* showed differences throughout the incubation period (Fig. 1).

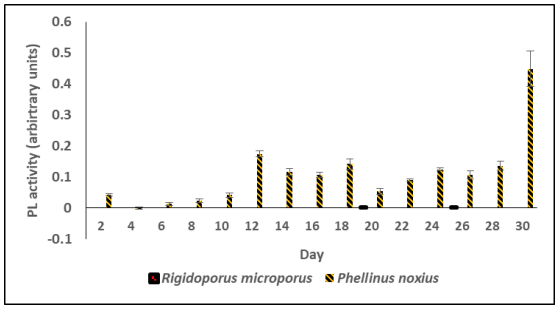


Fig. 1. Production of pectin lyase by *R. microporus* and *P. noxius*

In *P. noxius*, the PL production showed peaks at the 12th day and 30th day of incubation *R. microporus* showed no PL production during the incubation except for low PL production of 0.002 and 0.001 at day 20 and day 26, respectively. Moreover, the PL production of *R. microporus* was significantly lower than that of *P. noxius* at all incubation intervals (P=0.001).

When assayed with the cup plate method, the PG production of the two tested isolates of *R. microporus* and *P. noxius* was drastically different during the incubation period. In *P. noxius*, a PG production was present throughout the incubation with two peaks at the 10th day and 28th day of incubation (of clear zone diameter 1.4 cm and 1.1 cm, respectively). *R. microporus* showed no PG production throughout the incubation period. In accordance with the above observation, the assay method of viscosity reduction reported significant differences in PG production (Fig. 2).

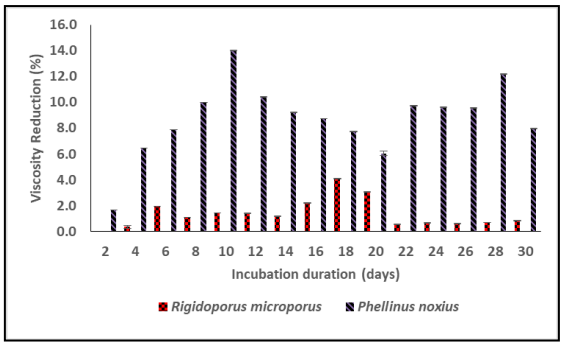


Fig. 2. Production of polygalacturonase by *R. microporus* and *P. noxius* (when assayed with the viscosity reduction method

In *P. noxius*, the PG production again showed peaks at the 10th day and 28th day of incubation while the PG production of *R. microporus* was significantly lower than that of *P. noxius* at all incubation intervals (P=0.001). On the 10th day of incubation, the percent viscosity reduction was 14.0308 and 1.4348 for *P. noxius* and *R. microporus* respectively while the above values were 12.1733 and 0.6705 respectively at the 28th day of incubation (the value for the respective day are significantly different for *P. noxius* and *R. microporus* when P=0.001).

Production of cellulolytic enzymes

The colour intensity developed due to the liberation of phenate ions was estimated at 403nm using UV visible spectrophotometer and the enzyme activity was expressed arbitrarily as the degree of absorbance. The production of cellobiase enzymes of the two tested isolates of *R. microporus* and *P. noxius* was different throughout the incubation period (Fig. 3).

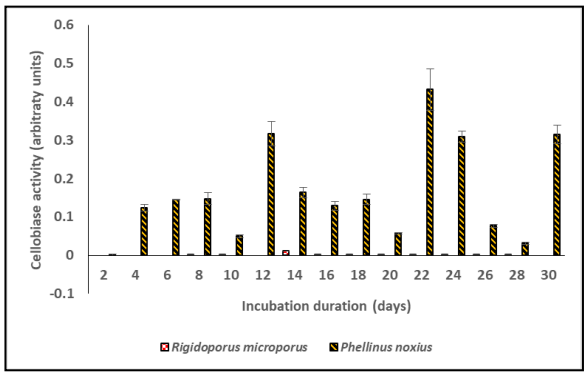


Fig. 3. Production of cellobiase by *R. microporus* and *P. noxius*

The cellobiase production of *R. microporus* was significantly lower than that of *P. noxius* at all incubation intervals (P=0.001). In *P. noxius*, the cellobiase production showed peaks at the 12th day, 22nd day and 30th day of incubation. On the 12th day and 30th day of incubation, *R. microporus* showed no cellobiase production. On the 22nd day of incubation, the mean values for the cellobiase enzymes production were 0.4300 and 0.000250 for *P. noxius* and *R. microporus*, respectively and the value of *P. noxius* is significantly higher than that of *R. microporus* at P=0.001. The production of β- glycosidase was also different in *R. microporus* and *P. noxius* (Fig. 4).

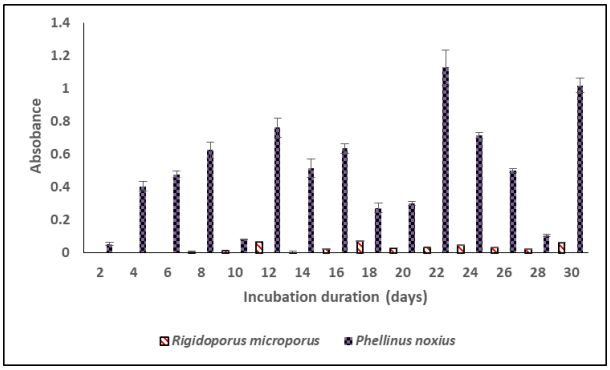


Fig. 4. Production of β- glycosidase by *R. microporus* and *P. noxius*

At all incubation intervals, the cellobiase production of *R. microporus* was significantly lower than that of *P. noxius* (P=0.001). In *P. noxius*, the β- glycosidase production showed peaks at the 12th day, 22nd day and 30th day of incubation. On the 12th day of incubation, the β- glycosidase production was 0.7648 and 0.07000 for *P.*

noxius and *R. microporus*, respectively while the above values were 1.1295 and 0.03175, respectively on the 22nd day of incubation. On the 30th day of incubation, the β- glycosidase production was 1.0178 and 0.06500 for *P. noxius* and *R. microporus* respectively (the values for the respective day are significantly different for *P. noxius* and *R. microporus* when P=0.001).

Production of laccases

When assayed using the colorimetric method, at all incubation intervals, the laccase production of *R. microporus* was significantly higher than that of *P. noxius* (P=0.001) (Fig. 5).

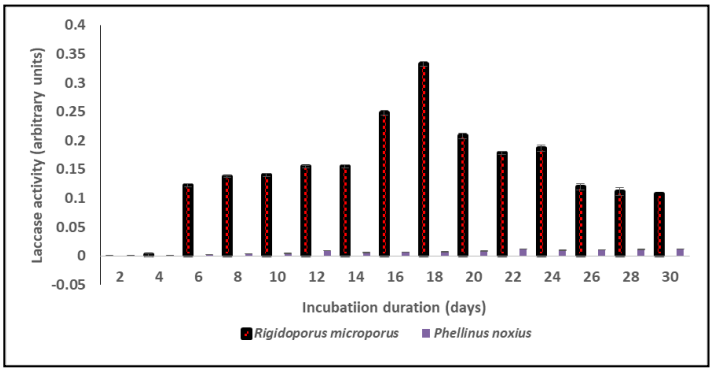


Fig. 5. Production of laccase by *R. microporus* and *P. noxius*

On the 18th day of incubation, where the laccase production of *R. microporus* showed a peak, the mean values were 0.3320 and 0.007250 for *R. microporus* and *P. noxius* respectively (M K R Silva, T H P S Fernando, B I Tennakoon and N Abeyrathne).

Comparison of the disease management aspects of the two diseases: White root disease and the brown root disease

Management with inorganic fungicides

In vitro screening of the fungicides: tebuconazole (Folicur, 250 EW, Bayer) and hexaconazole (Hayzole, 50 EC, Hayleys) was performed using the poisoned food technique (PFT) against one high pathogenic isolate from each pathogen. A series of concentrations: 0.1, 5, 10, 25, 50, and 100 ppm, was used to identify the effective range of the respective fungicide towards the two pathogen species. Percent inhibitions of growth in each of the treatments were calculated with respect to the control. The results were subjected to ANOVA and subsequently to the mean separation with Duncan Multiple Range Test (DMRT). The variation of percentage

inhibition of the two fungi at different concentrations of tebuconazole, is shown in Table 12.

Table 12. *Variation of percentage inhibition of the two fungi on tebuconazole*

Pathogen species	The percentage of inhibition of the fungus over the control at different concentrations of the fungicide (ppm)*					
	0.1	**5**	**10**	**25**	**50**	**100**
Phellinus noxius	100.0[a]	100.0[a]	100.0[a]	100.0[a]	100.0[a]	100.0[a]
Rigidoporus microporus	0.0[b]	36.2[b]	88.5[b]	100.0[a]	100.0[a]	100.0[a]

*Note: Values in the same column followed by the same letters are not significantly different at α=0.05

At the poison food technique on screening of the tebuconazole against the two pathogens, *P. noxius* showed no growth at any of the tested concentrations. However, *R. microporus*, exhibited a certain growth up to the 10 ppm concentration. Though no growth was observed above the concentration of 25 ppm, *R. microporus* could resume its growth when the fungal disk was transferred back to MEA. However, when exposed to the concentrations 50 ppm or above, it could not resume its growth after the fungicide treatment.

The variation of percentage inhibition of the two fungi at different concentrations of hexaconazole is shown in Table 13.

Table 13. *Variation of percentage inhibition of the two fungi on Hexaconazole*

Pathogen species	The percentage of inhibition of the fungus over the control at different concentrations of the fungicide (ppm)*					
	0.1	**5**	**10**	**25**	**50**	**100**
Phellinus noxius	100.0[a]	100.0[a]	100.0[a]	100.0[a]	100.0[a]	100.0[a]
Rigidoporus microporus	0.0[b]	8.5[b]	34.7[b]	100.0[a]	100.0[a]	100.0[a]

With hexaconazole too, *P. noxius* showed no growth at any of the tested concentrations while, *R. microporus* was able to grow under the concentrations below 25 ppm. Though it exhibited no mycelial growth thus attained the total inhibition at the concentration of 25 ppm, a slight growth of the fungus was observed on inoculated discs at the 25 ppm concentration. However, even at the 100 ppm concentration, it could resume its growth when transferred back onto poison-less MEA.

Management with antagonistic fungi

Six prospective-antagonistic fungal isolates obtained from the soil samples collected from rubber rhizosphere in different rubber growing areas of Sri Lanka were

tested against one isolate from each pathogen. The antagonistic ability was tested with the dual plate culture technique and the percentage inhibition of radial growth (PIRG) was calculated. PIRG of six prospective antagonistic fungal species against the two pathogens are shown in Figure 6.

R. microporus has shown a comparatively higher percentage inhibition of radial growth towards all the six tested antagonistic fungal species. Except for the percentage inhibition by AF4, the percentage inhibition values by all the other fungal species were significantly different between *P. noxius* and *R. microporus* (P=0.001). The mean PIRG value shown by six fungal species against *R. microporus* ranged from 68.0 to 88.6 whereas the value ranged from 2.9 to 72.2 against *P. noxius.* However, the highest mean PIRG value for both fungi was shown by the antagonistic fungal species AF4.

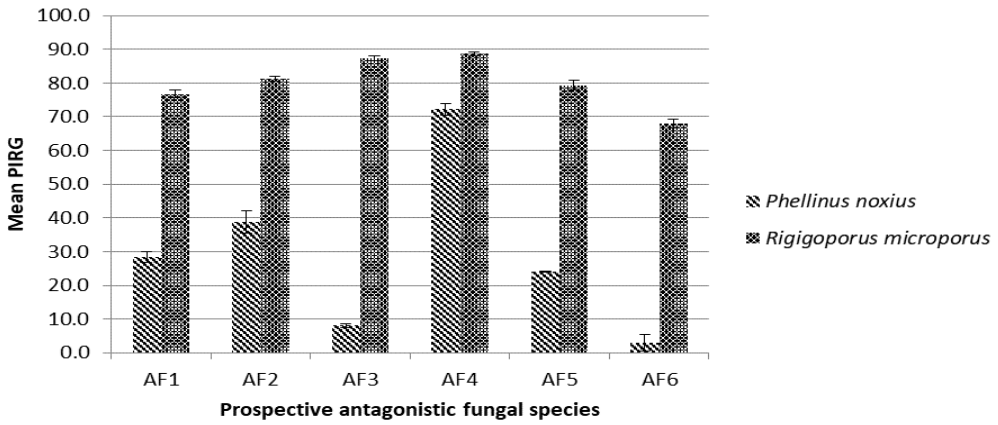


Fig. 6. Comparison of the mean PIRG values of six prospective antagonistic fungal species against the two pathogens

Management with antagonistic plants

The antagonistic ability of the diethyl ether extracts of four prospective antagonistic plant species: Galangalee (*Alpinia galanga*), Wild ginger (*Curcuma xanthorrhiza),* Ginger (*Zingiber officinale*) and Garlic *(Allium sativum* were compared against the two pathogens (isolate 9 of *P. noxius* and isolate Rm 1) of *Rigidoporus microporus* in Poisoned Food Technique (PFT). Diethyl ether extracts of freshly uprooted underground parts of the four respective antagonistic plants were prepared and finally, the percent inhibitions of growth in each of the treatment were calculated. The percentage inhibition values of the four prospective antagonistic plant species against the two pathogens are shown in Fig. 7.

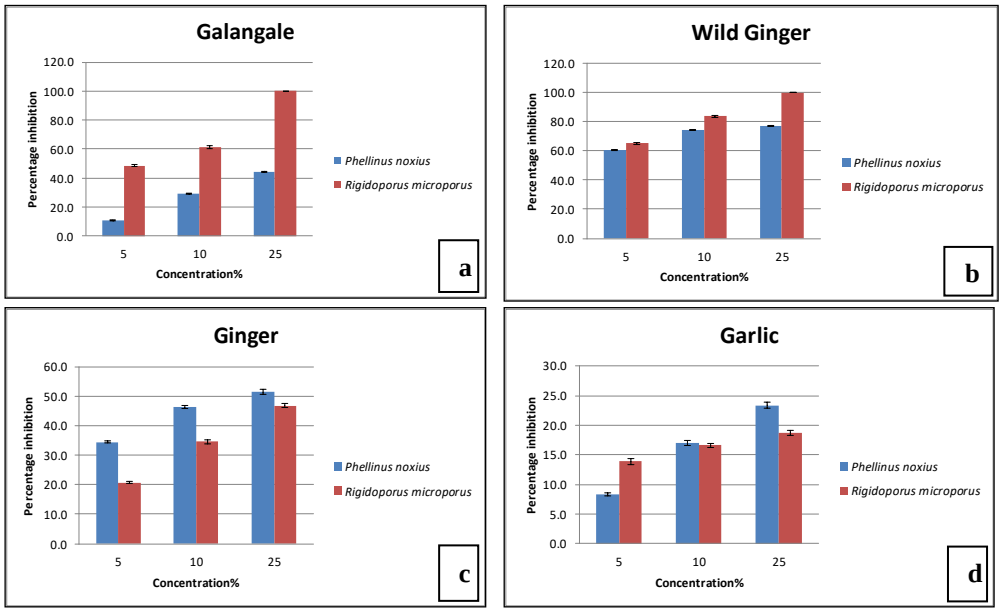


Fig. 7. Percentage inhibition values prospective antagonistic plant species against the two pathogens: **a)** *Alpinia galanga* (Galangale) **b)** Wild ginger (*Curcuma xanthorrhiza*) **c)** Ginger (*Zingiber officinale)* **d)** Garlic (*Allium cepa*)

Among the four species used, wild ginger (*Curcuma xanthorrhiza)* has shown an above-fifty percentage inhibition even at 5% concentration level towards both pathogens, while the percentage inhibition had attained 100% and 77.2% at 25% concentration against *R. microporus* and *P. noxius*, respectively. However, though *P. noxius* exhibits a low percentage inhibitory effect of 44.3% at 25% concentration, *R. microporus* had attained 100% inhibition by the same percentage of galangale (*Alpinia galanga*). At the 25% concentration, ginger has shown a moderate level (51.4% and 46.8125% for *P. noxius* and *R. microporus*, respectively) of percentage inhibitory effect against both pathogens. Garlic *(Allium cepa*) has shown the lowest inhibition rate of less than 25% even at the 25% concentration for both pathogens (M K R Silva, T H P S Fernando, B I Tennakoon and N Abeyrathne).

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 2020. The screening programme was not undertaken due to Covid condition (T H P S Fernando, E A D N Nishantha and E A D D Siriwardena).

Maintenance of nurseries for screening purposes

The below nurseries were established consisting of test clones in different climatic locations. The clones established RRIC 100, RRIC 102, RRIC 121, RRIC 130, PB 217, PB 28/59, RRIC 117, RRIC 133, RRISL 201, RRISL 202, RRISL 203, RRISL 205, RRISL 206, RRISL 211, RRISL 215, RRISL 217, PB 235, PB 260, BPM 24, RRISL 200, RRISL 204, RRISL 208, RRISL 218, RRISL 220, RRISL 221, RRISL 222, RRISL 226, GPS 1, PB 255, PR 255, RRII 105, RRISL 2000, RRISL 2001, RRISL 219.

Maintenance of nurseries for screening purposes - Ratnapura District

Fifty *Hevea* clones were re-established at the Kuruwita substation Ratnapura for clonal evaluation against leaf fall diseases (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 leaf fall diseases. Details are given above.(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 leaf fall diseases. Details are given above (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 leaf fall diseases. Details are given above (T H P S Fernando, M K R Silva, E A D D Siriwardena and A Mallikarachchi: 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 leaf fall diseases. Details are given above (T H P S Fernando, M K R Silva, B I Tennakoon: Funded by Development Project 23/1/15).

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 2021 (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 P 23/1/15)

Activities done under this project are listed below.

- Rubber growing areas in different agro-climatic zones of non-traditional areas were traced.
- Two Research Assistants were recruited and trained.
- A questionnaire was prepared to survey in Uva province to find potential Pests and Diseases.
- Sites have been selected for clonal screening nurseries in Padiyathalawa/Monaragala and Dartonfield and Rathnapura. The establishment of all the clones list the clones has been completed.
- Disease samples were collected from rubber and other intercrops in non-traditional rubber growing areas, Symptoms were recorded. Pathogens have been detected. Publications are being prepared to educate the growers on the identification and management of the diseases.
- Establishment of clearings (for disease screening) consisting of ten clones list the clones (six clearings); each clone consisting of 50 replicate trees.

Selected sites

Site	Ownership
Kandakaduwa Farm, Polonnaruwa	Army Camp (not properly maintained by the camp)
Padiyathalawa	Rubber Development Department premises
Anuradhapura	Mr Weerasekara, Pussiyankulama, Anuradhapura
Vavuniya	KPK Jayaweera, Bogaswewa, Vavuniyawa
Monaragala	TM Jayathilaka, Kukul Katuwa, Hambegamuwa
Dartonfield Estate	Reference cultivation

(T H P S Fernando, P Senevirathne, M K R Silva, B I Tennakoon, E A D D Siriwardena and 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

Development of strategies to combat the new leaf fall disease spreading in Sri Lankan rubber plantations

In July 2019, it was reported that a new leaf fall disease is spreading in Sri Lanka caused by two fungi namely *Colletotrichum* and *Pestalotiopsis* sp. The first epidemic of this disease had been reported from Malaysia 2017 – 2018. Later, the disease spread to Indonesia, India, Thailand devastating many rubber clones. It has

been reported from Indonesia that severe infections of this disease because leaf fall up to 100% and have the potential to reduce latex yield up to 30%. This leaf fall disease was first reported in Sri Lanka in July 2019. Based on a brief survey, by the end of 2020, around 10,000 ha are severely affected by this disease and another 10,000 ha show a mild infection level. Immediate actions were made to educate the Extension staff and the growers to identify the disease. After preliminary investigations, interim recommendations have been made for chemical controlling to stop the further spread of the disease. Moreover, a detailed research programme is needed to improve the knowledge on this new disease as no literature is available in any rubber growing country. The causative agents, their involvements in the disease development, the biology and the epidemiology of the pathogen, and the life cycles of the pathogens are needed to be well studied to formulate effective disease management protocols. Moreover, with the above knowledge, we would be able to formulate the identification of effective management strategies and disease-resistant clones if there are any. Development project proposals were forwarded submitted for 2021.

A number of disease samples were studied and the symptoms were illustrated to assist the growers in the identification of the disease (Fig. 8). The pathogens were isolated and revealed that there were mainly two micro-organisms groups. They are *Colletrotrichum* spp. and *Pestalotiopsis* spp. Several new *Colletotrichum* species have been detected while *Pseudopestalotiopsis* spp. and *Neopestalotiopsis* spp. too were present. A representation of isolates from all the rubber growing areas should be included in the study. Based on current observations interim recommendations were made to stop the further spread of the disease. (T H P S Fernando, M K R Silva, B I Tennakoon, E A D D Siriwardene, S C P Wijayaratne, E A D N Nishantha, A H M N R Aberathne and D A N Mallikaarachchi).

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

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

This study aimed to isolate and identify indigenous antagonistic microbes against WRD of rubber from different rubber growing agro-climatic areas, identify possible antagonists, understand their mechanisms, mass propagation of the antagonists test under field conditions in view of introducing a bio-pesticide suitable for commercial adaptation. Furthermore, the possibility of employing antagonistic plants for the management of the disease was identified. WRD caused by *Rigidoporus microporus* can be controlled by applying antagonistic fungi namely *Trichoderma* spp. *Penicillium* spp. and *Aspergillus* spp. The dual plate culture test indicated that five *Trichoderma* species were effective to show more than 65% inhibition against *R. microporus*. These included *T. hamatum, T. koningii, T. spirale, T. ghanense* and the teleomorph of *T. harzianum* (*Hypocrea lixii)* in DNA sequencing data after processing from Macrogen, Korea. Talc based formulation of *Trichoderma* isolates is the best one to control the pathogen, compared to compost-based media. Due to the bulkiness and handling difficulties of the compost-based media, talc-based media is an environmentally friendly and low-cost substitution to compost. The overall objective was to investigate biological control measures to develop integrated disease management strategies to irradicate white root disease of rubber plants.

Fungal isolates obtained from rubber growing soils

Initially, eighty fungal isolates were made from soil samples collected from different rubber growing soil. Soil pH varied between 4 to 6.7 (Table 13). In this study, the highest pH value was recorded in the Vavuniya district (6.68875) while the lowest value was recorded at Kalutara district *Pueraria* growing rubber land (4.6475). The observed organic carbon content in a few selected sites was found less than 2%, which needs proper soil management practices including appropriate organic matter or crop residue management. The higher moisture content was recorded in Kalutara district (22.7415%) while the lowest value was recorded at Polonnaruwa district (2.1204%).

Table 14. *Collection of potential fungal isolates from different rubber growing soils*

Location	cover crop	Soil pH	Moisture content%	Organic Carbon%	Isolate codes
Polonnaruwa Site 1	Absent	5.9	4.37	1.85	Isolate 1
Polonnaruwa Site 2	Absent	6.4	2.12	1.70	Isolate 2
Polonnaruwa site 3	Absent	6.4	4.83	1.68	Isolate 3 Isolate 4

Location	cover crop	Soil pH	Moisture content%	Organic Carbon%	Isolate codes
Kalutara	Present (*Mucuna*)	4.7	22.74	4.39	Isolates 5,6, 7,8,9
Kalutara	Present (*Pueraria*)	4.6	19.72	4.05	
Rathnapura	Present (*Mucuna*)	4.7	17.89	3.47	Isolates 10,11
Rathnapura	Present (*Pueraria*)	4.9	14.00	3.20	
Ampara	Absent	6.1	3.29	1.87	Isolates 12, 13,14,15, 16,17,18,19
Monaragala	Present (*Mucuna*)	5.2	6.06	2.73	Isolates 20,21,22
Monaragala	Present (*Pueraria*)	5.2	4.53	2.22	
Vavuniya	Absent	6.7	2.20	1.18	Isolate 23

Fungal culture

Twenty-three isolates were obtained from Kalutara, Ampara, Vavuniya, Rathnapura, Polonnaruwa, Monaragala districts including 4 *Aspergilus* sp., 13 *Trichoderma* sp., 1 *Penicilum* sp. and 5 unknown isolates. White root disease was found in the rubber tree plantation in Kalutara where the climate is suitable for this disease.

Identification of fungal isolates

The isolates produced irregular or circular colonies with filiform/entire or undulate types of margin. Sixteen isolates except for isolates 2,4,5,8,9,11 and 22 were characterized by flat elevation. Some isolates formed flat pustules in concentric rings. *Trichoderma* isolates conidial colour was altered from white to varying shades of green and colony reverse was amber or uncolored. On PDA, isolate 10 formed 1-2 concentric rings with green conidial production, and green conidia were distributed throughout the plate in a few isolates. In most isolates, conidia were formed by 48 h and turned green within 72 h. Each isolate having similar colony morphology may belong to the same species. Conidiophores of *Trichoderma* were usually long, infrequently branched conidiophores. The conidial shape was globose to ellipsoidal (Fig. 8). Morphology of the spores and sporulating structures of *Trichoderma* isolates were more or less similar, but significantly different in length and width. Conidiophores of *Aspergillus* were long, erect hyphal branches that enlarges at an apex. Conidia formed in chains and the youngest conidia presented at its base and the oldest conidia presented at the top.

DNA sequencing data of few isolates after processing from Macrogen, Korea were in Table 14. As examples, isolate 12 and 15 were identified as *Trichoderma koningii* and isolate 13 and 17 were *Trichoderma ghanense*. Isolate 19 and 23 were identified as *Hypocrea lixii*. Isolate 20 was identified as *Aspergillus niger* (T H P S Fernando, M K R Silva, P Seneviratne, Shehani Liyanage and E A D D Siriwardene: This project is partially funded by National Science Foundation- RG/2016/AG/01).

Table 15. *Identification of fungal isolates from different rubber growing soils to test for the antagonistic ability*

District	Isolate	Colony morphology			Species
		Form	**Margin**	**elevation**	
Polonnaruwa	Iso1	Irregular	Undulate	Flat/Raised	*Aspergilus* sp.
	Iso2	Circular	Filiform	Criteriform	*Trichoderma* sp**.**
	Iso3	Circular	Filiform	Flat	*Aspergilus* sp.
	Iso4	Circular	Filiform	Umbonate	Unknown
Kalutara	Iso5	Irregular	Filiform	Umbonate	Unknown
	Iso6	Circular	Filiform	Flat	Unknown
	Iso7	Circular	Entire	Flat	Unknown
	Iso8	Circular	Entire	Criteriform	*Trichoderma* sp**.**
	Iso9	Circular	Filiform/Entire	Criteriform	*Trichoderma spirale*
Rathnapura	Iso10	Irregular	Filiform/Entire	Flat	*Trichoderma hamatum*
	Iso11	Circular	Entire	Raised	Unknown
Ampara	Iso12	Irregular	Entire/Filiform	Flat	*Trichoderma koningii*
	Iso13	Circular	Entire	Flat	*Trichoderma ghanense*
	Iso14	Irregular	Entire	Flat	*Trichoderma* sp**.**
	Iso15	Circular	Filiform/Entire	Flat	*Trichoderma koningii*
	Iso16	Circular	Entire	Flat	*Trichoderma* sp**.**
	Iso17	Irregular	Filiform	Flat	*Trichoderma ghanense*
	Iso18	Circular	Entire	Flat	*Trichoderma hamatum* *Trichoderma spirale*
	Iso19	Circular	Entire	Flat	*Hypocrea lixii*
Monaragala	Iso20	Circular	Entire	Flat	*Aspergillus niger*
	Iso21	Irregular	Undulate	Flat/Raised	*Aspergillus* sp.
	Iso22	Circular	Filiform	Umbonate	*Penicilium* sp.
Vavuniya	Iso23	Circular	Entire	Flat	*Hypocrea lixii*

Screening of the isolates for the antagonistic ability

All tested fungi possess the antagonistic properties to control *R. microporus* by dual plate cultures (Fig. 9). Based on the results, 14 tested fungal isolates could inhibit the mycelial growth of *R. microporus* over 75% (Fig. 9). The results showed that *Aspergillus* sp. and *Aspergillus* sp. were highly antagonistic against *R. microporus* on MEA plate with inhibition of mycelial growth at 85.6% and 85.0%, respectively and both of them rapidly grew over *R. microporus* colony. Therefore, the highest inhibition percentage of those makes them very effective biocontrol agents.

The teleomorph of *T. harzianum* (*Hypocrea lixii)* and *T. koningii* inhibited the mycelia growth for 6 days as 81.0 % and 80.0% respectively. The results of dual culture showed that *Aspergillus sp.*, *Hypocrea lixxi* and *T. koningii* could inhibit the mycelial growth of *R. microporus* over 80%, especially the teleomorph of *T. harzianum* rapidly grown and could grow over the colony of the pathogen within a few days.

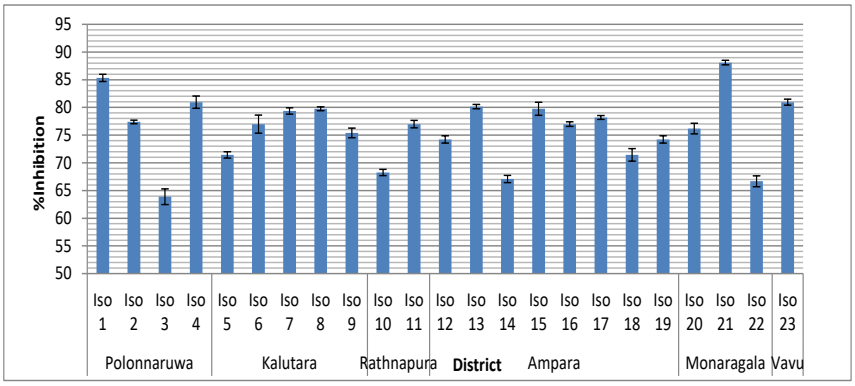


Fig. 9. Percentage inhibition of *R. microporus* in the dual culture with antagonistic isolates

Effect of volatile metabolites production by antagonistic fungi

The highest percentage inhibition due to volatile metabolites was observed in isolate 8, which was isolated from Kalutara district rubber land (Fig. 10). Except isolate 22, all other isolates were contributed to show inhibition of pathogen by producing volatile metabolites. Isolate 8, 14, 18, and 21 showed more than 40% inhibition of *R. microporus*. Although other isolates were given less than 40% inhibition, there was a significant impact to control the pathogen. Except the isolate 1, the other two *Aspergillus* spp. (isolate 3 and isolate 21) were recorded significant inhibition against the pathogen (T H P S Fernando, M K R Silva, P Seneviratne, Shehani Liyanage and E A D D Siriwardene: This project is partially funded by National Science Foundation - RG/2016/AG/01).

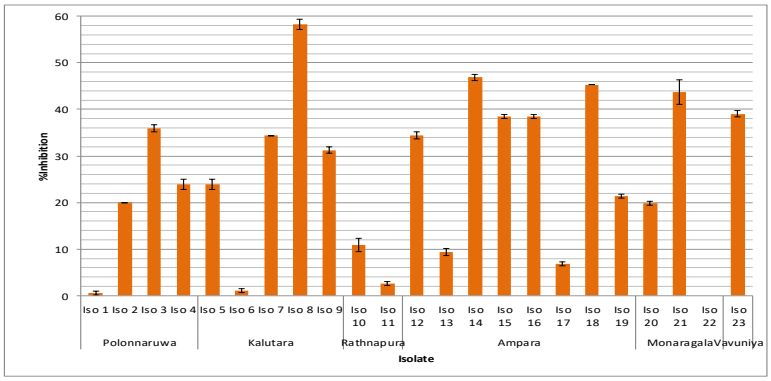


Fig. 10. Percentage inhibition due to volatile metabolite production of antagonistic fungi

Phosphorus solubilizing ability of antagonistic fungi

Eight isolates showed phosphorus solubilizing ability (Fig. 11) among all the eleven isolates. The highest phosphorus solubilizing ability was recorded in isolate 4. All the *Aspergillus* isolates showed phosphorus solubilizing ability compared to *Trichoderma* spp.

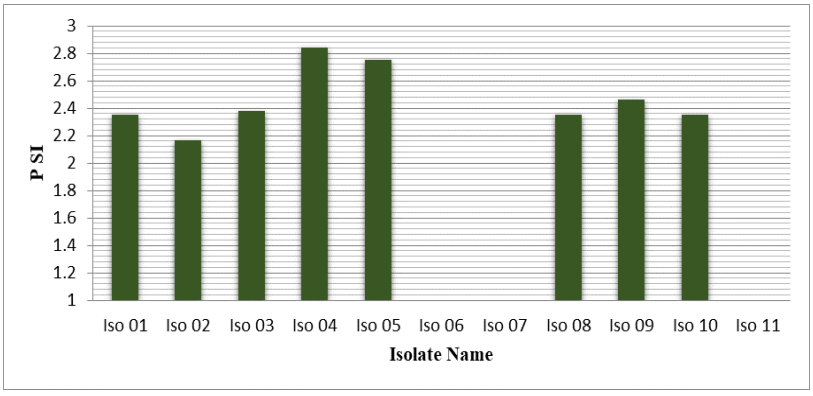


Fig. 11. Percentage solubilizing index (SI) of antagonistic fungi

Among all the isolates, isolate 03 showed the lowest sensitivity, while some isolates showing higher sensitivity (Fig. 12).

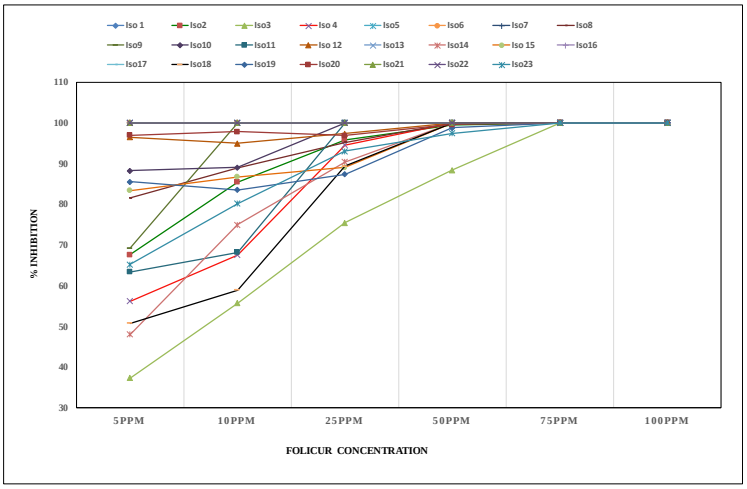


Fig. 12. The ability of native antagonistic fungi to tolerate the usage of fungicides for white root disease

IAA production by best antagonistic fungi

The highest IAA production was observed by Isolate 23 while the lowest value was by Isolate 21 (Fig.13).

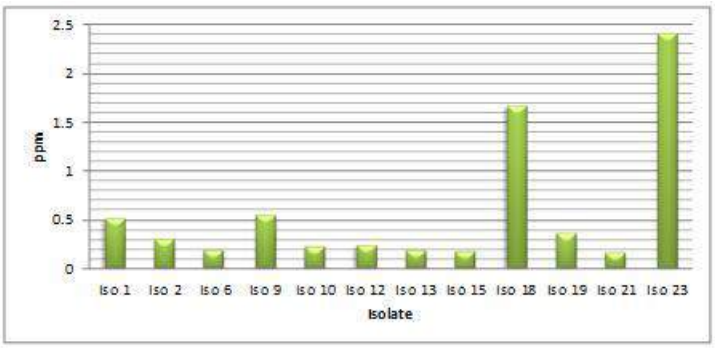


Fig. 13. IAA production by best antagonistic fungi

Effect of culture age, media and temperature on sporulation

On PDA, under normal dark and light regimes at room temperature, four isolates commenced production of spore after 72 h incubation and increased rapidly. The cultures showed maximum spore production after an incubation period of 8 days at RT (isolate 18 - 9.98 × 10^7, isolate 14 - 6.76 × 10^7, isolate 16 - 29.10 × 10^7 and isolate 23 - 33.23 × 10^7 spores cm^{-2}). All isolates sporulated on PDA, MEA and CDA,

and poorly on CMA, but not on LBA (Fig. 14). PDA proved to be the best suitable medium for the growth of *Trichoderma* isolates. Isolate 23 was the most prolific spore producer. The spore production of *Trichoderma* occurred between 10°C and 35°C. No sporulation of the tested isolates was observed at 5, 10 and 40°C after 7 days of incubation (Fig. 14). The highest spore production was at 25° C in all isolates. No mycelium growth of the colonies of the isolates was observed at the temperature of 5° C. Maximum mycelia growth at 30°C in cultures could be seen.

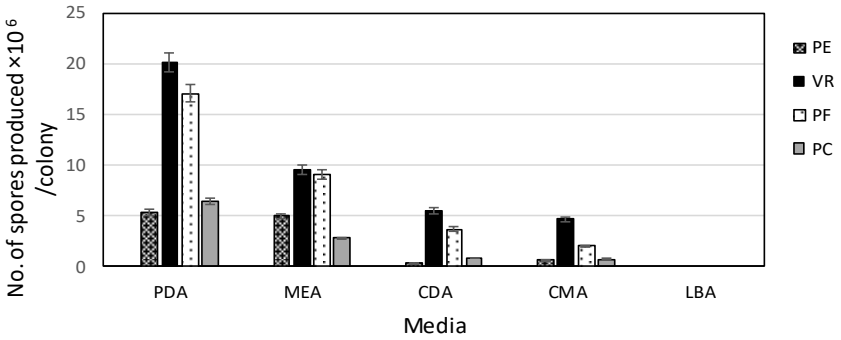


Fig. 14. Sporulation of four *Trichoderma* isolates on different media after 7 days incubation at RT

Factors affecting spore germination

This study has shown that germination of spores of *Trichoderma* isolates is influenced by incubation time, spore concentration and temperature. Spore germination on glass slides commenced after 4 hours and the percentage germination rapidly increased 14 hours after incubation. The maximum germination (around 95%) was observed after 24 hours of incubation (Fig. 15). At the conidia concentration of 4 × 10^7 spore/mL, 98% germination was observed. On PDA, increasing spore concentration resulted in an improvement in the germination of spores (Fig. 16). The percentage germination reduced significantly at concentrations 1.0 × 10^4 and 1.0 × 10^5 spores/mL (Table 16). Spore germination of *Trichoderma*, occurred at a temperature between 5 °C - 40°C. The optimum temperature range was between 20-35° C when incubated as wet smears on a glass slide. *Trichoderma* sp. presented a higher germination percentage at 30˚C and formed the maximum length of germ tubes. The germination was delayed when the temperature decreased to 15^{o}C (Fig. 17).

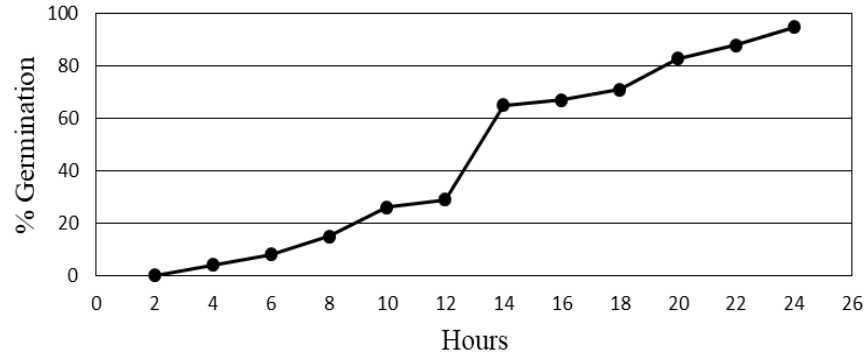


Fig. 15. Effect of incubation time on germination of *Trichoderma* isolate- 23 spores at room temperature

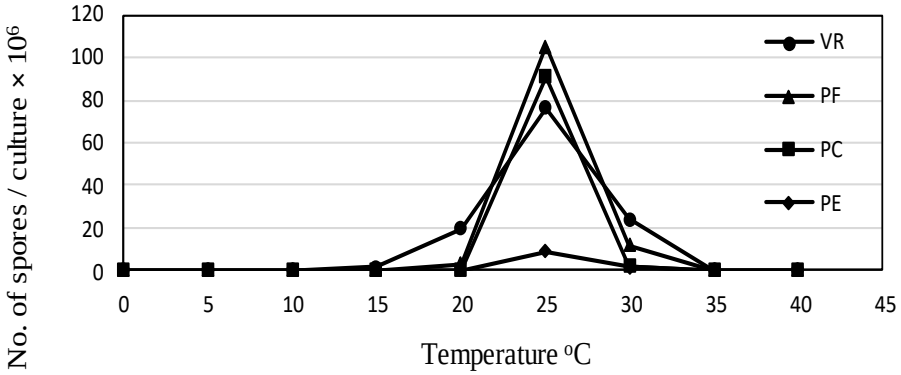


Fig. 16. Spore production of *Trichoderma* isolates after 7 days on PDA at different temperatures

Table 14. *Effect of spore concentration on germination in Trichoderma after 24 h*

Spore concentration (No of spores / mL)	**% Germination**
1.0×10^4	14
5.0×10^5	30
1.0×10^6	53
5.0×10^6	59
1.0×10^7	82
2.0×10^7	95
4.0×10^7	98
8.0×10^7	78

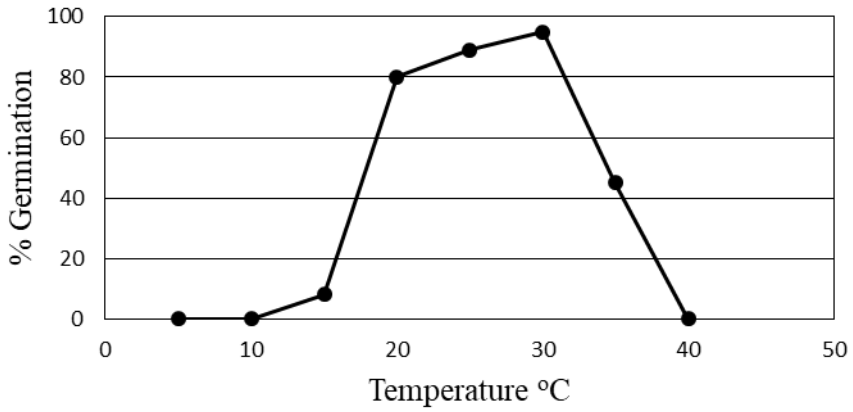


Fig. 17. Effect of temperature on spore germination of *Trichoderma* isolate VR on glass slide after 24h

Table 16. *Effect of spore concentration on germination in Trichoderma after 24 h*

Spore concentration (No of spores/mL)	% Germination
1.0×10^4	14
5.0×10^5	30
1.0×10^6	53
5.0×10^6	59
1.0×10^7	82
2.0×10^7	95
4.0×10^7	98
8.0×10^7	78

Cellulose secreting ability of fungi

Fungus with the ability to secret cellulase enzyme was not recorded according to the results.

Nitrogen-fixing ability of the antagonistic fungi

Nitrogen-fixing fungi were not identified (T H P S Fernando, M K R Silva, P Seneviratne, Shehani Liyanage and E A D D Siriwardene: This project is partially funded by National Science Foundation- RG/2016/AG/01).

Chitinase secreting ability of the antagonistic fungi against white root disease

Isolate name	Chitinase production ability
Isolate 1	+
Isolate 2	++
Isolate 3	++
Isolate 4	+
Isolate 5	++
Isolate 6	+
Isolate 7	++
Isolate 8	++++
Isolate 9	++++
Isolate 10	++++
Isolate 11	+++
Isolate 12	++++
Isolate 13	++
Isolate 14	++++
Isolate 15	++++
Isolate 16	++
Isolate 17	+
Isolate 18	+++
Isolate 19	++++
Isolate 20	+++
Isolate 21	+++++
Isolate 22	+++
Isolate 23	++++

(+ lowest production, ++ low production, +++ Moderate production, ++++ Higher production, +++++ Highest production)

Mass production of the inocula using the effective antagonistic fungi

Two fungal isolates have grown well in the carrier media while the others grew less effectively (Fig. 18 & 19).

Fig. 18. Mass production of antagonistic fungal isolates in paddy media

Fig. 19. *Trichoderma* inocula prepared in the talc base

Shelf life of the media

All three isolates showed a gradual decrease of $CFUg^{-1}$ with an increment of time. During the first two-three months a rapid reduction of $CFUg^{-1}$ was observed. As the talc media was absent of nutrients to grow the fungi the death of the live mycelia could be the reason for that reduction (Fig. 20). However, after twenty-two weeks, the reduction has become steady to some extent. Among the three antagonistic fungi, "Iso A" showed the highest $CFUg^{-1}$ within thirty weeks. Any color change of the talc media was not observed throughout the experiment.

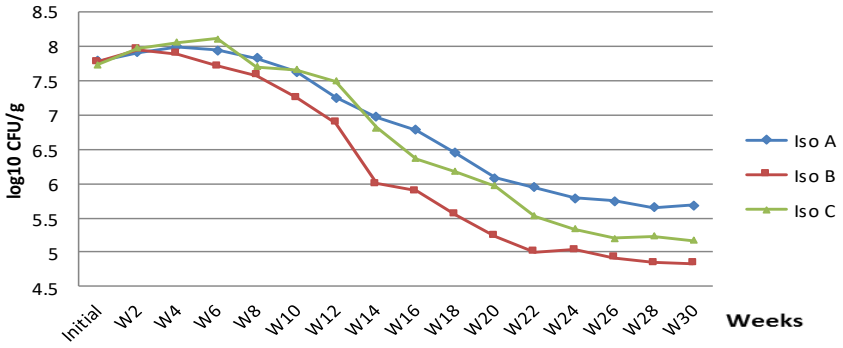


Fig. 20. Shelf lifetime of antagonistic fungi in the compost base

The initial count of $CFUg^{-1}$ which inoculated to the compost medium was between 7.5-7.8 $\log_{10}$ (Fig. 21). With time, the gradual decrease of $CFUg^{-1}$ was observed after ten weeks. As well as in the talc medium, "Iso A" showed the highest CFU value after thirty months. With the time "Iso B" showed the lowest $CFUg^{-1}$ value in both talc and compost medium.

