Cover Story

New approaches to combat White Root Disease of rubber Plantations

White root disease caused by the fungus, *Rigidoporus microporus* has become the most destructive disease in Sri Lanka. It is one of the main causes for reduced tree stand in rubber plantations resulting low productivity levels. Hence, this disease has become an important economic factor in the rubber plantation industry during the recent past. Moreover, labour usage in the land rehabilitation process due to this increases the cost of replanting and also the use of pesticides to control the disease poses many environmental hazards during the immature phase. This disease is usually identified through foliar symptoms: yellowing and bucking of leaves and premature flowering. To confirm the disease, the growers should look for the whitish rhizomorphs on the roots. At latter stages, characteristic bracket-shape fruit bodies appear at the collar region.

The most effective longterm strategy to manage the disease is to adopt correct land clearing practices to prevent the disease.

RRISL has introduced intergrated methods for disease management. Direct supervision will be of utmost importance in the prevention of the disease. Chemical controlling using the systemic fungicides; tebuconazole & hexaconazole is effective in controlling the disease. Early disease detection methods have also been introduced. The development project granted by the Ministry of Plantation Industries has facilitated free of charge White root disease surveying programmes followed by training programmes. Demonstration plots located in main rubber growing areas will show the efficacy of new research findings. Methods have been improved on land clearing techniques, chemical controlling methods and use of a native biopesticide. Moreover techniques are improved to stop further spread of the disease, for the rehabilitation of abandoned white root disease patches and also to make use of the unproductive disease patches.

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- Development Project 23/1/15 “Identification of the potential pest and disease problems of rubber in non - traditional areas to develop improved management strategies” funded by Ministry of Plantation Industries.
- Research Project 03.30X “Investigations on biological control measures for WRD of rubber to improve integrated disease management strategies” funded by National Science Foundation.

Rubber Research Institute of Sri Lanka

Annual Review - 2017

1st January 2017 to 31st December 2017

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Mr Justin Seneviratne - Representative of the Sri Lanka Association of Manufacturers & Exporters of Rubber Products
Mr R C Peiris - Representative, Planters' Association of Ceylon
Mr Anusha Perera - Representative from the Planters' Association of Ceylon
Dr J D H Wijewardana - Representative from Sri Lanka Council for Agricultural Research Policy
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Mr K H M R Herath - Nominated Member
Mr E G S Premachandra - Nominated Member

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Mr R B Premadasa, Director General, Rubber Development Department
Mr S S Poholiyadda, Chairman, Planters' Association of Ceylon

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Mr N V T A Weragoda, Chairman, Rubber Research Board
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Mr B S S Hewage, Senior Accountant, RRI
Mr Ajith Withanage, Deputy Director (Administration)

Audit and Management Committee

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Mr R B Premadasa, Director General, Rubber Development Department
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Dr W M G Seneviratne, Director, Rubber Research Institute
Mr Ajith Withanage, Deputy Director (Administration), Secretary
Mr T B Dissanayake, Elected Committee Member
Mr R A D Ranawaka, Elected Committee Member
Mr B S S Hewage, Senior Accountant, RRI (In attendance)

Chairman's Office & Board Secretariat

Chairman	- Mr N V T A Weragoda
Acting Secretary to the Board	- Dr (Mrs) Wasana Wijesuriya
Personal Assistant to the Chairman	- Mrs B H P Balasuriya
Management Assistants	- Mrs H N Kanchana
	- Mrs P S Ishara

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	Miss K K I Jayasundera, BSc (SL) (w.e.f. February 2017)
	D S Dissanayake, BSc (SL) (from July 2017)
	Mrs G R Tennakoon, BSc (SL) (w.e.f. July 2017)
Experimental Officer	S M A Samarakoon, Dip. Agric. (Kundasale)
Management Assistants (Clerical)	Mrs M K Wijetilleke (up to October 2017)
	Miss S V Shirani Madurika, BA (SL) (up to 20.02.2017)
	Mrs C Gunatilleke
	Mrs J N R Jayasinghe
	R G A S Dharmaratne
	Mrs S M Kaluarachchi
	T R C Silva
	Mrs K Y G M P Kumari, BA (SL)