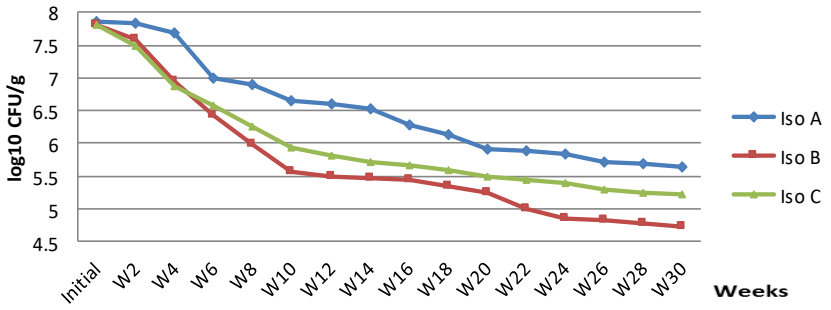


Fig. 21. Shelf lifetime the antagonistic fungi in the talc base

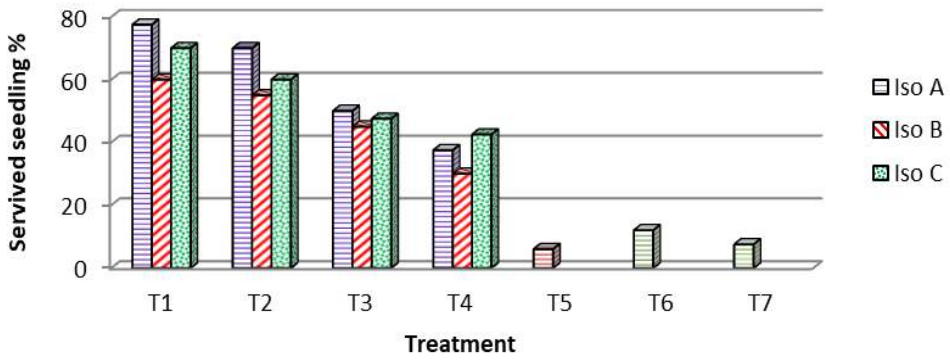


Fig. 22. *R. microporus* infected seedlings survival percentage in pot level

The recovery rate of the infected rubber seedlings with the antagonistic - products.

T1-potting medium + 250 g of Sterilized talc + Fungi, **T2**-potting medium + 250 g of Sterilized compost + Fungi, **T3**-potting medium + 250 g of Non sterilized talc: +Fungi, **T4**- potting medium + 250 g of Non sterilized compost +Fungi, **T5**- potting medium + 250 g of talc, **T6**- potting medium + 250 g of compost, **T7**-potting medium alone (Control).

According to the pot assay results of the talc medium, the highest seedling survival percentage was recorded by “Iso A” in the sterilized talc medium. However, the performance of “Iso A” had reduced in none sterilized talc media due to the influence of other microorganisms to the growth of the fungus. Compared to the control, T1, T2, T3 and T4 showed a significantly high ($P < 0.05$) survival percentage.

Only in the T4, Iso C showed the highest seedling survival percentage while in T1, T2 and T3 treatments Iso A showed the highest survival percentage. When the sterilized and non-sterilized media were compared, the sterilized media of both talc and compost showed the highest seedling survival percentage (T H P S Fernando, M K R Silva, K V V S Kudaligama, P Seneviratne, Shehani Liyanage and E A D D Siriwardene: This project is partially funded by National Science Foundation-RG/2016/AG/01).

SOILS AND PLANT NUTRITION

R P Hettiarachchi

DETAILED REVIEW

Staff

Dr (Mrs) R P Hettiarachchi, Principal Research Officer, Mrs H A R K Jayawardana and Mr T S Liyanaarachchi Research Officers were on duty throughout the year. Also, Experimental Officers Miss V Edirimanna, Miss A Thevarapperuma and Mr T Gunathileke, Technical Officers, Mrs K E de Silva, Mr G C Malawaraarachchi, Mr M W H Gayan, Mrs K M M E K Kulatunga, Mrs R M Baddevidana, Mrs P D S D O Rathnasooriya and Mr B N K Rangana and English Stenographer, Mrs L Rupasinghe were on duty throughout the year.

Research students

- K T T Samaranayake, a student from Faculty of Applied Sciences, Uva 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 "Eppawala Apatite and its application for rubber"	Scientific Committee Meeting
RP Hettiarachchi	Presentation on "Slow release fertilizers to enhance soil nutrient levels and plant growth of immature rubber (*Hevea brasiliensis*)"	Rubber Research Board

Seminars/Training Programmes/Workshops/Exhibition attended

Officer	Subject	Organization
RP Hettiarachchi	Fertilizer Advisory Committee Meeting	Ministry of Agriculture
	Introduction Session to Documentation of Sustainable Land Management (SLM) Technologies	Ministry of Environment
	Workshop on ISO 45001:2018	Sri Lanka Accreditation Board
RP Hettiarachchi HARK Jayawardana TS Liyanaarachchi	Scientific Committee Meeting	Rubber Research Institute of Sri Lanka

Visits

Advisory	3
Experimental	40
Others	25

LABORATORY AND FIELD INVESTIGATIONS

Soil fertility management

Isolation of effective microbes for soil fertility enhancement

Bacterial isolates (B) showed variations in colony size, shape, margin, appearance, pigmentation and optical property as presented in Table 1. There was a significant variation in shape of colony morphology on solid medium. Most of the colonies were circular. It could be observed that some bacterial isolates embedded within a matrix called extracellular polymeric substances (R P Hettiarachchi and K E de Silva).

Table 1. *Variability in cultural morphology produced by different bacterial isolates*

Bacterial No.	Shape	Margin	Surface texture	Appearance	Pigmentation
B_1	Circular	Undulate	Smooth	Dull	Yellow
B_2	Circular	Undulate	Smooth	Glistening	Cream
B_3	Circular	Entire	Smooth	Glistening	Cream
B_4	Irregular	Entire	Smooth	Glistening	Cream
B_5	Circular	Entire	Smooth	Glistening	Cream
B_6	Circular	Entire	Smooth	Dull	Cream

Decomposition of kitchen garbage and selection of suitable medium for earthworms

Kitchen garbage was tested for decomposition by the application of different earthworms. However, Black soldier fly infected medium decomposed rapidly compared to earthworms only application. Except the bad smell generates with Black soldier fly, they could be utilized to decompose large amount of garbage (R P Hettiarachchi and K M M E K Kulatunga).

Rehabilitation of degraded lands

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

Proper use of effective agro-management practices has been considered as a principal means in combating the reduction of soil fertility and biodiversity. However, there are limitations in implementing some of the practices, especially due to unavailability of materials in sufficient quantities and difficulties in handling the

labour consuming practices. Integrated soil fertility management is an approach to combine judicious use of inorganic fertilizers, organic sources, biofertilizers and other agronomic practices, which minimizes soil degradation while preserving sustainable soil fertility and crop growth in an environmental friendly manner.

NRC project activities were started in relation to the above mentioned principles in six estates; Parambe, Udabage, Elston, Penrith, halpe and Pussella. Planting was completed and pretreatment soil samples were collected and analyzed for the determination of soil fertility parameters. Low level of variations was observed in relation to the soil fertility parameter; pH, organic carbon, soil nitrogen, phosphorus, magnesium and calcium. However, higher variation was observed among different sites for soil potassium (Table 2) with high values in the Parambe series having glistening specks of mica parts throughout the soil mass (R P Hettiarachchi, V Edirimannne, T Gunathilake and K E de Silva).

Table 2. *Different soil fertility parameters in the top 0-15 cm soil layer in respect of different experimental sites*

Site	pH	O.C %	N %	P(ppm)	K(ppm)	Mg(ppm)	Ca(ppm)
Parambe	5.68	1.22	0.12	20	178	29	69
Uabage	5.67	0.92	0.11	22	76	23	61
Elston	5.75	0.98	0.11	30	78	31	74
Penrith	5.59	1.02	0.12	23	85	21	78
Halpe	5.82	1.00	0.10	26	112	23	68
Pussella	5.60	1.00	0.11	27	106	26	72

Organic manure application for rubber nursery plants

Organic and inorganic mulching for weed control in immature rubber plantations

The study was begun in the year 2017 to test the effect of Paddy straw, Oil palm refuse, Polythene and Shade net mulches on weed control around the base of the rubber plants in comparison to normal estate management practices. The testing on polythene, paddy straw and Oil palm refuse treatments was concluded in 2019 but shade net was maintained further with the objective of detecting its effective period for weed control (Annual Review 2019). According to the observations during the year 2020, even the shade net was not degraded at 3 years after its' application, observations showed that the size of the shade net mulch is insufficient to completely cover the plant base with the plant growth. However, shade net mulch was effective on weed control for the 3 years with less labour requirement only for removing the encroaching creepers when compared to the labor required for manual weeding (details of labor requirement is presented in the Annual Review 2018). It was the best mulch material among the treatments (Polythene, Oil palm refuse and Paddy straw). This study open path for further investigations with concern on size of the mulch,

weed population, cover crop type and age of the plantation (H A R K Jayawardana, A P Thearapperuma and T Gunatilleke).

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

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. This study will be carried out to investigate the effect of fertilizer application at levels of 100%, 75% or 50% of the recommended fertilizer by the Rubber Research Institute of Sri Lanka in combined with PBPH application on the growth of immature rubber plants.

Split plot design was arranged among two main plots; with PBPH and without PBPH. Three sub plots of different percentages of inorganic fertilizers; 100% inorganic fertilizers as F1 (100%) or 75% inorganic fertilizer as F2 (75%) or 50% inorganic fertilizer as F3 (50%) were practiced with four replicates including 5 plants per replicate. Three applications of treatments were done during the year under review. Plant diameter and height were recorded. Plant diameter values recorded are presented in Table 3. The treatments will be continued for further observation (H A R K Jayawardana, A P Thewarapperuma and T Gunatilleke).

Table 3. *Mean plant diameter values recorded in different treatments (in mm)*

	Without paddy husk			**With paddy husk**		
Fertilizer application	**Pre treatment**	**6 months after treatment**	**1st year after treatment**	**Pre treatment**	**6 months after treatment**	**1st year after treatment**
100% of recommended fertilizer	11.73	18.5	22.21	12.23	19.6	26.78
75% of recommended fertilizer	11.55	18.81	23.33	12.88	21.07	25.03
50% of recommended fertilizer	12.01	18.1	22.54	12.08	20.06	27.62

Data are not been statistically analyzed.

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 in the third year and the other site was in fourth year after establishment at Padiyathalawa and Mahaoya areas. However, both sites at the Moneragala area were in the third year.

Third-year plants at Moneragala and fourth-year plants at Padiyathalawa areas showed higher girth values 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 4). Leaf analysis data showed no differences for N, P, K & Mg contents between treatments (Table 5). Further, no differences could be observed related to soil fertility parameters; soil pH, organic carbon (OC), nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg) and calcium (Ca) 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. Moreover, all treatments showed over the satisfactory level of available P contents (Table 6).

Table 4. *Effect of different fertilizer mixtures on plant girth after 3rd and 4th year immature rubber plants at Moneragala and Padiyathala areas respectively*

Treatment	Plant girth (cm) at four feet height/Moneragala	Plant girth (cm) at four feet height/Padiyathalawa
(T1) R/SA 7:9:9:3	23.3	32.32
(T2) R/SA 7:9:9:3 +2K	24.2	28.05
(T3) R/SA 7:4:18:6 (New mixture)	24.2	32.53
(T4) R/U 12:14:14	21.3	27.39

Table 5. *Effect of different fertilizer mixtures on leaf nutrient contents after 3rd and 4th year immature rubber plants at Moneragala and Padiyathala areas respectively*

Area	Treatment	Leaf nutrients			
		N %	P %	K %	Mg %
Moneragala	(T1) R/SA 7:9:9:3	2.88	0.28	0.97	0.25
	(T2) R/SA 7:9:9:3 +2K	2.78	0.28	1.01	0.26
	(T3) R/SA 7:4:18:6 (New mixture)	2.70	0.27	0.98	0.25
	(T4) R/U 12:14:14	2.65	0.28	0.98	0.25
Padiyathalawa	(T1) R/SA 7:9:9:3	2.89	0.25	1.00	0.26
	(T2) R/SA 7:9:9:3 +2K	2.88	0.25	1.00	0.27
	(T3) R/SA 7:4:18:6 (New mixture)	2.85	0.24	0.98	0.25
	(T4) R/U 12:14:14	2.88	0.26	0.98	0.26

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

Table 6. *Effect of different fertilizer mixtures on soil nutrient contents after 3rd and 4th year immature rubber plants at Moneragala*

Treatments	Soil fertility parameters						
	pH	OC%	N%	P ppm	K ppm	Mg ppm	Ca ppm
(T1) R/SA 7:9:9:3	6.05	1.11	0.12	34	139	36	66
(T2) R/SA 7:9:9:3 +2K	6.08	1.03	0.11	33	153	31	79
(T3) R/SA 7:4:18:6 (New mixture)	6.06	1.04	0.12	33	147	33	75
(T4) R/U 12:14:14	6.02	1.03	0.12	33	159	33	72

Slow release fertilizer application

Coir based slow release fertilizer application for immature rubber plants

An experiment was laid down at Geekiyanakanda estate, to study the effectiveness of encapsulated coir bricks (ECB) on soil fertility, and their influence on mineral composition of rubber leaves and growth of immature rubber plants. Plants were manured according to the experimental design similar to the previous experiment which was started at Raigam estate in 2016. 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. Experiment was discontinued due to covid 19 situation in the country. However, data collected in 2019 showed that ECB treatments gave higher or equal growth parameters compared to control treatment in each and every intervals (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 mentioned in 2019 annual review. Plant girth was taken at 4 feet above the ground level of the plant at 24 months after the planting of young budding plants. The assessment of plant girth showed higher value with RPT treatments (T2 & T3) compared to control treatment (T1) (Table 7) (R P Hettiarachchi, V Edirimannne, T Gunathilake and M W H Gayan).

Table 7. *Effect of different fertilizer application treatments on plant girth after 24 months after planting*

Treatments	Girth (cm)
T1 (Control)	15.0
T2 (RPT type 1)	16.4
T3 (RPT type 2)	16.5

Above mentioned treatment combinations were also established at Elston estate to study the effectiveness of treatment combinations under Homagama soil series. Plant girth was taken at 4 feet above the ground level of the plant at 18 months after the planting of young budding plants. The assessment of plant girth and leaf N showed higher values with RPT treatments (T2 & T3) compared to control treatment (T1). Other parameters; leaf nutrients P, K and Mg showed comparatively no differences between treatments (T1, T2 & T3) (Table 8).

Table 8. *Effect of different fertilizer applications on growth and major leaf nutrient contents of immature rubber plants*

Treatments	Plant girth (cm)	Leaf nutrients (%)			
		N	P	K	Mg
T1 (Control)	13.6	2.56	0.14	0.80	0.191
T2 (RPT type1)	15.6	2.98	0.14	0.77	0.191
T3 (RPT type2)	15.7	3.30	0.15	0.80	0.210

Soil fertility parameters were measured as organic carbon (OC), total N, available P, exchangeable K, Mg and Ca also showed no differences between RPT treatments (T2 & T3) and control treatment (T1) (Table 9).

Table 9. *Effect of different fertilizer application treatments on soil pH, organic carbon, total N, available P, exchangeable K, Mg and Ca of the top 0-5 cm soil layer at the end of eighteen months after planting*

Treatments	pH	OC %	N %	P(ppm)	K(ppm)	Mg(ppm)	Ca(ppm)
T1 (Control)	5.67	0.985	0.10	33.0	83.6	31.8	86.5
T2 (RPT type 1)	5.79	1.010	0.11	28.5	80.3	27.0	83.0
T3 (RPT type2)	5.75	1.012	0.12	28.0	84.2	30.5	79.0

Land degradation and land suitability

Assessment of annual soil loss in rubber lands in Kalutara district using the Revised Universal Soil Loss Equation (RUSLE) model

Soil conservation is a timely topic as many cultivations and different human activities are heavily engaged with it. As rubber is one of the major plantation crops in Sri Lanka, which is grown by both the estate sector and smallholders, a special concern should be drawn to assess the soil erosion or soil loss due to crop management practices. The Revised Universal Soil Loss Equation (RUSLE) is one of the famous and recommended algorithms used to assess annual soil loss by scientists throughout the world. As a preliminary study, the Soils and Plant Nutrition Department attempted to assess the annual soil loss of smallholder rubber growing lands in the Kalutara district *via* the RUSLE in a Geographic Information System (GIS) platform. Kalutara district is located in the Wet Zone of Sri Lanka which comprises traditional rubber growing areas. This area is more prone to heavy soil losses and landslides due to high annual cumulative rainfall with heavy rainfall intensities and lands having high slopes, which aggravate the situation. Hence, finding the vulnerable areas for the soil loss is of great importance for efficiently manage these conditions and also to take management decisions to reduce the risk of disasters.

RUSLE Model

This is based on the Universal Soil Loss Equation (USLE) and RUSLE has more advantages compared to the USLE in estimating the loss of soils.

A= LS*R*K *C*P…… (1)

Where,

A Soil loss per unit area per year (Metric tonnes/hectare/year)
LS Slope length and steepness factor
R Rainfall erosivity factor (Mega Joule millimeter hectare^{-1} hour^{-1}Year^{-1})
K Soil erodibility factor (Metric tonnes hour Mega Joule^{-1} millimeter^{-1})
C The cover and management factor
P Support practice factor

Development of the soil erosion severity map

All the prepared digital layers of LS, R, K, C, and P were in 100 m spatial resolution which represents the 100*100 m (1 ha) grid on the space. The RUSLE equation (A= LS*R*K*C*P) was employed in the raster calculator tool of ArcGIS to multiply the factors in the equation to estimate the average annual soil loss per hectare per year for a 1 ha pixel on the map.

Resulted annual soil loss was categorized as low risk (0-7 t/ha/yr), moderate risk (7-15 t/ha/yr), high risk (15-25 t/ha/yr), very high risk (25-45t/ha/yr), severe risk

(45-65 t/ha/yr) and very severe risk (more than 65 t/ha/yr). According to the results, 15,738 ha of lands under rubber in Kalutara district are under low risk or annual soil loss is less than 7 tonnes per hectare per year. However, results revealed that 4,064 ha of lands are at very severe risk condition when considering annual soil loss per hectare, which is more than 65 tons per hectare per year. Moreover, 11,402 ha of rubber growing lands do not lose any soil mass throughout the year under natural conditions.

Table 10. *Rubber growing land area under different soil loss risk category*

Soil loss risk category	Area (ha)
Low risk	15,738
Moderate risk	1,755
High risk	1,247
Very high risk	2,012
Sever risk	1,492
Very severe risk	4,064

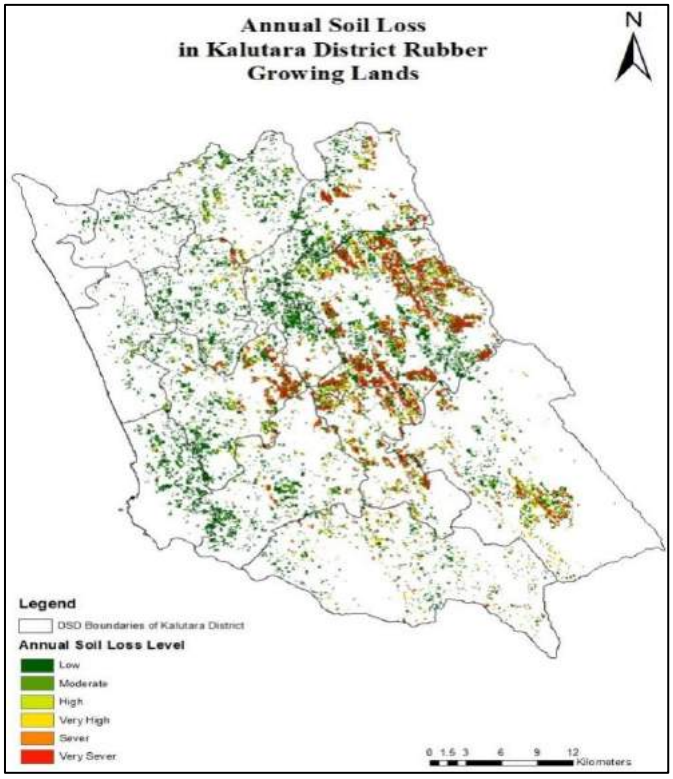


Fig. 1. Annual soil loss in Kalutara district rubber growing lands

The study revealed that 14,906 ha (56.7%) of rubber growing lands are prone to lose more than 1 t/ha/yr while 11,402 ha (43.3%) of lands are not prone to lose soil. Out of the extent of 14,906 ha, an extent of 5,556 ha (37%) of rubber growing lands are at the severe risk and very severe risk category. Therefore, special concerns should be drawn to check whether soil conservation practices recommended by the Rubber Research Institute of Sri Lanka (RRISL) are being practiced in these areas. Further, this high soil loss may occur due to the cultivation of rubber in adverse slopes not adhering to RRISL guidelines; *viz.* avoiding slopes more than 45% for planting rubber. The results of this study may be used to evaluate the management practices of rubber growing lands of the area and make aware the growers of the importance of preventing soil losses by adhering to proper soil conservation practices. However, the study will be fine-tuned by utilizing real-time rainfall data instead of long-term averages for considered areas (L A T S Liyanaarachchi and M W H Gayan).

Identification of potential land suitability to expand rubber in Embilipitiya and Kolonne areas using Geographic Information System (GIS) Based Model

Shrinking of arable lands for rubber cultivation in traditional rubber growing areas of Sri Lanka is one major issue to be addressed in near future. This is mainly because a considerable area in the Wet Zone where the rubber is cultivated in Sri Lanka has been replaced with other plantation crops such as oil palm and plantation forestry. Furthermore, traditional rubber growing lands were extensively used for other development activities to accommodate the increasing population. However, Embilipitiya and Kolonne Divisional Secretariat Division (DSDs) which are located in Ratnapura district belongs to the traditional rubber growing area, yet still have not been utilized for rubber cultivation effectively. Therefore, the study aimed at assessing the potential land suitability of the area for rubber employing the GIS-based Multi-Criteria Evaluation (MCE) model. Annual cumulative rainfall, minimum temperature, maximum temperature, great soil group, elevation and slope were considered as main criteria which affect on growth and performance of the rubber plantations. Analytical Hierarchical Process (AHP); which is used to allocate weights for digital layers was used in the allocation of weights for the above criteria when performing the analysis in GIS. Once weights were allocated for the main variables, ranks were allocated for the sub-categories of respective variables (Table 11).

Table 11. *Weights and ranks allocated for main variables and subcategories respectively*

Main variable	Contribution%	Sub category	Rank
Great soil group	25	Reddish Brown Earths & Low Humic Gley soils; undulating terrain	3
		Alluvial soils of variable drainage and texture; flat terrain	4

Main variable	Contribution%	Sub category	Rank
		Erosional remnants (Inselbergs)	5
		Reddish Brown Earths & Solodized Solonetz; undulating terrain	3
		Reddish Brown Earths & Immature Brown Looms; rolling, hilly and steep terrain	3
		Red-Yellow Podzolic soils with semi-prominent A1 horizon; hilly and rolling terrain	1
		Red-Yellow Podzolic soils; steeply dissected, hilly and rolling terrain	1
		Marsh	5
Annual Cumulative Rainfall	35%	> 1250 mm	5
		1250 - 1499 mm	4
		1500 - 1650 mm	3
		1650 - 2000 mm	2
		2000 - 2500 mm	1
		2500 - 2750 mm	1
		2750 - 3000 mm	1
		>3000 mm	3
Min. Temperature	10%	< 16 °C	5
		16 -17 °C	5
		17 - 18 °C	5
		19 - 20 °C	3
		> 20 °C	2
Max. Temperature	5%	26 - 28 °C	1
		28 - 31 °C	1
Elevation	11%	< 200 m	1
		200 - 400 m	2
		400 - 600 m	3
		600 - 800 m	4
		> 800 m	5
Slope	14%	0 - 20	1
		20 - 30	2
		30 - 45	3
		45 - 60	4
		>60	5

The following equation was employed to derive the land suitability map for the study area.

$$Ri = \frac{\sum Wj.\ Xij}{100} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

Where Ri is the capability value (land suitability) of a location/grid in the developed suitability map while Wj is the weight of the factor j. Xij is the ordinal rank capability of factor j in location/grid i.

According to the derived land suitability model, the "Most Suitable", "Suitable", and "Slightly Suitable" classes could be identified in these areas (Table 9). The land suitability map is presented in Figure 2.

Table 12. *Land extents under different suitability classes*

Suitability class	Area (ha)	Percentage (%)
Most suitable	4,775	8
Suitable	37,848	67
Slightly suitable	14,166	25

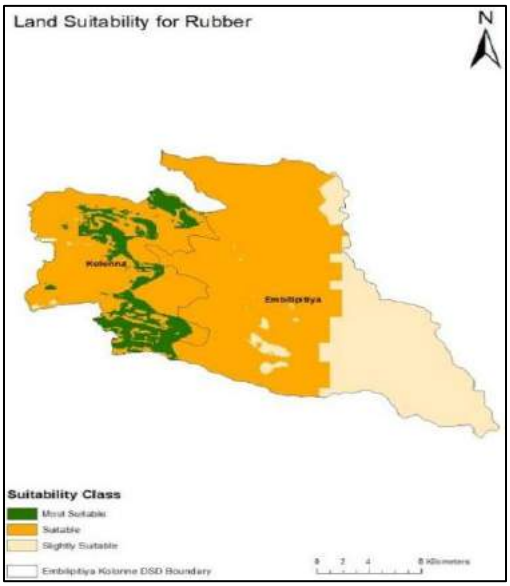


Fig. 2. Land suitability map for rubber in Embilipitiya and Kolonne DSDs

An extent of 4,775 ha lands are categorized as "Most Suitable" for expanding rubber in the study area. However, as the remaining lands have not been categorized as "Not Suitable" those areas may be suitable to cultivate rubber with some area-specific corrective measures. This kind of study provides preliminary data for the land suitability assessment. Therefore, a ground-level investigation should be done at a site-specific level before making decisions on introducing rubber (L A T S Liyanaarachchi and M W H Gayan).

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

This project was started in 2017 to modify conventional fertilizer recommendations for traditional rubber growing areas. For 2020, two estates were randomly selected as sampling sites in one main soil association in Colombo district. 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 (Table 10).

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

Sample associations	Site (Estate)	Extent (ha)	Samples collected		Parameters analyzed
			Soil	Leaf	
Pallegoda-Dodangoda-Homagama Complex	Ayre	100	14	15	215
	Siriniwasa	60	09	09	135

Services

Land selection and suitability for rubber cultivation

Under the routine land selection programme 490 hectares of land were surveyed for the suitability of rubber cultivation and six land suitability reports were issued. Details of the surveys are given in Table 14 (R P Hettiarachchi, G C Malawaraarachchi and all the staff of the department).

Table 14. *Details of the Land Selection program*

Place (GS Division)	Extent surveyed (ha)
Ampara - Bodagolla	200
Ampara - Uhana	100
Ampara - Aranthalawa	100
Polonnaruwa, Welikanda	30
Giragama	10
Bibile, Mdagama	50
Total	490

Site-specific fertilizer recommendation by soil and foliar survey programme

Under this programme, 2,846 hectares of mature rubber fields were surveyed and 19 fertilizer recommendations were given for the next three years of 2021-2023. Details of the survey are given in Table 15 (R P Hettiarachchi, A Thewarapperuma and all the staff of the department).

Analytical service

Under this programme, various samples received from estates, smallholders, universities and other private organizations were analyzed according to the SLSI methods. 456 samples (1,824 parameters) including 171 fertilizer samples from rubber growers were analyzed to assure application of good quality fertilizers to their rubber lands. Analytical service issued 54 analytical reports and details of the service are given in Table 15 (R P Hettiarachchi, K E de Silva, V Edirimanna, R M Baddevidana and all the staff of the department).

Table 15. *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	Pallegoda	4	11	-	-	7425.00	-
2	Weniwella	1	5	-	-	3375.00	-
3	Higgoda	1	3	-	-	2025.00	-
4	Mahaoya	8	30	-	-	20250.00	-
5	Atale	4	13	-	-	8775.00	-
6	Udabage	3	10	1	602.74	6750.00	78356.20
7	Pelawatta	4	10	-	-	6750.00	-
8	Rambukkanda	1	1	-	-	675.00	-
9	Hathbewa	1	3	-	-	2025.00	-
10	Ambadeniya	1	3	-	-	2025.00	-
11	Mirishena	1	5	-	-	3375.00	-
12	Yatadola	2	2	-	-	1350.00	-
13	Miriswatta	4	12	-	-	8100.00	-
14	Sirikandura	1	2	-	-	1350.00	-
15	Parambe	2	4	1	255.18	2700.00	33173.40
16	Edella	1	1	-	-	675.00	-
17	NFS	1	7	-	-	4725.00	-
18	Staar	1	3	-	-	2025.00	-
19	Madeniya	1	1	-	-	675.00	-
20	NR Agri	1	3	-	-	2025.00	-

	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.)
21	Geekiyanakanda	1	1	-	-	675.00	-
22	Hedigalla	1	1	-	-	675.00	-
23	Colombo National	1	15	-	-	10125.00	-
24	Eladuwa	2	8	-	-	5400.00	-
25	Pitiyakanda	4	12	1	595.01	8100.00	77351.30
26	Ayr	1	3	-	-	2025.00	-
27	Uskvalley	1	2	-	-	1350.00	-
28	Durampitiya	-	-	1	132.47	-	17221.10
29	Hapugastenna	-	-	1	109.35	-	14215.50
30	Culloden	-	-	1	100.33	-	13042.90
32	Mohomadi	-	-	1	13.61	-	-
33	Penrith	-	-	1	235.00	-	30555.00
34	Clyde	-	-	1	136.00	-	17680.00
35	Ketendola	-	-	1	27.04	-	3515.20
36	Elpitiya	-	-	1	115.77	-	15050.10
38	Glenrose	-	-	1	12.61	-	1639.30
39	Wellendura	-	-	1	126.37	-	16428.10
40	Lelwala	-	-	1	49.64	-	3453.20
42	Bentota	-	-	1	127.85	-	16620.50
43	Walpita	-	-	1	27.11	-	3524.30
44	Ambetenna	-	-	1	19.52	-	2537.60
45	Yataderiya			1	118.00		13340.00
46	Kiribathgala			1	42.00		5460.00
	Total	**54**	**171**	**19**	**2845.6**	**115425.00**	**363163.70**

BIOCHEMISTRY AND PHYSIOLOGY

K V V S Kudaligama

DETAILED REVIEW

Staff

Dr (Ms) K V V S Kudaligama, Principal Research Officer attended to the duties of the Head of Biochemistry and 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, Mr L T B K Fernando and Miss N N Abewardhana Technical Officers and Mrs H A M E Hettiarachchi, Management Assistant were on duty throughout the year.

Research students

Student name	University	Research topic
KGA Madhuhansika HRGN Peiris	Advance Technological Institute, Galle	Induction training programme of Higher National Diploma in Technology (Agriculture)
KGCR Kumara	Advance Technological Institute, Naiwala	Industrial training on Higher National Diploma in Technology (Agriculture)

Seminars/Conferences/Workshops/Exhibitions attended

Officer/s	Subject/Theme	Organization
KVVS Kudaligama NPSN Karunarathne	Scientific Committee Meeting	RRISL

Training programmes conducted

Officer/s	Subject/Theme	Beneficiary/Client
KVVS Kudaligama	Theoretical and practical training programmes on S/2 d4 system	Rubber smallholders in 08 RDO ranges
	Use of stimulant in low intensity harvesting	Induction Course for Planter Trainees, NIPM
	Use of stimulant in low intensity harvesting	Refresh training programme for RDOs of Rubber Development Department

Officer/s	Subject/Theme	Beneficiary/Client
	Effective introduction of new LIH systems to address current issues in rubber plantation industry (Capital Project)	Rubber Development Department (Uwa Province and Southern Province) Kelani Valley Plantations PLC (10 estates) Kegalle Plantations PLC (6 estates) Namunukula Plantations PLC (12 estates) Horana Plantations PLC (6 estates) Kahawatta Plantations PLC (2 estates) Elkaduwa Plantations (4 estates) Elpitiya Plantations (5 estates)

Field visits

Advisory - 23 visits
Experimental - 311 visits
Miscellaneous - 6 visits

Sample testing

% Dry rubber content of latex - 27 samples
Commercial Ethephon mixtures - 15 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 with RRIC 121/ RRISL 203/ RRISL 217 genotypes replanted in 2010 in Gallewatte division, Dartonfield estate (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 74. In all four blocks average DRC% of latex was 40%. Variation of yield of blocks was mainly due to degree of mixing clones in particular tapping blocks (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	76	40	56.13	14.03	3.55	1422
S/2 d4-Block 2	75	40	59.73	16.43	4.17	1670
S/2 d4-Block 3	67	40	64.04	17.61	4.02	1608
S/2 d4-Block 4	79	40	62.02	17.06	4.53	1811
Average	**74**	**40**	**60.48**	**16.28**	**4.07**	**1628**

Eight tapping blocks mixed with RRIC 121 and RRISL 203 clones from 2010 replanted field (No:2010/5.17) at Nivithigalakele division of Dartonfield estate have been selected for commercial level testing of S/2 d4. Total number of tapping days under d4 frequency was 73 and average productivity of the field was 1,728 kg. Variation of yield of blocks were mainly due to the degree of mixing clones (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	74	40	65.07	19.52	5.10	2041
S/2 d4 Block 2	73	39	52.35	15.71	4.09	1637
S/2 d4 Block 3	72	39	38.67	11.60	2.95	1180
S/2 d4 Block 4	71	39	49.94	14.98	3.95	1581
S/2 d4 Block 5	75	38	54.24	16.27	4.32	1727
S/2 d4 Block 6	74	40	63.17	18.95	4.97	1986
S/2 d4 Block 7	72	40	61.15	18.34	4.80	1921
S/2 d4 Block 8	75	40	52.73	15.82	4.38	1752
Average	**73**	**39**	**54.66**	**16.40**	**4.32**	**1728**

(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 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 in Galle, Matara, Hambanthota and

Moneragala Districts during the year. To improve the knowledge on adaptation, 04 awareness programmes were conducted and fourteen S/2 d4 demonstration fields were established in collaboration with the smallholders in above the districts. In total, 172 smallholders in 10 rubber growing districts were benefited by adopting S/2 d4 tapping system (Table 3).

Table 3. *District wise details of the smallholdings established low intensity harvesting systems*

District	No of smallholders	Extent (ha)
Kalutara	56	26.09
Kegalle	43	70.56
Rathnapura	7	10.01
Colombo	3	1.13
Gampaha	22	17.77
Kurunegala	19	18.22
Kandy	8	6.11
Moneragala	7	15.36
Galle	4	6.81
Hambanthota	3	7
Total	**172**	**179.06**

In 21 estates belong to three Regional Plantation Companies, about 1,371 ha were established with S/2 d4 system (Table 4).

Table 4. *Details of estates established with 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
Halpe	125.50
Salawa	26.08
Ayr	92.79
Siriniwasa	19.81
Penrith	117.87
Diurampitiya	31.62
Hapugasthenna (Rubber)	20.60
Ambetenna	19.52
Clyde	16.50
Culloden	105.48
Kiribathgala	57.00

Estate	Extent (ha)
Kiriwanaketiya	3.00
Peenkande	82.32
Niriella	31.43
Total	**1,370.94**

Officers, Field staff and workers of all the estates belongs to Kelanivalley Plantations PLC, Kegalle Plantations PLC, Namunukula Plantations PLC, Horana Plantations PLC and Kahawatta Plantations PLC were educated to establish S/2 d4 harvesting system in their estates. The similar awareness programmes were conducted to the officers and workers of Lelwala and Thalgaswala estates of Elpitiya Plantations PLC (K V V S Kudaligama, N P S N Karunarathne, M K P Perera, L T B K Fernando, P D T L Madushani and N N Abewardhana).

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

Growth and physiological performance of different clones planted under different Agroecological Zones

Padiyathalawa (Intermediate Zone)

Nine clones developed by RRISL were established in the experimental field in Rubber Development Department plant nursery premises at Padiyathalawa in 2017. Out of nine clones RRIC 121, RRISL 2001 and Centennial 3 performed well in height and RRISL 2001, Centennial 3 and RRISL 201 showed better performances in plant girth. Growth of RRIC 102 and RRISL 2100 clones were poor when compared to the other clones planted in Padiyathalawa site (Table 5).

Table 5. *Average plant growth performances of different clones planted in Padiyathalawa experimental field after 3 years of growth*

Clone	Average	
	Height (cm)	Girth at 4ft (cm)
RRIC 100	504.79	16.42
RRIC 121	643.51	16.06
RRIC 102	460.45	13.59
RRISL 203	631.00	16.93
RRISL 201	612.87	18.42
RRISL 2001	638.18	19.19
RRISL 2100	460.66	13.16
Centennial 3	635.98	18.64
Centennial 4	555.96	17.01

Hambegamuwa (Intermediate Zone)

Table 6. *Average plant growth performances of different clones planted in experimental field in Hambegamuwa*

Clone	Height (cm)	Girth @4ft (cm)	No. of leaf whorls
RRIC 100	465.67	16.14	5
RRIC 102	429.52	13.91	5
RRISL 203	494.27	17.29	5
RRISL 201	385.71	12.49	4
RRISL 2001	510.26	14.93	4
RRISL 2100	442.12	12.74	4
Centennial 3	441.95	14.28	4
Centennial 4	484.81	15.06	5

In Hambegamuwa site, RRISL 2001, Centennial 4 and RRISL 203 showed a comparatively higher plant height whilst RRISL 203, RRIC 100 and Centennial 4 showed a better performance in plant girth. RRIC 100, RRIC 102, RRISL 203 and Centennial 4 plants were with 5 leaf whorls and others clones had only 4 leaf whorls (Table 6).

Dartonfield (Wet Zone)

Growth of four different clones established at Meerigama and Dartonfield experimental sites in 2015 were assessed during 2020 in order to investigate their physiological performances in Wet Zone. However, investigations of physiological performances were only confined to the Meerigama site as Dartonfield site has severely been affected by the new leaf disease. As growth data, height to the branching point and girth at 4 feet were measured. In Dartonfield site growth of all four clones were more or less similar and height to the branching point also did not show much variation (Table 7). In Meerigama site, PB 260 plants showed poor growth performance showing the lowest height and girth. Height to the branching point of the trunk was highest in RRISL 203 whilst RRISL 2001 plants showed the plants with the highest girth (Table 8).

Table 7. *Average plant growth performances of different clones planted in Dartonfield experimental field in 2015*

Clone	Girth @4ft (cm)	Height to the branching point (cm)
RRIC 100	38.99	266.18
RRIC 121	39.05	259.20
RRISL 203	38.99	265.49
RRISL 2001	40.52	253.88

Table 8. *Average plant growth performances of different clones planted in Meerigama experimental field*

Clone	Girth @ 4ft (cm)	Height to the branching point (cm)
RRIC 121	32.60	442.01
RRISL 203	38.90	453.41
RRISL 2001	40.33	405.92
PB 260	31.82	364.21

Stomatal conductance, leaf wax content, relative water content, chlorophyll content and leaf area were assessed as the physiological parameters of above mentioned clones. Diurnal performance of stomatal conductance (Fig. 1) of all the *Hevea* genotypes was tested with environmental parameters in the field (wind speed, temperature and relative humidity) at the time of taking measurements (Table 9). Maximum stomatal conductance was observed in the clone RRIC 121 during evening and the minimum was in PB 260 in the morning. Lowest difference between morning and evening was observed in RRISL 2001 whilst highest difference was observed in PB 260 (Fig. 1).

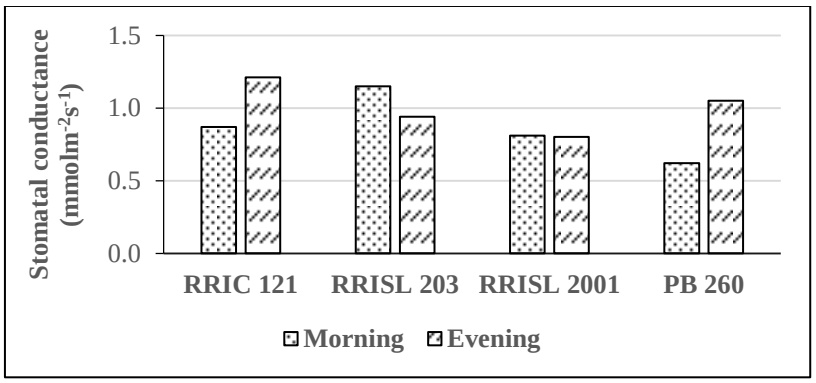


Fig. 1. Average stomatal conductance of different *Hevea* genotypes planted at Meerigama experimental site

Table 9. *Average environmental condition in Meerigama field at the time of measuring*

Clone	Wind speed (km/hr)		Air temperature (^{o}C)		Relative humidity (%)	
	Morning	Evening	Morning	Evening	Morning	Evening
RRIC 121	4.7	4.1	28.9	31.2	85.4	79.2
RRISL 203	4.2	6.2	30.4	29.0	80.3	86.9
RRISL 2001	2.3	3.8	30.3	29.2	86.9	88.8
PB 260	3.5	8.9	29.1	31.1	86.2	76.1

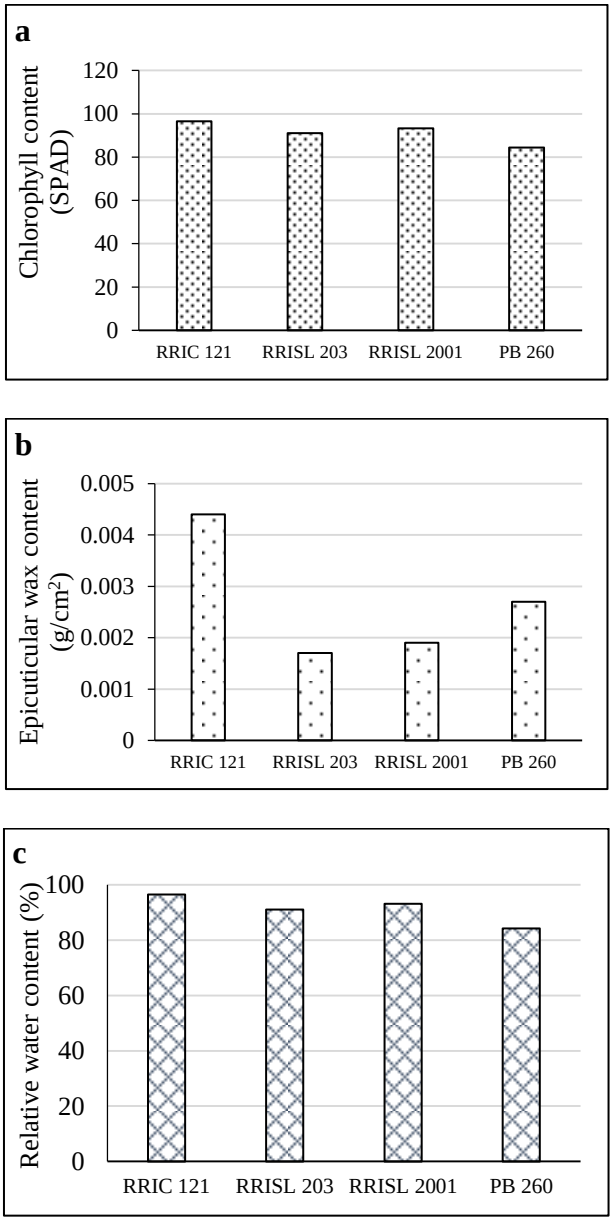


Fig. 2. Chlorophyll content, epicuticular wax content and relative water content of different *Hevea* genotypes planted at Pasyala experimental site

Chlorophyll content of the leaves varied among clones whilst highest and lowest values were observed in RRIC 121 (68.83 SPAD units) and PB 260 (64.45

SPAD units) clones, respectively (Fig. 2a). Among the genotypes tested, RRIC 121 had the maximum wax content (0.0044 g/cm^2) in leaves whilst RRISL 203 (0.0017 g/cm^2) had the minimum amount (Fig. 2b). The highest and lowest relative water contents of leaves were observed in RRIC 121 (96.5%) and PB 260 (84.3%), respectively (Fig. 2c) (K V V S Kudaligama, N P S N Karunarathne, M K P Perera, P D T L Madushani, L T B K Fernando and N N Abewardhana).

Effect of new leaf disease on yield and biochemical components of latex

To investigate any effect of new leaf disease on latex physiological factors that determined the yield of trees, an experiment was conducted in collaboration with Plant Pathology and Microbiology Department of RRISL. Tapping blocks were selected from 2010 replanted field in Gallewatte division of Dartonfield estate. Majority of the trees of RRIC 121 genotype and tapped on BO-1 panel. These field was severely infected with the new leaf disease in 2020. Investigations were done under S/2 d4 tapping system with the application of carbendazim (3 g/l) as the fungicide once in every two weeks in March - April, 2020. In the same time part of the field remained without fungicide application as the control. Latex physiological parameters were determined on weekly basis. Disease severity was assessed by the Plant Pathology and Microbiology Department, RRISL.

Sucrose, thiol, inorganic phosphorous, polyphenol contents and dry rubber content of latex have been investigated as the physiological parameters in the field tapped with S/2 d4 system with and without fungicide application. However, trees in the field sprayed fungicide had a higher sucrose, thiol and inorganic phosphorous content than in the field without fungicide spraying. Dry rubber content of latex was also slightly higher in trees applied fungicide. In both fields polyphenol content of latex was more or less similar (Table 10).

Table 10. *Average latex physiological parameters with and without fungicide application*

	With fungicide spraying	**Without fungicide spraying**
Sucrose content (mM)	4.42	3.72
Thiol content (mM)	0.08	0.05
Inorganic phosphorous content (mM)	14.19	13.98
Polyphenol content (mM)	1.45	1.44
Dry rubber content of latex (%)	41	40

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

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)

Locally formulated water based and oil based ethephon formulations were tested for their shelf life, efficacy and effect on latex physiological factors. Shelf life of the water based new formulation was tested by assessing any significant change in the acidity (pH), viscosity the active ingredient (ethephon) concentration and any microbial colony formations in the mixture with time. For the comparison existing commercially available water based formulation in market was also tested in the same time. Any significant change in the physical properties tested or any colony formation have not been observed for a period of 30 months from date of manufacturing (Table 11). Separation of ingredients or layering also have not been observed during this period.

Table 11. *Variation of properties of the water based formulation prepared over a 30 month period*

Time period	**pH**		**Viscosity (cP) (sp.4, RPM 100, Fungi lab viscometer)**		**Ethephon (w/w%)**		**Colony formation**	
	Existing	**New**	**Existing**	**New**	**Existing**	**New**	**Existing**	**New**
Initial	1.62	1.16	1907.2	1851.7	2.5	2.5	no	no
After 3 months	1.64	1.20	1910.2	1868.2	2.5	2.5	no	no
After 6 months	1.58	1.18	1898.2	1880.2	2.5	2.5	no	no
After 9 months	1.60	1.19	1899.2	1870.7	2.5	2.5	no	no
After 12 months	1.62	1.18	1896.2	1877.2	2.5	2.5	no	no
After 15 months	1.61	1.18	1892.6	1876.2	2.5	2.5	no	no
After 18 months	1.55	1.20	1951.7	1923.2	2.5	2.5	no	no
After 24 months	1.50	1.18	1890.8	1980.1	2.5	2.5	no	no
After 30 months	1.56	1.21	1920.3	1883.0	2.5	2.5	no	no

Prepared oil based new formulation was also tested for shelf life as done for water based ethephon formulation. Properties of new formulation was tested for a period of 30 months together with a commercially available oil based formulation and no any significant variation was observed in pH of the mixture and ethephon concentration. During this period, no any colony formation has also been observed (Table 12). However with aging, oil and water layers separation was apparent in the mixture. Therefore, commercially available surfactants such as lauryl alcohol

ethoxylate, polysorbate 80, arquard T50 and ethomeen were investigated for their suitability to enhance oil emulsification in the mixture. But they were also unable to overcome the issue.

Table 12. *Variation of properties of the oil based formulation prepared over a 30 month period*

Parameter	pH		Viscosity (cP) (sp.4, RPM 100, Fungi lab viscometer)		Ethephon (w/w%)		Colony formation	
	Existing	New	Existing	New	Existing	New	Existing	New
Initial	1.58	1.23	1100.3	1206.4	2.5	2.5	no	no
After 3 months	1.63	1.35	1036.4	1090.7	2.5	2.5	no	no
After 6 months	1.59	1.38	999.8	1108.0	2.5	2.5	no	no
After 9 months	1.62	1.29	1085.1	1008.9	2.5	2.5	no	no
After 12 months	1.57	1.27	1102.6	1042.9	2.5	2.5	no	no
After 15 months	1.60	1.30	1015.4	1164.2	2.5	2.5	no	no
After 18 months	1.61	1.28	1103.8	1090.8	2.5	2.5	no	no
After 24 months	1.57	1.24	1030.2	1101.1	2.5	2.5	no	no
After 30 months	1.60	1.30	1017.4	1162.2	2.5	2.5	no	no

Effect on latex physiological parameters

Latex physiology of trees treated with new water based (NWB) and new oil based (NOB) formulations was investigated together with existing water based (EWB) and existing oil based (EOB) ethephon formulations in the market as control treatments. Tapping system used for assessing was half spiral once in four days (S/2 d4) tapping system. No any pattern has been observed in variation of latex physiological parameters with four treatments. Sucrose content of latex of trees applied with NWB was significantly lower than other three treatments. Existing water based and oil based formulations showed comparable sucrose contents in latex whilst NOB formulation showed a significantly higher sucrose content in latex (Table 13). Thiol content of trees treated with EWB formulation was the highest whilst NOB formulation showed the lowest value with a significant difference. Among the four treatments, NWB and EOB formulations showed comparable latex thiol contents (Table 13). Inorganic phosphorous content under all four treatments was significantly different to each other. Highest average value was observed in trees applied with EWB formulation and lowest content was showed by the NOB formulation (Table 13). All four treatments except EOB had statistically comparable total solid content (TSC) higher than 42%. However, EOB showed about 45% TSC which was

significantly the highest (Table 13). Significantly highest and lowest latex polyphenol contents were observed in trees treated with EOB and NWB formulations (Table 13). Though significant variations in physiological parameters have been observed among four treatments, they all were within the desirable limits of a healthy tree.

Table 13. *Average latex physiological properties of trees treated with new water based (NWB), existing water based (EWB), new oil based (NOB) and existing oil based (EOB) ethephon formulations*

Treatment	Average latex physiological properties				
	Sucrose content (mM)	**Thiol content (mM)**	**Inorganic phosphorous content (mM)**	**Total solid content (w/w%)**	**Polyphenol content (mM)**
NWB	4.401[a] (±0.097)	0.236[b] (±0.007)	16.045[b] (±0.203)	42.74[a] (±0.12)	1.267[a] (±0.026)
EWB	5.057[b] (±0.113)	0.279[a] (±0.007)	18.076[a] (±0.226)	42.86[a] (±0.13)	1.740[b] (±0.019)
NOB	6.193[c] (±0.097)	0.134[c] (±0.004)	13.744[d] (±0.130)	43.03[a] (±0.15)	1.692[b] (±0.015)
EOB	5.102[b] (±0.112)	0.232[b] (±0.008)	15.388[c] (±0.198)	45.30[b] (±0.83)	1.801[c] (±0.017)
n	355	354	413	491	426

Means with the same letters are not significantly different ($p \leq 0.05$). Figures in the parentheses are standard error.

Effect on latex flow parameters

Initial flow rates of water based formulations were statistically comparable but significantly lower than oil based ethephon formulations which showed comparable initial flow rates (Table 14). Average plugging index (PI) was the lowest in NWB formulation with a significant difference whilst EOB showed a statistically higher PI. Plugging index of EWB and NOB was moderate and statistically comparable (Table 14). However, initial flow rate and PI of all four treatments were up to the desirable levels of a healthy tree.

Table 14. *Average latex flow parameters of trees treated with new water based (NWB), existing water based (EWB), new oil based (NOB) and existing oil based (EOB) ethephon formulations*

Treatment	Initial flow rate (ml/min)	Plugging index
NWB	4.84^{a} (±0.08)	3.35^{c} (±0.10)
EWB	5.05^{a} (±0.15)	3.84^{b} (±0.15)
NOB	5.95^{b} (±0.11)	3.77^{b} (±0.09)
EOB	5.89^{b} (±0.15)	4.29^{a} (±0.14)
n	155	151

Means with the same letters are not significantly different ($p \leq 0.05$). Figures in the parentheses are standard error.

Effect on yield parameters

On average EOB formulation showed a significantly higher dry rubber content of latex whilst other three formulations showed comparable values. Daily latex volume and dry rubber yield of a tree was the highest in NOB formulation with a significant difference. Other three formulations showed statistically comparable values lower than that of NOB formulation (Table 15).

Table 15. *Average yield parameters of trees treated with new water based (NWB), existing water based (EWB), new oil based (NOB) and existing oil based (EOB) ethephon formulations*

Treatment	Average yield parameters		
	Dry rubber content (%)	Daily latex volume/tree (ml)	Daily dry rubber yield/tree (g)
NWB	39.93^{b}(±0.14)	171.68^{a} (±5.10)	68.55^{a} (±1.38)
EWB	40.67^{b} (±0.80)	164.76^{a} (±5.04)	67.01^{a} (±1.95)
NOB	40.60^{b} (±0.12)	197.61^{b} (±4.99)	80.23^{b} (±1.27)
EOB	41.86^{a} (±0.11)	165.22^{a} (±4.51)	69.16^{a} (±1.35)
n	527	530	527

Means with the same letters are not significantly different ($p \leq 0.05$). Figures in the parentheses are standard error.

Commercial scale testing

Rubber fields established in 2011 at Elston estate, Puwakpitiya were selected to investigate the effectiveness of new water based (NWB) formulation together with two commercial ethephon mixtures available in the local market, *i.e.* existing water based (EWB) and existing oil based (EOB). Tapping system used was S/2 d4 system with application of 0.6g of 2.5% ethephon per tree at a rate of 10 rounds per year

avoiding wintering period. Tapping had been started in 2018 and experiment has been commenced since month of June in the same year. Tapping task size was 300-317 trees/tapper and for each formulation three tapping blocks were allocated. Dry rubber content of latex in tapping blocks applied three formulations were more or less similar and average value was about 37%. Intake per harvester in blocks applied with NWB, EWB and EOB was 16.72, 16.38 and 16.78 kg, respectively. Observed yield per hectare (400 trees) were 1,337, 1,311 and 1,343 kg, respectively (Table 16) (K V V S Kudaligama, T H P S Fernando, V H L Rodrigo, P Seneviratne, A P Attanayaka, K M E P Ferando, N P S N Karunarathne, M K P Perera, L T B K Fernando P D T L Madushani and N N Abeywardhena).

Table 16. *Variation of yield of tapping tasks (300 trees) harvested with S/2 d4 system using different types of ethephon formulations*

Type	**Dry Rubber Content (%)**	**Latex volume (L)**	**Intake per harvester (kg)**	**Daily dry rubber yield/tree (g)**
New water based	37.14	45.02	16.72	55.73
Existing water based	37.07	44.20	16.38	54.62
Existing oil based	37.24	45.07	16.78	55.95

ADVISORY SERVICES

P K K S Gunarathne

DETAILED REVIEW

Staff

Dr Anura Dissanayake, the Head of the Department, Mr P K K S Gunarathne, Advisory Officer, Mrs Priyasha Manahari, Assistant Training and Officer and sixteen Extension Officers (REOo) were on duty throughout the year Dr Anura Dissanayake, the Head of the Department, retired from the service with effect from 08th December 2020. Mrs Suja Kaluarachchi, Management Assistant retired from the service with effect from 12th June 2020.

Conferences/meetings/seminars/workshops/foreign tours attended

Officer/s	Subject/s	Organization/s
A Dissanayake PKKS Gunaratna	Scientific Committee Meetings	Rubber Research Institute of Sri Lanka
A Dissanayake PKKS Gunaratna	Budget Meetings	Rubber Research Institute of Sri Lanka
PKKS Gunaratna	Meeting in "Strategic Plan for Matara district rubber cultivation 2020-2025"	District Secretarial Office Matara
PKKS Gunaratna All REOs	Workshop on "Pestalotiopsis " at Dartonfield auditorium	Rubber Research Institute of Sri Lanka
PKKS Gunaratna	Workshop on "Writing a quality research paper: tips and tricks"	Post graduate Institute of Agriculture, University of Peradeniya
PKKS Gunaratna	Workshop on "Addressing Reviewers' Comments on a Manuscript"	Post graduate Institute of Agriculture, University of Peradeniya
PKKS Gunaratna	Presentation skills Training: How to create and deliver High - Impact Presentation	Post graduate Institute of Agriculture, University of Peradeniya
PKKS Gunaratna	7th International Conference on Multidisciplinary approaches - 2020	Faculty of Graduate studies, University of Sri Jayawardanapura
PKKS Gunaratna	25th International Forestry and Environmental Symposium - 2020	Department of Forestry and Environmental Science, University of Sri Jayawardanapura
PKKS Gunaratna	Online Educational Workshop for the Agricultural undergraduates of Uva Wellassa University on Agricultural Extension Services in Sri Lanka, 2020	Uva Wellassa University

PROGRESS OF PROJECTS AND SERVICES

Extension and advisory programmes were carried out under four 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 rubber sector and estate 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). As models, 71 immature and 83 mature holdings were fully developed (Figs. 1,2).

Fig. 1. Mature model rubber holding - Mr Nihal Susilasiri (Kosgama REO range)

Fig. 2. Immature model rubber holding - Mr Gamunu Atapattu (Kosgama REO range)

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

Region	No. of developed holdings	
	Mature	**Immature**
Colombo/Gampaha	5	4
Kegalle	25	16
Kalutara	24	26
Ratnapura	14	13
Galle/Matara	15	12
Total	83	71
		154

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

Advisory and extension support services were provided to maintain 21 "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 (Table 2).

Fig. 3. Model Rubber Processing Center - Mr Athula Egodawatta (Kandy/Matale range)

Table 2. *Participatory development of rubber processing centers*

Region	No. of model centers developed
Colombo/Gampaha	4
Kegalle	4
Kalutara	5
Ratnapura	5
Galle/Matara	3
Total	21

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

To popularize the rain guard technology as a short term strategy to increase the productivity of rubber smallholders, 38 demonstration plots were established under the supervision of Rubber Extension Officers (Table 3).

Fig. 4. Inter-crop model rubber holding - Mrs Chitra Pushpalatha (Bandaragama REO range)

Table 3. *Details of rainguard demonstration holdings*

Region	No. of demonstration holdings established
Colombo/Gampaha	2
Kegalle	12
Kalutara	13
Ratnapura	6
Galle/Matara	5
Total	**38**

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 31 new RSS production centers and rehabilitation of 11 substandard processing centers, to maintain them as cost effective units according to the requests of owners (Table 4) (Fig. 5).

Fig. 5. New Rubber Processing Center - B V Chandrawathi (Palindanuwara REO 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	0	1
Kegalle	18	5
Kalutara	8	1
Ratnapura	1	2
Galle/Matara	4	2
Total	31	11

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, 07 intercropping demonstration plots were established (Table 5). Type of intercrops were Pineapple and Banana (Pineapple – 04, Banana – 03).

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

Region	No. of demonstration
Colombo	1
Kegalle	3
Kalutara	2
Ratnapura	1
Total	**7**

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

The concept of establishment of "forward march rubber villages" was widened 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.

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

One thousand nine hundred thirty-five 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*

	Nature of advisory visit						
Region	**Model farm development**	**Introduction of intercropping systems**	**Introduction of rainguard technology**	**Maintenance of model RSS centers**	**Construction of new RSS centers**	**Rehabilitation of substandard RSS centers**	**Total**
Colombo/Gampaha	44	8	7	10	0	0	**69**
Kalutara	528	20	165	45	88	7	**853**
Kegalle	284	15	84	30	103	29	**545**
Rathnapura	63	0	06	77	26	22	**194**
Galle/Matara	185	0	22	20	28	19	**274**
Total	**1104**	**43**	**284**	**182**	**245**	**77**	**1935**

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

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

One hundred ninety advisory visits and 103 demonstrations were made by REOo to solve technology adoption problems of rubber smallholders in relation to all agronomic and processing aspects. A separate report was prepared by REOo on each visit and follow up actions were attended where necessary (Table 7).

Table 7. *Demonstrations conducted on requests of rubber stakeholders*

Type of demonstration	No. of demonstrations
Immature	
Planting holes	4
Planting	1
Soil conservation	2
Branch induction	1
Fertilizer application	2
Weed control	1
Diseases	1
Mature	
New panel marking	15
Tapping correction	14
Fertilizer application	2
Rainguard	16
New tapping knife	5
Disease	15
TPD	2
Other	2
Processing	
Sheet making	2
Racks	2
One day Smoke House	6
New Smoke House	7
Chimneys	2
Other	1
Total	**103**

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	0	7	0	7
Kegalle	7	24	9	40
Kalutara	12	39	5	56
Ratnapura	7	8	2	17
Galle/Matara	10	53	7	70
Total	**36**	**131**	**23**	**190**

The above advisory visits were categorized as follows (Figs. 6, 7 and 8).

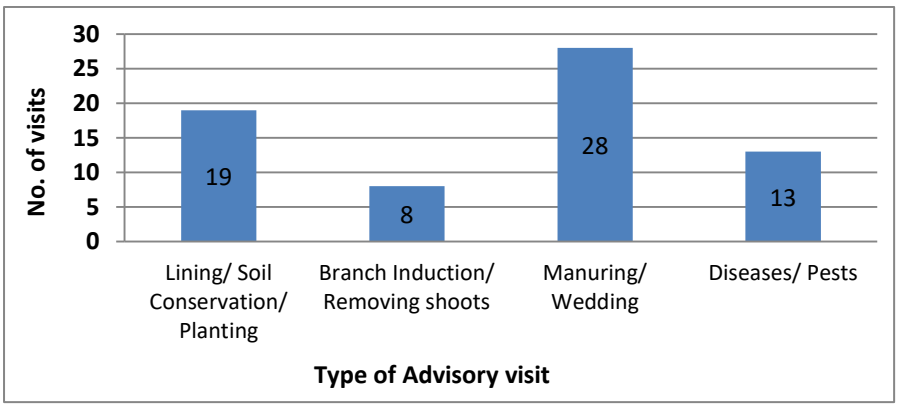


Fig. 6. Number of advisory visits conducted in immature holdings

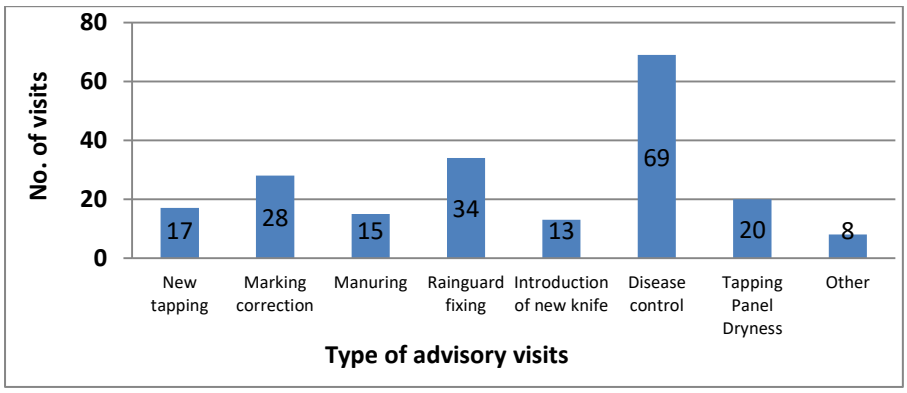


Fig. 7. Number of advisory visits conducted in mature holdings

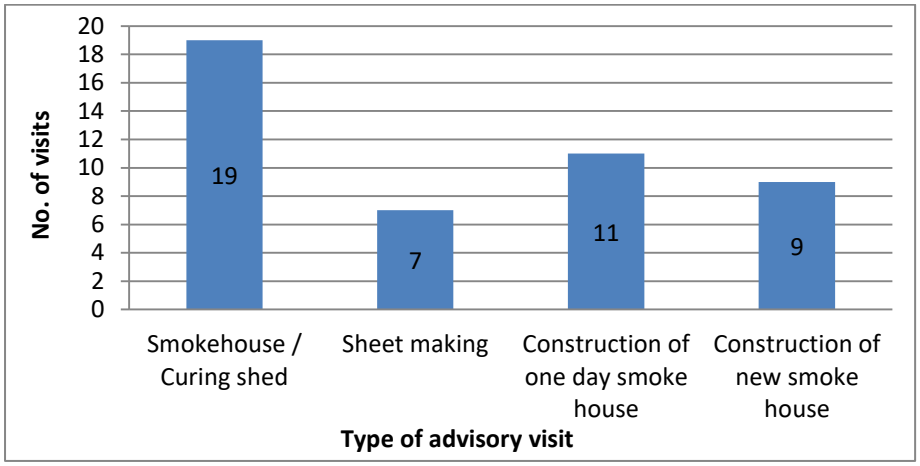


Fig. 8. Number of advisory visits conducted in processing centers

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 71 small land units in traditional rubber growing areas for necessary improvement (Table 9). A schematic representation of this activity is given in Figure 9.

Table 9. *Number of lands that conducted Vihidum Sathkara programmes for rubber smallholders*

Region	**No. of lands (Vihidum Sathkara)**	
	Immature	**Mature**
Colombo/Gampaha	5	0
Kegalle	0	0
Kalutara	16	0
Ratnapura	43	0
Galle/Matara	7	0
Total	**71**	**0**

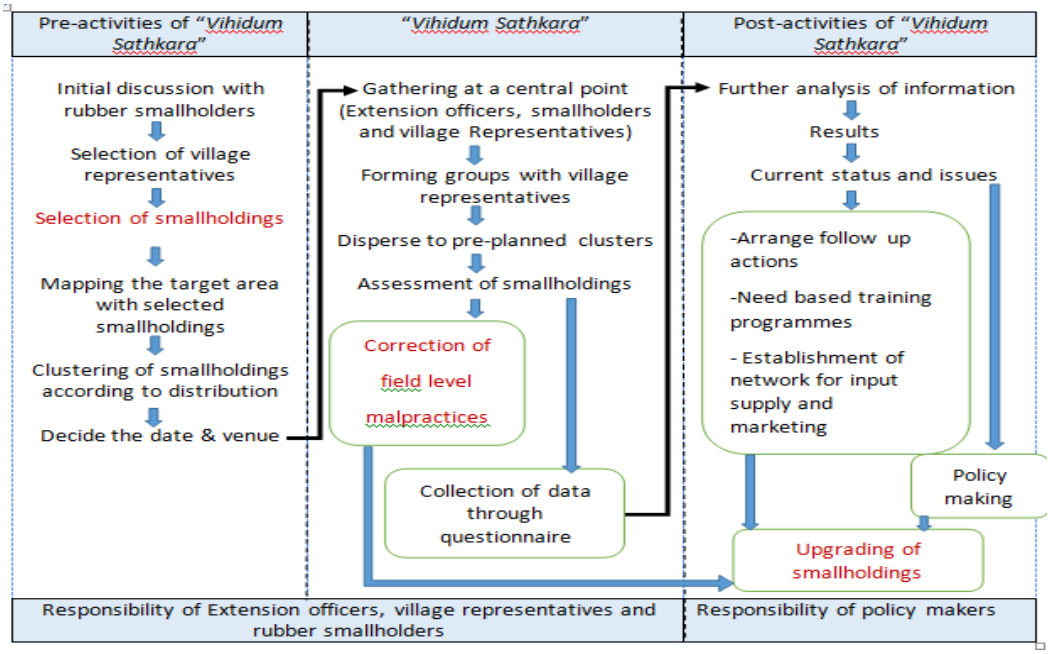


Fig. 9. Schematic representation of "Vihidum Sathkara" group advisory programme

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

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

Farmer awareness training programmes were conducted to educated 103 smallholders and 150 estate staff (Field Officers and Estate workers) on general cultivation aspects of rubber and rainguard application (Figs. 10 & 11). Participation from each estate for awareness programmes on general cultivation aspects of rubber and rain guard are summarized in Table 9 and Table 10.

Table 10. *Details of farmer participation for Awareness programmes on general cultivation and processing aspects of rubber in estate sector*

Name	No. of participants
Matuwagala estate - Balangoda Plantation (Field Officers)	16
Sunderland estate (Field Officers)	05
Elston estate (Field Officers)	11
Total	32

Table 11. *Details of farmer participation for Awareness programmes on rainguard in estate sector*

Name	No. of participants
Elston estate	36
Ayre estate	53
Sunderland estate	29
Total	**118**

Table 12. *Details of farmer participation for awareness programmes on rainguard in smallholder sector*

Region	No. of programmes	No. of farmers trained
Kegalle	1	24
Kalutara	1	47
Galle	2	32
Total	**4**	**103**

Fig. 10. Conducting field level awareness raising programme for Field Officers at Matuwagala estate (2020.03.18)

Fig. 11. Conducting rainguard awareness raising programme at Sunderland estate (2020.02.14)

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 29 new harvesting assistants were introduced to the rubber industry after 10 days of training.

Table 13. *Details of Tapper Training Programmes conducted for rubber tapper (smallholder sector)*

Region	No. of programmes	No. of new tappers trained
Kalutara	1	47
Total	**4**	**103**

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 545 selected harvesting assistants for smallholder sector and estate sector (Table 13,14) (Figs. 12,13,14).

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

Region	No. of programmes	No. of new tappers trained
Kegalle	1	22
Total	**1**	**22**

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

Region	No. of programmes	No. of new tappers trained
Penrith	1	60
Elston	1	49
Sunderland	1	52
Ayre	1	44
Eheliyagoda	1	49
Matuwagala	1	45
Halpe	1	44
Kelanivalley	1	49
Halwathura	1	47
Kegalle Plantation	1	27
Pussella	1	66
Total	**11**	**523**

Fig. 12. Tapping skill development programme conducted at Yatidariya Plantation - Kegalle Plantation (2020.08.13)

Fig. 13. Tapping skill development programme conducted at Wee oya Estate - Kelanivalley Plantation (2020.07.25)

Fig. 14. Tapping skill development programme conducted at Matuwagala Estate - Balangoda Plantation (2020.03.02)

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

- Participated for the education exhibition (02 days) organized by Labuduwa Siridhamma
- Participated for the education exhibition (02 days) organized by Piliyandala Central College

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 16. *Details of the services provided by REOs*

Name of the programme	Organization	Number of programmes
Quality improvement of RSS (one day)	Thurusaviya Fund	06
Harvester's training programme (seven days)	Thurusaviya Fund	05
Tapper Training School (one day)	Rubber Development Dept.	03
Rainguard awareness programme (one day)	Rubber Development Dept.	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, establishment of technical banners and preparation of exhibition area were completed.

c) Introduction and establishment of new fuel wood growing models in selected lands of smallholder rubber farmers

This project was started in 2017 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’)

As at 31st December 2020, 4.01 Mn from the total allocation of 10.45 Mn had been spent for 92 farmers to establish of different fuelwood growing models. Some of the planned activities during this period could not be done due to Covid -19 pandemic situation. Farmers were successfully maintaining rubber and Gliricidia plants in their farm lands using proper agronomic practices. REO’s made frequent visits to the sites to monitor the prevailing conditions. The total area of 62 ha was covered under the project. “Gliricidia Farming Unit” was established at Rubber Technology Park, Moneragala Sub Station aiming cultivation, maintenance, processing and marketing aspects of Gliricidia.

This unit consists of three parts.

1) Establishment of Gliricidia demonstration plots
   Land was prepared according to the recommended cultivation distances and agronomic practices. Proposed site was a “Deniya” land. So proper drainage system and several culverts ware installed to facilitate the drainage.
2) Establishment of exhibition area regarding Gliricidia cultivation and related aspects
   Main aim was transfer the knowledge to farmers, schools students, University students and community about Gliricidia industry. Main areas focused:

- History of Gliridia cultivation
- Present and future potentials
- Economic and environmental significance

   Awareness through relevant magazines, leaflets, electronic media (DVD, Internet) will be conducted in this area.

3) Preparation of Gliricidia for the market
   This unit was is in progress. Demonstrations will be conducted on stem cutting, chopping, drying and packaging to reflect on how Gliricidia is prepared for the target market.

RUBBER TECHNOLOGY AND DEVELOPMENT

Dilhara Edirisinghe

DETAILED REVIEW

Staff

Dr (Mrs) Dilhara Edirisinghe, Head of the Department and Mrs Aloka Weerasinghe, Research Officer were on duty throughout the year. Mr W D M Sampath, Research Officer reading for a PhD. degree was on full-time study leave from 28th October 2020.

Mrs Priyanthi Perera, Experimental Officer and Mr Mahesh Abeywardena, Miss Gayathri Bhagyawedha, Mr Indika Perera, Miss Ishani Jayaratne, Mr Nadun Tillekeratne and Miss Madhushani Gunawardena, Technical Officers were on duty throughout the year. Mrs Nushara Nanayakkara was on maternity leave from 17th June to 15th October 2020.

Miss Shashee Rekha De Alwis Wijerathne, Management Assistant was on duty until her service was requested by the Rubber Research Board office from 23rd June 2020.

Research students

Postgraduate students

- Mrs Hasara Samarasinghe (Research Officer, Polymer Chemistry Dept.), PhD. student, University of Moratuwa continued her research project on "Development of property correlations for nitrosamine safe binary accelerator systems in sulfur vulcanized natural rubber" under the supervision of Dr (Mrs) D G Edirisinghe.

- Mr W D M Sampath (Research Officer, Rubber Technology & Development Dept.), PhD student, Wayamba University of Sri Lanka initiated his research project on "Synthesis of nanographene and characterization of its composites based on natural rubber" under the supervision of Dr (Mrs) D G Edirisinghe.

- Ms Amali Weerakoon (Lecturer, ITUM), PhD student, University of Sri Jayewardenepura continued her research project on "Synthesis of phenol-formaldehyde resins and their adducts by utilizing the polyphenols from banana (*Musa paradaisica* L.) pseudostem for production of solid tyres" under the supervision of Dr (Mrs) D G Edirisinghe.

- Mrs Kirushanthi Thangavel, MPhil student, Uva Wellassa University of Sri Lanka completed her research project on "Innovative outdoor floor tiles derived

from natural rubber and polyurethane composites" under the supervision of Dr (Mrs) D G Edirisinghe.

- Mr Indika Perera (Technical Officer, Rubber Technology & Development Dept.), MPhil student, University of Sri Jayewardenepura continued his research project on "Modification of rigid polyurethane foam waste to develop blends with nitrile rubber for special applications" under the supervision of Dr (Mrs) D G Edirisinghe.

- Mr Danushka Wijewardena, MPhil student, Uva Wellassa University of Sri Lanka continued his research project on "Rheological and mechanical properties of ternary composites of thermoplastics and skim natural rubber" under the supervision of Dr Susantha Siriwardena and Dr (Mrs) D G Edirisinghe.

- Mr Lahiru Edirisinghe, MSc (Polymer Science and Technology) student, University of Sri Jayewardenepura conducted his research project on "A novel reclaiming agent for partially cured gasket spew of EPDM rubber: Property evaluation of blends of virgin natural rubber and reclaimed EPDM" under the supervision of Dr (Mrs) D G Edirisinghe.

- Mr Janaka Wijesinghe, MSc (Polymer Science and Technology) student, University of Sri Jayewardenepura conducted his research project on "Effect of antioxidant in cashew nut shell liquid on ageing properties of silica filled natural rubber compound" under the supervision of Dr (Mrs) D G Edirisinghe.

- Mr Lakshman Samarakoon, MSc (Polymer Science and Technology), University of Sri Jayewardenepura conducted his research project on "Evaluation of physico-mechanical properties of natural rubber and polystyrene-butadiene blended latex foam in continuous sheet manufacturing process" under the supervision of Dr (Mrs) D G Edirisinghe.

Undergraduate students

- Mr D M E Senevirathne, BSc (Chemical Technology Special) undergraduate student, Sabaragamuwa University of Sri Lanka conducted his research on "Development of nano-size coconut fibre filled natural rubber composites" under the supervision of Mr W D M Sampath and Mrs U A Weerasinghe.

- Mr K G Nandana Bandara, graduateship student, Plastics and Rubber Institute of Sri Lanka conducted his research on "Development of cashew nutshell powder filled natural rubber composites" under the supervision of Dr (Mrs) D G Edirisinghe.

Seminars/Training/Conferences/Workshops/Meetings attended

Officer/s	Subject/Theme	Organization
DG Edirisinghe and WDM Sampath	Scientific Committee Meeting	Rubber Research Institute of Sri Lanka (RRISL)
DG Edirisinghe	Launching ceremony of "Polymertech 20" magazine	Institute of Technology, University of Moratuwa

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

Officer/s	Subject/Theme	Beneficiary/Client
WDM Sampath	Compounding ingredients used in dry rubber	Students of the Certificate Course in Rubber Technology - PRISL
KIDP Perera	Compound formulations and processing techniques	Students of the Certificate Course in Plastics Technology - PRISL
KIDP Perera & KND Tillekeratne	Workshop on "Rubber based products manufacture" in Kosgama	Rubber Development Department/Entrepreneurs
DGMJ Abeywardena	Workshop on "Rubber based products manufacture" in Badalkumbura, Monaragala	Rubber Development Department/Entrepreneurs
KIDP Perera & KND Tillekeratne	Workshop on "Rubber based products manufacture" in Ratnapura	Rubber Development Department/Entrepreneurs
DGMJ Abeywardena	Workshop on "Rubber based products manufacture" in Aramanagolla, Horana	Rubber Development Department/Entrepreneurs
KND Tillekeratne	"Ridi Abises" Exhibition at Siridhamma Vidyalaya, Labuduwa, Galle	Siridhamma Vidyalaya/School Children/General Public
Staff of the department	Practical demonstration on "Latex based and dry rubber based products manufacture" at RRISL, Ratmalana	BSc (Agri. Sp.) undergraduates of the Department of Plantation Management, Wayamba University of Sri Lanka
Staff of the department	Field training on "Rubber Technology"	Undergraduate students of Palm & Latex Technology and Value Addition - Uva Wellassa University
Staff of the department	Field training on "Rubber Technology"	Undergraduate students of Dept. of Agricultural Technology, Faculty of Technology, University of Colombo

Industrial visits

The following rubber compound/product manufacturing industries were visited during the year for development/troubleshooting work.

Officer	Industry/Organization
DG Edirisinghe & KIDP Perera	Richard Pieris Natural Foams, FTZ, Biyagama
DG Edirisinghe & KIDP Perera	D. Samson Compounds, Galle
DG Edirisinghe	Green Rubber Toys, Kotikawatta
KIDP Perera	Lalan Rubbers, Biyagama

LABORATORY INVESTIGATIONS

Dry rubber technology

Development of rubber composites with waste materials for different applications

Recycling of rigid polyurethane (rPU) foam waste

This project, initiated at the request of D. Samson Industries, Galle was continued throughout the year. Thermoset rPU foam waste was mechano-chemically modified with 6 phr of carbamide (MA1), paraphenylenediamine (MA2), trimethyl-dihydroquinoline (MA3), thiuram (MA4) and natural protein (MA5) based modifying agents using a two-roll mill at a temperature closer to ambient temperature (28 ^{o}C). The five modified rPU foam waste samples were characterized using FTIR spectroscopy and Rubber Process analyzer (MonTech D-RPA 3000). Composites of 70:30 virgin NBR/mechano-chemically modified rPU foam waste blends were prepared according to the ASTM oil seal formulation.

Initial characterization of virgin NBR/modified rPU 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 also determined according to the relevant ISO standards. Out of the five composites, MA5 composite showed the best processing properties. MA4 and MA5 composites showed lower compression set and abrasion volume loss in comparison to the others. As MA4 is known to be a harmful chemical, MA5 was selected as the most suitable environmentally friendly modifying agent among the candidate agents.

Thereafter, five rPU foam waste samples were mechano-chemically modified with the selected modifying agent (MA5) by varying the loading from 2-10 phr at 2 phr intervals and characterized. Five composites of 70:30 virgin NBR/mechano-chemically modified rPU foam waste with different loadings of MA5 were prepared according to the ASTM oil seal formulation and characterized. Lowest values for plasticity and Mooney viscosity were shown by the virgin NBR/rPU foam waste modified with 6 phr of MA5 modifying agent. The composite, virgin NBR/mechano-chemically modified rPU foam waste prepared with 6 phr MA5 modifying agent showed the highest values for tensile strength, hardness and tear strength. Therefore,

the best loading of MA5 modifying agent for mechano-chemical modification of rPU foam waste was selected as 6 phr.

Further, five virgin NBR/modified rPU foam waste blends were prepared with 10, 20, 30, 40, and 50% of mechano-chemically modified rPU foam waste prepared with 6 phr of MA5 modifying agent according to the ASTM oil seal formulation and characterized. Results showed that replacement of 20% of virgin NBR with mechano-chemically modified rPU foam waste prepared with 6 phr of MA5 modifying agent retains about 76-77% of tensile strength, modulus at 100% elongation. Tear strength, elongation at break, resilience, abrasion volume loss and compression set increased by 12%, 5%, 3%, 26% and 32%, respectively (K I D P Perera, D G Edirisinghe and L Karunanayake - Dean, Faculty of Applied Science, University of Sri Jayewardenepura, Sri Lanka).

Synthesis of natural nano-fibres and development of rubber composites with nano-fibres

Development of nano size coconut fibre filled natural rubber composites

Natural fibre–reinforced polymer composites are gaining favor over synthetic fibre-reinforced ones owing to their lower cost and environmentally friendly characteristics. Natural fibres from coconut husk, banana stem, areca nut husk, pineapple crown, palmyra, sisal, rice straw, *etc*. have been incorporated into natural rubber (NR) composites for reinforcement with a green approach. In this study, coconut or coir fibre (CF) was chemically treated to obtain nano size fibres and separated according to different size ranges of the fibres. Thereafter, NR composites were prepared with 2 phr loading from each size range and properties were evaluated. The fibre size variation was designated as in Table 1. In addition, composite prepared with 5mm size coir fibres was used as the control (C1). Strength properties, ageing properties and water absorption of the composites were evaluated and compared.

Table 1. *Ranges of coir fibre size of the NR composites*

Composite	Range of coir fibre size (µm)
C_2	250-350
C_3	125-175
C_4	75-125
C_5	25-75
C_6	below 50

According to Figure 1, there is an increasing trend in tensile strength with the decrease of fibre size. This could be attributed to improved dispersion of coir fibre in the NR matrix as the fibre size decreases. However, Figure 2 indicates a decreasing trend in tear strength with the decrease of fibre size. As the fibre size decreases, weak interfacial area between the fibre and NR increases and hence an initiated crack can

easily propagate through this weak interface leading to a decrease in tear strength. These figures show an increase in tensile and tear strengths, after ageing due to the formation of additional crosslinks during ageing leading to an increase in crosslink density.

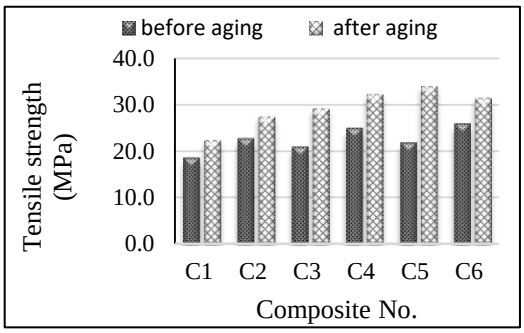


Fig. 1. Tensile strength of CF filled NR vulcanizates

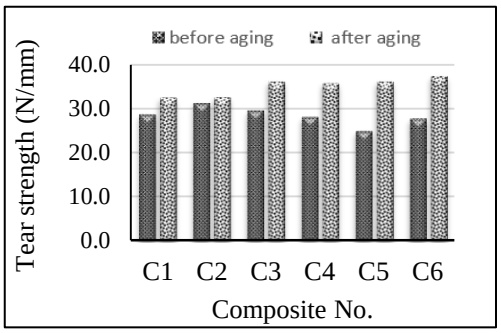


Fig. 2. Tear strength of CF filled NR vulcanizates

The retention values of both tensile strength (Fig. 3) and tear strength (Fig. 4), after ageing indicate higher performance as the values are greater than 100% for all the composites.

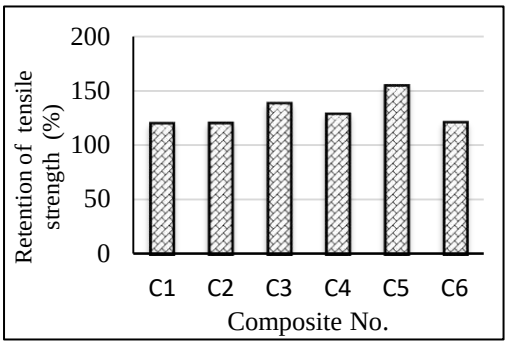


Fig. 3. % Retention of tensile strength of CF filled NR vulcanizates

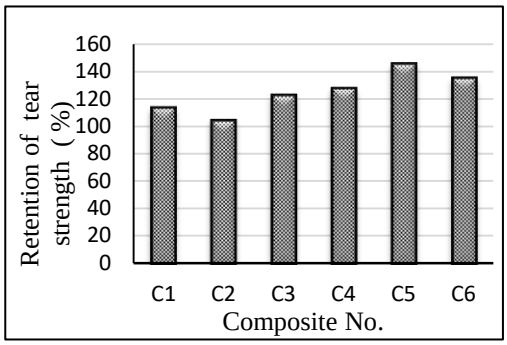


Fig. 4. % Retention of tear strength of CF filled NR vulcanizates

Water absorption results (Fig. 5) showed a significant increase in the composite C6, where the finest CF (less than 50 µm) was incorporated and could be attributed to the higher surface area of coir fibre. This observation indicates a higher cooling effect for the composites as the fibre size decreases.

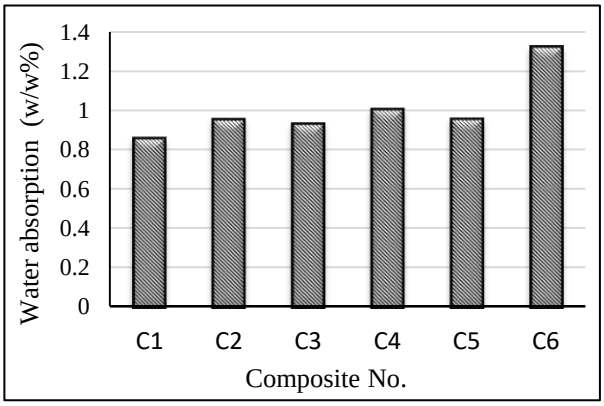


Fig. 5. Water absorption of CF filled NR vulcanizates

A research paper was written on this study and published in the Journal of the Plastics and Rubber Institute of Sri Lanka, 2020 [W D M Sampath, U A Weerasinghe**,** D G Edirisinghe, D M E Senewirathne - BSc (Chemical Technology Special) Undergraduate student, Sabaragamuwa University of Sri Lanka].

Development of calcium carbonate filled cellular rubber products with dry rubber for special applications

Three series of dry natural rubber based cellular compounds were prepared using three blowing agents of different types namely, $NaHCO_3$, DNPT and isopropanol by varying the loading from 2-10 phr at 2 phr intervals. The effect of the addition of 5 phr of calcium carbonate ($CaCO_3$) filler on properties was evaluated. Cure characteristics of rubber compounds, mechanical and water absorption properties of cellular rubber produced were evaluated according to international standards. Results of compounds prepared with and without filler were compared.

As expected, in the absence of filler, the tensile strength of cellular rubber prepared with all three blowing agents decreases with the increase of blowing agent loading (Figs. 6, 7 and 8). Also, it is observed from the figures that the tensile strength of cellular rubber prepared with filler is higher than that of cellular rubber prepared without filler. However, Figure 6 shows an increasing trend in tensile strength of cellular rubber prepared with $NaHCO_3$ blowing agent and the filler in comparison to that of cellular rubber prepared with the other two blowing agents, DNPT and isopropanol in the presence of filler (Figs. 7 and 8). One possible reason for this observation could be the cellular structure generated by these different blowing agents. According to the literature, $NaHCO_3$ generates an open-cell structure, whereas DNPT and isopropanol generate closed-cell structures. The open-cell structure enables the filler particles to disperse more evenly within the composite

eventually leading to more rigid cell wall generation and hence higher tensile strength.

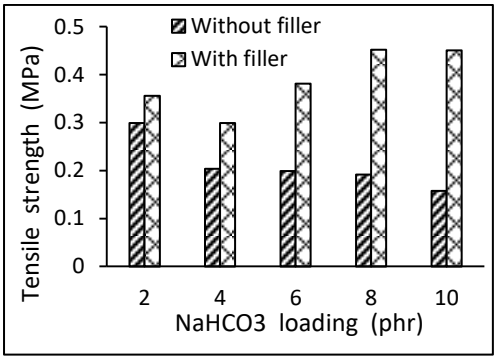


Fig. 6. Tensile strength of cellular rubber prepared with $NaHCO_3$

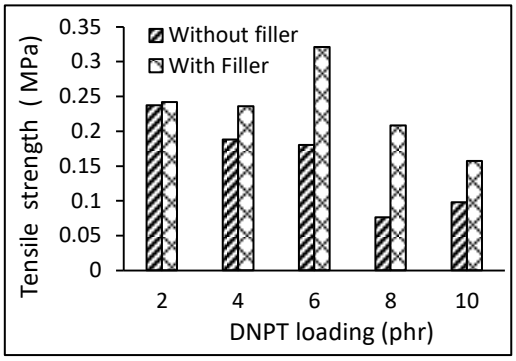


Fig. 7. Tensile strength of cellular rubber prepared with DNPT

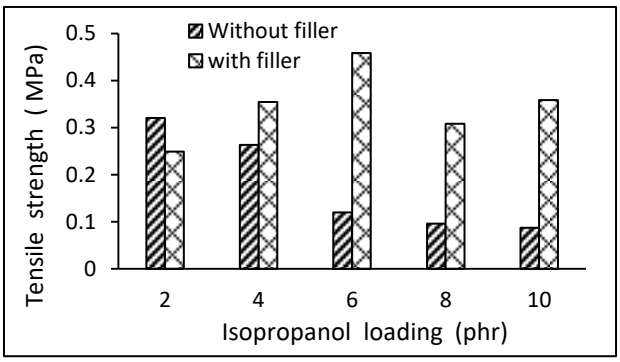


Fig. 8. Tensile strength of cellular rubber prepared with isopropanol

As expected, open-cell generating cellular rubber prepared with $NaHCO_3$ blowing agent shows higher water absorption compared to closed-cell generating cellular rubber prepared with the other two blowing agents with or without filler (Figs. 9 and 10). Further, $CaCO_3$ filled cellular rubber prepared with all three blowing agents shows higher water absorption than the unfilled counterparts. This behaviour could be attributed to the hydrophilic nature of the $CaCO_3$ filler.

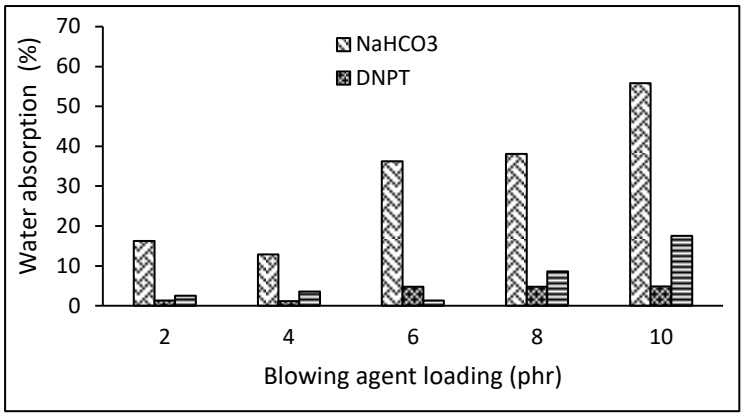


Fig. 9. Water absorption of unfilled cellular rubber

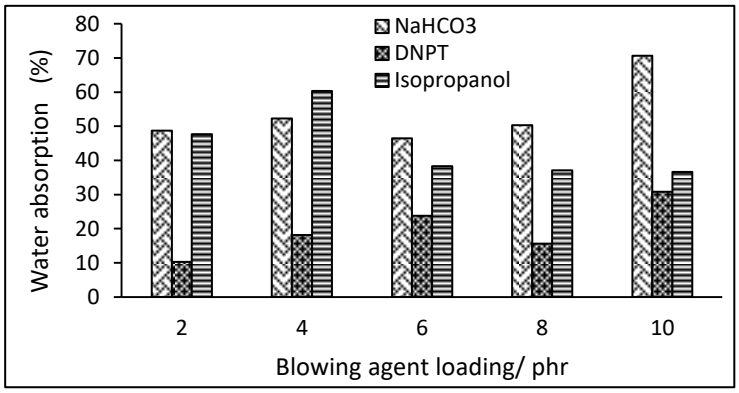


Fig. 10. Water absorption of $CaCO_3$ filled cellular rubber

Although $CaCO_3$ filler provides a certain level of stiffness to the cellular rubber composites, water absorption of the composites increases substantially in the presence of this filler. Increased stiffness combined with increased water absorption can be beneficial for certain applications (U A Weerasinghe, D G Edirisinghe, K N D Thilakarathne and A H D M N Gunawardana).