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 Officer	W D M Sampath, BSc (SL)
Experimental Officers	Mrs S I Yapa, Dip. Rubber Tech. (PRI)
	S L G Ranjith, Dip. Rubber Tech. (PRI), BSc (SL)
	P L Perera
	Mrs G M Priyanthi Perera, BSc (SL), MSc (SL)
Technical Officers (Research & Development)	V G M J Abeywardena, NDT
	Miss S G P Bhagayawedha, NDT
	K I D P Perera, BSc (SL)
	Miss P K I L Jayaratne, BSc (SL) (w.e.f. July 2017)
	P D A Gunasekera, BSc (SL) (w.e.f. July 2017)
Management Assistant (Clerical)	Miss S M D S R de A Wijeratne

Polymer Chemistry *(at Telewela Road, Ratmalana)*

Research Officer	Mrs I H K Samarasinghe, BSc (SL)
	Y R Somaratne, BSc (SL)
Experimental Officer	Mrs N Jayawardane, Dip. Agric. (Bibile)
Technical Officers (Research & Development)	Mrs H M H Dhanukamalee, BSc (SL)
	Miss P S V Rupasinghe, BSc (SL) (w.e.f. February 2017)
	D V D Mallikarachchi, BSc (SL) (w.e.f. July 2017)
	Miss H L T Tharaka, BSc (SL) (w.e.f. Sept. 2017)
Management Assistant (Clerical)	M A W K Tillekeratne

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

Senior Research Officer	Mrs A P Attanayake, BSc (SL), PhD (SL) (w.e.f. September 2017)
Research Officer	A M K S P Adikari, BSc (SL), MPhil (SL)
Experimental Officers	Mrs H V K Gamage
	Mrs C S Lokuge
	Miss D M S Wijesekera, Dip. Rubber Tech. (PRI)
	L P P Vitharana
Technical Officers (Research & Development)	Miss S P Wijewardena, BSc (SL)
	Miss N C Y Kithmini, BSc (SL) (w.e.f. January 2017)

Technical Officers (Research & Development)	Miss M U D S Weerasinghe, BSc (SL) (w.e.f. January 2017)
	Miss L K I Madushani, BSc (SL) (from January - September 2017)
	H D M S Wijewardena, BSc (SL) (w.e.f. July 2017)
	K A S T Koswatta, BSc (SL) (w.e.f. July 2017)
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)
Experimental Officers	Mrs W K C Nalinie, Dip. Rubber Tech. (PRI)
	Mrs U M S Priyanka, BSc (SL), MSc (SL)
	Mrs V C Rohanadeepa
	A K D W Prasad
Technical Officers (Research & Development)	R D Illeperuma, BSc (SL) (w.e.f. January 2017)
	Miss P K N N Sandamali, BSc (SL) (w.e.f. January 2017)
	W R U de Silva, Dip. in Chem. (w.e.f. July 2017)
Management Assistants (Clerical)	Miss H A Janani Lakshika, BA (SL)
	Miss A R M de Alwis
	Mrs K K Geetha, BA (SL)
	Miss 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)
Experimental Officers	Mrs H K D C S Munasinghe, NCT Polymer (Moratuwa), Dip. Rubber Tech. (PRI), Dip. Computer Science (IDM)
	O V Abeyawardene, Dip. Agric. (Kundasale)
Management Assistants (Clerical)	Mrs W W L S Shashikala, BA (SL)

Adaptive Research Unit	*(at Dartonfield, Agalawatta)*
Principal Research Officers	S M M Iqbal, BSc Agric. (SL), MPhil (SL) PhD (Essex) (up to 21.04.2017)
	Mrs E S Munasinghe, BSc Agric (SL), PhD (SL) (w.e.f. February 2017)
Research Officer	Mrs B M D C Balasooriya, BSc Agric (SL)

Technical Officer (Research & Development)	P M M Jayatilleke, NDT (Agric.) Mrs N M Piyasena, Dip. in Agric. (w.e.f. July 2017)
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	S U Amarasinghe, BSc (SL), MA (SL), ASLLA (up to 15.06.2017)
Library Assistant & Assistant Publication Officer	Mrs R M Amaratunga, Intermediate; Lib. Sci. Doc. & Info. (SLLA)
Library Assistant & Publication Assistant (Ratmalana)	Mrs D N C Amarathunga (w.e.f. January 2017)
Management Assistants (Clerical)	P M P Jayantha N W E C Maduranga

Audio Visual and Information Technology Unit	*(at Dartonfield, Agalawatta)*
Network Administrator	S R D C P Peiris, BSc (SL)