Industrial extension

The following properties of materials were tested and test reports were issued to the respective companies/government organizations at their request.

Sole crepe (Hardness)	**Rubber compound** (Physico-mechanical properties)	**Rubber product** (Physico-mechanical properties)	**Polythene** (Tensile properties)
Atale Estate, Kegalle Plantations	Samson Compounds (Pvt.) Ltd.	Ceyflex Rubber Ltd.	Lalan Rubbers (Pvt.) Ltd.
Elston Estate, Pussellawa Plantations Ltd.	Polymer Products Impex (Pvt.) Ltd.	DPL Premier Gloves Ltd.	Rubber Development Department
Panawatte Estate, Kelani Valley Plantations PlC.	BGN Industrial Tyre (Pvt.) Ltd.	Hanwella Rubber Products Ltd.	
Dewalakanda Estate, Kelani Valley Plantations PlC.	John Keels Research	Quality Latex Products (Pvt.) Ltd.	
	Mount House Hameed Brothers Colombo (Pvt.) Ltd.	Dipped Products Plc.	
	Paboja Trading	Textrip (Pvt.) Ltd.	
	Ali Brothers (Pvt.) Ltd	Sri Lanka Customs	
	Samson Rubber Products (Pvt.) Ltd.		
	Microcells (Pvt.) Ltd.		
	Road Development Authority		
	Atire (Pvt.) Ltd.		

Development of rubber compounds/rubber products/reclaimed rubber

The following rubber compound/rubber product/reclaimed rubber developments were conducted on requests made by the respective clients.

Development	**Client**
Can sealant compound	Entrepreneur
Foam rubber adhesive compound	Entrepreneur
NR latex based catheter	R.A.P. Engineering (Pvt.) Ltd.
NR latex compound as a water-proof coating material for tents made out of fabric	Entrepreneur
Novel glove to protect against the Covid-19 pandemic	Entrepreneur
NR based outsole compound for leather boots	D.I. Shoe Co.
Reclaiming of NR based rubber band waste	Lalan Rubbers (Pvt.) Ltd.
Mat compound out of NR product waste	D. Samson International (Pvt.) Ltd.
Reclaiming of NR based glove waste and rubber band waste	Entrepreneur

Development	Client
Low-density NR latex foam	Richard Pieris Natural Foams
Reclaiming of micro-cellular rubber based slipper sole waste	D. Samson Compounds (Pvt.) Ltd.
NR based composites with durian husk fibres	Undergraduate student, Textile Department, The Open University of Sri Lanka
NR latex based films with coconut husk powder	Coconut Research Institute of Sri Lanka
NR latex based eco-friendly material for table design	Undergraduate student, Department of Multidisciplinary Design, University of Visual & Performing Arts
Novel NR latex based fashionable gloves	Rubber Research Institute of Sri Lanka

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.

Research students

- Ms R N M Wehigaldeniya, a BSc (Chemistry sp.) undergraduate student from the University of Peradeniya conducted her third year industrial project entitled 'Fabrication of processed waste-mica/natural rubber composites by latex mixing method' under the supervision of Mr Y R Somarathna.

Lectures/Seminars/Training/Workshops/Conferences conducted

Officer/s	Subject/Theme	Beneficiary/ Client
YR Somarathna	Value added natural rubber grades	Students of Advance Certificate Course in Plantation Management, National Institute of Plantation Management
YR Somarathna	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	Scientific Committee Meeting	Rubber Research Institute of Sri Lanka
	Workshop on advanced instrumentation (GCMS and its applications)	Techno Instruments (Pvt) Ltd
	Workshop on Thermal Conductivity Analyzer	The Open University of Sri Lanka
	Evaluating Simultaneous Thermal Analysis (STA) measurements- Special applications	NETZSCH GmbH

LABORATORY INVESTIGATIONS

Development of property correlations for nitrosamine safe binary accelerator systems in sulfur vulcanized natural rubber

The combined effect of nitrosamine free diisopropylxanthogen polysulfide (DIXP) and nitrosamine safe tertiary butyl benzothiazolesulphenamide (TBBS) was studied. Cure characteristics of the compounds, tensile properties, tear strength, hardness, and crosslink density of the vulcanizates prepared with three different ratios of the above accelerator combinations were determined and compared with vulcanizates prepared with DIXP and TBBS single accelerators. Rheographs of the compounds prepared with three combinations of DIXP and TBBS accelerators and the single accelerators are shown in Figure 1. The graphs clearly show that progressive replacement of DIXP by TBBS has made a noticeable influence in regard to most of the cure properties such as scorch time (ts_2), optimum cure time (t_{90}), maximum torque (M_H), and delta cure [M_H-M_L (minimum torque)].

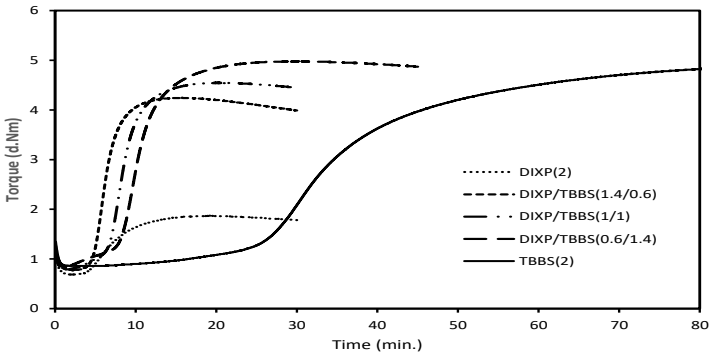


Fig. 1. Rheographs of NR compounds prepared with different combinations of DIXP/TBBS binary accelerator system

Figures 2, 3, 4, and 5 illustrate, a significant increment in tensile properties, tear strength, hardness, and crosslink density of the vulcanizates prepared with binary combinations compared to the DIXP accelerated vulcanizate while tensile strength of the vulcanizates are comparable to that of TBBS alone system. All the observed values are above the predicted values on the additive functionality line of the two accelerators indicating a synergistic effect of the two accelerators on the said properties.

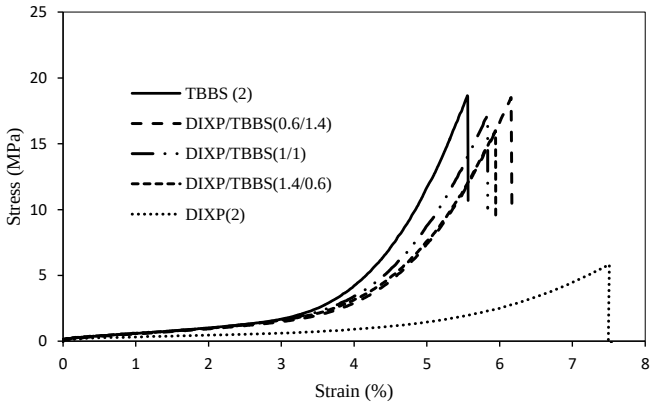


Fig. 2. Stress-strain curves of NR vulcanizates prepared with different combinations of DIXP/ TBBS binary accelerator system

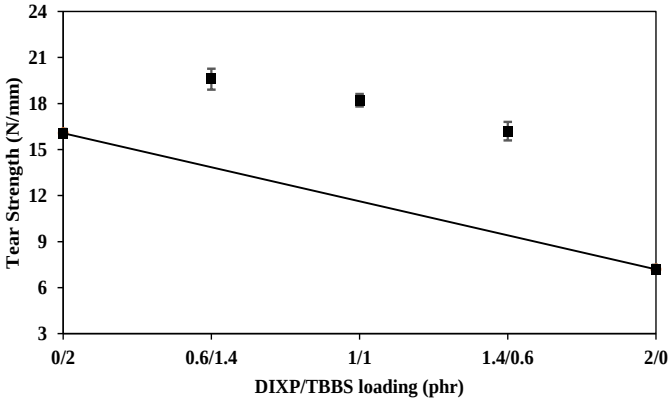


Fig. 3. Variation of tear strength of NR vulcanizates prepared with different combinations of DIXP/TBBS binary accelerator system

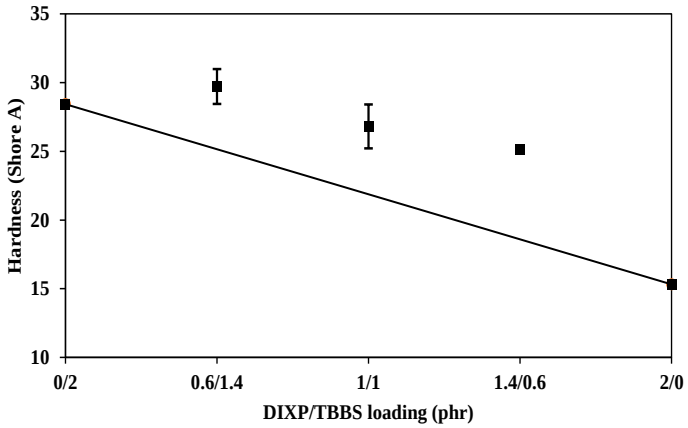


Fig. 4. Variation of hardness of NR vulcanizates prepared with different combinations of DIXP/TBBS binary accelerator system

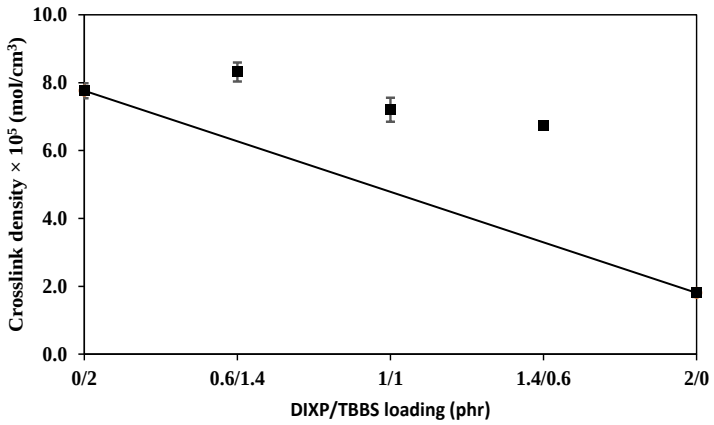


Fig. 5. Variation of crosslink density of NR vulcanizates prepared with different combinations of DIXP/TBBS binary accelerator system

(I H K Samarasinghe, D G Edirisinghe, S Walpalage and S M Egodage - Senior Lecturers, Dept. of Chemical and Process Engineering, University of Moratuwa and P S V Rupasinghe)

Preparation of processed-mica waste/ natural rubber (PMW/NR) composites by latex mixing method

In this study the latex stage mixing method was employed to incorporate processed-mica waste (PMW) into natural rubber. The specific objectives of this study are to enhance the distribution of PMW in the rubber matrix through the latex stage blending of filler, and to add value to mica waste, which is collected by dust collectors and discarded from a mica processing factory in Matale, Sri Lanka.

Firstly, different loadings of PMW incorporated rubber sheets were prepared by the latex mixing method. The sheets were then compounded in a ball mill followed by the determination of curing characteristics, physico-mechanical properties (tensile properties, hardness, and abrasion) and dynamic mechanical properties.

Table 1. *Cure characteristics of PMW/NR composites*

Sample name	Filler loading	Scorch time (T_{S2})	T_{C90}	S_{max}	S_{min}
PMW0	0	2.98	5.65	7.36	1.03
PMW10	10	2.96	5.94	7.84	0.89
PMW20	20	3.49	7.06	8.52	1.00
PMW30	30	4.04	8.26	9.34	1.06
PMW40	40	3.53	7.14	9.38	1.02

The scorch time (T_{s2}) and cure time (T_{C90}) of PWM/NR composites increase with increasing PMW loading up to 30 phr. It is further noticed that all the (PMW/NR) composites possess high S_{max} (maximum torque) when compared to that of control (PMW0).

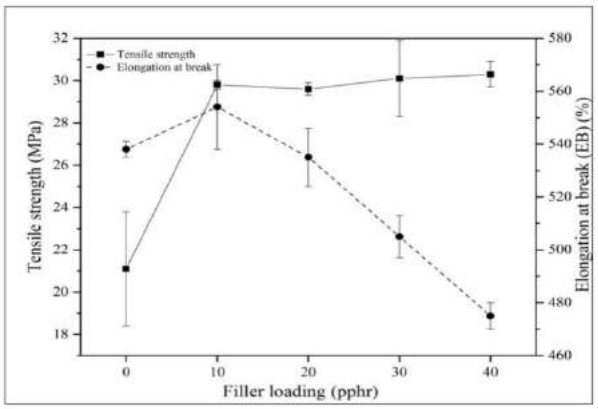


Fig. 6. Tensile strength and Elongation at break of NR composites with different PMW loadings

Figure 6 depicted the variation of tensile strength and elongation at break against the PWM loading. Accordingly, the tensile strength of PMW/NR composites possesses excellent tensile properties when compared with that the control sample. However, it is interesting to note that the tensile strengths of PMW/NR composites have slightly increased with increasing filler loading from 20 to 40 phr. Figure 6 further showed that the elongation at break values decreases when increasing filler loading. The highest elongation at break value was reported in the PMW10 sample.

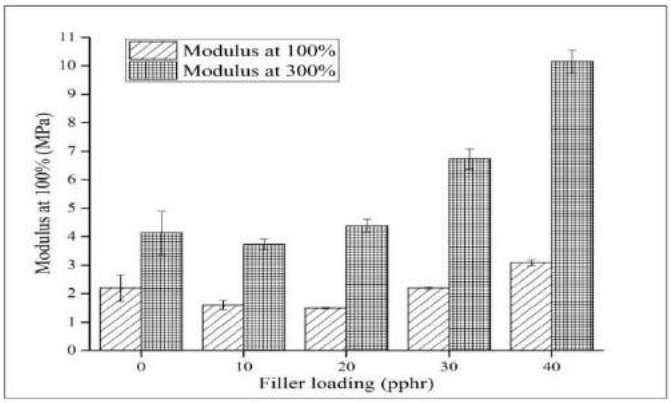


Fig. 7. Modulus at 100% elongation of NR composites with different filler loadings

Rapid increasing trend of modulus at 100 and 300% elongation data from 20 to 40 phr (Fig. 7) indicated good rubber-filler interactions at higher loadings of PMW.

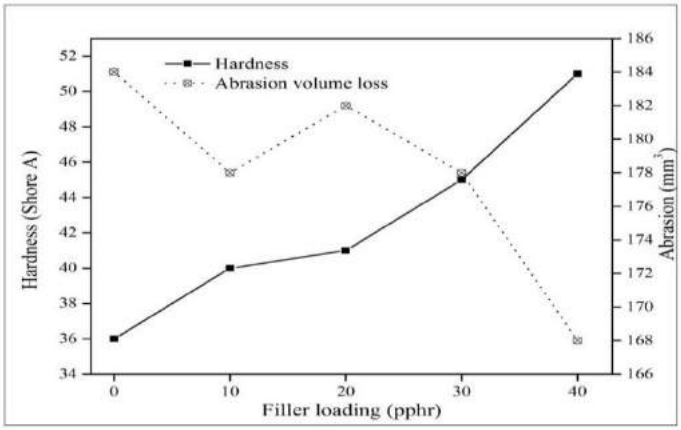


Fig. 8. Variation of hardness and abrasion volume loss in NR composites with different filler loadings

The hardness of PMW incorporated NR composites has shown a gradual increase with increasing filler loading. Hence, the results indicate the reinforcing ability of PMW. Further, an abrupt decrease of abrasion volume loss in NR composites with 20 to 40 phr PMW loading indicates strong rubber-filler interfacial bonds between PMW and NR.

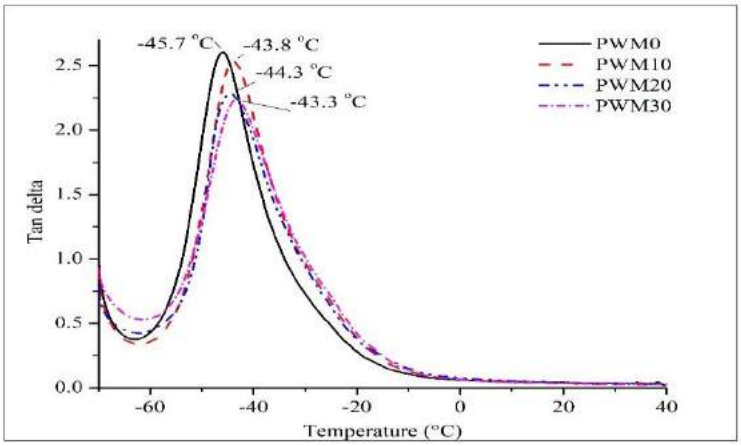


Fig. 9. Variation of tan delta of NR composites

Figure 9 presents the tan delta of NR composites obtained from the Dynamic Mechanical Analyzer. The data specified that the glass transition temperatures of PMW loaded NR composites (PMW10, PMW20 and PMW30) are higher than that of PMW0, indicating the reinforcing ability of PMW in natural rubber (Y R Somarathna, Nirmala Jayawardena, H M H Dhanukamalee, D V D Mallikarachchi, P S V Rupasinghe, H L T Tharaka and R N M Wehigaldeniya - Undergraduate Student of University of Peradeniya, Sri Lanka).

Industrial extensions

Following clients obtained both technical and consultancy services from the Department throughout the year.

- Associated Motorways (Pvt.) Ltd .
- Associated Specialty Rubbers (Pvt.) Ltd.
- Dipped Products PLC
- Elastomeric Technologies (Pvt.) Ltd.
- Export Development Board
- Jefferjee Brothers Export (Pvt.) Ltd.
- National Water Supply & Drainage Board

- Polymer Products Impex (Private) Limited
- Samson Compounds (Pvt.) Ltd.
- Samson International PLC
- Samson Rubber Industries (Pvt.) Ltd.
- Samson Rubber Products (Pvt.) Ltd.
- Sewwandi Rubber Industrial
- Sri Lanka Railway Department
- Textrip (Pvt.) Ltd.
- University of Colombo
- University of Peradeniya
- University of Ruhuna
- University of Sri Jayewardenepura

RAW RUBBER AND CHEMICAL ANALYSIS

Anusha Attanayake

DETAILED REVIEW

Staff

Dr (Mrs) A P Attanayake, Senior Research Officer was the in-charge officer of the overall activities of the department throughout the year. Mr A M K S P Adhikari, Research Officer was granted study leave for three years commencing from 04th April 2019 to carry out his post-graduate studies at University Putra Malaysia, Malaysia.

Mrs C Lokuge and Miss M Wijesekera, Experimental Officers were on duty throughout the year. 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. Miss S P Wijewardana was resigned from RRISL with effect from 28th February after 8 years of service. Management Assistant Miss W D D Samanmali was on duty throughout the year.

Seminars/Training Programmes/Workshops/Exhibitions conducted

Officer/s	Subject	Beneficiary/Client
AP Attanayake	Technical properties of dry rubber and latex properties	Students from University of Wayamba, Specialization: Plantation product development
The staff of the department	Management practices of rubber cultivation	Students from the University of Colombo, Department of Agricultural Technology
Subadra Jayasinghe	Awareness program on ISO 17025 Laboratory Accreditation	The staff of the department

Lectures/Seminars/Workshops/Meetings attended

Officer/s	Subject	Organization
AP Attanayake	Writing project proposals	Hector Kobbekaduwa Agrarian Research Council
AP Attanayake	Technology Update	RRISL, Agalawatta
AP Attanayake	Research Meeting	RRISL, Agalawatta
AP Attanayake	Staff Meeting	RRISl, Agalawatta
AP Attanayake	Trouble Shooting activities	Green Rubber Toys, Rajagiriya
AP Attanayake, CS Lokuge	Trouble Shooting activities	Lalan Rubber, Mahaoya Group, Dehiowita
AP Attanayake, CS Lokuge	Trouble Shooting activities	Halpe estate, Pussellawa Plantation

LABORATORY INVESTIGATIONS

Comparison of dynamic and mechanical properties of crepe rubber (UFUB) with different grades of technically specified rubber

Dynamic and mechanical properties of different grades of TSR were studied with comparison to un-fractioned unbleached crepe rubber. Five types of TSR were used for the study TSR-L is a light colour rubber produced from high-quality latex, having low ash and dirt content. TSR 5 is produced from fresh coagulum and or from un-smoked sheets. TSR 10 is also produced from clean and fresh field coagulum or un-smoked sheets. TSR 20 is a large volume grade of technically specified natural rubber. It is produced mostly from field coagulum with a lower grade of RSS.

According to the glass transition temperature results, crepe rubber showed a similar tg value compared to TSR L grade. Dynamic behavior of TSR 10 and TSR 20 showed significant variations with TSR 50 grade.

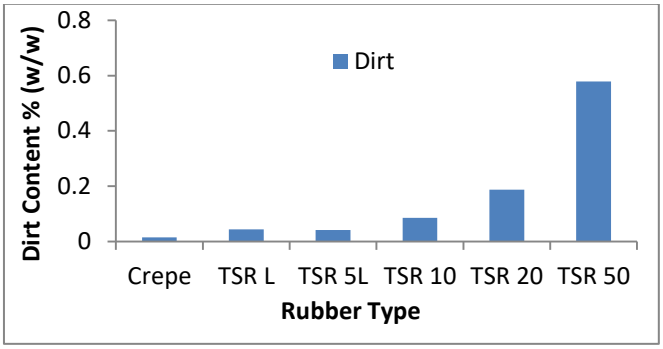


Fig.1. Variation of dirt content with rubber type

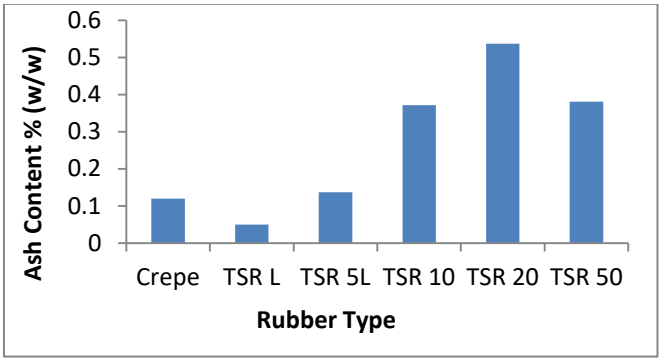


Fig. 2. Variation of ash content with rubber type

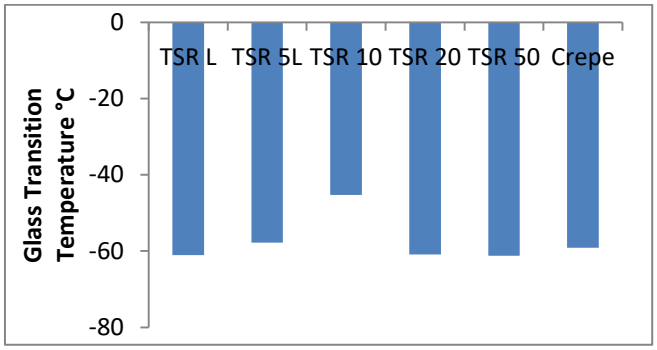


Fig. 3. Glass transition temperature of different grades of TSR

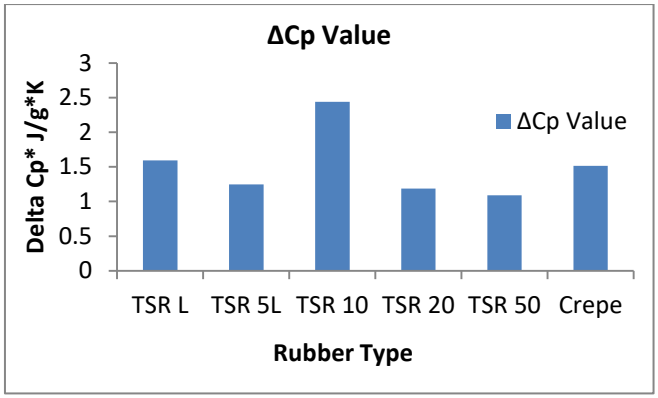


Fig. 4. Delta Cp value of different grades of TSR

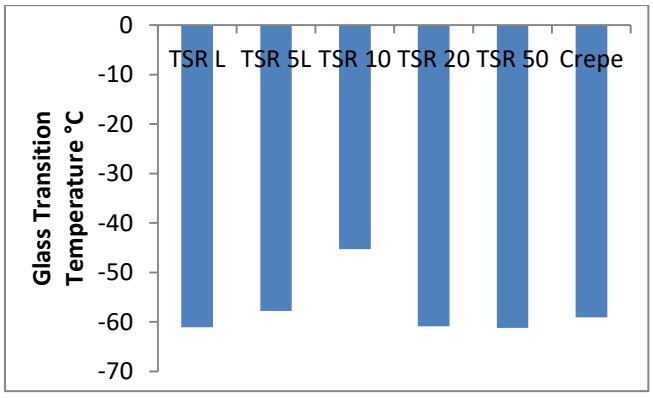


Fig. 5. Glass transition temperature of different grades of TSR

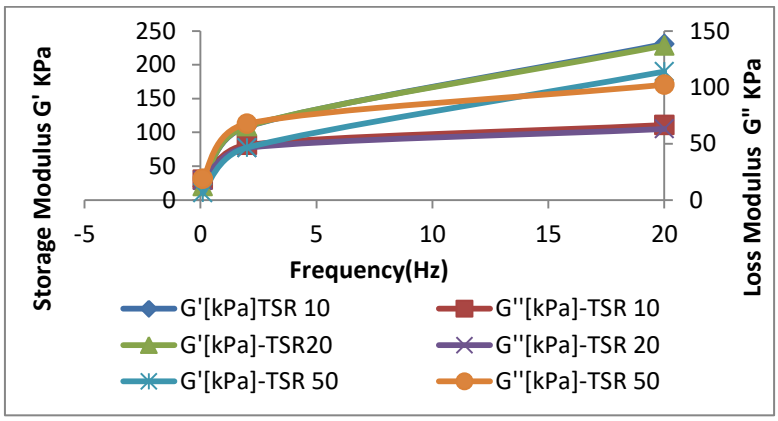


Fig. 6. Variation of storage modulus G′ and loss modulus G″ under frequency sweep for different rubber types

Raw rubber and latex properties of new clones introduced by RRISL

Raw rubber and latex properties for eight new clones were started with a request made by Genetics and Plant Breading department. The samples have collected just after wintering period and the end of July which is considered the cropping season of rubber clones. Variation of latex properties could be observed during the two seasons studied. Most of the clones showed a reduction of TSC and DRC values together with latex viscosity with the wintering effect.

Table 1. *Latex properties of new clones*

Clone	DRC	TSC	Alkalinity	Viscosity	VFA
2006	37.07	40.33	0.72	18	0.284
370	37.97	40.81	0.7	14	0.028
201	30.33	33.74	0.68	8.5	0.032
203	35.65	38.51	0.69	15	0.028
208	36.69	39.91	0.71	14	0.025
124	35.5	38.66	0.71	10.5	0.026
132	26.64	29.64	0.72	7.5	0.039
129	29.69	32.47	0.73	8	0.036

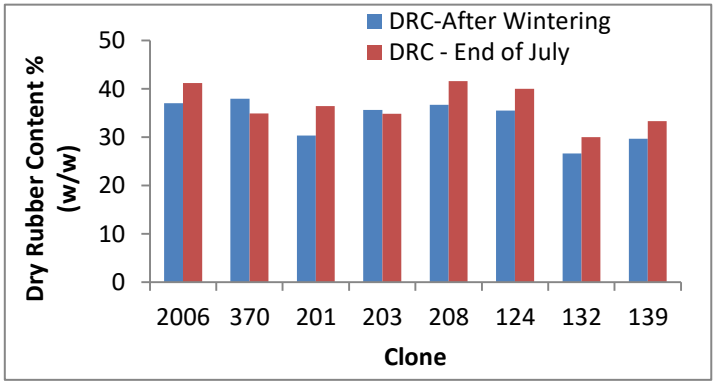


Fig. 7. Variation of dry rubber content of different clones with time

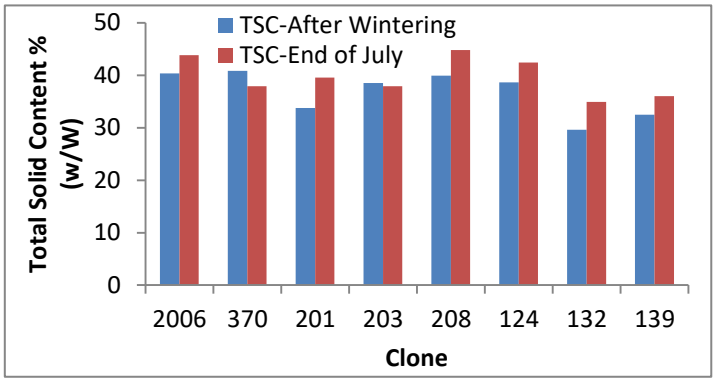


Fig. 8. Variation of the total solid content of different clones with time

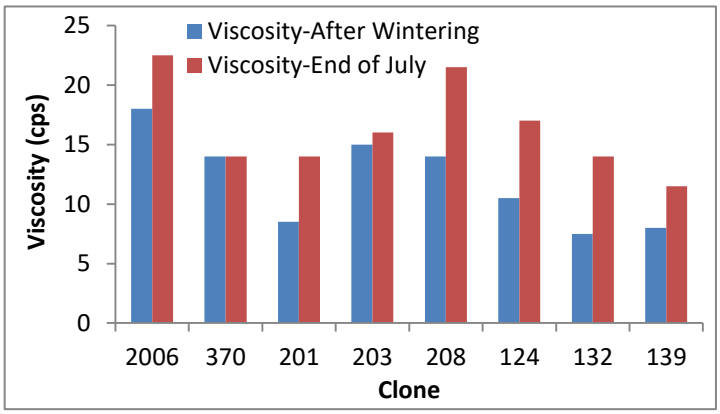


Fig. 9. Variation of latex viscosity of different clones with time

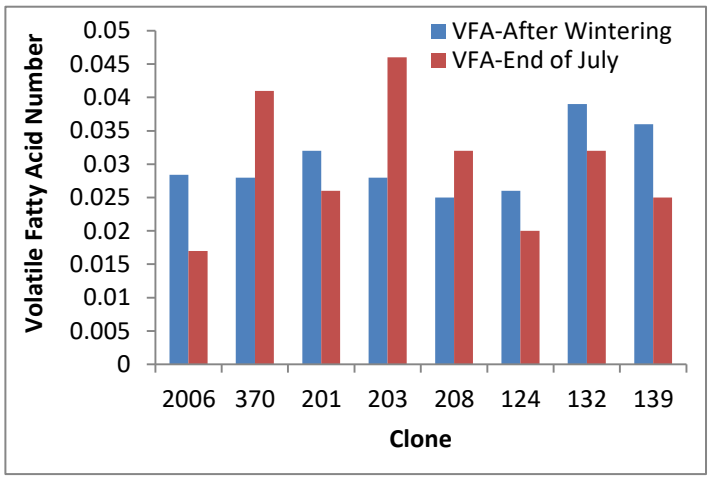


Fig. 10. Variation of volatile fatty acid number of different clones with time

Raw rubber properties of new clones

Unfractionated - unbleached crepe rubber samples were prepared out of the latex collected from each of the new clones. The first sample was collected just after the wintering period. The second set of samples were prepared during the mid of the year. Following observation was made during two seasons studied.

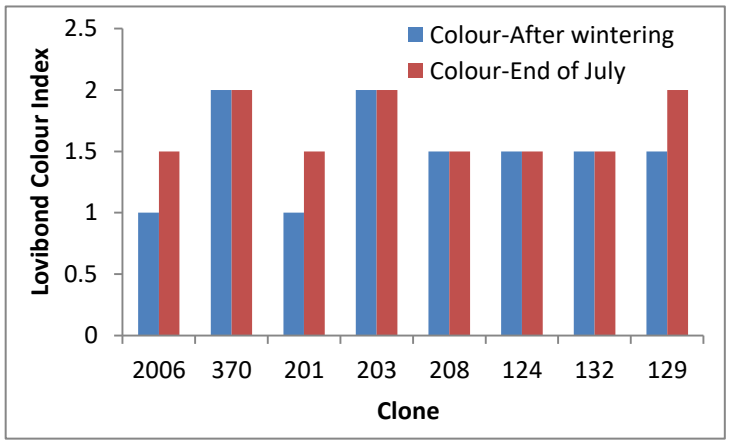


Fig. 11. Variation of Lovibond Colour Index of different clones with time

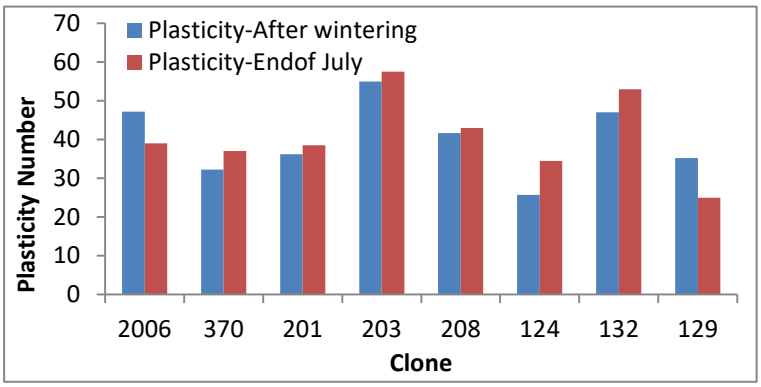


Fig. 12.Variation of Plasticity number of different clones with time

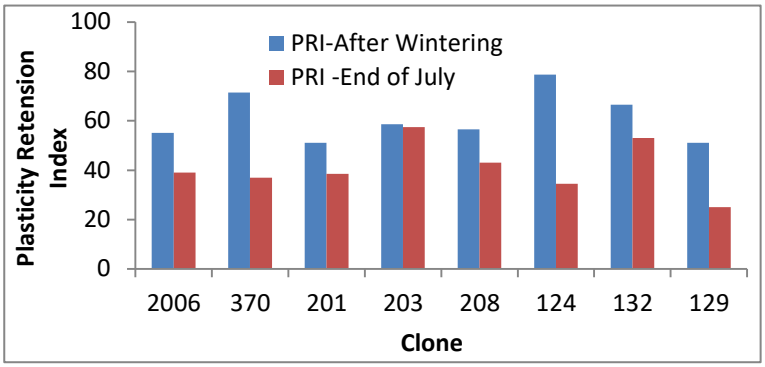


Fig. 13.Variation of Plasticity retention index of different clones with time

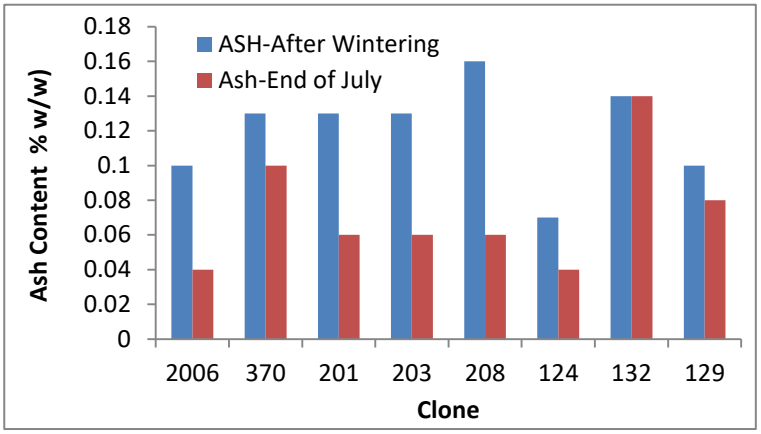


Fig. 14. Variation of ash content of different clones with time

All the properties studied were varied with the season. However, the extent of deviation depends on the clone. With the wintering effect, PRI and ash content showed a significant increase while the reduction of plasticity number.

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	257
Latex sample test	1,161
Chemical samples	26
Testing certificates	512

RAW RUBBER PROCESS DEVELOPMENT AND CHEMICAL ENGINEERING

S Siriwardena

DETAILED REVIEW

Staff

Mr Y C Y Sudusingha, a Research Officer covered up the duties of the Head of the Raw Rubber Process Development and Chemical Engineering Department rendered his resignation with effect from 02nd October, 2020. Messrs U M S Priyanka, V C Rohanadeepa, A K D Warnajith, Experimental Officers and Messrs R D Illeperuma. Asela Sampath and P K N N Sandamali, Technical Officers were on duty throughout the year. Mrs H A Janani Lakshika, Management Assistant was on duty throughout the year.

Research students

- D S Wijewardena, a MPhil degree student from Uva Wellassa University of Sri Lanka, continued his research project titled "Preparation of Polypropylene and Skim Natural Rubber Thermoplastic Natural Rubber" under the supervision of Dr Susantha Siriwardena and Dr Dilhara Edirisinghe.
- N G P Chamara, a BSc (special) student from Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka, completed her research project titled "Development of the compounded latex with prolong stability by addition of a retarder" under the supervision of Mr Yohan Sudusingha.
- Ms P M G Hansani, a 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.
- S A V Dananjaya, a BSc (undergraduate student) from Sri Jayawardenapura University of Sri Lanka, completed his final year research project titled "Mica Waste Filled Natural Rubber Latex Foam: A Comparison of the Use of Creamed Latex as the Source Latex *vs.* Typical Centrifuged Latex" under the supervision of Dr Susantha Siriwardena.
- M A D D Kumara, a BSc undergraduate student from Faculty of Applied Sciences University of Sri Jayewardenepura completed her final year research project titled "A novel preservative system for natural rubber latex" under the supervision of Dr Susantha Siriwardena.
- W K A Nilmini, BSc undergraduate student from Technology, Faculty of Technology from Sri Jayawardenapura University of Sri Lanka, commenced her final year research project titled "The effect of hand sanitizing chemicals on the

physic-mechanical properties of gloves" under the supervision of Dr Susantha Siriwardena.

- G D D K Karunathilaka, BSc (Technology), Faculty of Technology from Sri Jayawardenapura University of Sri Lanka, commenced her final year research project titled "effects of disinfections used for Covid 19 on the tyre tread performance" under the supervision of Dr Susantha Siriwardena.
- Mihiri Karunanayaka, BSc (Technology), Faculty of Technology from Sri Jayawardenapura University of Sri Lanka, commenced his final year research project titled "a study on the effect of carbon black particle size on the curing behavior characteristics of carbon black filled natural rubber composites" under the supervision of Dr Susantha Siriwardena.
- U G P Maduranga, a Higher Diploma student of Plastics and Rubber Institute of Sri Lanka carried out his research component on a project titled "Drinking water treatment sludge for partial replacement of aluminium silicate in filled natural rubber white composites" under the supervision of Dr Susantha Siriwardena.

Seminars/Training programs/Workshops/Conferences/Meetings attended

Officer/s	Subject	Organization
YCY Sudusingha	Workshop GCMS	TECNO Instrument

Seminars/Training programs/Workshops/Exhibitions conducted

Officer/s	Subject	Organization
YCY Sudusingha	Certificate course in Rubber & Plastic	Plastic & Rubber Institute
	Training Programme on Raw Rubber Processing	Aquinas College
	Training Programme on Raw Rubber Processing	Marketing Officers for Damro (Pvt) Ltd
	Diploma Course - Raw Rubber Processing & waste water treatment technology, Drying technics used in raw rubber manufacturing processing	National Institute of Plantation Management
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 (Two Programmes)	Thurusaviya Trust Fund

Officer/s	Subject	Organization
AKD Warnajith	Training Program on Collection, Preservation and Weighing for Field Staff, Assistant Managers and Managers	Balangoda Plantation Ltd.
	Training Program on "Sheet Rubber Processing, Soring and Grading" for Technical Staff	Rigid Tyre Corporation
	Certificate course in Rubber & Plastics	Plastic & Rubber Institute

Advisory visits

Services provided

Services provided	No. of factories/visits
Process and quality improvements	09
Waste water treatment	04
Waste water sample collection for testing	14
Plans issued for construction of new SS drying systems with capacity less than 100 kg	06
Miscellaneous advisory and troubleshooting	17
Tank calibration	11

Waste water analysis

Collection of waste water samples from raw rubber processing and allied industries and analysis were carried out throughout the year.

Sample tested and certificates issued

Sample tested	No. of samples/ Certificates
Waste water- rubber related	67/56
Waste water- Non rubber related	15/12
Processing water	04/03
Miscellaneous Sample (Metal ions, ZnO *etc*.)	22/07
Analysis of extractable proteins	21/08
No of "certificates of epidemic prevention" issued for sole crepe	33

Miscellaneous

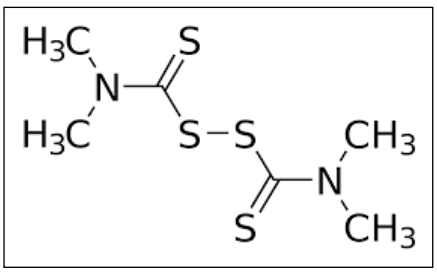
A contract research agreement was signed between Rubber Research Institute and University of Aukland, New Zealand to carry out a feasibility study of a commercial (Geo 40) colloidal silica provided from Geo 40 Pvt. Ltd., New Zealand in rubber product manufacturing application. The intended project carries out a feasibility study of the use of GEO Silica dispersions in preparation of natural rubber

latex-silica master batch and their potential on the use of them in dry rubber and natural rubber latex based product manufacturing applications. The study focuses on preparation and characterization of (i). stable Natural Rubber Latex-Silica (NRLS) masterbatch, (ii) vulcanised thin films made out of NRLS master batches and (iii). Raw rubber and vulcanised properties of silica incorporated natural rubber composites made out using NRLS. Selected compounds from the above studies will be used for industrial scale trials to evaluate their potential for industrial applications. The outcome of the findings will be compiled and presented to the contractor. In addition, it was agreed to produce a preliminary techno-economic analysis on the potential use of Geo silica in tyre and rubber glove manufacture. Raw Rubber Process Development and Chemical Engineering Department conducts the project collaboratively with faculty of Technology, University of Jayewardenepura, Dipped Products (DP) and Global Rubber Industries (GRI) Tyres. Total contact amount is Rs.1,081,140.63 (Sri Lankan Rupees) exclusive of any applicable taxes.

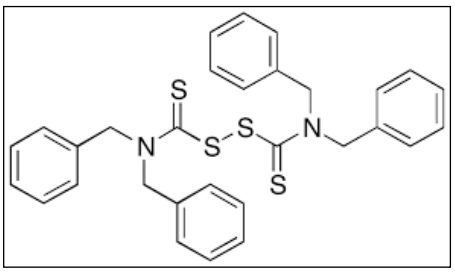
LABORATORY AND FIELD INVESTIGATIONS

Nitrosamine free preservative system for natural rubber latex

Tetrabenzylthiuram disulphide (TBzTD) is a nitrosamine free chemical from same thiuram chemical group as Tetramethylthiuram disulphide (TMTD). TBzTD has been tested as an alternative for TMTD in rubber vulcanization systems due to its lower potential to produce nitrosamine under heated environment. In the present study, use of TBzTD as a secondary preservative to replace TMTD in NR latex preservation was investigated.



TMTD



TBzTD

10% (w/w) Ammonia solution was used as the primary preservative and both field latex and centrifuged latex were preserved at 0.3% ammonia. Secondary preservatives were added to the latex as presented in Table 1 and Table 2. The preserved samples were kept for 24 hours and were centrifuged after removing precipitated magnesium salts.

Table 1. *Combinations of secondary preservative added to field latex*

Sample	Concentration % (w/v) g/l		
	TMTD/ZnO	ZnO (12.5%)	TBzTD (12.5%)
Control		-	-
F1	-	0.0125	0.0075
F2		0.0125	0.0100
F3		0.0125	0.0125
F4		0.0125	0.0150
F5		0.0125	0.0175

Table 2. *Combinations of secondary preservatives added to concentrated latex*

Sample	Concentration % (w/v) g/l		
	TMTD/(12.5%)	ZnO (12.5%)	TBzTD (12.5%)
Control	0.0125	-	-
C1	-	0.0125	0.0075
C2	-	0.0125	0.0100
C3	-	0.0125	0.0125
C4	-	0.0125	0.0150
C5	-	0.0125	0.0175

While maintaining the Ammonia content up to 0.3%, the VFA development of each field latex sample was measured for a week. Same procedure was conducted for the preserved NR concentrated latex for three months. VFA developments with the time for filed latex and centrifuged latex are presented in Figures 1 and 2 respectively.

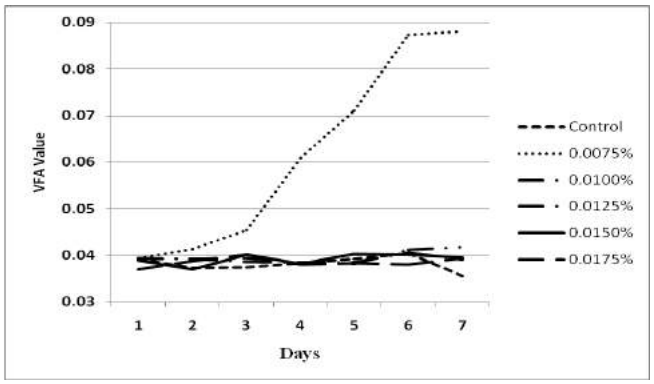


Fig. 1. VFA development of field latex

It could be seen that VFA of all the, TBzTD preserved field latex except sample treated with 0.0075% TBzTD show the similar VFA development behavior to the control sample during one week studied. It was also found that increase of the TBzTD concentration reduces the VFA values of the preserved latex.

Figure 2 shows that the lowest VFA level at each week is indicated by concentrated latex preserved with conventional TMTD/ZnO preservative system. However, it was shown the potential of TBzTD in reduction of VFA development of centrifuged significantly if added more than 0.0075 g/l. It was also shown that increase the dosage of TBzTD reduces the VFA level.

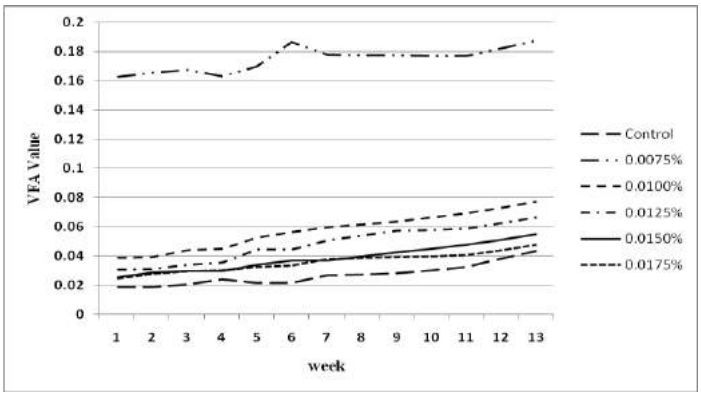


Fig. 2. VFA development of field latex

Mechanical Stability Time values of the preserved centrifuged latex after 21 days are presented in Table 3. It could be seen that MST developed with the time and at higher TBzTD concentrations, treated samples show comparable MST development in the preserved centrifuged latex. The promising results suggest further studies to establish optimum ratios and to investigate the economic feasibility.

Table 3. *MST values of samples initially and after 21 days*

Sample	Seconds (Initial)	Seconds (After 21 days)
Control	255	550
C1	310	370
C2	269	470
C3	140	330
C4	290	675
C5	170	770

Above results, revealed that conventional TMTD/ZnO system performed better than TBzTD/ZnO system. However, TBzTD could be used to replace the TMTD to preserve both field latex and centrifuged latex in applications where

maximum latex VFA level of 0.06 is permitted. Hence, this system could be used preserved NR latex for specific latex based products instead of conventional LA ammonia preservative systems (Y Sudusinghe and N Sadamalee).

Water soluble preservative for Natural Rubber Latex

Different combinations of low ammonia levels (below 0.3%) and 1, 2-Benzisothiazol-3-one (BIT) as a novel preservative system were introduced to natural rubber field latex and centrifuged latex. Their preservation ability were studied. For field latex, ammonia content was varied from 0.15% (m/m) to 0.25% (m/v) with 0.05% intervals while BIT was varied from 0.010% (m/v) to 0.025% (m/v) with 0.005% intervals. Ammonia concentration was kept at a constant value of 0.25 (w/w) and amount of 1, BIT was varied from 0.025 to 0.100% with 0.025% intervals in centrifuged latex. The combinations of different preservative systems used in field latex are shown in Table 4.

Table 4. *Different preservative systems used for field latex*

Sample identification	Amount of BIT % (m/m)	Amount of Ammonia % (m/m)	Amount of TMTD/ ZnO % (g/l)
Control	-	0.25	0.025
S 1-1	0.025	0.25	-
S 2-1	0.020	0.25	-
S 3-1	0.015	0.25	-
S 4-1	0.010	0.25	
S 1-2	0.025	0.20	
S 2-2	0.020	0.20	
S 3-2	0.015	0.20	
S 4-2	0.010	0.20	
S 1-3	0.025	0.15	
S 2-3	0.020	0.15	
S 3-3	0.015	0.15	
S 4-3	0.010	0.15	

Samples prepared for centrifuged natural rubber latex at a constant ammonia concentration with different BIT concentrations are shown in Table 5. TMTD/ZnO preservation system used as the control sample.

Table 5. *Different preservative systems used for centrifuged latex*

Sample Identification	Amount of Ammonia % (m/m)	Amount of BIT % (m/m)	Amount of TMTD/ZnO % (m/m)
Control	0.25	-	0.025
P-1	0.25	0.100	-
P-2	0.25	0.075	-
P-3	0.25	0.050	-
P-4	0.25	0.025	-

Investigation was based on the measurement of volatile fatty acids (VFA) of the treated latex. As evidenced from the VFA values presented in Table 6, Ammonia/BIT combination has a lesser effect irrespective of the composition. However, the new system has a potential to considerably control the VFA development of field latex. Therefore, its effect on the concentrated latex where reduced non rubber substances are present was also studied. Ammonia concentration was maintained at a constant level at 0.25%. The VFA development of 0.25% ammonia and different ratios of BIT were presented in Table 7.

Table 6. *VFA development of preserved field latex*

Sample	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Control	0.025	0.026	0.027	0.027	0.028	0.028	0.028
S 1-1	0.025	0.025	0.025	0.026	0.026	0.030	0.032
S 2-1	0.025	0.028	0.030	0.030	0.030	0.032	0.032
S 3-1	0.024	0.024	0.027	0.029	0.030	0.032	0.034
S 4-1	0.026	0.026	0.026	0.027	0.028	0.032	0.032
S 1-2	0.028	0.028	0.028	0.028	0.028	0.032	0.032
S 2-2	0.027	0.027	0.029	0.032	0.032	0.032	0.034
S 3-2	0.025	0.025	0.028	0.028	0.028	0.034	0.034
S 4-2	0.026	0.026	0.027	0.028	0.030	0.033	0.034
S 1-3	0.028	0.028	0.028	0.028	0.029	0.032	0.032
S 2-3	0.028	0.028	0.028	0.028	0.028	0.034	0.034
S 3-3	0.025	0.026	0.029	0.030	0.030	0.032	0.034
S 4-3	0.028	0.028	0.028	0.032	0.032	0.034	0.034

The results yielded for VFA development of concentrated latex preserved with Ammonia/BIT system show that this hybrid system show almost similar performance to the conventional Ammonia/TMTD/ZnO system.

Table 7. *VFA development of concentrated latex*

Sample	Day 1	Day 7	Day 14	Day 21	Day 43	Day 64	Day 83
Control	0.0095	0.0104	0.0210	0.0208	0.027	0.032	0.0393
P-1	0.0107	0.0154	0.0179	0.0217	0.030	0.035	0.040
P-2	0.0115	0.0155	0.0152	0.0185	0.022	0.026	0.034
P-3	0.0111	0.0120	0.0125	0.0177	0.024	0.025	0.033
P-4	0.0067	0.0105	0.0124	0.0176	0.023	0.0312	0.0329

Investigation was based on the measurement of volatile fatty acids (VFA) number of the treated latex. During the investigation it was confirmed that novel Low Ammonia with BIT is a comparably better preservative system over the control, based on VFA values of centrifuged latex during a period of three months (Table 7). However, it was noted that it slow down the MST of the Ammonia/BIT preserved system (Y Sudusinghe, R Illeperuma and A K D Warnajith).

A study on the potential a commercially available proteolytic enzyme in the manufacture of deproteinized crepe rubber

Preserved natural field latex was coagulated using an Aqueous Solution of Proteolytic Enzyme (ASPE). Different ASPE dosages varying from 1 to 4 ml with 1 ml intervals per 1 litre of the diluted field latex at 10% DRC were added as the coagulant (Table 8). The control sample was prepared using 1% formic acid as a coagulating agent. Enzymatically treated samples were kept for 24 to 72 hours while keeping the control sample for 24 hours for coagulation.

Table 8. *Preservative systems studied*

Sample	Coagulant and dosage (ml/l)	Maturation period (hrs)
Control	1% Formic acid	2
ASPEC1M24	ASPE; 1	24
ASPEC2M24	ASPE; 2	24
ASPEC3M24	ASPE; 3	24
ASPEC4M24	ASPE; 4	24
ASPEC1M48	ASPE; 1	48
ASPEC2M48	ASPE; 2	48
ASPEC3M48	ASPE; 3	48
ASPEC4M48	ASPE; 4	48
ASPEC1M72	ASPE; 1	72
ASPEC2M72	ASPE; 2	72
ASPEC3M72	ASPE; 3	72
ASPEC4M72	ASPE; 4	72

All coagula were converted into pale crepe form following the standard pale crepe rubber manufacturing procedure. The impact of the maturation period (24-72 hours) on raw rubber properties was also studied using the selected sample which meets the lowest Nitrogen Content (NC) among all the candidate samples. The results are tabulated in Table 9.

Table 9. *Status of coagulation and raw rubber properties of crepe rubber*

Sample	Status of coagulation	Nitrogen content (w/w)
Control	1 % Formic acid	0.31
ASPEC1M24	ASPE; 1	24
ASPEC2M24	ASPE; 2	24
ASPEC3M24	ASPE; 3	24
ASPEC4M24	ASPE; 4	24
ASPEC1M48	ASPE; 1	48
ASPEC2M48	ASPE; 2	48
ASPEC3M48	ASPE; 3	48
ASPEC4M48	ASPE; 4	48
ASPEC1M72	ASPE; 1	0.14
ASPEC2M72	ASPE; 2	0.12
ASPEC3M72	ASPE; 3	0.12
ASPEC4M72	ASPE; 4	0.10

The results presented in Table 9 show that the increase of ASPE volume and the maturation period reduce the Nitrogen content in the crepe rubber manufactured and hence the nitrogen content. All enzyme-treated samples showed lower NC (0.10-0.14%w/w) than the control (0.31%w/w). It was noticed that increase of ASPE volume and maturation period reduced the NC in the samples. It was also found a reduction of PRI and ash content and an increase in P_o values with the increasing ASPE dosage and maturation period. Raw rubber properties of the enzyme-treated samples with 72-hour maturation period have complied with the required specifications of DPNR except for Plastic Retention Index (PRI). It was found a reduction of PRI and ash content while increasing in Po values with the increment of ASPE dosage and maturation period. More importantly, the enzyme treatment (4 ml/litre) with 24-hour maturation period was able to achieve the slightly higher PRI value (63.3%) than the recommended value (60%) for both control and DPNR. Overall, it can be concluded that the particular proteolysis studied has higher feasibility to use as an enzyme to produced DPNR (Y Sudusinghe, R Ileperuma and C Rohandeepa).

Mica waste filled natural rubber latex foam: A comparison of the use of creamed latex as the source latex *vs*. typical centrifuged latex

Mica waste were incorporated as a filler into both centrifuged and creamed latex at different loading. The latex composite was then converted into natural rubber latex foam (NRLF) and their properties were evaluated. Formulations used were shown in Table 10.

Table 10. *Formulation and designation of PMW filled Natural Rubber Latex Foams*

Ingredient	**Phr**											
	C0	**C1**	**C2**	**C3**	**C4**	**C5**	**R0**	**R1**	**R2**	**R3**	**R4**	**R5**
Centrifuged Latex	100	100	100	100	100	100	-	-	-	-	-	-
Creamed Latex	-	-	-	-	-	-	100	100	100	100	100	100
50% Potassium oleate soap	6	6	6	6	6	6	6	6	6	6	6	6
50% SLS	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
50% ZDEC	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
50% ZMBT	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Processed waste mica	0	2	4	6	8	10	0	2	4	6	8	10
50% Sulfur	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
50% poly (dicyclopentadiene-co-P-cresol)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
50% DPG	2	2	2	2	2	2	2	2	2	2	2	2
50% ZnO	6	6	6	6	6	6	6	6	6	6	6	6
12.5% SSF	7	7	7	7	7	7	7	7	7	7	7	7

Studies carried out on particle size distribution revealed that the average particle size of unprocessed mica waste (UMPW) and processed mica waste ranges between 30.70±19.92 μm and 19.62±12.52 μm, respectively.

The morphology of selected samples are illustrated in Figure 3, demonstrating the effect of latex type and mica loading on foam morphology. Comparison of Figure 3 (C0) and (RO) indicates that both have spherical shape open cell structure of different cell sizes. It is also seen that cell sizes of latter fall in a larger and wider range than the cell sizes of the counterpart.

The SEM micrographs of the creamed latex based foam rubber loaded with 10 phr [(Fig. 3 (Rc)] however, showed a collapse of the cell structure whereas foam composite of the counterpart composite at same filler loading maintains its cell

structure. This observation implies that foam rubber from centrifuged latex could hold higher filler loading than creamed latex based once in their foam structures.

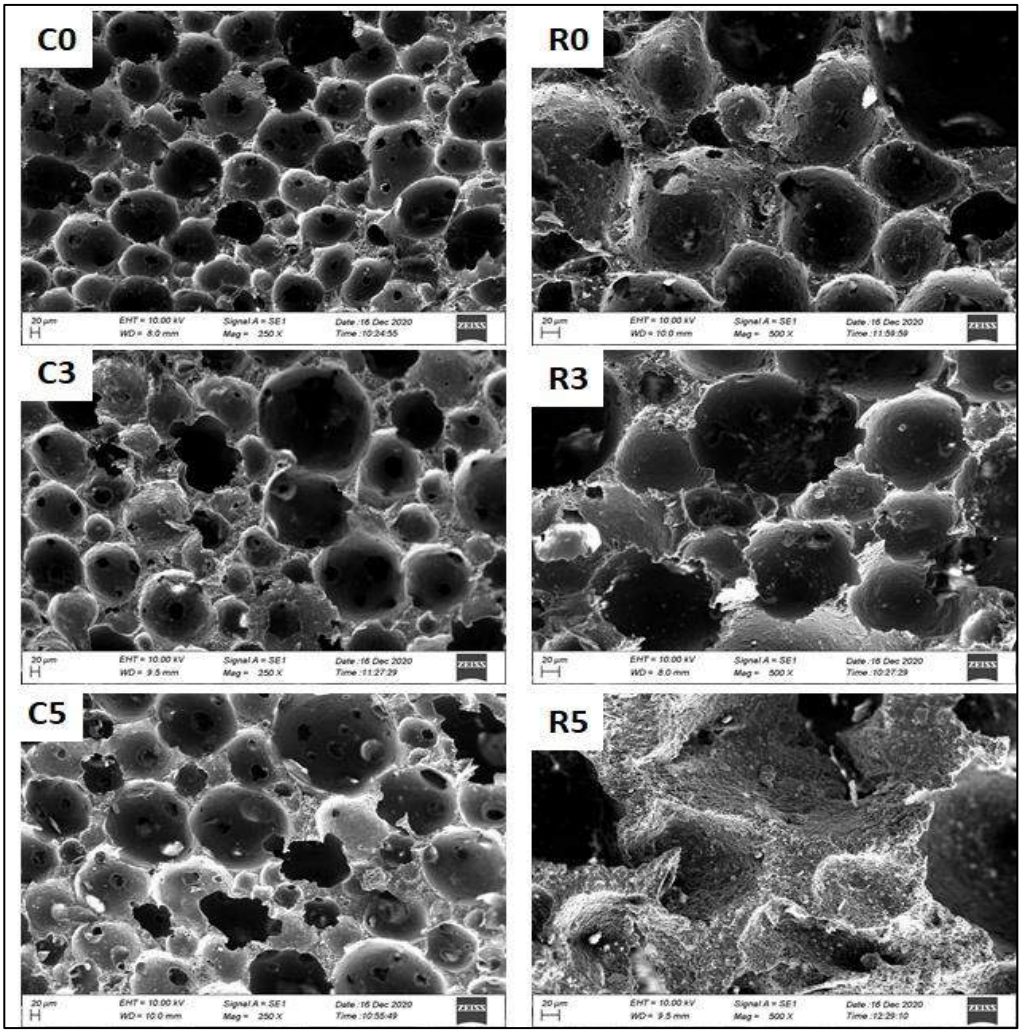


Fig. 3. Micrographs of natural rubber foam composites

(CO): 0 phrin centrifuged latex (C3):6 phr in centrifuged latex (C5):10 phr in centrifuged latex (R0) 0 phr in creamed latex; (R3) 2 phr in centrifuged latex (R5):10 phr in centrifuged latex

Tensile strength

As sown in Figure 4, incorporation of PMW improves the tensile strength of both types of foam rubber. It is show that in both cases, increase of PMW loading increases tensile strength during the entire range of filler loading studied.

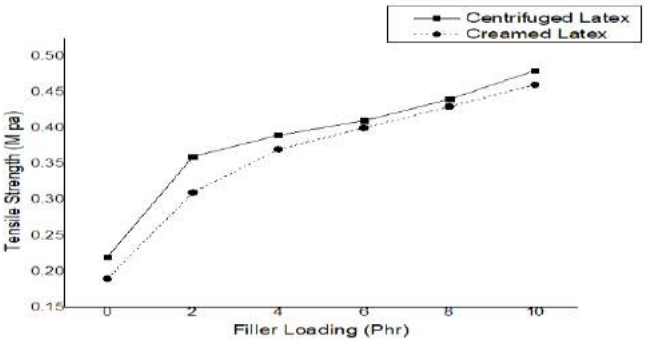


Fig. 4. Comparison of tensile strength and mica filled creamed and centrifuged NRLFs

Gelling content

Irrespective to the latex type, gelling time shows a similar trend with the PMW loading (Fig. 5). It is already reported that mica could reinforce the rubber matrix through forming interactions between the mica particles and rubber matrix. Further, the various multivalent ions present in the filler dispersion could also support the sub interactions between rubber molecules through them. Therefore, all the above factors influences the reduction of gelling time with the addition of PMW.

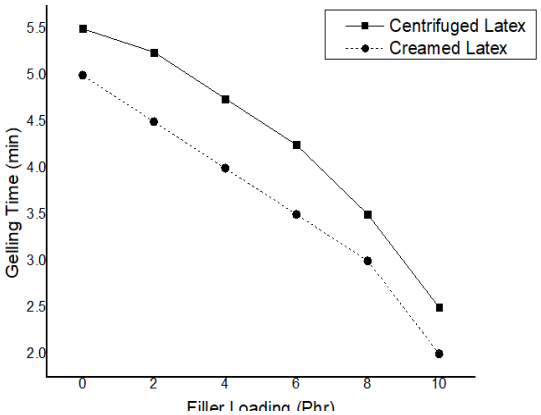


Fig. 5. Gelling time of composites

Density

It is shown in Figure 6 that increase in volume fraction of filler increases the density of the foam composites. In creamed latex, it contains additionally added high molecular weight creaming agent making higher total solid content containing a higher density material. Consequently, expansion of same volume of latex increase the weight of rubber phase in the unit volume of foam rubber made out of creamed latex. Therefore, foam rubber made out of creamed latex exhibits higher density than the counterpart at the same filler loading. Similarly, incorporation of PMW with higher density into latex also increases the density of both types of latex and hence the density of foam rubber.

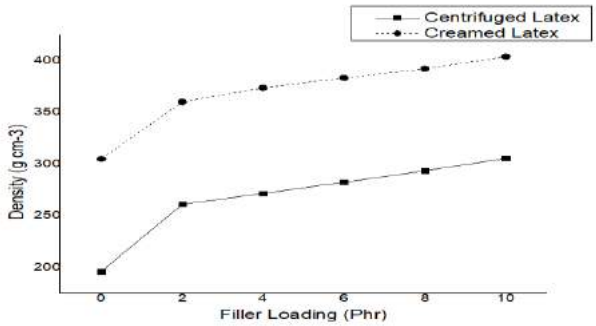


Fig. 6. Effect of latex type and PMW loading on density

Shrinkage

Shrinkage of the NRLF composites as can be seen in Figure 7, shows a similar pattern of variation with the change of PMW loading in foam composites irrespective of the latex type used to manufacture them. As mica is loaded, it reinforces the matrix as indicated by the tensile strength. This study showed that creamed latex based foam rubber exhibits higher shrinkage values.

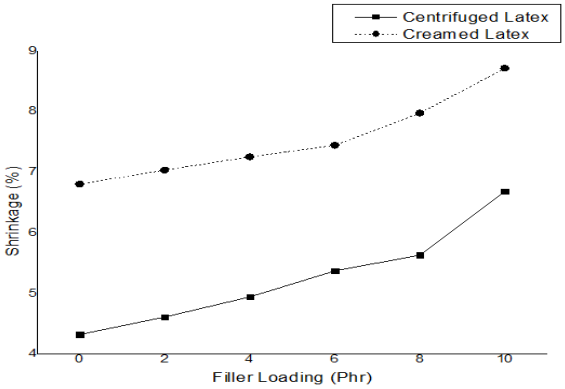


Fig. 7. Effect of latex type and PMW loading on shrinkage

Electrical properties

Electrical conductivity was determined by the resistance between two points with a fixed distance. As shown in Figure 8, increase of filler loading increases the electrical resistivity. As the filler loading increases, pore sizes and cell diameters are increased as shown in SEM images. Therefore, air voids percentage in the foam rubber increases with the increased filler loading yielding higher electrical resistivity. It could be further seen that the rate of electrical resistivity has increased as the mica loading exceeded 6 phr.

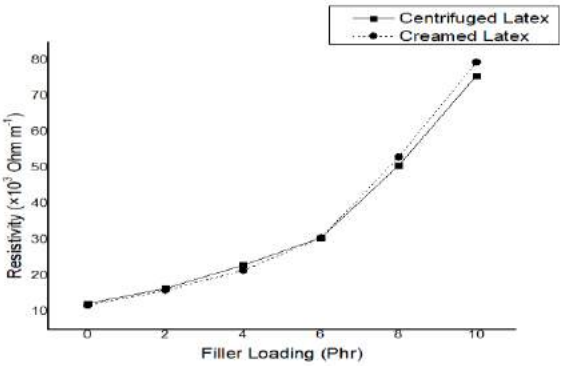


Fig. 8. Effect of latex type and PMW loading on electrical conductivity

Water absorption

Larger pore sizes may make room for retention of more water in the cells after water absorption. NRLFs made out of creamed latex have higher cell diameters or pore sizes than those made out of centrifuged latex as confirmed by SEM images. Higher water absorption capacity of creamed NRLFs than that of centrifuged latex based foam rubber shown in Figure 9 could therefore be elucidated by the presence of larger pore sizes. This observation, however, cautions the selection of latex type for preparation of foam rubber for industrial applications due to the associated mould growth and discolourations issues.

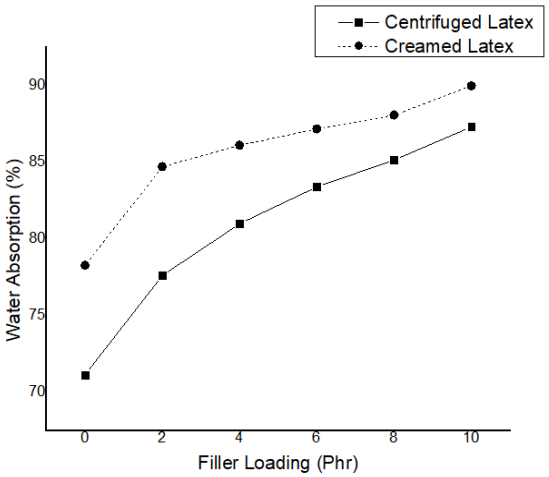


Fig. 9. Effect of latex type and PMW loading on water absorption

Leachable protein content

With the incorporation of PMW, the bulk density increases while the natural rubber content available per unit mass of the final foam product too is reduced (Fig. 10). Further, the other non-rubber materials including extractable proteins in foam rubber too is reduced. Extractable protein content of NRLFs reduces with the increase of the filler loading irrespective of the latex type used for the preparation of foam rubber. In addition, crystalline nature of mica may also restrict the diffusion process of extractable proteins out of the NR phase. Therefore, a gradual reduction of extractable protein content of NRFs with PMW loading as shown in Figure 10 could be anticipated.

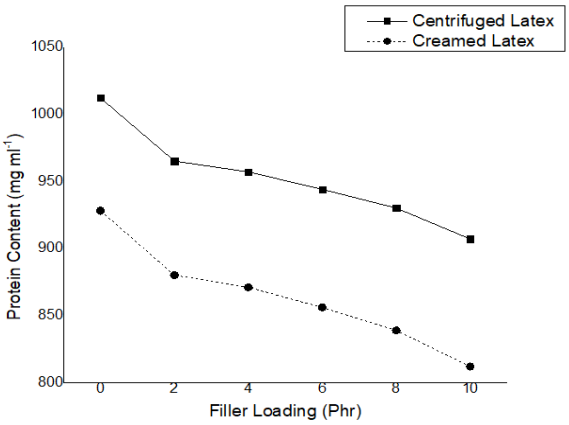
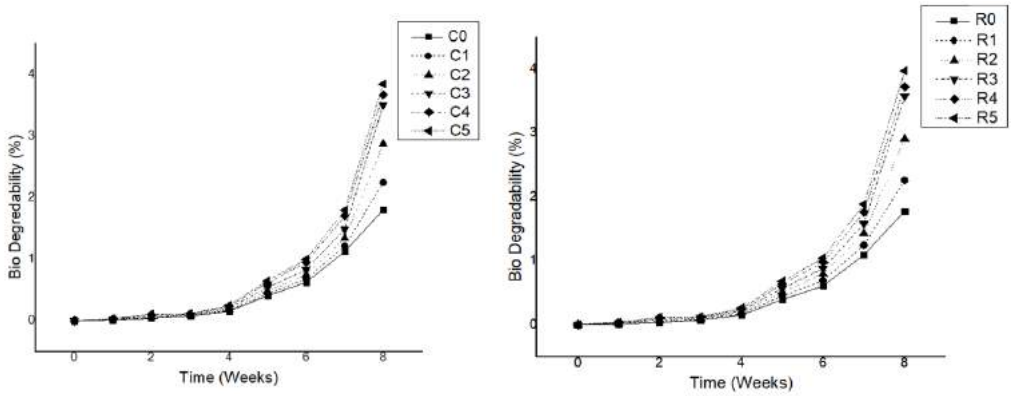


Fig. 10. Effect of latex type and PMW loading on leachable protein content

Biodegradability

Biodegradability of mica filled foams with time is shown in Figure 11 (a & b). Biodegradability was measured as the percentage loss of weight of the sample. After the fourth week, all samples have shown an increase in the rate of bio degradation while registering a higher biodegradability as the mica loading is increased. The initiation of growth of microbes and fungus starts very slowly. Microbes start to grow on the samples and multiplicate with time. Therefore, the mass of the samples reduced at a higher rate with time. This observation suggests that processed mica could be used to promote the biodegradability of foam samples bringing them more towards greeneer products. Therefore, in addition to the improved mecanical and physical proprties achieved, mica could be incorporated to improve the bio degradability of the foam composites.



(a) **(b)**

Fig. 11. Effect of latex type and PMW loading on biodegradability

Antibacterial properties

As shown in Figure 12, the antibacterial activity of the NRLFs on E. coli was characterized by inhibition zone testing against E. coli. In overall, effect of E. coli for both centrifuged and creamed NRLFs seems to be similar. It can be seen that NRLF without mica had no antibacterial activities against E. coli. However, when the mica loading is increased, the inhibition zone expands. It provides evidence of increased antibacterial activity with the incorporation of mica in the NRLF composites.

The technical assistance provided by the Plant pathology and microbiology department of the institute to carry out this study was acknowledged for this study.

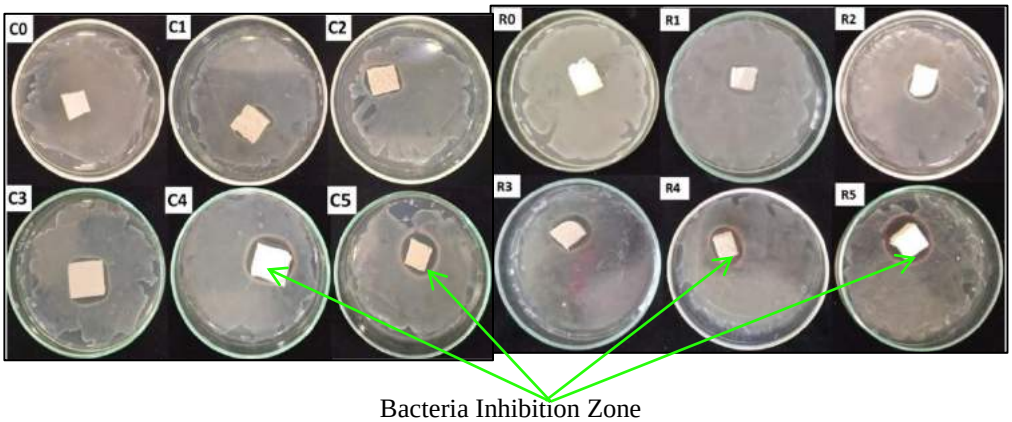


Fig. 12. Effect of latex type and PMW loading on antibacterial activity
(S A V Dananjaya, U M S Priyanka, I Perera, Y Somarathne and S Siriwardena)

Development of the compounded latex by addition of a retarder

In this study, the effect of a retarder (pre-vulcanization inhibitor) to increase the durability of compounded latex with required quality than conventionally prepared compounded latex was investigated. Four compounded latex samples were prepared by addition of 1 phr, 2 phr, 3 phr and 4 phr of N-cyclohexylthiopthalimide (CTP) amount. Control sample was used as a normal compounded latex sample without CTP. According to the chloroform test, control sample reached to the over vulcanization stage in a very short time period within 18 days while sample 1, sample 2 and sample 3 took 24 days, 30 days and more than 50 days respectively. Moreover, sample 4 has stayed in stage 2 for more than 50 days. Therefore, this study suggests that by adding a retarder to compounded latex will result in increase in the compound stability while improving the tensile properties (N G P Chamara, R Ileperuma, Y Sudusinghe and S Siriwardena).

Drinking water treatment sludge for partial replacement of aluminum silicate in filled natural rubber white composites

Tank sludge generated at the drinking water treatment plant, National Water Supply and Drainage Board, Karadana, Bomuwala, Kalutara, Sri Lanka was first partially air dried, grined and convert to filler foam. Figure 13 summarizes the conversion process of sludge into workable filler referred to as DWTS in this work.

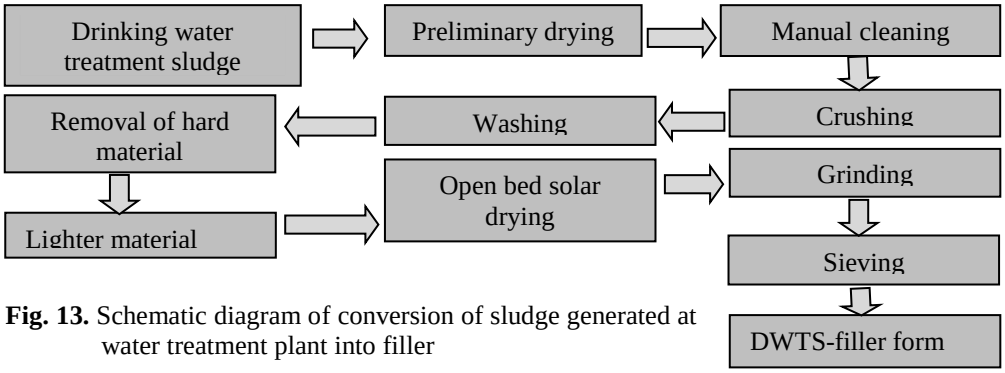


Fig. 13. Schematic diagram of conversion of sludge generated at water treatment plant into filler

Preparation of composites

Formulations used and the mixing sequence are given in Tables 11 and 12 respectively. The total loading of the filler including DWTS was fixed at 60 parts per hundred rubber (pphr). Industrial aluminium silicate (IAS), a commercial filler was replaced with DWTS while maintaining the total loading of both these fillers at a constant level of 30 pphr. A fixed loading level of commercially available filler, namely $CaCO_3$, was used for the balance filler loading at 30 pphr.

The composites were prepared on a conventional laboratory two-roll mixing mill (David Bridge & Co. Ltd., England, size 150 – 300 mm) at 28 ^{o}C ± 2 available at Rubber Research Institute of Sri Lanka following the mixing sequence given in Table 12.

Table 11. *Formulations used in preparation of composites*

Ingredient	Parts per hundred rubber (pphr)				
	Control sample (NR 01)	NR 02	NR 03	NR 04	NR 05
NR	100	100	100	100	100
DWTS	0	7.5	15	22.5	30
IAS	30	22.5	15	7.5	0
Calcium Carbonate	30	30	30	30	30
Zinc Oxide (ZnO)	3.5	3.5	3.5	3.5	3.5
Stearic acid	2	2	2	2	2
Tetramethylthiuram disulphide (TMTD)	0.4	0.4	0.4	0.4	0.4
N-cyclohexyl-2-benzothiazolesulfenamide (CBS)	0.8	0.8	0.8	0.8	0.8
Sulphur	1.2	1.2	1.2	1.2	1.2

Table 12. *Mixing sequence*

Time (minutes)	Ingredients
0	Rubbers (NR)
3	ZnO + Stearic acid
4	Aluminium silicate + Calcium carbonate + DWTS
6	CBS
7	TMTD
8	Sulphur
10	Dispatch

Characterization of tank sludge

Fourier transform Infra-Red Spectroscopy (FTIR)

Figure 14 shows the Fourier Transform Infrared (FTIR) spectrum of the processed water tank sludge (DWTS). The peak found in the region of 539 cm^{-1} could be attributed to the characteristic Mg-oxide or Al- Oxide peak of kaolin (magnesium-aluminium silicate) while the peaks at 457 cm^{-1}, 495 cm^{-1} are corresponding to the Si-O asymmetric blending. Peaks at 912 cm^{-1}, around 1000 cm^{-1} and 3600 cm^{-1} correspond to the characteristic peaks of Si-OH, Si-O-Si stretching and surface OH stretching respectively. Peak around 1539 cm^{-1} may represent the H_2O associated with the filler (Table 13).

Therefore, the FTIR spectrum obtained for DWTS suggests that its composition is much similar to the SiO_2 and it is one of the major components of the sludge.

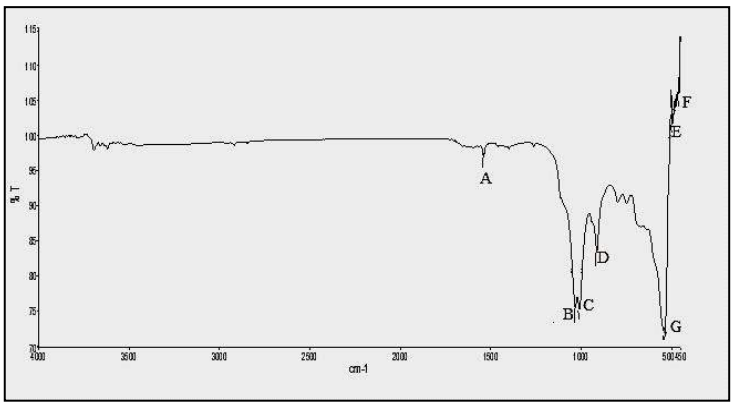


Fig. 14. The Fourier Transform Infrared (FTIR) spectrum of the processed DWTS

Table 13. *Peaks of the FTIR graph of the processed DWTS*

Peak identity	Wave length (cm^{-1})	Transmission (T)%
A	1539.20	97.02
B	1031.00	75.43
C	1008.20	75.17
D	912.39	83.35
E	495.84	101.66
F	457.46	106.02
G	539.25	70.81

Moisture content

Sludge samples collected were first sundried for seven days during which the moisture content was reduced from 63.8% to 9.45%. It was then crushed, ground and dried under the sun for another three days when the final moisture content was reduced to 2.5% on 10th day just before the preparation of NR compounds (Table 14).

Table 14. *Moisture content of DWTS*

Day	Moisture content (%)
01	63.82
07	9.45
10	2.55

Particle size (PS) and particle size distribution (PSD)

Particle size distribution studies showed that the mean and median particle sizes of the processed filler (DWTS) were found to be 19.62 μm and17.17 μm respectively with 90% of the particles were found to be have a particle size lesser than 37.21 μm. It can also be seen that around 50% of the particles are around17.17 μm in size.

Cure characteristics of the compounds

Figures 15 to 19 depict cure characteristics of NR composites with different ratios of DWTS and IAS loading while total loading was kept at a constant loading. Addition of inorganic rigid fillers irrespective of its reinforcing ability generally tends to increase the M_L value above that of gum compounds due to the restricted macromolecular movements brought about by the filler particles. However, depending on the filler characteristics, incorporation of certain fillers could also yield a reduction of the M_L value. In this study, the total filler content of hybrid system (IAS and DWTS) in each compound was fixed at 30 pphr and the amount of DWTS varied from 0 to 30 pphr at 7.5% intervals. It could be seen that replacement of IAS with DWTS has shown only a slight increase of M_L up to the incorporation of 15 pphr

of DWTS in the compound thus the viscosity too. Possible increased filler to matrix interactions due to smaller particle size or the higher surface area of the DWTS particles may be responsible for this observed trend. Further replacement of IAS exceeding 15 pphr with DWTS diminishes this effect and does not show any more increments of ML. Therefore, it could be deduced from this observation that almost similar processing conditions could be used for higher DWTS loaded composites (NR 03 to NR 05) due to their almost similar viscosities.

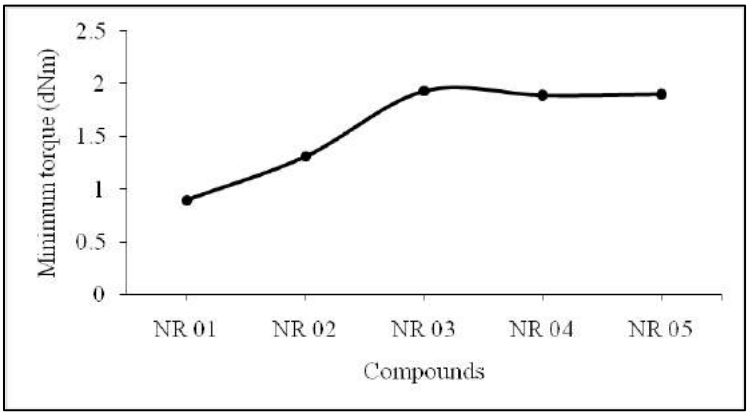


Fig. 15. Minimum torque values of the compounds

However, observed slight increase of M_L with the replacement of IAS by DWTS suggests that the additional processing energy is required for compounding of composites up to 15 pphr with the increase of DWTS loading.

All rubber compounds except the NR 05 sample where IAS is completely replaced with DWTS (Fig. 16) have shown almost similar M_H values. It infers that replacement of IAS with DWTS did not show any significant effect on cross-link density of the vulcanizates. However, with the increase of DWTS loading, the metal oxides and moisture present in DWTS may have positively influenced the vulcanization reactions leading to form more crosslinks via sulphur between the macromolecules. These factors may be responsible for the exhibited higher M_H value of NR 05 over the other compounds and is consistent with higher Tan δ values exhibited by NR 05 compound as could be seen in Figure 17.

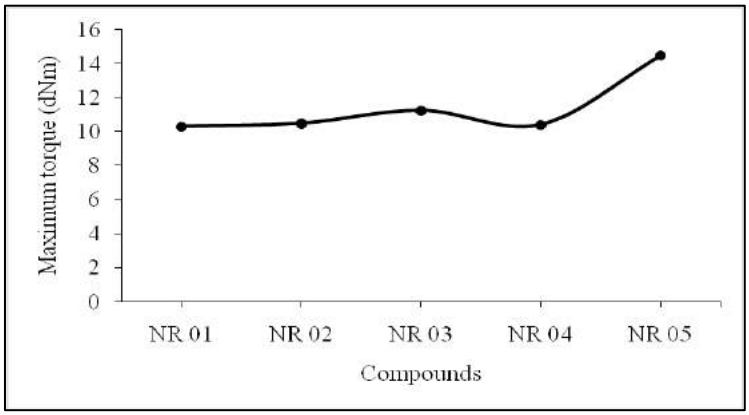


Fig. 16. Maximum torque values of the compounds

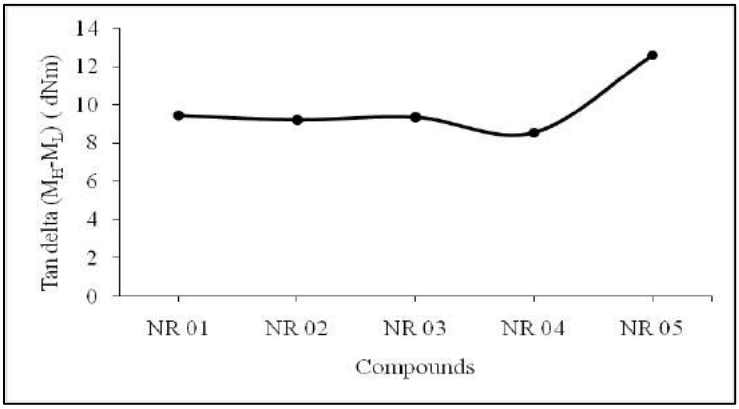


Fig. 17. Tan δ values of the compounds

The results show that scorch time (ts_2) is at the maximum with 50% (w/w) replacement of IAS and then it slightly decreases when DWTS content is further increased (Fig. 18).

The same trend is exhibited for the cure time (t_{90}) of the compounds shown in Figure 19. Filler particles could absorb some curing ingredients on to their surfaces preventing their effective contribution on activating the cross linking reactions. This delays the curing reactions. As mentioned earlier, the presence of various metal oxides and water in filler could accelerate the curing reactions. If the heat development is significant due to higher viscosity of the filled compound too, it could also accelerate curing. There was a slight gradual increase in the M_L values at the lower DWTS loadings. This provides evidence that there was no significant change in the filler to matrix interactions and hence heat generation during compounding is not

expected at low DWTS loadings. However, as DWTS exceeds 50%, there may be a heat development which could influence the curing reactions. Further, since filler is processed from a waste material, DWTS has higher moisture content and minor quantities of other metal oxides compared to the commercially available IAS. In these compounds studied, DWTS may have more absorbing ability of curing ingredients than that of the IAS which delays the curing reactions. Therefore, as DWTS loading exceeds 50% of the hybrid filler percentage (NR 03), influence of factors mentioned above on the rate of curing may dominate over the delay caused by adsorbing curing ingredients. These combined factors may have registered maximum values for ts_2 and t_{90} in NR 03 composite where IAS was replaced by 50% of DWTS.

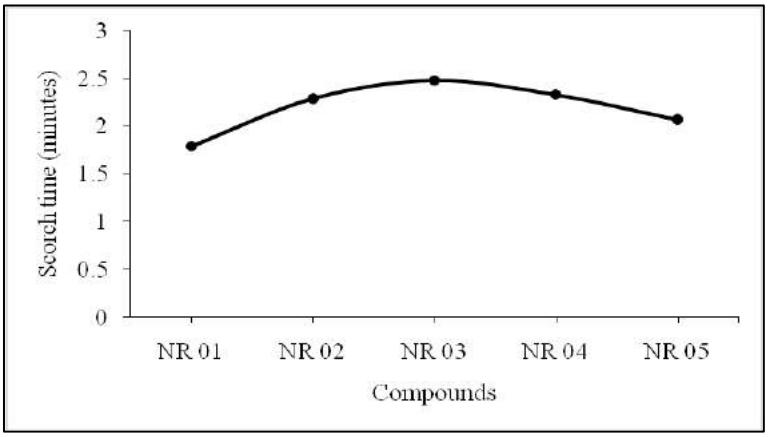


Fig. 18. Scorch times of the compounds

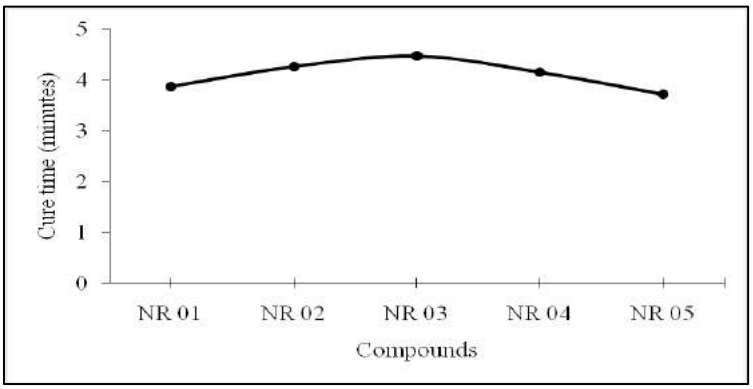


Fig. 19. Cure time of the compounds

Mechanical properties of the vulcanizates

Tensile strength

Tensile strengths of the vulcanizates are presented in Figure 20. It is interesting to note that tensile strength of the vulcanizates has shown a gradual increase with the replacement of IAS with DWTS up to 75% (NR 04). Thereafter, it is decreased with further increasing of DWTS loading (NR 05). At the low filler DWTS loading, smaller particle sizes of these filler particles may contribute to the increase in the tensile strength. However, with further incorporation of DWTS, these particles may tend to form agglomerates reducing the tensile strength of the vulcanizates as it reduces the degree of filler to matrix interactions.

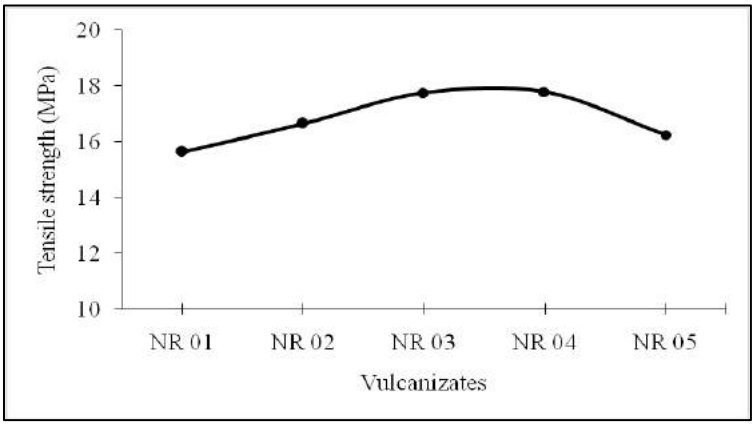


Fig. 20. Tensile strength of the filled vulcanizates

Modulus at 100% Elongation (M100)

M100 values of the vulcanizates presented in Figure 21 show that replacement of IAS does not affect the M100 significantly. It shows that modulus varies in a narrow range (1.35-1.52 MPa). In this study, the total filler loading is fixed. Therefore, any variation of M100 should be a result of different degree of filler to matrix interactions. The trend observed with regard to M100 explains that IAS/DWTS filler ratio has no appreciable influence on filler to matrix interactions in the vulcanizate. In vulcanized system, cross link density too affect the M100. The highest M_H value exhibited in NR 05 vulcanizate suggests that there is an increase in cross link density in the 100% DWTS filled vulcanizate. However, this may not be adequate enough to influence the stiffness (M100) and indicates that replacement of IAS with DWTS would not affect the stiffness of the final vulcanizates.