Administration Department (Agalawatta)	*(at Dartonfield, Agalawatta)*
Senior Administrative Officer	D M S Dissanayake, BSc (Mgt.) (SL), MHRM (SL)
Registered Medical Practitioner	M Subasinghe
Administrative Officer	Mrs P Mandalawatta (Dip. in HRM)
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
Pharmacist	Mrs W H A Manohari (w.e.f. October 2017)

Administration Unit (Ratmalana)	*(at Telewela Road, Ratmalana)*
Administrative Officer	Mrs U K Akila Tharinduni, BSc (SL) (w.e.f. September 2017)
Management Assistant (Clerical)	A T Senaratne
	D P N P Dissanayke
Telephone Operator	Miss G D D Kalamini (w.e.f. 02.01.2017)
Internal Audit Unit	*(at Dartonfield, Agalawatta)*
Internal Auditor	Mrs M S I Senadeera, AFA, IIPF, IRCA, LICA
Internal Audit Officer	K C Fernando (up to 26.07.2017)
Management Assistants (Clerical)	Mrs S N Munasinghe
Works Section	*(at Dartonfield, Agalawatta)*
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 K C S Wickremasinghe
	Mrs J A S Dharshanie (Dip. in Management)
	Mrs K K D K P Ranaweera
	Mrs M S W H Kumari, BSc (SL)
	Udaya Smantha Munindradasa, BA (SL)
Work Supervisor (Electrical)	T M R P Tennakoon (up to 17.05.2017)
Accounts Section	*(at Dartonfield, Agalawatta)*
Senior Accountant	S S Hewage, CPFA (UK), CBA, FPFA
Accountant	Mrs A M Lasanthi, BSc (SL)
Accounting Assistant	D D R Lankatilaka, BCom (SL) (up to August 2017)
Management Assistants (Accounting)	Mrs R Handungoda
	Mrs G P Kukulewithana
Management Assistants (Clerical)	Mrs K J M C R Fernando
	Mrs C Dissanayake
	A K D A Wickremasinghe
	Mrs S I K Pathirage
	Miss K T D Jayawathi (up to January 2017)
	Mrs S A Niluka Harshani
	Mrs K K D Y L Ranaweera
	Miss K K T L Jayasekera
	Miss R P Thilini
	J A J R Lakmal, BA (Mgt.)
	K A Dilan Sampath
	Mrs Erandi Kanchana Jayasinghe, BA (SL)

Management Assistants (Clerical)	Mrs S R Sinhabahu
	Harith Kalutharawithana, BSc (SL)
	G N K Gunasena
	Mrs K G P Hasara
Cashier	Mrs G A D D Jayawardena
Kuruwita Sub-Station	*(at Kuruwita)*
Manager	S A R Samarasekera
Management Assistants (Clerical)	D S Jayasinghe
	K D P Senaratne
Polgahawela Sub-Station	*(at Narampola Estate, Nungamuwa, Yatigaloluwa)*
Management Assistant (Accounting)	W A C Weeramanthree (up to 10.12.2017)
Moneragala Sub-Station	(*at Kumbukkana, Moneragala*)
Field Officers	V G D Nishantha Gunaseela
	N V U S Vijitha Kumara
Management Assistants (Clerical)	Mrs D M P Sandun Kumari
	M M Chamath Kumara

DARTONFIELD GROUP

Senior Manager - Estate	P A Lukshaman, BSc (SL)
Management Assistants	H D D Achinda
	M A N Sachith Pawinda
	T D Harsha
Field Officers (Nivitigalakele)	B M Siriwardena
	K K S D Kumara, Dip. in Agric. (January - August 2017)

* No pay leave

Awards

Dr. N.M.C. Nayanakantha, Head of Plant Science Department of RRISL, received an Award for the "Best Oral Presenter" for the paper entitled "Assessment of growth and bud-grafting performance of selected clonal seedling rootstocks of rubber (*Hevea brasiliensis*)", presented in the technical session on "Crop Production and Protection", at the First International Symposium on Agriculture, Eastern University, Chenkalady, Batticaloa.

RUBBER RESEARCH INSTITUTE OF SRI LANKA

DIRECTOR'S REVIEW

W M G Seneviratne

This review consists of the Research and Development activities conducted by the six Agronomy departments, three units at Head Office, Dartonfield, Agalawatta and the four Technology departments at Ratmalana. This is also consisted with the progress review of Library and Publication Unit, Audio Visual and Information Technology Unit and the two estates, Dartonfield Group and Kuruwita, Polgahawela and Moneragala Substations.