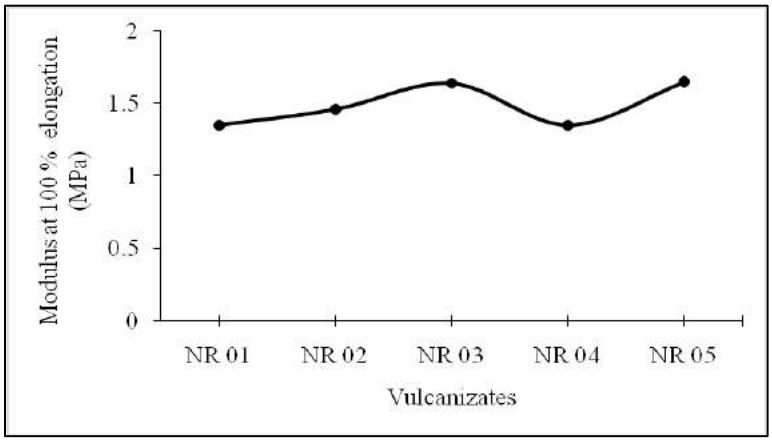


Fig. 21. Modulus at 100 % elongation of the filled vulcanizates

Elongation at Break (EB)

The effect of DWTS loading on elongation at break is shown in Figure 22. It could be seen from the results that replacement of IAS with DWTS has also shown a general trend of a slight reduction of EB. As seen in other properties, variation of EB also occurs in a narrow range with replacement of IAS by DWTS and it suggests that replacement of IAS by DWTS has no significant negative impact on the elongation at break of the corresponding vulcanizates.

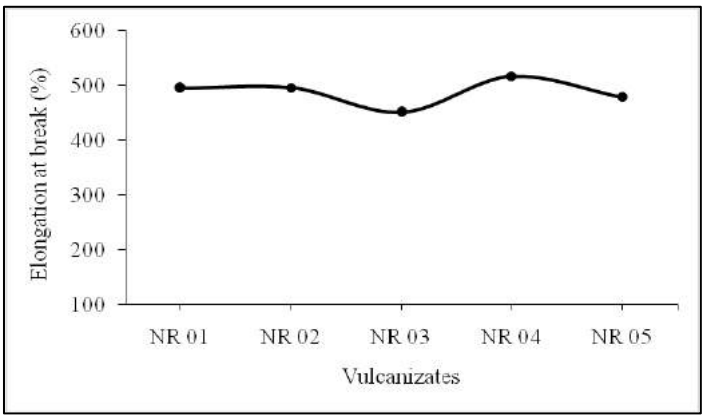


Fig. 22. Elongation at break of filled vulcanizates

Hardness

It could be seen that the hardness of all the composites studied except NR 05 were comparable to each other (Fig. 23). The hardness of a rubber vulcanizate is influenced by the restrictions exerted by filler particles against the movement of macromolecules or the cross-link density of the vulcanizates and hardness of the filler material itself. In this study, replacement of industrial aluminium silicates (IAS) by DWTS in the hybrid filler system was investigated keeping the total filler loading and rubber content constant. Therefore, it could be deduced that, there may be no particular influence of DWTS in comparison to IAS on the restrictions exerted on macro molecular movements of the vulcanizates which is adequate enough to influence the hardness despite it has shown an impact on M_L of the unvulcanised composites at low DWTS loading. Therefore, replacement of IAS by DWTS would not affect reinforcement of the macromolecules. However, slightly higher hardness value registered for the NR 05 vulcanizate may be attributed to the possible higher crosslink density of the vulcanizate due to the accelerated curing reactions involving DWTS as mentioned earlier. This result shows that up to 75% wt. of the IAS can be substituted with the DWTS in hybrid filler system without much effect on the hardness.

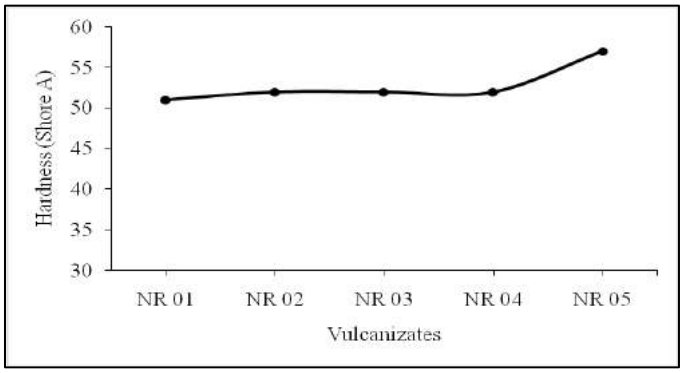


Fig. 23. Hardness of filled vulcanizates

Rebound resilience

According to Figure 24, there is no any significant difference between rebound resilience values of the vulcanizates studied. It implies that incorporation of DWTS does not significantly affect the energy recovery of DWTS filled vulcanizates compared to the control (NR 01). Ratio of the rubber matrix to fillers is one of the factors which govern the response of vulcanizates on rebound resilience. All the vulcanizates studied have same rubber to filler ratio, and this result suggests that there are no significant variations in the filler to matrix interactions with respect to both fillers (IAS and DWTS). As the rubber content in all the vulcanizates are kept

constant and same cross linking system was used, variation either in cross link density or in cross link structure in the vulcanizates may not adequate enough to influence the rebound resilience among the vulcanizates studied despite slightly higher hardness exhibited by the NR 05 vulcanizate. Therefore, this result shows the potential of replacing IAS by DWTS without having a considerable influence on the heat development of the vulcanizates.

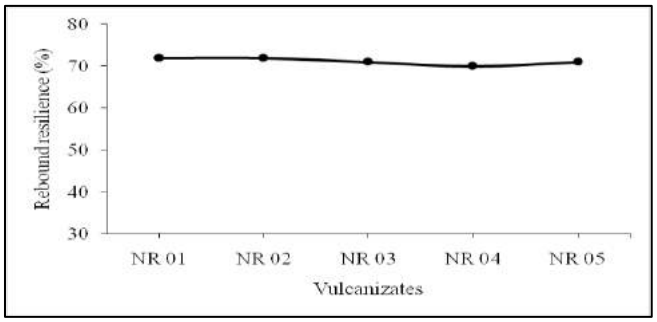


Fig. 24. Rebound resilience of filled vulcanizates

Abrasion volume loss

Abrasion resistance of the vulcanizates, expressed as abrasion volume loss, is presented in Figure 25. It shows that all the vulcanizates exhibit similar abrasion volume loss except NR 03 vulcanizate which shows a slightly higher abrasion volume loss. Abrasion volume loss occurs due to the oxidation of the materials due to the heat generation resulted from the friction caused by the contacting surface on the moving objects. When considering the composites studied, they all have the same filler loading with different ratios of IAS and DWTS. In DWTS, it has a notable amount of iron oxides as well as traces of manganese which could act as catalysts for rubber oxidation reactions.

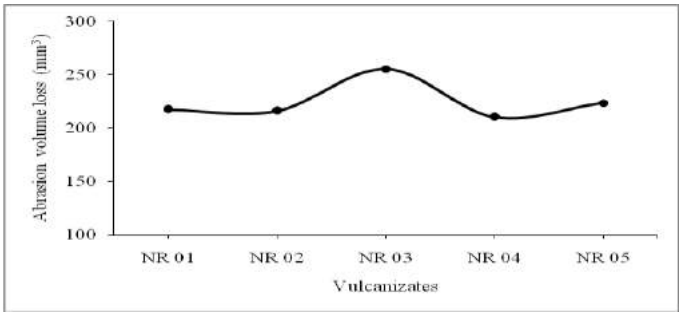


Fig. 25. Abrasion volume loss of filled vulcanizates

Compression set

According to Figure 26, compression set values of the vulcanizates passes through a maximum value at 50% DWTS when the DWTS loading is increased. However, it varies only in a narrow range between 7.5 and 10% similar to the EB values. It could be seen that the variation observed for compression set was in agreement with higher M_H value of the NR 05 compound. However, it could be suggested that replacement of IAS with DWTS did not show a considerable influence on the compression set of the vulcanizates.

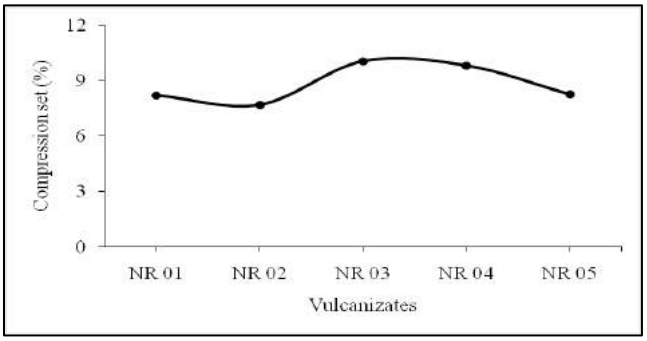


Fig. 26. Compression set of filled vulcanizates
(N G P Chamara, R Ileperuma, Y Sudusinghe and S Siriwardena)

Preparation of polypropylene and skim natural rubber thermoplastic natural rubber: Determination of optimum compatibilizer loading

A series of Skim Natural Rubber (SNR) and Polypropylene (PP) blends of 50:50 blend ratio (P50 SNR DV) with different EPDM loadings were prepared in an internal mixer - Haake (MX300- TQ) at pre-determined processing conditions (200^0C of setting temperature and 70 rpm of rotor speed). EPDM loading was varied from 0 to 20 phrat 5 phr intervals. Table 15 shows the compounding formulation of preparation of P50 SNR DV compatibilized blends. The mixing was continued until a plateau torque was reached. The mixing schedule used is given in the Table 16.

Table 15. *Compounding formulations used in preparation of P50 SNR dynamically vulcanized blends with compatibilizer*

Compound	Quantity/phr				
	C0	**C1**	**C2**	**C3**	**C4**
PP	100	100	100	100	100
SNR	100	100	100	100	100
EPDM	0	5	10	15	20
IPPD	0.75	0.75	0.75	0.75	0.75
ZnO	2.5	2.5	2.5	2.5	2.5
Stearic Acid	1	1	1	1	1
TMTD	1.25	1.25	1.25	1.25	1.25
TBBS	1	1	1	1	1
Sulphur	0.25	0.25	0.25	0.25	0.25

Table 16. *Mixing schedule used for preparation of SNR/PP and SLR/PP blends*

Activity	Initiating time (min)
PP was added & rotor was started at 10 rpm	0
Rotor speed was adjusted to 70 rpm	5
NR was added with IPPD	8
EPDM was added	10
Stearic acid and ZnO were added	13
TBBS and TMTD were added	14
Sulphur was added	16
Mixing was stopped and dumped (two minutes after the stabilization torque was achieved)	18-20

Tensile and ageing properties

Stress-strain curves of non-aged and aged P50 SNR DV blends with different EPDM loadings are presented in Figure 27 and Figure 28, respectively. All curves have shown the behavior of typical Thermoplastic Elastomers (TPEs) with relatively high initial modulus and less defined yield stress. Figure 27 shows the aged and un-aged tensile strength of PP/SNR (50/50) blends against different EPDM loading. It was found that the PP/SNR (50/50) blend with 10 phr of EPDM concentration exhibit the highest tensile strength. Thermal ageing studies carried out indicated the improved ageing resistance offered by EPDM to the compatibilized P50 SNR DV blends.

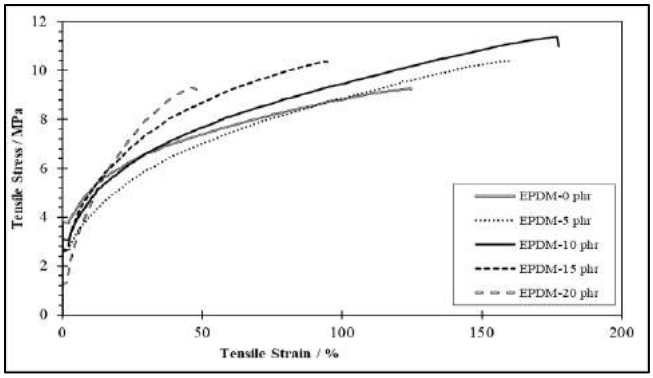


Fig. 27. Stress-strain curves of non-aged P50 SNR DV blends with different EPDM loadings

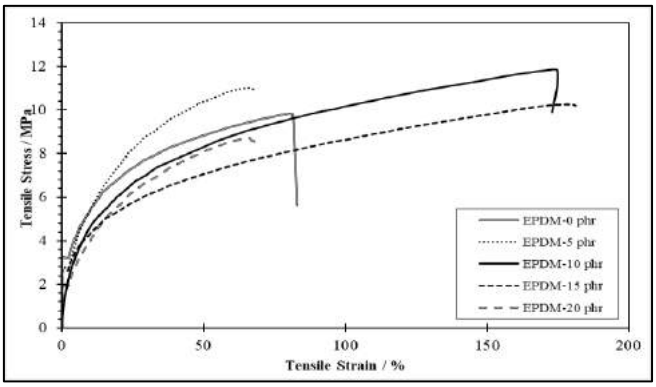


Fig. 28. Stress-strain curves of aged P50 SNR DV blends with different EPDM loadings

Figure 28 shows the elongation at break results of before and after aged P50 SNR DV blends with different EPDM loadings. EPDM is a rubber with low EB and hence replacement of EPDM from NR could leads to a reduction of EB. In other hand, in PP/NR blend systems inclusion of EPDM could improve the tensile properties due to its possible compatibilizing effect. Therefore, increment of elongation up to 10 phr of EPDM exhibit by the blends could be due to the compatibilization effect of EPDM while reduction of EB yielded with further addition of EPDM could be attributed to the low EB of the material. In Figure 29, it can also be seen material properties in term of EB has shown improved ageing properties at the higher EPDM loadings showing that excellent ageing properties of EPDM has an influence on the blend properties.

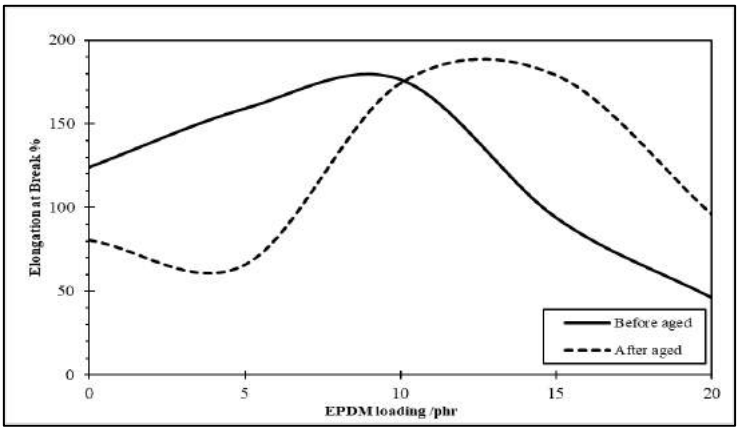


Fig. 29. Elongation at break results of before and after aged P50 SNR DV blends with different EPDM loadings

Hardness

The Figure 30 shows the hardness of P50 SNR DV blends with different EPDM loadings. It could be seen that there is no significant impact on hardness with varying EPDM loading.

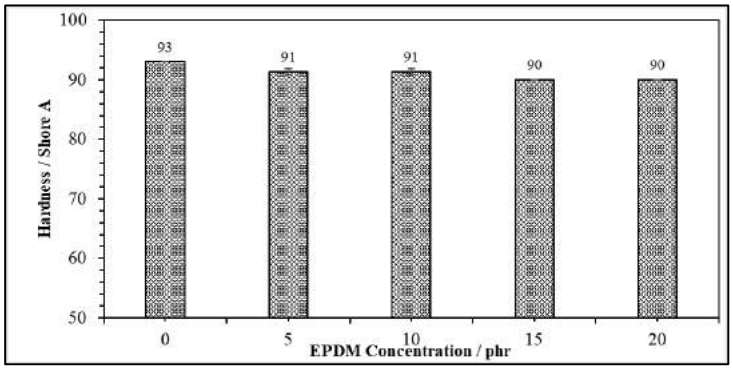


Fig. 30. Effect of EPDM loading on hardness of P50 SNR DV blends

Extractable protein test

Leachable protein content of P50 SNRDV blends with different EPDM loadings are shown in Figure 31. It was found that the extractable protein content of

all the compatibilized blends falls below 60 ppm. Therefore, it could be concluded that the use of EPDM has a positive impact on the extractable protein content.

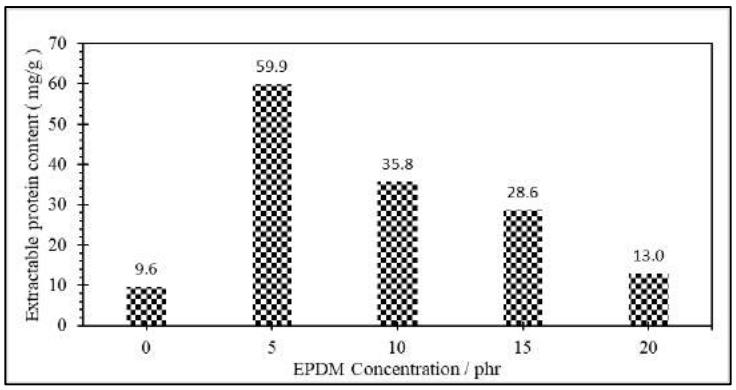


Fig. 31. Effect of EPDM loading on extractable protein content of P50 SNR DV blends

(D S Wijewardena, S Siriwardena, Y C Y Sudusingha and D G Edirisingha)

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.

Research students

- A M U K Attanayaka, a student of Postgraduate Institute of Agriculture, University of Peradeniya carried out his research project on 'Rubber cultivation in non-traditional areas: Factors influence in adoption by smallholders in Ampara district of Sri Lanka' under the supervision of Dr (Mrs) E S Munasinghe and Dr (Mrs) W Wijesuriya.

- U I Ranasinghe, a student of Postgraduate Institute of Agriculture, University of Peradeniya carried out his research project on 'Socioeconomic and Agronomic Reasons for Substandard Growth of Immature Rubber in Eastern Province of Sri Lanka' under the supervision of Dr (Mrs) E S Munasinghe and Dr (Mrs) W Wijesuriya.

- A M G A Amarakoon, an undergraduate student, Faculty of Engineering Technology, Open University of Sri Lanka carried out her final year research project on 'Beekeeping under smallholder rubber plantations in Kegalle district, Sri Lanka: an assessment of current status and its potential' under the supervision of Mrs B M D C Balasooriya.

Seminars/Training/Workshops/Exhibitions conducted

Officer/s	Subject/Theme	Beneficiary/Client
ES Munasinghe	Awareness programme on Carbon Trading	Rubber smallholders in Ampara & Moneragala districts

Seminars/Training/Workshops/Meetings/Conferences attended

Officer/s	Subject/Theme	Organization
ES Munasinghe	Project Implementing & Monitoring Committee Meeting on Carbon Trading	RRISL
	Stakeholder Consultative Meeting	Forest Stewardship Council
ES Munasinghe &	Research Meeting	RRISL
BMDC Balasooriya	Scientific Committee Meeting	RRISL
BMDC Balasooriya	Workshop on Statistics for Research	SLCARP

Field visits

Experimental - 52
Advisory - 04
Other - 18

FIELD INVESTIGATIONS

Expansion of rubber cultivation to non-traditional areas (ARU/01)

- 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 rubber yield at smallholder conditions in the Eastern Province, daily yield records were maintained throughout the year. Due to the restriction of field visits caused by the COVID19 pandemic, the collection of yield records was limited to six mature rubber smallholdings in Padiyathalawa and Mahaoya Divisional Secretariat areas.

The highest average yield per tree per tapping was observed in March whilst the lowest was in October (Fig. 1). The average annual latex yield was recorded as 1,375 kg/ha on the virgin panel (Panel B). The average number of tapping days was 144 per year and average stand was 300 per hectare (E S Munasinghe, V H L Rodrigo, P M M Jayathilake and N M Piyasena).

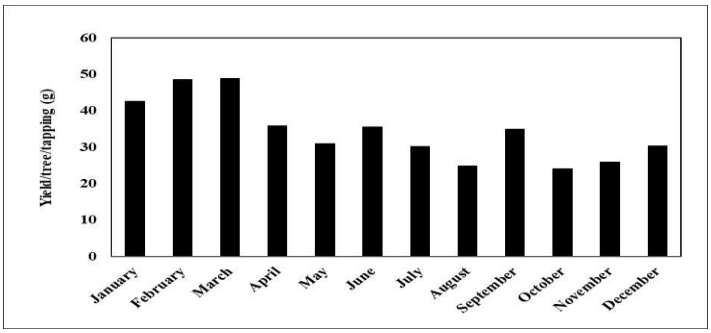


Fig. 1. Seasonal yield variation under smallholder conditions of Eastern province

- Improving the protocols available to cultivate rubber in the Dry Zone

With the aim of improving suitable protocols available to cultivate rubber in the Dry Zone, farmer participatory adaptive research trials were maintained in the Northern and North Central provinces of the country.

Growth performance (in terms of girth and height) of immature rubber plants of sites in Kilinochchi, Mullaithivu and Anuradhapura was assessed (Table 1).

Table 1. *Details of rubber planting sites in the Dry zone*

Sites	Year of planting	Site code	Land extent (Ac)	Clone	Mean girth at 120 cm (cm)	Mean height (cm)
Kilinochchi	2017	2017/K1	½	RRISL 203	13.2 ± 0.41	
	2017	2017/K2	½	RRISL 203	17.8 ± 0.41	Not taken
	2017	2017/K3	½	RRIC 121	14.6 ± 0.44	
Mullativu	2013	2013/M1	½	RRIC 121	44.82±0.11	Not taken
	2017	2017/M2	½	RRIC 121	18.93±0.42	
Anuradhapura	2017	2017/A1	2	RRISL 203	25.1±0.20	Not taken
			2	RRIC 121	25.6±0.18	
	2019	2019/A2	½	RRIC 121	7.04±0.13	301±10.18
			½	RRISL 203	5.39±0.18	189±6.71
			½	RRISL 2001	5.79±0.25	198±5.86
	2019	2019/A3	¾	RRISL 203	7.14±0.16	315±7.48
	2019	2019/A4	1	RRISL 203	7.56±0.19	347±8.67
	2019	2019/A5	1	RRIC 121	5.94±0.19	225±5.41
			½	RRISL203	5.77±0.14	188±7.00
			½	RRISL 2001	5.76±0.19	187±9.04

The firstly harvested smallholder rubber field in the Vavuniya District of the Northern Province reported an average yield of 22.5 g of dry rubber per tree per tapping.

Feasibility of cultivating rubber in Anamaduwa Divisional Secretaries division of Puttlam district was assessed and initial arrangements were made to establish rubber in 8 ha with a smallholder in collaboration with Rubber Development Department. Due to the COVID19 pandemic, some essential establishment operations could not be attended at the correct time, therefore planting was postponed to the next season (E S Munasinghe, V H L Rodrigo, P M M Jayathilake and N M Piyasena).

- Water requirement of young rubber plants in the Dry zone

This study was conducted to assess the water requirement of young rubber plants in the Dry Zone of the country. The experiment was laid out as a farmer participatory adaptive research trial 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 with two different clones, *i.e.* RRIC 121 and RRISL 203. Each treatment plot contained 8 trees.

During the dry period prevailed during March to April (no rains above 0.03 mm/day for 43 day period), following watering schedule was followed;

T1 - 4 l in 5 day interval
T2 - 4 l in 6 day interval
T2 - 4 l in 6 day interval
T3 - 4 l in 7 day interval
T4 - 8 l in 5 day interval
T5 - 8 l in 6 day interval
T6 - 8 l in 7 day interval
T7 - 12 l in 5 day interval
T8 - 12 l in 6 day interval
T9 - 12 l in 7 day interval

The growth of rubber plants was monitored in terms of girth at 120 cm height. Within the year, no significant difference in mean girth increment rates among treatments was observed. However, the clone RRISL 203 reported higher rates than those of the clone RRIC 121 in all treatments (Table 2).

Table 2. *Mean girth increment rates of rubber plants under different watering systems*

Watering system	**Mean girth increment (cm per month)**	
	RRIC 121	**RRISL 203**
T1 - 4 l in 5 day interval	0.88[a]	1.11[a]
T2 - 4 l in 6 day interval	0.92[a]	0.99[a]
T3 - 4 l in 7 day interval	0.99[a]	1.05[a]
T4 - 8 l in 5 day interval	0.93[a]	0.91[a]
T5 - 8 l in 6 day interval	0.97[a]	1.05[a]
T6 - 8 l in 7 day interval	0.99[a]	1.17[a]
T7 - 12 l in 5 day interval	0.97[a]	0.97[a]
T8 - 12 l in 6 day interval	0.87[a]	1.11[a]
T9 - 12 l in 7 day interval	0.96[a]	1.08[a]

At the latter part of the dry period, physiological measurements such as stomatal conductance and relative water content of rubber leaves were taken.

No significant difference was found among the stomatal conductance of the clone RRIC 121 in both morning and evening of the day. However, the evening values of the clone RRISL 203 were significantly ($P \leq 0.05$) higher in 5 day watering systems (T1, T4 and T7) whilst no significant difference was reported in the morning (Table 3).

Table 3. *Stomatal conductance of rubber leaves under different watering systems*

Watering system	Stomatal conductance ($\mu molm^{-2}s^{-1}$)			
	RRIC 121		RRISL 203	
	Morning	Evening	Morning	Evening
T1 - 4 l in 5 day interval	0.22[a]	0.20[a]	0.20[a]	0.22[a]
T2 - 4 l in 6 day interval	0.26[a]	0.16[a]	0.26[a]	0.15[c]
T3 - 4 l in 7 day interval	0.27[a]	0.22[a]	0.29[a]	0.21[ab]
T4 - 8 l in 5 day interval	0.20[a]	0.20[a]	0.24[a]	0.24[a]
T5 - 8 l in 6 day interval	0.22[a]	0.16[a]	0.24[a]	0.13[c]
T6 - 8 l in 7 day interval	0.18[a]	0.14[a]	0.20[a]	0.20[ab]
T7 - 12 l in 5 day interval	0.23[a]	0.16[a]	0.30[a]	0.22[a]
T8 - 12 l in 6 day interval	0.20[a]	0.18[a]	0.20[a]	0.15[c]
T9 - 12 l in 7 day interval	0.19[a]	0.18[a]	0.18[a]	0.17[cb]

Further, there was no significant difference observed in relative water content (%) of rubber leaves among the treatments in both clones (Table 4).

Table 4. *Relative Water Content of rubber leaves under different watering systems*

Watering system	Relative water content (%)	
	RRIC 121	RRISL 203
T1 - 4 l in 5 day interval	58.39[a]	59.63[a]
T2 - 4 l in 6 day interval	55.72[a]	59.11[a]
T3 - 4 l in 7 day interval	56.5[a]	60.82[a]
T4 - 8 l in 5 day interval	58.39[a]	57.31[a]
T5 - 8 l in 6 day interval	58.09[a]	54.55[a]
T6 - 8 l in 7 day interval	57.17[a]	56.22[a]
T7 - 12 l in 5 day interval	53.08[a]	58.45[a]
T8 - 12 l in 6 day interval	58.30[a]	56.17[a]
T9 - 12 l in 7 day interval	55.19[a]	57.15[a]

(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. A pre-tested semi-structured questionnaire survey was used for data collection and a stratified random sampling technique was used for the sample selection. At the moment, 850 questionnaires have been completed and the study is in progress.

According to the results, it was found that the percentage use of flatlands, moderately steep lands and steep lands for rubber cultivation were respectively 10%, 84% and 6%. The age of the farmers of the sample varies from 20 years to 89 years and the average age is 56 years. The farming experience of the farmers in the sample ranged from 1 to 60 years and the mean value is 20 years. Out of the sample, 57% of the farmers were attached to rubber related society. Farmers of 88% of the samples were producing Ribbed Smoked Sheets (RSS) and only 12% were selling as latex. Based on the data set, the adoption awareness rates of a few major agronomic practices were computed and reported in Table 5.

Table 5. *Adoption awareness rates of few major agronomic practices*

Agronomic practice	Awareness rate (%)	Adoption rate (%)
Fertilizer application	97	76
Weed management	99	96
Application of rainguard	75	09
Usage of new tapping knife	66	34
Correct time of planting	94	91
Correct depth of planting	83	60

(B M D C Balasooriya, P Seneviratna and N M Piyasena)

- On-farm behaviour of smallholder rubber farmers in traditional rubber growing areas

This study was started to identify the on-farm productivity and production variability among smallholder rubber farmers in traditional rubber growing areas. Kegalle and Kurunegala districts were selected for the study representing 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 was in progress. Data collected from 11 smallholder fields from Kurunegala and Kegalle districts are summarized and shown in Figures 2 and 3. It was reported an

average yield of 1,232 kg/ha and 1,188 kg/ha from Kegalle and Kurunegala districts respectively for the given 12 months period (B M D C Balasooriya, P Seneviratna and N M Piyasena).

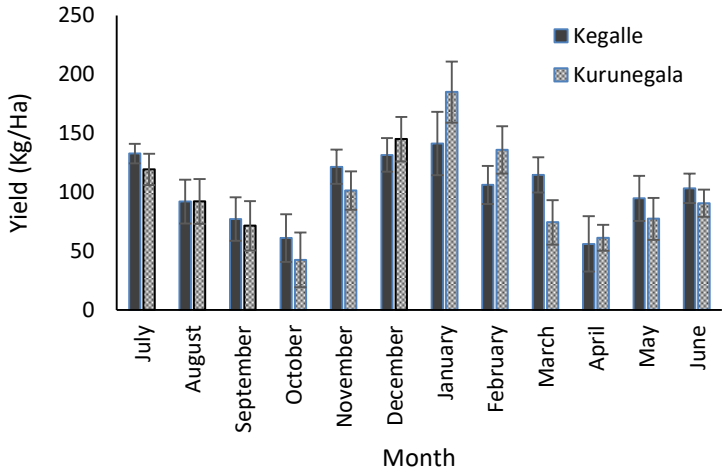


Fig. 2. Seasonal yield variation from July 2019 to June 2020

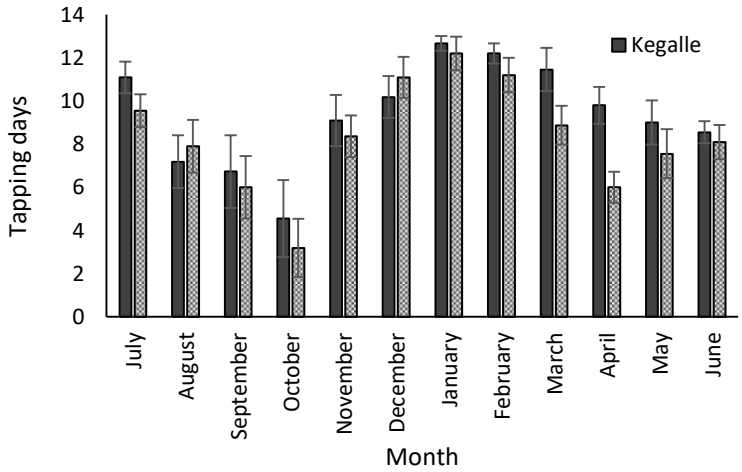


Fig. 3. Variation in tapping days from July 2019 to June 2020

- Adaptability of new mammalian pest repellent under smallholder conditions

This trial was started with the collaboration of the Plant Pathology and Microbiology Department to identify the suitable application frequency of newly

introduced mammalian pest repellent. Four sites were selected (three smallholder fields and Polgahawela Sub-station field) 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 were kept as the control (without applying the repellent). Damages were recorded in treated and untreated plots (Table 6).

Table 6. *Percentage of mammalian pest damaged trees in research fields*

			Damaged tree %							
			After 6 months		After12 months		After 24 months		After 36 months	
Field	Planting year	Clone	Treated	Not treated	Treated	Not treated	Treated	Not treated	Treated	Not treated
1	2015	RRISL 203	0	5	8	10	5	4	3	2
2	2014	RRIC 121	0	10	17	12	8	10	7	8
3	2012	RRIC 121	0	13	33	35	15	18	10	12
4	2012	RRIC 121	0	5	8	8	10	10	7	5

According to the results, the application frequency of six months is suitable for the Intermediate Zone. Thereafter no significant difference seen between treated and not treated plots. Tapping was commenced in smallholder field 3 and Polgahawela Sub-station field. With the commencement of tapping also a reduction was observed in mammalian pest attacks. This may be due to increased human activities 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).

- Beekeeping in rubber plantations

Beekeeping was recommended for mature rubber cultivations to enhance the income level of rubber smallholders in the country. According to the recommendation, five bee colonies can be kept in one-acre land, and 750 – 2,250 ml of bee honey can be harvested from a bee colony during a harvesting season. With the average market price of Rs.1,750.00/750 ml, there is a potential of earning Rs.8,750.00 - 26,250.00 income from one-acre land per season. Though it provides fairly good income for rubber farmers, popularity is not at a satisfactory level. With this background, this study was commenced to identify the current status of beekeeping in rubber plantations and identify the willingness to accept beekeeping by rubber smallholders in Kegalle district.

Pre-tested semi-structured questionnaire survey was implemented in the area to collect the cross-sectional data of rubber smallholdings. Information on rubber

cultivation, demographic conditions and willingness to accept beekeeping by farmers were gathered from 250 rubber smallholdings (Table 7).

Table 7. *Demographic information of the smallholders*

Variable		Mean	Minimum	Maximum	Percentage
Age (years)		55	24	80	
Farming experience (years)		21	1	50	
Extent (acres)		2	0.25	10	
Gender	Male	-	-	-	82
	Female	-	-	-	18
Education level	No schooling				1
	Primary education				18
	Up to O/L				35
	Up to A/L				35
	Higher education				10

Among the rubber farmers, 55% are interested in beekeeping, however, 46% of the farmers are not aware of the possibility of beekeeping with rubber. Figure 4 depicts the likelihood of a farmer to accept beekeeping under rubber with the income received from beekeeping. It was noticed that there is a 50% probability for occupying beekeeping if the income from beekeeping would be at least Rs.20,950.00/acre/year (B M D C Balasooriya, E S Munsinghe, N M Piyasena and P M M Jayathilake).

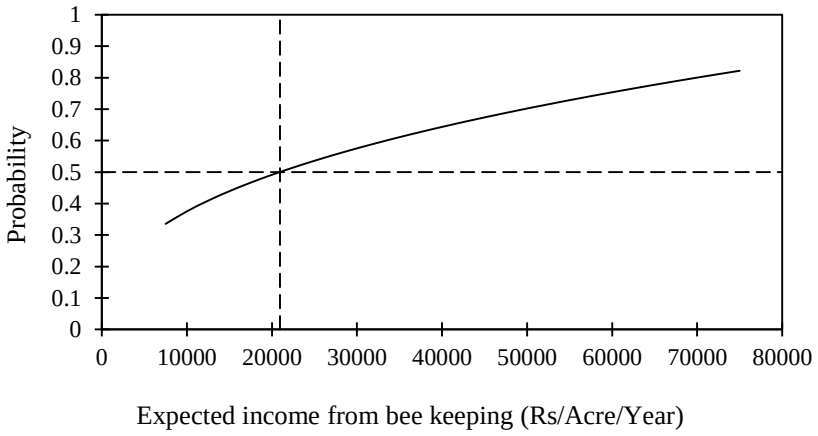


Fig. 4. Likelihood of a rubber smallholder to be engaged in beekeeping at different income levels

Socioeconomic improvement in plantation workers (ARU/03)

The study was commenced to identify the psycosocioeconomic status of the rubber plantation workforce. The study was intended to conduct initially in Dartonfield Group Agalawatta and then to expand into two other rubber estates in the Kalutara district. A semi-structured pre-tested questionnaire survey is planned for the data collection. Gender issues, child protection and education systems among plantation workers were the key criteria focused. The questionnaire preparation and pre-testing were completed (B M D C Balasooriya, E S Munsinghe, V H L Rodrigo, 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 the sustainable rubber industry (Treasury Funded Development Project)

The project was initiated with the objective of developing a carbon trading project to obtain Verified Carbon Standards (VCS) for 2,500 ha of new rubber cultivations in Uva and Eastern Provinces. Preparation of draft Project Description Document (PDD) was completed in collaboration with Carbon Consulting Company (CCC) and the project was listed in one of the most recognized international accredited VCS registry; VERRA. Identification of GPS locations of *ca*. 1,500 ha of new rubber smallholdings (planted from 2016 to 2018) in Moneragala and Ampara districts were done in collaboration with STaRR Project. Workshops were conducted to educate rubber farmers in Moneragala and Ampara districts on carbon trading and its benefits in collaboration with STaRR project and CCC.

Initial data collection for the estimation of the Carbon Footprint of Rubber Research Institute was completed (V H L Rodrigo and E S Munasinghe).

BIOMETRY

Wasana Wijesuriya

DETAILED REVIEW

Staff

Dr (Mrs) Wasana Wijesuriya, Principal Research Officer and Mr Dilhan Rathnayaka, Research Officer, and the Experimental Officer, Mr Vidura Abeywardene were on duty throughout the reporting year. Mrs I N S Silva, Technical Officer (Research and Development) has resigned with effect from the 22nd August. Mrs S N Munasinghe, Management Assistant attached to the Biometry section was on no-pay leave from 18th September till the end of the year.

Research students

The following students are registered for postgraduate studies under the supervision of Dr (Mrs) Wasana Wijesuriya.

- L A T S Liyanaarachchi - Continued work for his MPhil on "Indicator based identification, forecasting and mapping of droughts in Sri Lanka" at the Wayamba University.

- Ms P W Jeewanthi - Continued work for her MPhil on "Forecasting rainfall anomalies and modeling rainfall extremes to minimize the risk in Agriculture Sector" at the Postgraduate Institute of Agriculture, University of Peradeniya.

- A M U K Attanayaka - Continued work on "Rubber cultivation in non-traditional areas: Factors influencing adoption by smallholders in Ampara district of Sri Lanka" for his MSc at the Postgraduate Institute of Agriculture, University of Peradeniya.

- U I Ranasinghe - Continued work on "Socioeconomic and agronomic reasons for substandard growth of immature rubber in Eastern Province of Sri Lanka" for his MSc at the Postgraduate Institute of Agriculture, University of Peradeniya.

Seminars/Training/Workshops addressed/conducted

Mrs Wasana Wijesuriya and Mr Dilhan Rathnayaka conducted the following training programmes organized by RRISL. Mr Vidura Abeywardene assisted in practicals on meteorological data recording.

Subject/Theme	Beneficiary/Client
Climatic conditions and rainfall distribution in rubber growing areas	Participants of the Advanced Certificate Course in Plantation Management, Officers of Rubber Development Department
Technology update	Experimental/Technical/Extension Officers of RRISL and Officers of Rubber Development Department

Seminars/Conferences/Meetings/Workshops attended

Officer	Subject/Theme	Organization
Wasana Wijesuriya	Climate change adaptation strategy	Ministry of Environment
Wasana Wijesuriya & Dilhan Rathnayake	Experiences during the 2019/20 North East monsoon season	Department of Meteorology
	Experiences during the 2020 South West monsoon season	Department of Meteorology
	Workshop series in National Climate Change Data Sharing Network	Ministry of Environment

Seminars/Conferences/Workshops/Meetings/Training sessions addressed

Mrs Wasana Wijesuriya addressed the following Seminars/Conferences/ Workshops/Meetings.

Subject/Theme	Organization
Experiences during the 2019/20 North East monsoon season	Department of Meteorology
Experiences during the 2020 South West monsoon season	Department of Meteorology
Presented a paper on "Preparedness of the Sri Lankan Rubber Sector to minimize the impact of climate change" in the workshop "Natural rubber systems and climate change"	CGIAR/CIFOR/World Agroforestry/ IRRDB/ANRPC/CIRAD
Technology update	Rubber Research Institute of Sri Lanka

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 the proper use of these methods.

Structural Equation Models (SEM) to assess employees' job satisfaction in the Rubber Research Institute

The purpose of this study was to introduce Structural Equation Modelling (SEM) to assess the satisfaction level of the employees and identify the factors that affect employee job satisfaction. 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. Working environment, salary, job security, human resource development, and relationship with co-workers are the key influential factors identified for this analysis through past literature.

This was a quantitative research that used the deductive approach and the survey strategy. The close ended questionnaire with a five-point Likert scale was used in primary data collection method. This sample represented research staff and extension staff of the Rubber Research Institute of Sri Lanka.

Structural Equation Modeling (SEM) is a second-generation multivariate data analysis Method. It can test theoretically supported linear and additive causal models. With SEM, researchers can visually examine the relationships that exist among variables of interest in order to prioritize resources to better serve the needs. Unobservable and hard-to-measure latent variables can be used in SEM which makes it ideal for tackling research problems.

SmartPLS is one of the prominent software applications for Partial Least Squares Structural Equation Modeling (PLS-SEM). It was used in this study since the measurements were made in Likert scale. PLS is a modeling approach to SEM with no assumptions about data distribution. The PLS path modeling estimation for the study is shown in Figure 1.

According to this analysis, Working Environment is the most decisive factor affecting job satisfaction. It seems the employees are not much concerned about Job Security. It is expected to use the SEM technique in other areas of research, especially

when latent variables (those cannot be measured) are involved (W Wijesuriya, D Rathnayaka, P G N Ishani and J K S Sankalpa).

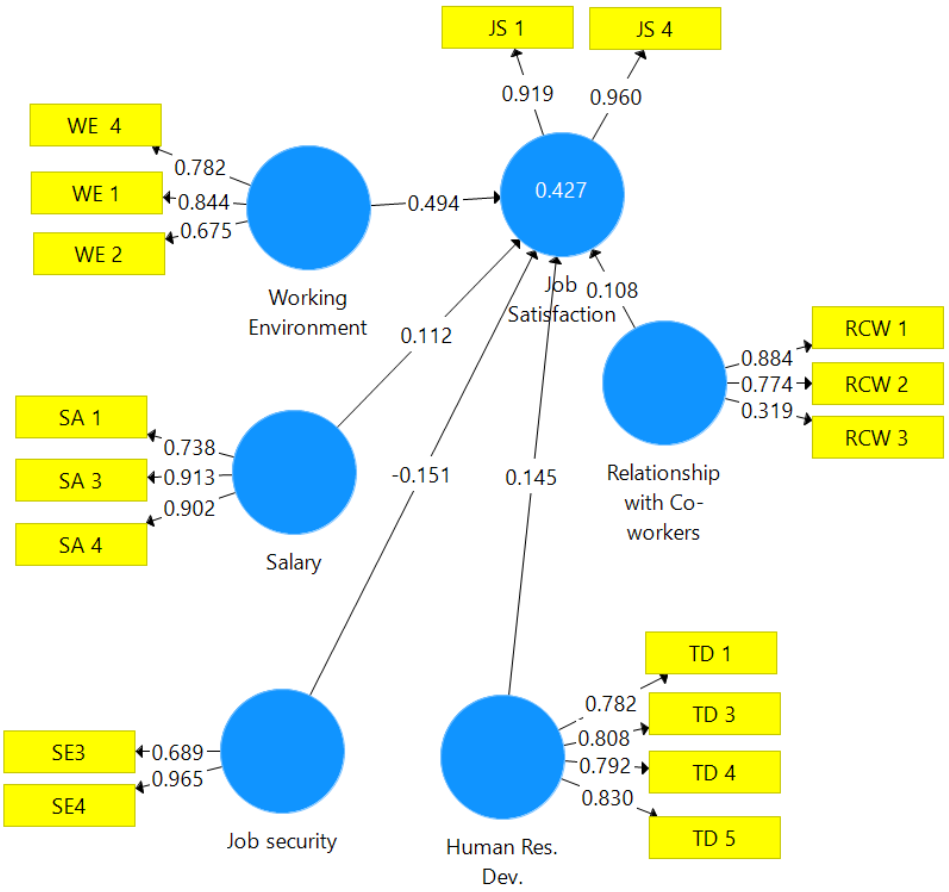


Fig. 1. PLS path modeling estimation for job satisfaction

Improving the knowledge base on climate, climate change and variability for better decision making in rubber growing areas (BM 02)

Maintenance and establishment of meteorological and agro-meteorological stations (BM/02/a)

Maintenance and data recording is being done in the meteorological stations owned by RRISL by visiting and inspecting these sites and by providing instruments when necessary. These include the AGROMET station at Dartonfield and rainfall stations in Moneragala, Kuruwita, Nivitigalakele, Polgahawela, Galewatta and

Nivitigalakele. The data and information pertaining to these stations are explained in the Meteorological Summary of this report. A detailed analysis was done based on the historical rainfall data and an article was prepared titled "Revisiting the rainfall variability at Dartonfield, Agalawatta in the Low Country Wet Zone (WL_{1a})" (W Wijesuriya, D Rathnayaka and O V Abeywardene).

Maintenance of databases on meteorological data in rubber growing areas (BM/02/b)

The database with daily meteorological data collected at Dartonfield 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 are given in Table 1. It was noted that 2020 was a year with below-average precipitation in most of the rubber-growing areas (W Wijesuriya, D Rathnayaka and V Abeywardene).

Analysis of data to identify changes in patterns and trends in rainfall, identification of drought impacts and spatial analysis of droughts (BM/02/b)

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 reported the occurrence of extreme rainfall events employing the Standardized Precipitation Index (SPI) in the review last year. 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.

This study employed rainfall data from 1983 to date in selected stations, representing Wet, Intermediate and also areas where rubber cultivation is recently introduced. The indices recommended by the World Meteorological Organization are being used in this ongoing study (Dilhan Rathnayaka and W Wijesuriya).

Table 1. *Monthly rainfall in rubber growing areas in 2020*

Month	Location										
	Hanwella	**Rathnapura**	**Agalawatte**	**Galle**	**Kekenadura**	**Nittabuwa**	**Kurunegala**	**Monaragala**	**Uhana**	**Matale**	**Badulla**
	WL1a	**WL1a**	**WL1a**	**WL2a**	**IL1a**	**WL3**	**IL1a**	**IL1c**	**DL2a**	**WM3b**	**IM1a**
January	35.1	122.5	157.7	44.2	13.0	64.7	22.3	49.3	84.5	50.1	68.8
February	52.4	21.4	91.0	27.4	0.0	6.8	0.6	18.1	51.4	9.2	45.5
March	107.8	150.1	145.7	17.7	7.0	38.5	52.7	3.6	0.0	0.0	11.7
April	254.5	191.6	389.9	182.5	110.6	235.5	428.0	58.6	19.3	54.8	93.1
May	288.1	737.1	285.5	314.4	222.0	294.6	316.9	197.1	164.0	210.6	198.5
June	288.9	328.0	344.1	138.2	108.8	167.4	95.3	75.2	108.0	31.3	144.0
July	220.0	253.2	424.7	311.3	336.8	167.2	119.3	110.2	62.1	140.0	99.5
August	123.4	192.9	189.6	164.9	105.4	101.6	83.0	100.4	44.4	90.4	159.0
September	778.9	590.8	748.1	448.8	249.2	812.9	370.5	136.8	71.2	170.8	129.4
October	126.7	207.4	206.0	160.2	123.0	108.1	52.4	52.4	83.8	49.8	41.4
November	418.7	437.7	424.8	233.3	222.0	301.3	276.1	279.4	160.3	134.7	289.3
December	310.5	214.5	243.4	155.1	72.0	270.4	195.7	239.6	429.7	539.7	187.4
Total rainfall (mm)	3005.0	3447.2	3650.5	2198.0	1569.8	2569.0	2012.8	1320.7	1278.7	1481.4	1467.6
No. of rainy days	141	220	210	184	112	168	148	115	71	114	146

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 socio-economic surveys and constructing indices for the combined benefit and monetary advantage. The details of activities conducted during this year are presented in the review of the Advisory Services Department. This is a collaborative project between Advisory Services Department, Agricultural Economics Unit and the Biometry Section. The progress of this project is adversely affected by the Covid-19 endemic situation.