Rubber industry of Sri Lanka

Rubber production

The natural rubber production of the country in the year 2017 has increased to 83,072 tonnes which was approximately 5% improvement against the year 2016. Slight increase in Natural Rubber price in the market would have been attributed to this. After gradual decline of rubber prices since year 2012 to 2016, Local and international rubber price recovery was observed only during the year 2017 and has resulted in increase of tapping days and hence, the increase in rubber production marginally. It has also been seen that this gradual price decrease have resulted since 2012, approximately a 50% decrease in total NR production by 2016. This was mainly due to the COP of the Production was found to be higher than that of the selling price in most occasions and hence, most small holder farmers abandoned tapping from their own rubber fields.

In addition, among the plantation companies, diversification of rubber lands into oil palm cultivation seems to have increased further during the year under review, from 9,413ha to a higher extent as per the latest statistics reported at the end of 2016. This has seriously affected the rubber production and if the trend continues further, the rubber plantation industry will face serious drawbacks in the supply side which may finally result in drastic effect and dramatic turn over of the flourishing rubber products manufacturing industry in the country.

Two largest contributors to the total rubber production in the country, RSS rubber increased from 39,754 tonnes to 41,523 tonnes, an increase of 4.4% and Crepe rubber has decreased from 14,984 tonnes to 11,468 tonnes which accounted for a decrease of a 23%, respectively. Concentrated latex production in the country was estimated to be 28,877 tonnes in the year 2017. Average price of RSS1 was around Rs.239.42 per kg at the end of 2016 increased to Rs.336.21 per kg at the end of 2017, which is a 40% increase. Similar trend was observed for the Latex Crepe 1X price which was increased by 34% from Rs.269.09 in 2016 to Rs.350.25 in 2017.

Rubber extent

Total rubber extent in the country in the end of 2017 was around 136.8 thousand hectares while the extent under tapping was around 101.8 thousand hectares. The increase in rubber extent was due to the extent of new planting which accounted for 1500 ha.

NR consumption exports and imports

NR consumption in the country in 2017 reduced to 129,000 tonnes from 142,000 tonnes in 2016. Sri Lanka has exported around 17,230 tonnes of natural raw rubber in the year 2017 against the year 2016 which was 16,166 tonnes of exports.

Rubber manufacturing sector

Earnings through raw rubber exports was Rs.5,920 million in year 2017 against the Rs.4,758 million in year 2016. Export earnings from finished products was recorded as Rs. billion 127 in 2017, an increase of about 14% against the previous year. Exports earnings from semi processed rubber has reported as Rs.642 million in the year 2017, while it was Rs.766 million in the year 2016.

Global rubber industry review

Natural rubber supply

Total world NR production increased to 13,287 thousand tonnes in 2017 against the year 2016 which was around 12,429 thousand tonnes. World NR production has increased by 6.9% according to ANRPC statistics. The provisional data received from the member countries of ANRPC indicated an increase of 5% year-on-year. This is mainly due to the favorable markets in the major markets in Asia Pacific region during the end of the year. NR production more likely to rise by 1.9% in Thailand, 5.3% in Vietnam, 14.4% in India, 33% in Cambodia, 8.5% in Malaysia and 8.1% in Indonesia, as per the provisional estimates received by ANRPC.

Table 1 gives the annual average yield and mature area in the ANRPC group in years 2017 and 2016. While the average yield has declined in Thailand, China, Cambodia and Sri Lanka, it has been shown slight increase in Malaysia, India, Indonesia, Philippine and Vietnam during 2017. The expansion in mature area reflects the large scale planting undertaken during the period from year 2005 to 2012. Average annual yield figures reflect the achievements made by producing countries in clone improvements crop management and adoption of harvesting technologies have translated into improvement in average yield in most of the ANRPC countries. By contrast, further improvements are necessary in few countries like Sri Lanka, Thailand and Cambodia. Improvement in rubber prices especially during the year 2017 has aggravated the yield performance further.