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 analytical methods. Data collection through questionnaire surveys and focused group interviews are 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. The Covid-19 endemic situation has seriously affected the progress of this project [Dr (Mrs) Wasana Wijesuriya and Mrs Dammika Balasooriya represent the research team of this project].

Involvements in IRRDB activities

Mrs Wasana Wijesuriya continued to assist IRRDB in attending to the duties of the Liaison Officer of the Socioeconomic Specialist Group during 2020. During the Annual meeting of IRRDB in Myanmar in 2019, the proposal submitted to conduct a Workshop on "Understanding fundamentals in GIS and geo-spatial applications" and a Conference on "GIS for Better Decision Making" was approved. The objective of this Workshop is to develop the capacity of Socio-economists in employing GIS in the discipline of socio-economics. The Workshop could not be held as scheduled in September 2020 in Sri Lanka due to the Covid-19 endemic situation.

The International Conference 2020 and Annual Meetings scheduled to be held in Guatemala were also postponed. Mrs Wijesuriya presented a paper on “Preparedness of the Sri Lankan Rubber Sector to minimize the impact of Climate Change” in the Workshop “Natural Rubber Systems and Climate Change” jointly organized by IRRDB and several other Institutions, on a virtual platform.

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

Most of the physical gatherings throughout the year were halted due to the Covid-19 pandemic and Officers of AEU participated in the virtual meetings conducted by the institute.

Services

Research support

Following cost-benefit and economic analyses were conducted on the request of other researchers.

- Cost-benefit analysis of different clones and stimulation treatments (For more information: Please refer to the Department of Plant Science)

Database management

The databases on auction prices in Sri Lanka and International rubber prices were 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 40 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 RSS3 in the years 2019 and 2020 are given in Figures 1(a) and 1(b), respectively. The highest average price of RSS1 was Rs.430, recorded in December. Yearly average prices of all grades of RSS were higher than that of the previous year (2019). The average RSS 1 price difference against the previous year was around Rs.62. Yearly average RSS1 price has increased

by 21% when compared to 2019. This was mainly due to supply chain disruption prevailed in the international market.

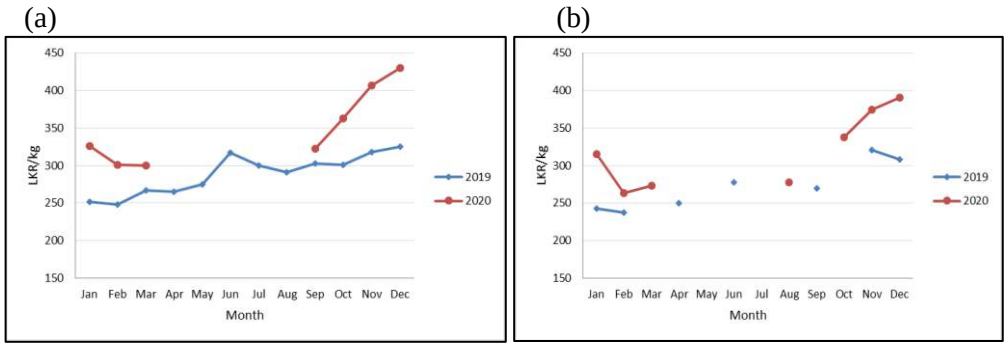


Fig.1. The monthly average prices of RSS 1 (a) and RSS 3 (b) in 2019 and 2020

Prices of Latex Crepe (LC)

Prices of Latex Crepe1X (LCIX) for 2019 and 2020 are shown in Figure 2. LC1X prices have remarkably increased during the latter part of 2020. The gap between LC prices of 2019 and 2020 was high at the beginning of the year. Prices gradually declined up to September and then increased remarkably at the end of the year. The average LC1X price ranged from Rs.288 (July) to Rs.459 (December) during 2020. The average price of LC1X in 2020 was Rs.358 and was an 18% improvement compared to the previous year.

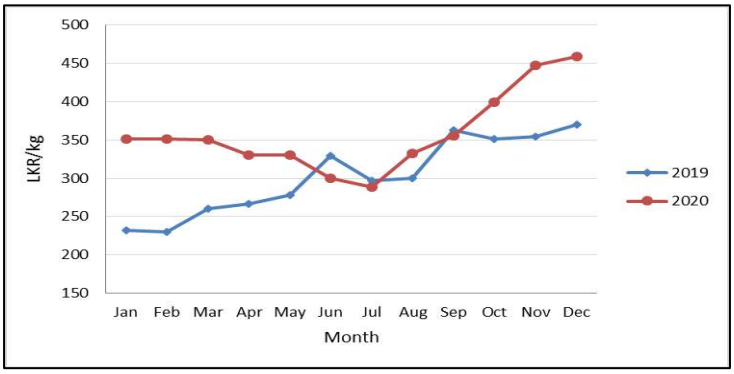


Fig. 2. The monthly average of nominal Latex Crepe 1X price in years 2019 and 2020

Table 1. *The monthly Auction Prices of Rubber (L. Crepe, Sheet and Scrap) in the year 2020*

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	326	319	315	280	272	351	349	336	322	264	256	257	255	249	253
Feb	301	unq	263	256	253	351	349	338	330	253	247	245	241	238	231
Mar	300	288	273	Unq	250	350	352	350	346	245	243	232	238	230	224
Apr		Unq		Unq	Unq	331	333	302	276	211	201	200	191	Unq	195
May		Unq		Unq	Unq	330	321	298	265	195	191	195	189	188	190
Jun		Unq		Unq	Unq	300	297	271	253	199	194	191	193	190	181
Jul		270		245	255	289	295	281	274	226	219	204	211	207	193
Aug		293	278	270	264	332	331	312	296	272	260	252	234	228	210
Sep	323	Unq		Unq	Unq	355	355	341	327	299	291	253	234	230	215
Oct	363	330	338	Unq	Unq	399	386	373	365	346	284	263	255	250	250
Nov	407	417	375	303	Unq	447	445	434	421	405	336	288	287	270	265
Dec	430	unq	391	380	Unq	459	456	448	441	388	343	325	311	294	293
2020 Average	350	319	319	289	259	358	356	340	326	275	255	242	236	234	225

RESEARCH

The following studies were conducted in 2020.

Rubber industry analysis (AE/01)

Competitiveness of Sri Lankan rubber products in the global market: A constant market share analysis

This study examines the competitiveness of Sri Lankan rubber products exports in the international market and determines the contributing factors behind the export growth of these products. Four rubber products, pneumatic tyres, retread and solid tyres, gloves of vulcanised, unhardened rubber and other articles of vulcanized rubber products which account for more than 95% of the rubber products export earnings during the last five years, were selected for the analysis.

The Constant Market Share (CMS) model was applied to decompose the export growth of the above-mentioned products into its contributing factors accountable for the export performance. CMS approach is the most common approach used to measure the competitiveness of export products according to the literature. Export growth of a product is due to three major factors; structural effect, the competitive effect, and the second-order effect according to the CMS approach.

Structural effect means the changes in exports due to the change in the world demand for a particular product. The changes in exports are due to the change of exporting country's competitiveness is called as competitive effect. A positive value indicates a strong competitiveness of the exporter in the international trade. The second-order effect measures the effect of the interaction between market share changes and demand changes. The CMS approach uses an exporter's market share in the global market as a measurement of competitiveness. The competitiveness improves in line with the improvement in market share.

Overall, exports of the above-mentioned four rubber products to their major import destinations have grown during the study period of 1999-2019. Sri Lanka's exports of new pneumatic tyres have increased in the selected import destinations during this study period. Major import destinations for this product were the USA, European Union (EU), India, Tanzania and United Arab Emirates (UAE). Export revenue growth of this product was mainly due to the growth in value of world pneumatic tyre exports (structural effect) and the competitiveness effect (Table 2). Since Sri Lankan share in the world's new pneumatic tyre exports is less than 1% and the export growth is negative, it is necessary to take action to improve the growth and share of pneumatic tyre exports in the world market.

Table 2. *The average results of the yearly CMS decomposition of the change in export value for Sri Lanka's new pneumatic tyres from 1999-2018 (US$ '000)*

	USA	EU	India	Tanzania	UAE
Change in export	49,779	40,505	5,538	5,159	1,449
Value	100%	100%	100%	100%	100%
First level of decomposition					
Structural effect	25,455	13,925	12,679	1,865	1,718
	51%	34%	229%	36%	119%
Competitive Effect	12,421	25,239	-5,674	26,490	41
	25%	62%	-102%	513%	3%
Second order Effect	11,903	1,341	-1,467	-23,195	-310
	24%	3%	-26%	-450%	-21%

Major importers of solid tyres from Sri Lanka were the EU, the USA, Canada, Australia and Japan. Retreated and solid tyre exports from Sri Lanka to major importers have increased during the study period. The results of the decomposition indicated that the major contributing factor to the export growth is the competitive effect for all import destinations except for Japan (Table 3). The structural effect was the main factor in improving Sri Lankan exports into the Japanese market.

Table 3. *The average results of the yearly CMS decomposition of the change in export value for Sri Lanka's retreated and solid tyres 1999-2019 (US$ '000)*

	EU	USA	Canada	Australia	Japan
Change in export value	122,318	103,228	13,191	6,732	1,581
	100%	100%	100%	100%	100%
First level of decomposition					
Structural effect	-93547	-33738	-2410	-945	5164
	-76%	-33%	-18%	-14%	327%
Competitive effect	3,024,777	176,252	14,695	8,722	-755
	2473%	171%	111%	130%	-48%
Second order effect	-2808912	-39286	905	-1045	-2828
	-2296%	-38%	7%	-16%	-179%

The major import destinations of Gloves of Vulcanised, Unhardened Rubber from Sri Lanka were the EU, USA, Brazil, Canada and India. The gloves exports from Sri Lanka to all selected import destinations have increased during this study period. A major contributor to the export growth is the structural effect for all these import markets except for Brazil (Table 4). The competitive effect is the major

contributor to the export growth of gloves to Brazil. The significant influence of the structural effect on the export growth of gloves provides an indicator of the vulnerability of the long-term export prospects.

Table 4. *The average results of the yearly CMS decomposition of the change in export value for Sri Lanka's gloves of vulcanised, unhardened rubber 1999-2019 (US$ '000)*

	EU	USA	Brazil	Canada	India
Change in export value	58,266	28,203	12,874	5,245	12,435
	100%	100%	100%	100%	100%
First level of decomposition					
Structural effect	60,096	37,182	2	4,312	22,909
	103%	132%	0.02%	82%	184%
Competitive effect	1,961	-3,585	7,143	2,402	-7,761
	3%	-13%	55%	46%	-62%
Second order effect	-3,790	-5,394	5,729	-1,469	-2,712
	-7%	-19%	44%	-28%	-22%

Major importers of other articles of vulcanized rubber products during the study period were the EU, USA, Japan, Canada and Australia. The export of vulcanized rubber products has increased in all selected import destinations during the studied period. The major contributory factor to the export growth was the competitive effect for all market destinations except for Japan (Table 5). The structural effect was the main contributory factor to the export growth into the Japanese market. Since the world export share of vulcanized rubber products is less than 1% and the growth rate is a moderate one, it is necessary to implement relevant policy measures to rectify this existing situation.

Table 5. *The average results of the yearly CMS decomposition of the change in export value for Sri Lanka's other articles of Vulcanized Rubber 1999-2019 ($ US '000)*

	EU	USA	Japan	Canada	Australia
Change in export value	40860	38551	2525	7089	1303
	100%	100%	100%	100%	100%
First level of decomposition					
Structural effect	15450	10,782	2,489	-506	964
	38%	28%	99%	-7%	74%
Competitive effect	17,058	29,812	1,232	7,526	647
	42%	77%	49%	106%	50%
Second order effect	8,352	-2,042	-1,195	69	-308
	20%	-5%	-47%	1%	-24%

Analysis of livelihood development of rubber-based farming systems (AE/02)

A study was in progress to analyze the livelihood capital development of rubber agroforestry farmers. Planting food crops as intercrops in natural rubber (*Hevea brasiliensis* Mull Arg.) lands may contribute to household food security. The expansion of rubber cultivation into non-traditional areas has generated several benefits such as high land availability and low incidence of diseases reported. The livelihood choices are impacted by the livelihood assets of the households and access to livelihood capitals by farm households improves their farm management abilities and boosts their entrepreneurial competencies. Identification of livelihoods of rubber agroforestry farmers is crucial in formulating exact policies and implementing effective extension planning to sustain rubber farmers. This study, therefore, focuses to analyze the implications of livelihood capitals of smallholder rubber agroforestry farmers via creating the Livelihood Capital Index (LCI).

The Moneragala district was selected as the study area since it was the first District in the non-traditional areas where the rubber agroforestry commenced. The survey sample (220 respondents) was selected based on the number of rubber agroforestry farm households and sampling was done according to the farm households representation in the eight divisional secretariat divisions. Variables falling into five livelihood capitals (Table 6) and sociodemographic information of the farm households were collected. Our indicator approach is in line with the sustainable livelihood framework which was developed by the Department for International Development (DFID). We did normalisation of variables as described in the literature (Kumar *et al*., 2016; Kale, *et al*., 2016; Sendhil *et al*., 2018). Principal component analysis (PCA) was selected to determine the weights of each livelihood capital. The livelihood capital index was calculated is as given in the equation below. Where LCI_i is the livelihood capital index of the i^{th} farm household. W_j represents the weight of livelihood capital *j*. LC_{ij} represents the livelihood capital *j* of rubber agroforestry farm household *i*. ANOVA test was performed to find the implication of livelihood capital indicators among the livelihood strategies, rubber agroforestry practices, and the location of the agroforestry practices.

$$LCI_i = \sum_{j=1}^{5} w_j LC_{ij} (i \in 1,2,..220;\ j \in 1,2,..5)$$

Table 6. *Variables selected for the study*

Type	Indicator
Sociodemographic information	Gender, Age. Education
Livelihood capitals	
Financial	Annual income, Annual investment in farming
Human	Number of years of formal education, Adult family members
Natural	Per capita cropland, age of the rubber trees
Social	Number of societies involved annually, time duration (hours) per month spent with the societies
Physical	Distance to a major road, Percentage investment on machinery
Livelihood strategies	Rubber agroforestry and other agricultural income Rubber agroforestry and non-farm income Rubber agroforestry income

Descriptive statistics of rubber agroforestry practices

The banana was the most cultivated companion crop (36%) in the Moneragala district followed by cocoa (17%), maize (16%), pepper (12%), groundnut (5%), passionfruit (3%), and dairy cattle (3%). The five livelihood capitals indicate different weights based on the Principal Component Analysis (PCA) results (Natural = 0.14, Physical = 0.24, Financial = 0.25, Human = 0.3, Social = 0.17). Rubber-based groundnut practice shows the highest average LCI (0.54) followed by rubber-based cattle (0.53), cocoa (0.51), passionfruit (0.51), pepper (0.49), maize (0.49), banana (0.48). Except for the human capital, a statistically significant difference was observed for all the livelihood capital indicators of rubber agroforestry practices. Except for the physical capital, there was a significant difference was observed for livelihood capital indicators with the two groups; rubber agroforest and other livelihood strategies. Also, eight regions were differentiated due to LC indicators except for the human capital (J K S Sankalpa, P G N Ishani, W Wijesuriya, S Ratnayaka and O V Abewardena).

Analysis of the profitability of rubber intercropping practices (AE/03)

A study was conducted to analyze the farmer's perception of the profitability of the use of intercrop in rubber land. The maintenance of farm income is one of the key objective of agricultural policy. With the high volatility of natural rubber prices and escalating cost of production, rubber farmers encounter a serious problem of generating a steady income. Intercropping rubber with another remunerative crop is a popular term in this regard targeting spatial and temporal optimization in land use. In

that regard, this paper intends to assess the financial benefits of some potential intercrops under the rubber cultivations.

Financial analyses were conducted with nine intercrops including three annual crops (Maize, Groundnut, Cowpea), three semi perennials (Passion Fruit, Banana and Pineapple) and three perennial crops (Pepper, Cinnamon and Cocoa). The annual crops and semi perennials can be cultivated in the first four years of rubber cultivation. Perennials like cinnamon, pepper and cocoa could be intercropped throughout the economic life span of rubber plantations (Rodrigo, 2001; Sankalpa, 2020). We gathered the quantities of labour and other material inputs together with their market rates from the farmers involved in intercropping for farm-level cost estimations. Also, crop yields and farm gate prices of harvests were collected from the same to value the income. Benefit-Cost ratio (BCA), Net Present Value (NPV), Internal Rate of Return (IRR), Initial investment required, Average monthly income and Payback periods were used to evaluate the different intercropping systems.

Among the annual intercrops, cowpea has become the low input crop in terms of labour and materials and therefore a low level of the initial investment was required for the establishment of cowpea (Table 7). From the three annual crops selected in this study highest NPV and BCR values are recorded from the groundnut system. Therefore, it could be considered as the best annual crop for intercropping on financial aspects.

Table 7. *Financial analysis of annual intercrops*

	Initial investment (LKR/ha)	**NPV (LKR)**	**BCR**
Maize	75,828	66,316	1.25
Groundnut	63,418	419,909	2.90
Cowpea	31,029	106,749	1.99

Semi-perennials are limited to the first four years of rubber cultivation. Among the crops investigated, pineapple has become the most profitable crop though it required a high level of initial investment particularly for land preparation and planting materials (Table 8). The next in line was the passionfruit. However, both these crops need to have proper marketing arrangements to gain such profits according to the authors own experiences on the marketing channels of intercrops. Banana seems to be the most companion crop grow with the rubber though it generates a lower return compared to other intercrops. The higher adoption of banana in rubber lands was reported in many areas of the non-traditional region in Sri Lanka (Rodrigo *et al.* 2001; Sankalpa *et al.* 2020) and this was mainly driven by the easy access to the market and the low level of inputs required for the cultivation.

Table 8. *Financial analysis of semi perennial intercrops*

	Initial investment (LKR/ha)	NPV (LKR)	BCR	IRR (%)	Payback period (Year)
Pineapple	533,887	2,211,609	3.46	63	2
Banana	184,055	511,699	1.52	55	2
Passionfruit	320,611	1,094,932	2.55	78	2

The initial investment required for cinnamon was the highest among the three selected perennial crops for the study; however, its overall profit seemed to be the highest among the perennials tested (Table 9). In general, pepper and cocoa are rather shade-tolerant; hence, long-term cultivation with rubber is feasible. Cinnamon is a sun-loving crop and in the case of intercropping, the planting density of rubber has to be compromised. Therefore, its preferability as an intercrop becomes limited with the maturity of rubber plants.

Table 9. *Financial analysis of semi perennial intercrops*

	Initial investment (LKR/ha)	NPV (LKR)	BCR	IRR (%)	Payback period (Year)
Pepper	441,425	966,639	1.22	26	3
Cinnamon	530,039	4,527,966	3.53	20	5
Cocoa	89,089	839,937	2.62	24	5

As shown by all indicators, all crops tested here as intercrops are financially worthwhile. However, the selection of a particular intercrop should be done according to the socio-economic characteristics of the farmer where social, human, physical, natural and financial assets are considered. However, if a particular crop is promoted at a high scale based on the present level of profitability, the market for its products could be affected by reversing the profitability through an oversupply of the produce. Therefore, crop diversity is required and proper guidance by the extension personnel is essential to identify the most suitable intercrop by the respective farmer (P G N Ishani, J K S Sankalpa and V H L Rodrigo).

Job satisfaction of latex harvesters (AE/04)

A study was conducted to analyze the overall satisfaction and their determinants of latex harvesters in the smallholder rubber lands. This study was conducted collaboratively with the Advisory Services Department (ASD). Tasks in rubber industries are highly labour-demanding and the labour cost in harvesting latex is two-thirds of the total cost of production. Rubber cultivation and production are identified as difficult tasks and it needs extensive and skilled labour during its life cycle. Latex harvesting is not only a high labour demanding activity but also a skilled

labour job. Workers in the rubber plantations do not have a well-defined wage rate and they suffer due to poor working conditions. However, without enough supporting data, this claim appeals mainly to people's perception and no prominent studies were focused to find the existing level of latex harvesters' satisfaction and factors that influence the satisfaction. This study exclusively presents the hired labour perspective on latex harvesting from the bottom of the supply chain and it helps to understand the satisfactory level of latex harvesters by the rubber farm owners. Thus, it helps to uplift the existing job status of latex harvesters that ensure higher labour productivity and helps to attract more workers into the industry.

Kegalle District is the focused area of this study. Structured questionnaires were the survey instruments used in this study and primary data were collected from smallholder farmers who hired workers to harvest rubber latex. Rubber statistics issued by the Department of Rubber Development (RDD) of Sri Lanka were used to prepare a sampling frame. From the farmers who own mature rubber lands, a total of 231 farmers from DS divisions were randomly selected for the interview. The dependent variable selected for our study is overall satisfaction according to ordered categories. The overall satisfaction was categorized as very satisfied, satisfied, neutral, dissatisfied, and very dissatisfied. The independent variables falling into the working environment and socio-demographic factors were selected based on the previous studies reported in the literature. The dependent variable of our model is a form of ordered categories and therefore, we used ordinal regression with a logit link function. Table 10 presents the results of the logit estimation.

Model estimation is based on the assumptions of the ordered logit model and one of the common assumptions is the relationship between each pair of outcome groups (satisfactory level) is the same (parallel regression assumption).

Table 10. *Predicted probability of satisfaction (outcome=3) after ordered logit estimation*

Variable	Coef.	Marginal effects
Salary		
Neutral	3.98 (0.92)***	0.05(0.01)***
Satisfied	4.97 (1.63)***	0.08 (0.02)***
INCT		
Neutral	4.47(0.92)***	0.11(0.03)***
Satisfied	3.79(1.25)***	0.09(0.03)***
ENVTS		
Neutral	2.64(0.86)***	0.07(0.02)***
Satisfied	4.03(0.97)***	0.11(0.02)***
RLOW		
Neutral	1.01(0.61)	0.02(0.01)
Satisfied	3.11(0.68)***	0.09(0.02)***

Variable	Coef.	Marginal effects
SOCLP		
Neutral	1.02(0.74)	0.03(0.02)
Satisfied	1.82(0.73)**	0.05(0.02)**
WRKS		
Neutral	0.75(1.11)	0.02(0.02)
Satisfied	2.06(0.54)***	0.06(0.01)***
GRVNC		
Neutral	1.63(0.62)**	0.04(0.02)**
Satisfied	2.30(0.66)***	0.06(0.01)***
HOUS		
($Yes^{=1}$)	-1.20(0.97)	-0.03(0.02)
AGE	-0.02(0.02)	-0.001(0.001)
GEND ($Male^{=1}$)	0.18(0.42)	0.005(0.012)
EDU	0.05(0.12)	0.001(0.003)
/cut1	2.98(2.24)	
/cut2	13.53(2.67)	
Log likelihood =	-74.65	
LR $chi^2(18)$ =	264.93	
Pseudo R^2 =	0.63	

Standard errors are in parenthesis. *** significant at 99% confidence level. ** significant at 95% confidence level

Note: INCT = incentives, ENVTS = job environment, RLOW = relationship with the owner, SOCLP= social prestige, WRKS= low work-related stress, GRVNC= grievances handling, HOUS= own house for a living, AGE= age of the harvester, GEND= gender of the harvester, EDU= education level of harvester (J K S Sankalpa, P K K S Gunaratne, P G N Ishani, W Wijesuriya and D Ratnayake)

Use of GIS in rubber plantation management (AE/05)

The preparation of field information map for the Polgahawela substation was completed collaboratively with the Polgahawela substation in the year 2020 and spatial database preparation was in progress. AEU has been 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" and mapping of the locations of the use of fuelwood with rubber was in progress.

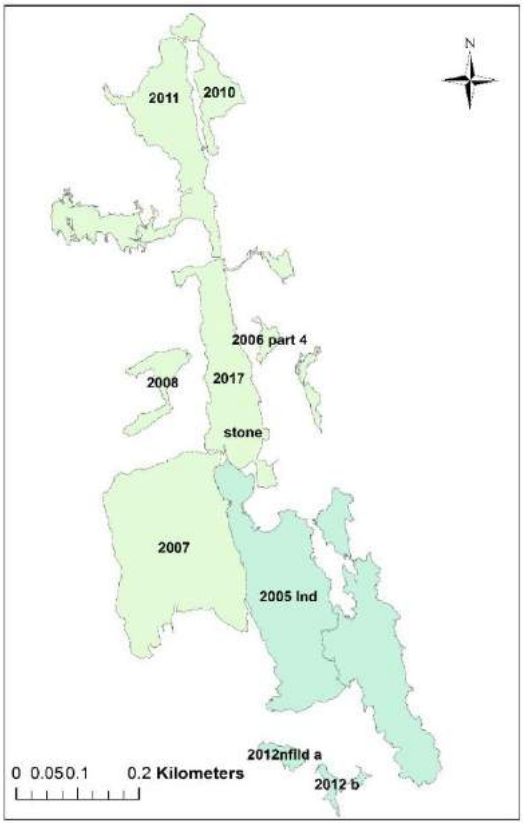


Fig. 3. Field map of Polgahwela substation before the preparation of spatial database (J K S Sankalpa, D C Balasooriya, O V Abewardena and P A Lakshman)

Updating databases on the rubber industry, analysis on rubber end products manufacturing sector and other economic evaluations (AE/05)

The Agricultural Economics unit has conducted several studies to analyse the rubber international trade and rubber prices that prevailed in the international and local markets. The aim was to present the current status 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 2020 (J K S Sankalpa, P G N Ishani and O V Abeywardena).

Fig. 3 (b) shows the earnings from rubber end products from 2016 to 2020. The quantity of raw rubber export has increased by 24% in the year 2020 against the previous year. The average export quantity was in a declining trend for the period of 2017-2019. Earnings from rubber finished and semi-processed products have

decreased by 19% and 24% year on year from 2019 to 2020. Earnings from finished and semi-processed were recorded as Rs.144 billion in the year 2020 while, it was Rs.158 billion in the year 2019.

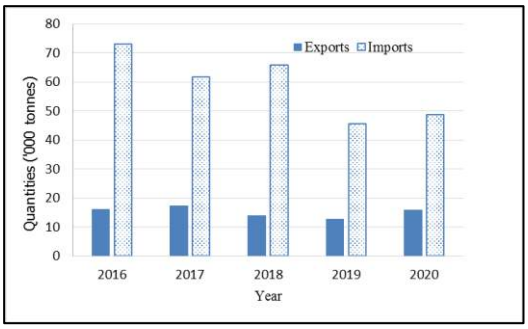


Fig. 3. (a) Raw rubber exports and imports quantities

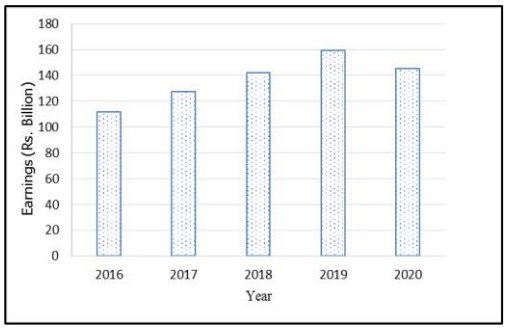


Fig. 3. (b) Earnings from end products and semi-processed products

LIBRARY AND PUBLICATION

N C D Wijesekara

DETAILED REVIEW

Mrs N C D Wijesekara, Librarian and Publication Officer, Mrs R M Amaratunga, Library Assistant and Assistant Publication Officer, Mrs D N C Amaratunga, Library Assistant and Publication Assistant (Rathmalana Library), Mr P M Prema Jayantha, Management Assistant and two Library Attendants were on duty throughout the year.

Publications

The following RRISL regular publications were published during the year.

- Annual Review 2018
- Annual Report 2019

List of books purchased during the year

No	Title	Publisher	Year of publication
01	තීරු ලිපි එකතුව	කර්තෘ ප්‍රකාශනයකි	2020
02	තීරු ලිපි එකතුව	කර්තෘ ප්‍රකාශනයකි	2020
03	Land Use and Land Cover Sri Lanka (02 copies)	Land Use Policy Planning Department	-
04	ISO 37 - Rubber Vulcanized or Thermoplastic Determination of Tensile Stress - Strain Proportion	ISO Copyright Office	2017
05	International Standard ISO 127- Rubber Natural Latex Concentrate Determination of KOH number	ISO Copyright Office	2018
06	International Standard ISO 19050. Rubber Raw, Vulcanized - Determination of Content by ICP - OES	ISO Copyright Office	2015
07	Standard Test Method for Thermoplastic Elastomers Measurement of Polymer Melt Rheological Properties and Congealed Dynamic Properties using Rotorless Shear Rheometers	ASTM International USA	2020

No	Title	Publisher	Year of publication
08	Standard Practice for Stress Relaxation Testing of Raw Rubber, Vulcanized Rubber Compounds and Thermoplastics Elastomers	ASTM International USA	2020
09	Standard Test Method for Rubber Properties Measurement of Cure and After - Cure Dynamic Properties using a Rotor less Shear Rheometers	ASTM International USA	2020
10	International Standard ISO 6502 - 3 Rubber Measurement of Vulcanization Characteristics Using Cure Meters Part 3: Rotor less Cure meter	ISO Copyright Office	2018
11	International Standard ISO 6502 - 2 Rubber Measurement of Vulcanization Characteristics Using Cure meters Part 2: Oscillating disc Cure meter	ISO Copyright Office	2018
12	International Standard ISO 6502 - 1 Rubber Measurement of Unvulcanization Characteristics Using Cure meters Part 2: Introduction	ISO Copyright Office	2018
13	International Standard ISO 13145 Rubber - Determination of Viscosity and Stress Relaxation using a Sealed shear Rheometers	ISO Copyright Office	2012
14	International Standard ISO 35 Natural Rubber Latex Concentrate Determination of Mechanical Stability	ISO Copyright Office	2004
15	International Standard ISO 124 Latex rubber - Determination of total solids content	ISO Copyright Office	2014
16	Standard practice for Rubber from natural sources - sampling and shorting bales based on predicted processing properties	ISO Copyright Office	2020
17	Standard test method for analysis of aqueous extractable protein in latex natural rubber and elastomeric products using the modified Lowry method	ASTM International	2020
18	Standard test method for rubber - Measurement of unvulcanized rheological properties using rotor less shear rheometers	ASTM International	2020
19	Standard test method for rubber property vulcanization using rotor less cure meters	ASTM International	2020

No	Title	Publisher	Year of publication
20	බොදු සිතුවිලි සහ ඵලදායිතාව	සඳීපා ප්‍රකාශන මන්දිරය	2014
21	Writing Research Proposals	Sarasavi Publishers	2019
22	Google - ගූගල් සර්ච්	කර්තෘ ප්‍රකාශනයකි	2017
23	ඔසු ගුණෙන් සපිරි ඉගුරු කොත්තමල්ලි	කර්තෘ ප්‍රකාශනයකි	2007
24	හිසට උපන් තුරුලතා	කර්තෘ ප්‍රකාශනයකි	2015
25	ශ්‍රී ලංකාවේ සාමාන්‍ය දැනීම තොරතුරු අත්පොත	කර්තෘ ප්‍රකාශනයකි	2019

DARTONFIELD GROUP

P A Lukshaman

DETAILED REVIEW

Mr P A Lukshaman Senior Estate Manager, Mr Dinesh Achinda and Mr M N S Pavinda Management Assistants, Mr T D Harsha covering up the work of Factory Officer, Mr B M Siriwardena Field Officer and Mr K A Sarath Kumara and Mr Jagath Nakandala Junior Assistant Field Officers and Mr Lasantha Sampath covering up the work of Junior Assistant Field Officer, were on duty throughout the year.

The Group cadre stood as follows at the end of the year.

Senior staff	01
Assistant staff	07
Minor staff	04
Total	**12**

Land utilization summary - Dartonfield group

Land utilization 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	125.05	33.76	181.97
Immature area	8.44	36.35	9.55	54.34
Cinnamon under power line	0.80	1.63	-	2.43
State land take in	0.27	-	-	0.27
Nurseries	0.11	1.08	2.00	3.19
Paddy/Deniya land	0.75	1.22	1.22	3.19
Waste land	0.19	0.18	-	0.37
Earth slipped area	4.88	1.26	-	6.14
Jungle	0.80	0.50	1.03	2.33
Rocky areas	2.14	6.07	3.04	11.25
Roads	2.92	6.57	0.36	9.85
Building	16.92	4.44	7.79	29.15
Play Ground	1.00	-	-	1.00
Proposed replanting area	11.71	-	12.32	24.03
Proposed Cinnamon Ns.	0.20	-	-	0.20
Streams	-	-	2.17	2.17
Grand total	**74.29**	**184.35**	**73.24**	**331.88**

Rainfall

The annual rainfall recorded for the year was 3,376.8 mm with 177 wet days.

Table 2. *Annual rainfall and wet days of the group for last five years*

	2016	2017	2018	2019	2020
Rainfall (mm)	2,682.1	4,068.1	3,773.3	4,389.7	3,376.8
Wet days	181	188	195	204	177

Crop

A total crop for 165,971 kg have been harvested against the estimated crop of 197,393 kg (84%) showing a difference of 31,422 kg.

Table 3. *The total crop harvested (Crop) and yield per hectare (YPH) in kilo grams of the Dartonfield group from 2016 to 2020*

Hect.	2016		2017		2018		2019		2020	
	181.28		176.05		178.02		178.02		181.97	
Division	**Crop**	**YPH**	**Crop**	**YPH**	**Crop**	**YPH**	**Crop**	**YPH**	**Crop**	**YPH**
Dartonfield	23,635	734	19,124	649	19,477	841	15,683	677	17,774	767
Gallewatta	123,207	1,016	106,531	938	119,458	986	104,699	865	116,501	932
N'kele	29,294	1,053	35,800	1,086	39,600	1,173	300,34	890	31,696	939
Group total	176,136	972	161,455	917	178,535	1,003	150,416	845	165,971	912
Group estimate	197,474	1,089	185,606	1,054	193,037	1,084	197,295	1,108	197,393	1,085

Tappers productivity

The average Intake per tapper (IPT) during the last five years are given in Table 4.

Table 4. *The average IPT (kg) of Dartonfield group from 2016 to 2020*

	2016	2017	2018	2019	2020
Dartonfield	5.7	6.4	7.1	6.7	6.8
Gallewatte	7.9	7.6	7.9	7.1	8.0
Nivitigalakele	7.3	8.4	8.7	7.8	9.2
Group average	**7.4**	**7.6**	**8.0**	**7.2**	**8.0**

Tapping days

Breakdown of tapping days in terms of Normal tapping (NT), Late tapping (LT), Double tapping (DT) and No tapping of Dartonfield estate is given in Table 5.

Table 5. *Details of tapping days of Dartonfield group during last five years*

	2016	2017	2018	2019	2020
Normal tapping	258	224	222	201	217
Late tapping	07	02	6	19	11
Cash/Double tapping	(29)	(18)	(25)	(21)	(18)
No tapping	39	69	52	80	52
Rain guard tapping	62	69	85	65	85
Slight Rain	-	01	-	-	-
Total no of tapping days	327	296	313	285	314

Rainguards

An extent of 181.97 hectares was rainguarded during the year and an additional crop of 41,024 kg was harvested which amounts to 25% of total crop harvested. Additional tapping days done with rainguards during the year were 46, 113 and 97 for Dartonfield, Galewaththa and Nivithigalakele respectively. Profit generated due to rain guarding was Rs.4,065,836.16 and profit per hectare was Rs.22,325.04.

Table 6. *Additional income generated by fixing of rainguards (Rs/kg)*

	Dartonfield Division	Gallewatta Division	Nivithigalakale Division	Total
Hectare	23.16	125.20	33.76	182.12
No. of rainguards fitted	5,577	31,980	7,474	45,031
Additional crop (kg)	2,267	27,833	10,924	41,024
Rainguard cost per kg.	69.84	50.99	71.84	56.78
Tapping cost per kg.	138.17	138.17	138.17	138.17
C.O.M. Rs/kg	38.94	38.94	38.94	38.94
Total cost Rs/kg	246.95	228.10	248.95	233.89
N.S.A. Rs./kg	333.73	333.73	333.73	333.73
Additional profit Rs./kg	86.78	105.63	84.78	99.84
Additional profit from rainguards (Rs.)	196,730.26	2,939,999.79	926,136.72	4,065,836.16
(Additional profit per hectare (Rs.)	8,494.40	23,482.43	27,432.96	22,325.04

Total profit and profitability per hectare

The total profit and profit per hectare were Rs.1,402,836.24 and Rs.7,709.16 for the year under review.

Table 7. *Comparative statement of the revenue profit per kg and profit per hectare*

	Years				
	2016	**2017**	**2018**	**2019**	**2020**
Mature area (ha)	181.28	176.05	178.02	178.02	181.97
Total profit/(loss) (Rs.)	(1,107,895.44)	6,207,944.75	(2,319,169.65)	(8,226.251.04)	5,448,827.93
Profit/(loss) per ha. (Rs.)	(6,111.52)	35,262.40	(13,027.58)	(46,209.70)	29,943.55

Cost of production and productivity

Table 8. *Labour rates and break down of cost of production from 2016 to 2020 (Rs./kg)*

	2016	**2017**	**2018**	**2019**	**2020**
1. Labour wages	687.50 up to Sept. & 805 from Oct.	805	805	805.00 up to Jan. & 855.00 from Feb.	855.00
2. Cost of production	241.13	280.55	268.43	330.91	300.90
2.1 Tapping	116.46	122.77	115.63	139.94	138.17
2.2 Manufacture	32.35	34.47	33.08	35.35	38.94
2.3 General charges	74.43	97.29	98.10	124.18	94.87
2.4 Mature/area upkeep	17.89	26.02	21.62	31.44	28.92
3. N.S.A.	234.84	319.00	255.44	276.22	333.73
4. Profit/(loss) per kg	(6.29)	38.45	(12.99)	(54.69)	32.83

Manufacture

Out of the latex crop of 165,971 kg harvested, 116,154 kg has been graded as Pale Crepe No. 01 which is 82%. Details are given in Table 9.

Table 9. *Summary of grades manufactured during the year*

Grade	**Quantity (kg.)**	**Percentage %**
Latex crepe No.1	116,154	82
Latex crepe No.2	1,550	01
Latex crepe No.3	6,350	04
Latex crepe No 4	18,055	13
Total	**142,109**	**100**
RSS No.01	3,400	56
RSS No.02	2,125	35
RSS No.03	425	07
RSS No.04/05	175	03
Total	**6,125**	**100**
Scrap crepe No. 1	16,721	96
Scrap crepe No.2	692	03
Scrap crepe No.3/4	324	01
Total	**17,737**	**100**
Grand total	**165,971**	**-**

Different types of rubber manufactured, percentage of grades received for pale crepe and RSS are shown in Figures 1(a) and (b).

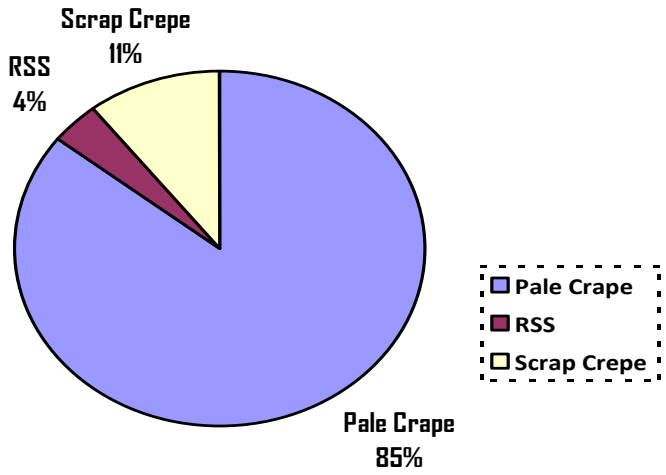


Fig. 1(a). Grade percentages of different types of rubber manufactured Pale Crepe

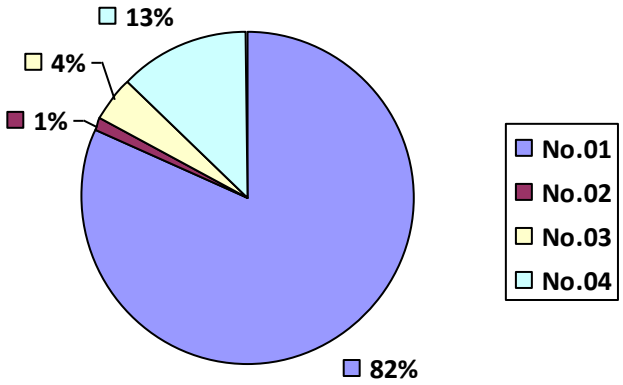


Fig. 1(b). Percentage of grade of Pale Crepe manufacture

Dartonfield Estate Group has received the best Auction prices of sheet rubber category one (Pale Crepe) for 18 times during out of 32 dispatches of the year 2020 (Table 10). The highest value for the best price received for the Pale Crepe was LKR. 526.00 in January 2021 and higher prices have been enhanced by the favorable market condition prevailed during the latter part of the year.

Table 10. *Best auction prices received in the year 2020 by the Dartonfield Estate Group*

Date	**Category**	**Quantity sold (kg)**	**Price at auction (LKR/kg)**
28-Jan	RSS1	2,200	325.00
27-Feb	LCR No.01X	4,525	348.00
11-Mar	LCR No.01X	3,200	356.00
23-Apr	LCR No.01X	3,400	320.00
		2,400	
21-May	LCR No.01X	2,475	330.00
23-July	LCR No.01X	1,350	316.00
13-Aug	LCR No.01X	4,300	328.00
27-Aug	LCR No.01X	2,550	335.00
03-Sept.	LCR No.01X	2,750	345.00
	LCR No.01X	1,125	
17-Sept.	LCR No.01X	5,400	365.00
		650	
02-Oct	LCR No.01X	1,950	350.00
15-Oct	LCR No.01X	2,525	395.00
29-Oct	LCR No.01X	5,725	452.00
19-Nov	LCR No.01X	4,725	445.00
26-Nov	LCR No.01X	3,750	472.00
23-Dec	LCR No.01X	4,125	455.00
15-Jan	LCR No.01X	4,900	475.00
21-Jan	LCR No.01X	3,775	526.00

KURUWITA SUB - STATION

P A Lukshaman

DETAILED REVIEW

Staff

Mr P A Lukshaman, Senior Manager (Estate) (overlook), Mr D S Jayasinghe and 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.

Senior staff	- 01
Assistant staff	- 03
Minor staff	- 04
Total	**- 08**

Land utilization

A summary of the land distribution 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 79,457 kg was harvested during the year, recording an increase of 7,149 kg on previous year's crop.

The actual yield per hectare (YPH) was 1,001.2 kg showing an increase of 90.08 kg from the value for 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				
	2016	**2017**	**2018**	**2019**	**2020**
Estimated	1,339.54	1,318.57	1,320.61	1271.00	1238.60
Actual	1,383.17	1,086.67	1,025.11	911.10	1001.20

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	63.9
February	50.2
March	69.4
April	79.2
May	68.7
June	83.0
July	98.2
August	106.5
September	76.6
October	96.9
November	113.5
December	95.1

Tapper productivity

The average intake per tapper (IPT) 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				
	2016	**2017**	**2018**	**2019**	**2020**
Intake per tapper	9.1	9.0	8.6	7.3	7.4

Rainfall

The annual rainfall recorded during the year was 3,428.3 mm with 215 wet days (Table 5).

Table 5. *Annual rainfall figures and the number of wet days of the estate for the past 5 years*

	Year				
	2016	**2017**	**2018**	**2019**	**2020**
Rainfall (mm)	3,342.8	4,768.4	4,560.8	3,976.8	3,428.3
Wet days	222	246	244	226	215

Tapping days

There were 337 tapping days recorded during the year (Table 6). This was possible mainly 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				
	2016	**2017**	**2018**	**2019**	**2020**
01.Total tapping days	**352**	**321**	**324**	**323**	**337**
1.1 Normal	260	203	232	250	241
1.2 Late	08	-	-	11	-
1.3 Rain Interference	-	40	-	-	-
1.4 Rainguarded Tapping	84	78	92	62	96
02. Recovery Tapping	-	-	-	-	-
03. No tapping	14	44	41	42	29

When compared with the last year, there was a decrease in normal tapping days by 9.

Rainguard

Due to the use of rainguards, an additional 96 tapping days were recorded during the year. This contributed to 25% of the total crop yielding an additional profit of Rs.3,073,539.70.

Details of usage of rainguards for the years 2017, 2018, 2019 and 2020 are given in Table 7.

Table 7. *Usage use of rainguards (Rs./kg)*

	Year			
	2017	**2018**	**2019**	**2020**
Hectarage (ha.)	63.46	64.96	70.25	79.36
No. of rainguards fitted	19,904	22758	23212	23150
Additional tapping days	78	92	62	96

	Year			
	2017	**2018**	**2019**	**2020**
No. of kilos harvested	18,710	18419	12113	19558
Rainguard Cost per (kg.)	39.20	49.76	82.55	26.75
Tapping cost (Rs./ kg.)	99.08	105.14	127.94	127.79
Total cost (Rs./ kg.)	138.28	154.90	210.49	154.54
N.S.A (Rs./Kg.)	294.18	244.89	263.54	311.69
Additional Profit (Rs./ kg.)	155.90	89.99	53.05	157.15
Additional profit from rainguards (Rs.)	2,916,889.00	1,657,525.81	642,594.65	3,073,539.70
Additional profit per hectare (Rs.)	45,964.21	25516.10	9,147.25	38,729.07

Total profit and profitability per hectare

The total profit and profit per hectare were Rs.1,535,903.81 and Rs.19,353.63 respectively for the year 2020.