Table 1. *The annual average yield per hectare in ANRPC member countries and extents under tapping*

Country	Total area ('000 ha)		Total area ('000 ha)		Total area ('000 ha)	
	2016	2017	2016	2017	2016	2017
Cambodia	433	436	127	170	1,143	1,136
China	1,161	1,160	720	744	1,075	1,118
India	818.8	829	445	477	1,402	1,467
Indonesia	3,639	3,659	3,042	3,054	1,104	1,188
Malaysia	1,073	1,078	481	493	1,400	1,420
Philippines	223	244	143	153	694	700
Sri Lanka	136	137	96	102	819	835
Thailand	3,734	-	3,118	3,251	1,394	1,363
Vietnam	973	972	622	653	1,659	1,665

Global rubber supply and demand:

Total rubber demand including Synthetic and Natural rubber was estimated as 29,300 thousand tonnes in 2017 compared to 27,459 thousand tones in the previous year. This increase accounted for an increase of 3% growth during the respective period. Statistics revealed that NR demand increased about 3.2% while Synthetic rubber demand approximately increased by 3.5%. Total NR production was 13,200 thousand tonnes at the end of year 2017 which was 12,451 thousand tonnes in year 2016. This increase includes approximately 6% increase of NR production.

Natural rubber demand:

Apart from economy's dominant role, the demand for NR is greatly influenced by geographical shifting of manufacturing base, capacity expansion in auto tyre industry, substitution between natural and synthetic rubber and change in consumption basket. Table 2 shows the trends in NR consumption and their growth in ANRPC member countries and total consumption in other countries in the world.

Table 2. *Trends in NR demand by major consumers*

	Consumption ('000 tonnes)		Growth (%)
	2016	2017	2017
ANRPC	8,150	8,249	1.2
EU - 28	1,188	1,236	4
USA	932	950	2
Japan	677	682	0.7
Brazil	428	434	1.5
Turkey	157	167	6.4
Canada	119	124	4.5
Russia	106	116	9.8

	Consumption ('000 tonnes)		Growth (%)
	2016	**2017**	**2017**
Mexico	101	102	1.1
Rep of Korea	381	415	8.8
Taiwan	101	110	8.5
Others	387	383	-1
World total	**12,726**	**12,968**	**1.9**

Based on the statistics released by the ANRPC, China consumed 38% (5,386 kmMn) of the total consumption of natural rubber globally during 2017. Other major consuming countries or regions are the European Union (9%), India (8%), the US (7%), Japan (5.2%), Indonesia (4.8%), Thailand (5.3%) and Malaysia (3.9%). The growth rate of demand for NR has increased in all major consumers including Russia (9.8%), Rep of Korea (8.8%), Taiwan (8.5%), Turkey (6.4%), EU-28 (4%) and USA (2%).

NR demand and supply gap

Global NR demand experienced a growth of 2.0% in 2017 while the supply has headed for a 6% increase. The resultant demand supply position for 2017 is shown in Table 3 in comparison with the previous two years. Global NR stocks at the end of year 2017 was 231 thousand tonnes. Consumption of natural rubber in ANRPC member countries, which account for 65% of the global demand, grew at 1.2% growth during 2017 against the previous year, according to the latest statistics.

Table 3. *Outlook for the demand supply gap*

	Quantity ('000 tonnes)			Growth (%)*	
	2015	**2016**	**2017**	**2016**	**2017**
Production	12,271	12,451	13,199	1	6
Consumption	12,140	12,726	12,968	5	2
Gap	131	-275	231		

(ANRPC, 2018)

World NR price movement

Despite of the declining trend prevailed in most of the market starting from the year 2011 to 2016, prices shown an increase in the year 2017. Sri Lankan annual average RSS3 price was US$ 1.54 a kg in year 2016 increased to 2.20 a kg. The average price of RSS3 recorded as US$ 2.03 in Bangkok in year 2017 against the previous year average value which was US$ 1.62. Average Indian RSS4 has increased to US$2.09 from US$ 1.82per kg against the previous year. According to the ANPRC countries, global natural rubber prices are likely to stay firm due to stronger crude oil prices, consumption growth and increase Chinese demand and appreciation of US dollar *etc*.

List of Abbreviations

ANRPC	- Association for Natural Rubber Producing Countries
COP	- Cost of Production
CSD	- Civil Security Department
EU 28	- European Union Countries
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

GENETICS AND PLANT BREEDING

S P Withanage

DETAILED REVIEW

Staff

Dr (Mrs) S P Withanage, Head of the Department, Mr K K Liyanage, Senior Research Officer, Mrs P V A Anushka, Ms T T D Dahanayake, Research Officers, Mr I D M J Sarath Kumara, 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, Miss W A D R Tharanga, Technical Officers and Mrs S D P K L Peiris, Management Assistant were on duty throughout the year.