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				
	2016	**2017**	**2018**	**2019**	**2020**
Mature extent (ha.)	75.66	77.66	79.16	79.36	79.36
Total profit (Rs.)	3,959,993.84	3,727,550.47	(2,908,957.77)	(5,363,084.36)	1,535,903.81
Profit per hectare (Rs.)	52,339.33	47,998.33	(36,747.82)	(67,579.19)	19,353.63

Cost of production and profitability

The cost of production has decreased by Rs.45.35 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 breakdown of the cost of production from 2016 to 2020 (Rs./kg.)*

	Year				
	2016	**2017**	**2018**	**2019**	**2020**
Labour rate	Jan. - Nov. 687.50 from December 805.00	805.00	Jan.-Oct. 805.00 from Nov 855.00	855.00	855.00
Cost of production	179.27	250.01	279.36	337.71	292.36
Tapping cost	89.65	99.08	108.80	134.74	137.41
Manufacturing	21.49	32.65	36.33	33.11	37.12
General chargers	54.48	92.38	97.16	135.40	89.49
Field & cultivation cost	13.65	25.90	37.07	34.47	28.35
N.S.A	217.11	294.18	244.89	263.54	311.69
Profit per kg.	37.84	44.17	(34.47)	(74.17)	19.33

POLGAHAWELA SUB STATION

P A Lukshaman

DETAILED REVIEW

Mr P A Lukshaman, Senior Estate Manager overlooked the activities of the Substation and Mr D P Nuwan Dissanayaka, Management Assistant was on duty throughout the year.

Crop

Total crop of 17,080 kg have been harvested against the estimated crop of 20,739 kg showing a gap of 3,659 kg. The total crop, YPH and IPT for 2015, 2016, 2017, 2018, 2019 and 2020 are given in Table 1.

Table 1. *Total crop (kg), YPH (kg) and IPT (kg) for last six years*

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	13.75	14710	1070	9.9
2019	17.75	15678	883	9.4
2020	17.75	17080	962	8.8

Rainfall

The annual rainfall recorded for the year was 2,385.5 mm with 118 wet days.

Table 2. *Annual rainfall and wet days of the estate for last six years*

	2015	2016	2017	2018	2019	2020
Rainfall	2,817.01	1,947.07	1,974.8	2,683.7	2,170.5	2,385.5
Wet days	162	109	164	153	139	118

Tapping days

Annual variation of Tapping days and No tapping days are given in Table 3.

Table 3. *Annual Tapping days and No tapping days*

	2015	2016	2017	2018	2019	2020
Tapping days	291	246	223	293	310	301
No tapping days	74	119	142	72	55	65

Meteorological Summary

Dartonfield Station

Wasana Wijesuriya

The AGROMET station at Dartonfield, Agalawatta is maintained by the Rubber Research Institute of Sri Lanka. This station located in the Agro-Ecological Region WL_{1a} recorded an average annual rainfall of 4,088 mm during the last 20 years. Out of the 20 years since 2000, total rainfall of less than 3000 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 2020 was 3651 mm, which accounted for a decrease of 16%, compared to the previous year. The annual rainfall in 2020 was observed below average for Dartonfield. The average annual rainfall is marked as a horizontal line in Fig. 1.

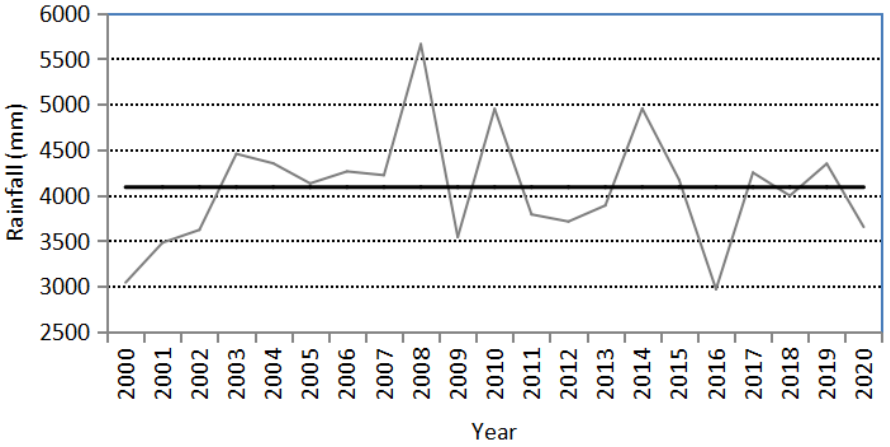


Fig. 1. Variation in annual rainfall at Dartonfield from 2000 to 2020

The statistics for annual rainfall recorded in Dartonfield for different base periods adopted by WMO are listed in Table 1 indicating more or less similar statistics.

As indicated in Fig. 2, the rainfall distribution at Dartonfield during this year departed from the usual bimodal rainfall pattern. Remarkably high above-average monthly rainfall was observed in September as in the previous year. An above-average rainfall was also observed in July. The months, January and December

recorded rainfall totals close to the long-term average. The monthly totals in March, May, August and October were considerably lower than the long-term average. The rest, February, April and June recorded slightly lower totals, compared to the long-term average monthly rainfall. The minimum monthly rainfall of 91 mm was recorded in February whilst the maximum monthly rainfall of 748 mm was recorded in September.

Table 1. *Descriptive statistics of annual rainfall for different base periods according to WMO*

Period	Average annual rainfall (mm)	Standard deviation (SD) mm	Coefficient of variation (CV %)
1964-2020[1]	4,189	554	13.2
1964-1990[2]	4,259	563	13.2
1981-2010[2]	4,178	567	13.6
1991-2020[2]	4,125	545	13.2

[1]Overall mean [2] Base periods suggested by WMO

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 (1,992 mm) during 2020. This rainfall amount contributed 49% to the total rainfall, which is close to the long-term average contribution (48%). Rainfall during IM2 (October & November) in 2020 brought 631 mm whilst IM1 (March & April) recorded a low rainfall of 536 mm. During the North East season (December 2020 to February 2021), 883 mm of rain was recorded, which is comparatively higher (22%) than the long-term average contribution (15%) of this season.

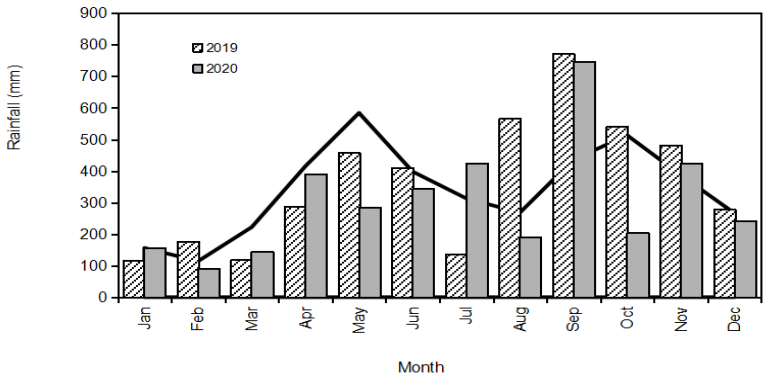


Fig. 2. Distribution of monthly rainfall in 2019 and 2020 at Dartonfield (The line graph indicates the long-term average)

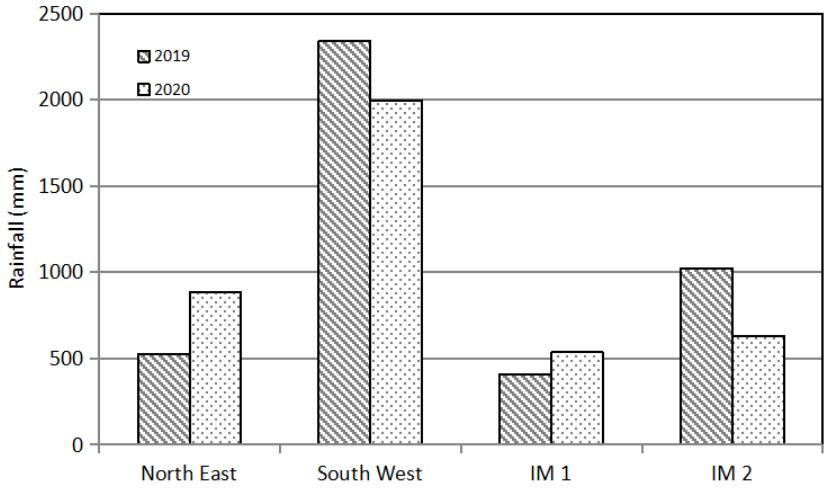


Fig. 3. Seasonal distribution of rainfall at Dartonfield in 2019 and 2020

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 250 mm was observed in the 35th standard week (27th August to 02nd September).

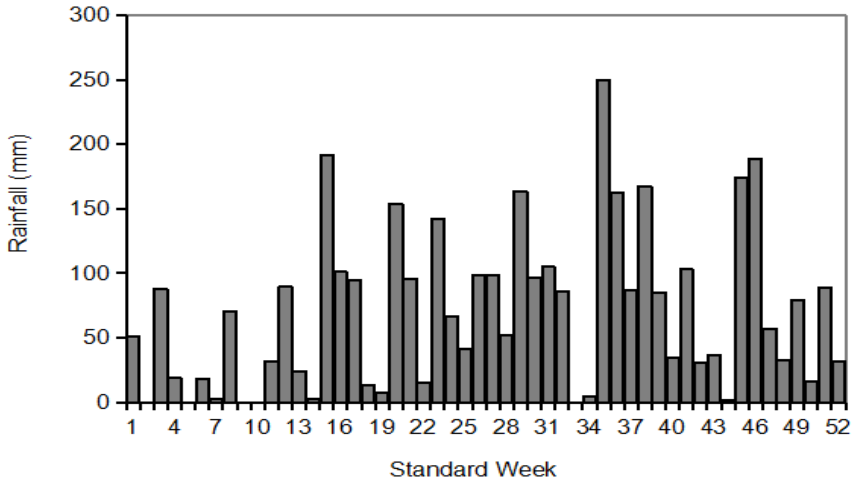


Fig. 4. Weekly variation in rainfall in 2020

There were 2 rainfall events (207 mm on the 1st of September and 127.5 mm on the 19th of July) that exceeded the hazardous limits for landslides (100 mm of rainfall during a day) reported during the year under review. A dry spell lasted over a month or more can have adverse impacts on rubber plantations. There were only 5 dry spells greater than or equal to 7 days; the longest being 20 days, from 24th February to 14th March. The details of the dry spells are given in Table 2.

Table 2. *Details of dry spells at Dartonfield in 2020*

Dry spell No.	Period	No. of days
1	6th - 16th January	11
2	24th January - 4th February	12
3	24th February - 14th March	20
4	21st March - 29th March	9
5	12th August - 22nd August	11

The amount of rainfall and the number of rainy days under low, moderate and high rainfall categories are listed in Table 3. The observed total number of rainy days of the year was 210, which is lower than the long-term average of 220 days.

Rainfall at RRISL Substations

There are five substations maintained by RRISL in Kuruwita (WL_{1a}), Narampola (IL_{1a} bordering WL_{2b}), Moneragala (IL_{1c}), Galewatta (WL_{1a}) and Nivithigalakele (WL_{1a}). The annual rainfall totals of 3,439 mm, 2,379 mm, 1,260 mm, 3,329 mm and 3,018 mm were recorded, respectively, in Kuruwita, Narampola, Moneragala, Galewatta and Nivithigalakele stations during 2020. The details of rainfall in these stations are given in Tables 4 to 8.

Table 3. *Monthly variation of rainfall and rainy days in 2020 at Dartonfield, Agalawatta*

Month	Total rainfall (mm)	Average** (mm)	No of rainy days *	Avg.** Days	No. of days under each category			Evaporation (mm)
					0.3-2.5 (mm)	2.6-50 (mm)	>50 (mm)	
January	157.7	(156)	9	(11)	2	7	0	106.9
February	91.0	(114)	6	(09)	2	3	1	106.1
March	145.7	(222)	7	(13)	1	5	1	115.0
April	389.9	(415)	20	(18)	2	16	2	108.2
May	285.5	(584)	21	(24)	6	14	1	85.2
June	344.1	(398)	23	(23)	6	14	3	83.5
July	424.7	(313)	24	(22)	3	20	1	80.2
August	189.6	(268)	14	(20)	3	11	0	102.3
September	748.1	(436)	28	(22)	5	20	2	63.3
October	206.0	(513)	21	(23)	4	17	0	90.9
November	424.8	(387)	20	(20)	5	13	2	81.2
December	243.4	(266)	17	(15)	6	11	0	92.8
Total	3650.5	(4072.0)	210	(220)	45	151	13	1115.6

* A rainy day is defined as a day with a rainfall ≥ 0.3 mm

** Average values for 1980-2005 are shown in parentheses

Table 4. *Monthly variation of rainfall and rainy days in 2020 - 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	50.9	11	4	7	0
February	36.4	6	2	4	0
March	88,8	10	3	7	0
April	154.7	15	6	8	0
May	631.0	24	6	14	0
June	354.9	23	6	16	0
July	305.0	23	5	17	1
August	244.1	14	3	10	0
September	653.4	29	3	23	2
October	282.5	17	2	15	0
November	291.1	19	4	13	2
December	345.7	20	3	15	2
Total	**3438.5**	**211**	**47**	**149**	**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 2020 - Gallewatta*

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	129.9	7	0	6	1
February	46.1	3	0	3	0
March	117.6	5	0	4	1
April	343.8	17	3	12	2
May	270.3	19	6	12	1
June	214.9	19	4	14	1
July	400.4	18	2	14	2
August	235.6	10	0	10	0
September	713.8	24	1	20	2
October	168.0	14	1	13	0
November	461.3	17	0	14	3
December	227.4	13	2	11	0
Total	**3329.1**	**166**	**19**	**133**	**13**

*****A rainy day is defined as a day with a rainfall ≥ 0.3 mm

Table 6. *Monthly variation of rainfall and rainy days in 2020 - 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	150.7	8	0	8	0
February	51.2	3	0	3	0
March	223.0	6	1	3	2
April	162.2	10	1	9	0
May	217.0	14	1	12	1
June	298.2	17	2	13	2
July	335.8	16	0	15	1
August	173.6	10	1	9	0
September	656.6	26	0	23	2
October	191.2	15	0	15	0
November	394.6	16	0	14	2
December	178.2	11	0	11	0
Total	**3018.0**	**151**	**6**	**134**	**10**

*****A rainy day is defined as a day with a rainfall ≥ 0.3 mm

Table 7. *Monthly variation of rainfall and rainy days in 2020 - 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	59.8	4	0	4	0
February	22.8	4	0	4	0
March	0.0	0	0	0	0
April	71.5	8	0	8	0
May	206.7	11	2	8	1
June	48.2	4	0	4	0
July	91.8	8	2	6	0
August	73.0	3	2	0	1
September	145.6	6	0	5	1
October	46.2	6	2	4	0
November	275.8	18	5	10	3
December	218.2	13	2	11	0
Total	**1259.6**	**85**	**15**	**64**	**6**

*A rainy day is defined as a day with a rainfall ≥ 0.3 mm

Table 8. *Monthly variation of rainfall and rainy days in 2020 - 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	9.2	3	2	1	0
February	0.0	0	0	0	0
March	74.2	3	0	3	0
April	421.0	18	2	14	2
May	328.5	13	1	11	1
June	207.3	13	3	9	1
July	119.1	9	1	8	0
August	167.9	9	0	9	0
September	528.7	16	0	14	2
October	117.3	8	0	8	0
November	245.9	12	0	11	1
December	159.6	15	3	12	0
Total	**2378.7**	**119**	**12**	**100**	**7**

*A rainy day is defined as a day with a rainfall ≥ 0.3 mm

Other meteorological parameters:

Table 9 depicts the monthly values of some important meteorological observations together with averages from 1980 to 2005 at Dartonfield. Daily fluctuations of the minimum and maximum temperatures at Dartonfield are illustrated in Fig.5. During the year under review, the minimum temperature did not drop below 20 ^{0}C. 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 monthly minimum temperature of 22.5 ^{0}C was observed in January while the highest monthly mean maximum temperature of 34.3 ^{0}C was observed in March. However, any signs of adverse conditions concerning the temperature regime at Dartonfield were not reported during the year.

A total of 1,857 bright sunshine hours was received at an average rate of 5.1 hours/day which was comparatively higher 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 45% of the days, while in 31% 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 2020 was observed in the range, 59% to 97%. The mean RH values recorded at 08:30 and 15:30 were 86% and 72%, respectively.

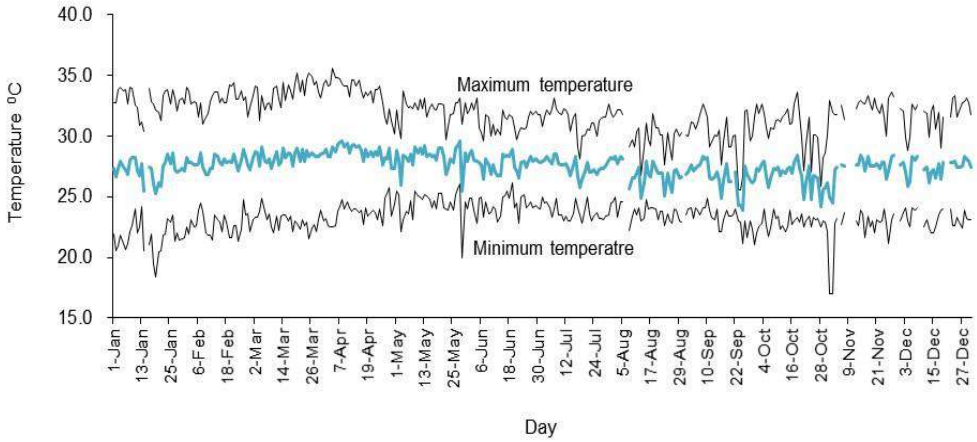


Fig. 5. Daily minimum, maximum and average temperature distributions in 2020

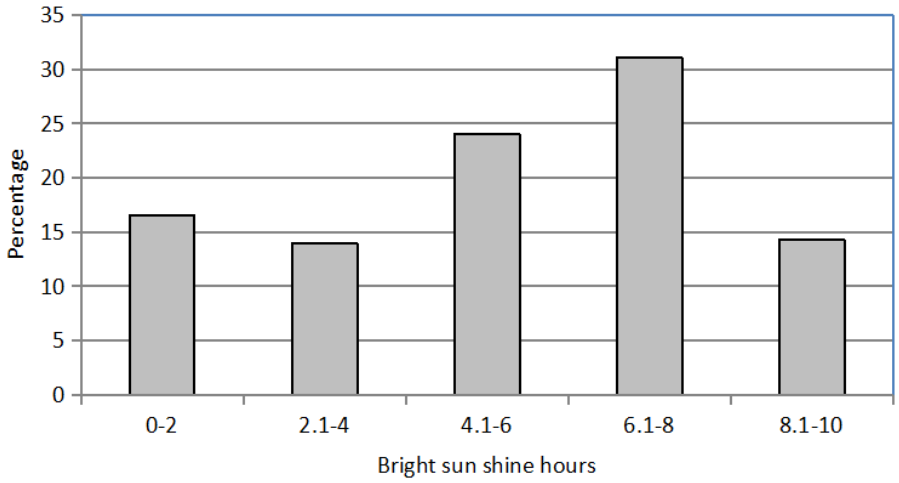


Fig. 6. Distribution of bright sunshine hours in 2020

Table 9. *Variation of observed meteorological factors at Dartonfield – 2020*

Month	(*Latitude $6^0$32'; Longitude 80.09 E; Altitude 65.50 mm) Temperature (^{0}C)*				Sun shine hours	Relative humidity (%)			Mean wind speed (kmh^{-1})
	Mean Max	Mean Min	Mean	No of days Min. Temp<20		8.30 am	No of days 8.30am>90%	3.30 pm	
January	33.1	22.5	27.8(26.7)	0	7.0	83(88)	3	63(68)	1.1
February	33.3	23.1	28.2(27.1)	0	7.0	80(86)	1	64(65)	0.9
March	34.3	23.2	28.7(27.6)	0	7.2	79(85)	0	61(68)	0.8
April	33.7	23.4	28.5(27.8)	0	6.1	84(85)	4	75(75)	0.5
May	32.0	24.7	28.3(27.6)	0	4.1	88(88)	13	76(77)	0.5
June	31.3	24.2	27.7(26.9)	0	3.5	89(89)	12	72(77)	0.5
July	30.8	24.3	27.5(26.7)	0	3.4	90(89)	15	73(75)	1.0
August	31.2	23.5	27.3(26.6)	0	5.1	88(88)	11	77(74)	0.7
September	29.9	23.2	26.5(26.7)	0	2.9	89(88)	13	79(75)	0.2
October	31.2	23.4	27.3(26.6)	0	5.4	85(86)	6	73(77)	0.6
November	32.6	22.9	27.7(26.6)	0	4.9	85(85)	6	69(77)	0.3
December	32.2	22.8	27.5(26.7)	0	5.6	83(85)	4	74(73)	0.2

** Average values for 1980-2005 are shown in parentheses

List of Publications

Scientific Journals
(Bold type - Employees of Rubber Research Institute of Sri Lanka)

Anushka, P.V.A., Withanage, S.P., Karunaratne, N.P.S.N., Kudaligama, K.V.V.S., Dahanayake, T.T.D. and **Peiris, H.P**. (2019). Assessment and selection based on girth and yield performance of new *Hevea g*enotypes generated from controlled hybridization. *Journal of the Rubber Research Institute of Sri Lanka* **99,** pp.126-141.

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Fernando, L.T.B.K., Kudaligama, K.V.V.S., Fernando, T.H.P.S., Lakmini, W.G.D., Somasiri, H.P.P.S., **Karunarathne, N.P.S.N., Fernando, K.M.E.P., Attanayaka, A.P., Rodrigo, V.H.L**. and **Seneviratne, P**. (2019). Effectiveness of a locally developed ethephon formulation on yield and related latex physiological factors of *Hevea brasiliensis. Journal of the Rubber Research Institute of Sri Lanka* **99**, pp.115-125. DOI: http://doi.org/10.4038/jrrisl.v99i0.1894.

Fernando, T.H.P.S., Siriwardena, D., Wijerathna, C., Nishantha, N., Balasooriya, P. and Buddika, Nishantha. (2019). Field screening of RRISL recommended rubber clones against Corynespora Leaf Fall Disease. *Journal of the Rubber Research Institute of Sri Lanka* **99**, pp.57-65.

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Gunarathne, **P.K.K.S.,** Tennakoon, T.M.S.P.K. and Edirisinghe, Jagath C. (2020). Capital assets impact on rubber farming in Moneragala in Sri Lanka: Rubber smallholders' perception**.** *Journal of the Rubber Research Institute of Sri Lanka* **100,** pp.22-37.

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Hettiarachchi, R.P., **Chandrasiri, J.A.S., De Silva, K.E**., **Edirimanna, V., Thewarapperuma**, **A.**, **Gunathilake**, **T**., **Malawaraarachchi, G.C., Kulathunge, K**.**M**.**M**.**E**.**K**., **Gayan**, **W.H.** and **Siriwardana**, **N.S. (**2019). Effectiveness of coir dust and rubber latex based slow release fertilizer on the growth of immature rubber *(Hevea*) and soil nutrient availability**.** *Journal of the Rubber Research Institute of Sri Lanka* **99**, pp.66-75.

Hettiarachchi, R.P., **Seneviratne, G., Jayakody, A.N.**, **De Silva, E**., **Gunathilake**, **P.D.T.C., Edirimanna, V.**, **Thewarapperuma**, **A.**, **Chandrasiri, J.A.S., Malawaraarachchi, G.C.** and **Siriwardana**, **N.S. (**2018). Effect of biofilmed biofertilizer on plant growth and nutrient uptake of *Hevea brasiliensis* nursery plants at field condition**.** *Journal of the Rubber Research Institute of Sri Lanka* **98**, pp.16-27.

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GENETICS AND PLANT BREEDING

The annual hand pollination programme was done at Neuchatle Estate and fifty-five new genotypes were raised. Five genotypes belong to the 2014 hand-pollinated progeny showed outstanding performances and selected for commercial-scale evaluation along with small-scale testing. After evaluating the 2000 hand-pollinated progeny for sixteen years, seven genotypes as best latex-timber clones and three genotypes as best timber – latex clones were identified. After the characterization of ten genotypes selected from the 1995 hybridization program where non-Wickham clone GPS 1 was used as the male parent, three promising genotypes as 95HP55, 95HP1, and 95HP41 were identified for future breeding and selection programs. The small scale estate and smallholder collaborative trials established in both traditional and non-traditional areas were maintained satisfactorily. The multiplication process of foreign clones is continued with adaptability trials and plants were prepared to establish two trials at Galewatta, Dartonfield Estate. Two Indian clones RRII 430 and RRII 414 were bud grafted at Sapumalkanda nursery, Lalan Rubber (Pvt.) Ltd. Routing maintenance of bud wood nurseries and breeding garden was carried out at both Neuchatle Estate and Nivitigalakele breeding premises.

PLANT SCIENCE

Growth and physiological data were recorded in nursery experiments on the effects of seed quantity and row arrangements on the growth and budgrafting performances of Hevea in Moneragala. About 1600 plants were transplanted in 7"x18" poly bags. Growth and physiological data were recorded in "a super plant" experiment at Kekirawa. A new experimental trial was established at Kumarawatta Estate, Moneragala to see the effect of holing, using a digger machine, on the growth of rubber.

Latex and tea yield were recorded for Tea X Rubber intercropping trials and hard pruning was done for rambutan trees in Rubber X Perennial crops trial at Kuruwita. New experimental trials on the "effects of different spacing for Rubber X Cardamom and Rubber X Cinnamon" were established at Labugama and Kuruwita respectively. Growth and physiological data were recorded for Rubber X Fruit crops trials at Moneragala and Ampara. Aquilaria plants were inoculated with a fungal culture of different concentrations and were harvested 10 months after inoculation.

Latex yields, annual growth and bark measurements were recorded in the new tapping experiment at Sirikandura estate. Yield and weather data were recorded for the early morning tapping experiment for a few months. A prototype of a new tapping machine was tested and found to be impracticable. Antioxidant application, bark measurements, and yield recordings were done for TPD experiments.

42 nursery visits were made and about 618,900 plants were certified. Weak plants in RDD nurseries were discarded in collaboration with Rubber Development Department. Budwood nurseries were inspected for Rubber Development Department nurseries. 30 advisory visits were made and a total of 30 training programmes (nursery management, budgrafting and tapping) were conducted.

PLANT PATHOLOGY AND MICROBIOLOGY

The secondary leaf fall diseases; Powdery mildew and the Colletotrichum leaf fall disease was mild during the year 2020. There were some disease vulnerable sites with a moderate level leaf fall condition. The clonal screening programmes could not be continued due to the covid-19 pandemic situation. Hence, no new records of new Corynespora susceptible clones were reported. The new leaf fall disease continued to appear by April. Nearly 20,000 ha were under the disease by the end of 2020. A chemical controlling programme was undertaken by RRISL collaboratively with the Rubber Development Department to stop the further spread of the disease. Advisory Circulars were sent to all the RPC's and RDD guiding to identify the disease and also giving directions on chemical control. The chemical controlling recommendation against White root disease was revised. Thirty-six demonstration plots were established for chemical controlling of White root disease to educate the growers on the new developments. Chemical screening against Brown root disease revealed that tebuconazole was effective in controlling the disease at very low concentrations.

A thesis on "A Study of the Brown Root Disease of rubber and its causative fungus Phellinus noxius" was submitted to the University of Colombo for the fulfillment of the PhD degree by Mrs M.K.R. Silva.

Bud wood nurseries type experiments were established in Padiyathalawa, Moneragala, Ratnapura, Kalutara, and Kelani Valley areas to screen the available clones against economically important leaf diseases. The project conducted to identify antagonistic micro-organisms for White root disease, funded by National Science Foundation was completed successfully. A compost based biopesticide has been developed and it is to be commercialized. Experiments were continued to identify plant growth promoting microorganisms (bacteria & fungi). The potential bacteria and fungi alone and in combinations were tested for the ability of antagonistic nature, phosphorus solubilizing ability, production of Indole Acetic Acid (IAA), and growth-promoting substances and analyses. Promising isolates were identified among the collection for further studies.

SOILS AND PLANT NUTRITION

Research activities on improvement of soil fertility, increasing fertilizer use efficiency, soil, water and nutrient conservation and weed control attended. Special capital project titled "Modification of fertilizer recommendations system of Hevea with reference to plant, soil and field parameters" continued. Activities of 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" were conducted in six estates with the funds of the National Research Council. Shade net mulch was found superior to polythene mulch in weed control around the plant base in immature rubber fields along with Mucuna cover crop. Reusable Porous Tube (RPT) provided higher girth of immature Hevea plants than the traditional way of applying fertilizer. Spatial variability of major soil nutrients under Pestalotiopsis disease pandemic in rubber was evaluated to identify any associations between the disease and nutrient stress.Potential annual soil loss in rubber growing areas was estimated employing Revised Universal Soil Loss Equation (RUSLE) at Geographic Information Systems (GIS) and Remote Sensing (RS) platforms. A land suitability model was developed to derive area specific preliminary land suitability status using soil, climate and topography data at GIS platform. Among the different fertilizer mixtures tested in non traditional rubber growing areas i.e. in Moneragala, Mahaoya and Padiyatalawa, R/SA based mixtures (i.e. R/SA 7:9:9:3, new fertilizer mixture and potassium double recommended mixture) provided better plant growth compared to the urea based mixture R/U 12:14:14. Combine use of agro management (CAM) practices such as cover management, biofertilization, stone terrace, coconut husk and vetiver terracing with reduced amount of inorganic fertilizer application was adopted at Elston, Parambe, Udabage, Penrith, Halpe and Pussella estates. According to soil, plant and field parameters in different soil associations representing 160 ha of 2 estates in Colombo district, significantly higher value of available soil phosphorus content was observed compared to those values in early studies, indicating a possibility of cutting down the amounts of Eppawala Rock Phosphate (ERP) to be applied. Site specific fertilizer recommendation programme provided 19 fertilizer recommendation reports for 2645 ha of mature rubber. Six land suitability reports were issued for 490 ha under the land selection programme. Analytical service offered 54 analytical reports including 759 parameters based on 171 fertilizer & soil samples to assure the application of good quality fertilizer for rubber lands.

BIOCHEMISTRY AND PHYSIOLOGY

Technology transfer programmes for effective introduction of low intensity harvesting systems were conducted to the Rubber Development Officers in Galle, Mathara and Hambanthota Districts. Awareness progammes on low intensity harvesting systems and usage of ethephon were conducted to the Managers, Field staff and workers of all the estates belongs to Kelani Valley Plantations PLC, Keglle Plantations PLC, Namunukula Plantations PLC, Horana Plantations PLC, Kahawatta Plantations PLC and Elkaduwa Plantations PLC. Under the special capital project received, S/2 d4 low intensity harvesting system was adopted in about 1,550 ha of smallholder and estate sector rubber fields.

Growth data were collected from experimental fields established at Padiyathalawa and Hambegamuwa with different Hevea clones in order to identify the best clones for the sub-optimal climatic conditions in non-traditional rubber growing areas.

An experiment has been conducted to investigate effect of new leaf disease on yield determining latex physiological factors in collaboration with Plant Pathology and Microbiology Department, RRISL.

Further investigations on locally formulated water based and oil based new ethephon formulations were conducted under the National Science Foundation research project RG/2017/AG/1. Commercial scale testing has also been conducted.

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 154 rubber lands were developed as model rubber holdings. Twenty-one rubber processing centers were developed as models and construction of 31 new RSS processing centers and rehabilitation of 11 substandard centers were attended. Basic data and information were collected to developed selected villages as model rubber villages and action plans were prepared. Preparation and establishment of technical banners for Techno Park at Monaragala Substation was completed.

Under the project started in 2017 on "Introduction and Establishment of new fuel wood growing models in selected lands of smallholder rubber farmers" with FAO funding, 4.01 Mn from the total allocation of 10.45 Mn had been spent by the end of the year for 92 farmers to establish of different fuel wood growing models.

Farmer training programmes were conducted to educate 103 smallholders and 150 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 71 small land units in traditional rubber growing areas for necessary improvements. One hundred ninety advisory visits were carried out to solve problems in technology adoption on requests made by smallholders.

RUBBER TECHNOLOGY AND DEVELOPMENT

Natural rubber (NR) composites were produced with the different sizes of synthesized coir fibre and strength properties, ageing properties and water absorption were evaluated. Dry NR based cellular compounds were prepared using three blowing agents of different types. Effect of addition of calcium carbonate filler on properties such as cure characteristics of cellular compounds, mechanical properties and water absorption of cellular rubber produced were evaluated. Rigid polyurethane (rPU) foam waste was recycled according to a mechano-chemical modification process using five different modifying agents. The best modifying agent was selected in terms of properties of virgin NBR/mechano-chemically modified rPU foam waste blend compounds.

Can sealant compound, foam rubber adhesive compound, NR latex based catheter, NR latex compound as a water-proof coating material for tents made out of fabric, novel glove to protect against the Covid-19 pandemic, NR based outsole compound for leather boots, NR based composites with durian husk fibres, NR latex based films with coconut husk powder, NR latex based eco-friendly material for table design, low-density NR latex foam, mat compound out of NR product waste, reclaiming of NR based glove waste, rubber band waste and micro-cellular rubber based slipper sole waste and novel NR latex based fashionable gloves were developed.

Tested 94 sole crepe samples, 118 rubber compounds and 504 rubber and polythene product samples at the request of the rubber industry. Eighteen SMEs and three groups of University students were trained at RRISL, Ratmalana on "Manufacture of NR based Products". Four workshops on "Rubber based Products Manufacture" were conducted in collaboration with the Rubber Development Department. Participated in the "Ridi Abises" exhibition held in Labuduwa, Galle.

POLYMER CHEMISTRY

Research activities related to the project on development of property correlations for nitrosaminesafe binary accelerator systems were continued throughout the year.Therein, the combined effect of nitrosamine free diisopropylxanthogen polysulfide (DIXP) and nitrosamine safe tertiary butyl benzothiazolesulphenamide (TBBS) accelerator system on the cure characteristics, physico-mechanical properties, and crosslink density of the vulcanizates were determined and compared with single-accelerator systems.

The processed-mica waste (PMW), a silica-containing mineral filler was incorporated into natural rubber by the latex stage mixing method. The effect of the PMW loading on the curing properties, tensile properties, and dynamic mechanical properties was evaluated. The results of the study indicated improved tensile and dynamic properties at lower filler loadings of PMW.

More than a thousand samples of polymeric materials and compounding ingredients received from industry and academia were analyzed using advanced instrumentation including, Fourier transform infrared spectrophotometer (FTIR), Differential Scanning Calorimeter (DSC), Dynamic Mechanical Analyzer (DMA) and Thermo-gravimetric Analyzer (TGA).

RAW RUBBER AND CHEMICAL ANALYSIS

This department provides analytical testing services as per industry demands and needs. Our scope is to empower the raw rubber producers, rubber exporters and, small and medium scale industrialists by providing internationally accepted testing facilities. The department offered testing, analytical and certification services on raw natural rubber and rubber chemicals to all sectors of the rubber industry. These services were also extended to rubber traders, researchers from fellow 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 thousand four hundred forty- four samples of natural rubber latex, dry rubber, and processing chemicals were tested for their quality during the year. This included 257 dry rubber samples, 1161 latex samples, and 26 rubber processing chemicals. 512 no 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 major research projects during the year.

Eight new clones were tested for their latex and raw rubber properties with the aim of clone recommendation. Dynamic properties of five grades of technically specified rubber were studied with comparison to Unfractioned unbleached crepe rubber produced in Sri Lanka. A collaborative research project was conducted with the University of Ruhuna on the Purification and commercialization of pyrolytic carbon char generated from waste tire pyrolysis plants in Sri Lanka.

The department staff provided two training programs on raw rubber and natural rubber latex testing for university undergraduates. Three factories visited were made for troubleshooting activities during the year.

RAW RUBBER PROCESS DEVELOPMENT AND CHEMICAL ENGINEERING

A study carried out showed that replacement of Tetramethylthiuram Disulfide (TMTD) from nitrosamine free Tetrabenzylthiuram disulfide (TBzTD) in TMTD/ZnO preservative system has a potential to be used a preservative for both field and centrifuged latex. A comparison was made over the preservation performance of the conventional Low Ammonia TMTD/ZnO and low ammonia/TB_2TD/ZnO systems. It was found that novel Low Ammonia TB_2TD/ZnO is a comparably performing preservative system over the control, based on assessment of VFA development.

A study carried out on Aqueous Solution of Proteolytic Enzyme showed that ASPE could act as an effective deproteinizing enzyme in preparation of Deprotenized Crepe Rubber.

A comparative study on Processed Mica Waste (PMW) filled Natural Rubber Latex Foam (NRLF) made out of centrifuged and creamed latex was carried out.

Morphological studies reveal that both types of composites possess open cell structures. Incorporation of PMW in to creamed latex lead to generate foam rubber structures with larger cell sizes. Increasing PMW loading increases gelling time, tensile strength, bulk density, Shrinkage, water absorption, electrical resistivity, biodegradability and antibacterial properties while reducing swelling index and leachable protein content. Irrespective of the type of latex, incorporation of PMW showed no influence on the electrical resistivity and the biodegradability of foam composites.

The effect of a retarder (pre-vulcanization inhibitor) to increase the durability of compounded latex was investigated. It was found that application of N-cyclohexylthiopthalimide (CTP) at 4 phr loading could improve the keeping qualities of latex compounds more than 50 days.

A simple low cost process was developed to convert sludge generated at drinking water purification plants into powdery materials. It was found that replacement of Industrial Aluminum Silicate (IAS) by DWTS caused to decrease the scorch time and cure time. However, maximum and minimum torque values were observed to be not significantly affected. It was found that processed DWTS could be used to replace commercially used aluminium silicates at least by 75%.

A study carried out on the compatibilization of skim rubber and polypropylene blends using Ethylene propylene di ene monomer (EPDM) as a compatibalizer found that optimum EPDM loading is 10 pphr.

The staff of the department continued to provide 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

The smallholder rubber field opened for tapping in 2019 in the Vavuniya District of the Northern Province (Dry Zone of the country) reported an average yield of 22.5 grams of dry rubber per tree per tapping. The feasibility of cultivating rubber in the Anamaduwa Divisional Secretaries division of Puttlam district was assessed. A study conducted in the Kegalle district to assess smallholder's willingness to beekeeping in rubber plantations revealed that there is a 50% probability for occupying beekeeping if the income is over Rs. 21,500 per acre per year. The project developed to approach the voluntary carbon market with the rubber cultivation in Eastern and Uva Provinces was listed in an International Accredited Registry; VERRA. GPS locations of ca. 1,500 ha of new rubber smallholdings in Moneragala and Ampara districts were identified in collaboration with Smallholder Tea and Rubber Revitalization (STaRR) Project.

BIOMETRY

The action plan for 2020 of the Biometry section is focused on biometrical aspects especially on the development, modification and application of statistical methodologies related to the needs of the rubber sector. Statistical methods, research support and studies on Climatology are the three major research and development focuses of the Biometry section. Research support extended to other departments included assisting the design of experiments, data analysis, design and analysis of surveys, interpretation of results and database management. Databases on meteorological data collected in the stations at Dartonfield, Moneragala and Kuruwita and rainfall data collected in stations at Nivitigalakele, Galewatta and Polgahawela were updated and provided data for scientific purposes on request. Data collected from the Dartonfield AGROMET station were provided to the Department of Meteorology as monthly reports. The database on rainfall in rubber growing areas was updated for the reporting year. The Officers of the Biometry section have been involved with multi-disciplinary studies with different departments of RRISL, Universities, other crop research institutions and Regional Plantation Companies.

AGRICULTURAL ECONOMICS

Analysis of the economics of the use of intercrops in rubber lands explored the Livelihood Capital (LC) development of smallholders through the rubber agroforestry practices. Further, analysis of the competitiveness of Sri Lankan rubber exports, and the investigation of overall satisfaction of latex harvesters in the smallholder rubber lands were the major studies focused during the year. In collaboration with the Advisory Services Department and Biometry section of RRISL, analysis of the use of fuelwood growing model in rubber lands was continued under the project titled "Introduction and Establishment of New Fuelwood Growing Models in Selected Lands of Smallholder Rubber Farmers". Also, a few spatial maps were developed for the rubber lands in the Polgahawela estate using Geographic Information Systems (GIS). Agricultural Economic Unit (AEU) analysed the Sri Lankan rubber trade in the international market and rubber prices behaviour throughout the year. AEU also conducted several field inspections and provided valuation reports based on the requests from the stakeholders.

LIBRARY AND PUBLICATION

The Library and Publication Unit continued with its regular services in collecting and disseminating information on natural rubber and related subject areas and also processing and publishing of its regular publications. The library and Publication Section supported the staff of the institute by providing primary as well as secondary sources, by maintaining permanent collections and providing access to all necessary materials. Our library services are mainly, Lending, Reference, Inter-library Loan, Photocopying, Indexing Service, Content Pages Service, Current Awareness Service and Selective Dissemination of Information (SDI) Service.

Twenty -six text books were added to the reference section of the library bringing the total collection up to 6208.

While two journals were purchased -20 titles were received on an exchange basis.

DARTONFIELD GROUP

A total crop of 165,971 kg has been harvested during the year achieving 84% of the estimated crop. When comparing with the previous year, crop records an increase of 10%. The crop harvested on wet days due to the rain guards was 41,024 kg which amounts to 25% of total harvested crop.

Average Yield per Hectare (YPH) for the year was 912 kg showing an increase of 67 kg from the previous year.

The average intake per tapper recorded during the year was 8.0 kg from a tapping task of 251 trees. The highest intake per tapper of 12.7 kg was recorded from the 5.17 ha field planted in 2010 year tapped with a tapping task of 225 trees of clone Mix 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 217,11, 85 and 52 days, respectively.

Total rainfall recorded for the year was 3376.8 mm with 177 wet days showing 1012.9 mm less rainfall and 27 wet days than the values recorded in the previous year.

The Cost of Production (COP) and Net Sale Average (NSA) recorded for the year was Rs.300.90 and Rs.333.73 respectively, giving a profit of Rs.32.83 per kg and a total profit of Rs.5.4 Million. Profit per hectare recorded for the year was Rs.29,943.55.

KURUWITA SUB - STATION

The mature extent of the Kuruwita Sub Station was 79.36 hectares during the year.

A total crop of 79,457 kg was harvested during the year recording an increase of 7149 kg on previous year's crop.

The actual yield per hectare (YPH) was 1,001.2 kg. The average intake tapper (IPT) of the estate was 7.4 kg showing an increase of 0.1 kg from the previous year.

The total number of Normal, Rainguarded, and No tapping days recorded during the year were 241, 96 and 29 respectively.

The annual rain fall recorded during the year was 3,428.3 mm with 215 wet days against 3976.8mm with 226 wet days in the previous year.

The cost of production (C.O.P) and the net sale Average (N.S.A) for the year were Rs. 292.36 and Rs. 311.69 per kg, respectively. The profit made for the year was Rs. 1.5 million and the profit per hectare recorded for the year was Rs. 19,353.63.

POLGAHAWELA SUB - STATION

A total crop of 17,080 kg, has been harvested during the year. Although it was 82% of the estimated crop, it showed 8.9% increase when compared to the previous year's crop.

The YPH for the year was 962 kg. This was an increase of 79 kg (8.9%) over the last year's value recorded.

The average intake per tapper during the year was 8.8 kg. The highest intake per tapper of 11.2 kg was recorded from the 2008 field with a tapping task of 269 trees of clone RRIC 121 tapped on S/2 d3 systems.

The total number of Normal, Late, and No Tapping days during the year were 301, 0 & 65, respectively.

Total rainfall recorded for the year was 2,385.5 mm with 118 wet days. Out of the total manufactured RSS, the share of No.01 grade was 86%.

METEOROLOGICAL REPORT

The total annual rainfall at Dartonfield during this year was 3651 mm, 437 mm below the long-term average and a decrease of 16 % compared to the previous year. Remarkably high above-average monthly rainfall was observed in September as in the previous year. An above-average rainfall value was also observed in July. The months, January and December recorded rainfall totals close to the long-term average. The monthly totals in March, May, August and October were considerably lower than the long-term average. The rest, February, April and June recorded slightly lower totals, compared to the long-term average monthly rainfall. The minimum monthly rainfall of 91 mm was recorded in February whilst the maximum monthly rainfall of 748 mm was recorded in September.

The South West monsoon season (May – September) carried most of the rains (1992 mm) during 2020. This rainfall amount contributed 49% to the total rainfall, which is close to the long-term average contribution (48%). Rainfall during IM2 (October & November) in 2020 brought 631 mm whilst IM1 (March & April) recorded a low rainfall of 536 mm. During the North East season (December 2020 to February 2021), 883 mm of rain was recorded, which is comparatively higher (22%) than the long-term average contribution (15%) of this season.

There were 2 rainfall events (207 mm on the 1st of September and 127.5 mm on the 19th of July) that exceeded the hazardous limits for landslides (100 mm of rainfall during a day) reported during the year under review. A dry spell lasted over a month or more can have adverse impacts on rubber plantations. There were only 5 dry spells greater than or equal to 7 days; the longest being 20 days, from 24th February to 14th March.

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 monthly minimum temperature of 22.5 ^{0}C was observed in January while the highest monthly mean maximum temperature of 34.3 ^{0}C was observed in March.

A total of 1857 bright sunshine hours was received at an average rate of 5.1 hours/day. Bright sunshine hours exceeded 6 in 45% of the days, while in 31% of the days it was below 4 hours. The mean RH values recorded at 08:30 and 15:30 were 86% and 72 %, respectively.

There are five substations maintained by RRISL in Kuruwita (WL_{1a}), Narampola (IL_{1a} bordering WL_{2b}), Moneragala (IL_{1c}), Galewatta (WL_{1a}) and Nivithigalakele (WL_{1a}). The annual rainfall totals of 3439 mm, 2379 mm, 1260 mm, 3329 mm and 3018 mm were recorded, respectively, in Kuruwita, Narampola, Moneragala, Galewatta and Nivithigalakele stations.