Mrs Y S L Kumaranayake was assumed duties as a Technical Officer with effect from 14th August.

Seminars/Training Programmes/Workshops/Exhibitions conducted

The department staff provided the necessary training for the NIPM trainees, undergraduate students and stakeholders of various categories.

Lectures/Training and Workshops conducted

Officer/s	Subject/Theme	Date	Beneficiary/Client
SP Withanage	*Hevea* breeding and clone recommendation	15th July	NIPM Advance Certificate Course in Plantation Management BMICH, Colombo
SP Withanage	CRT Exhibition Rubber Sector	13th August	BMICH, Colombo
KK Liyanage	CRT Exhibition– Rubber Sector	11th -13th August	
	Hevea Breeding and Clone Recommendation	16th August	NIPM (Advance Certificate Course in Plantation Management)

Meetings/Seminars and Workshops attended

Officer/s	Subject/Theme	Date	Organization
TTD Dahanayake	Workshop on Laboratory Accreditation systems at Ratmalana, RRISL	13th January	RRI, Ratmalana
SP Withanage	CARP/NCCIA* Meeting	20th January	CARP/Colombo
KK Liyanage	Workshop on use of GPS and Google Earth tools in Research	09th February	Sri Lanka Foundation Institute, Clolombo

Officer/s	Subject/Theme	Date	Organization
SP Withanage KK Liyanage PVA Anushka TTD Dahanayake	Technology Update	28th February	RRI/Dartonfield
SP Withanage	CARP/NCCIA* Meeting	08th May	CARP/Colombo
	Workshop on Bioinformatics & Systems Biology	15th-17th June	University of Sri Jayewardenepura
	CARP/NCCIA* Meeting	24th July	CARP/Colombo
	CARP/NCCIA* Meeting	03th August	CARP/Colombo
SP Withanage KK Liyanage PVA Anushka TTD Dahanayake	Technology Update	06th Sept.	RRI/Dartonfield
	Scientific Committee Meeting	15th Sept.	RRI/Ratmalana

Lectures/Training and Workshops conducted (continued)

Officer/s	Subject/Theme	Date	Organization
SP Withanage	IRRDB Fellowship training Workshop	09th -10th October	IRRDB/RRISL, Dartonfield
SP Withanage	Workshop on Present status of Research Activities on Climate Change Adaptation & Development of Road Map for future Research Programs	06th November	CARP & Sri Lanka Foundation/Colombo
SP Withanage	Awareness workshop on ICGEB** Grant Schemes & proposal writing for collaborative Research	07th November	NSF/Colombo
	Program(CRP) of ICGEB CARP/NCCIA*Meeting	24th November	CARP/Colombo
PVA Anushka	IRRDB Fellowship training on sustainable rubber cultivation	9th to 17th October	IRRDB/RRISL, Dartonfield, Sri Lanka and Bogor, Indonesia
	World Plantation Conference & Exhibition and International Rubber Conference	18th to 20th October	IRRDB, Jakarta, Indonesia

Note. ***** ***National Committee of crop improvement and Agronomy***
****** ***International Centre for Genetic Engineering and Biotechnology***

Screening of selected* Hevea brasiliensis *L. genotypes from 2005 HP progeny for Corynespora leaf fall disease (CLF) resistance using Microsatellite Molecular markers

Thirty Microsatellite molecular markers were screened with parents, grandparents and moderately susceptible control clones and found polymorphism in four primers and they were used to assess progeny along with six clones (RRIC 100, RRIC 103, RRIC 52, PB86, RRISL 201 and RRISL 208). In the field screening, it has been observed that the clones RRIC 100 and PB 86 are resistant, RRISL 201 and RRISL 208 are moderately resistant and RRIC 103 and RRISL 201 are susceptible to CLFD**.** Pairwise genetic distance matrix was developed based on those two amplified DNA fragment of four primers in reaction to CLF disease, using Power marker program V 3.25 and the dendrogram was constructed using "MEGA 6.06" computer program (V 3.25). All six clones and 35 genotypes were grouped in to two main clusters (S P Withanage, W A D R Tharanga and Y S L Kumaranayake).

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

Ten genotypes selected from 1995 hybridization programme where non-Wickham clone GPS 1 was used as male parent, were characterized. Fifteen Microsatellite molecular markers were screened and three distingue groups were developed. Other parameters such as girth, bark thickness, bole height, branching pattern and canopy density were also used in genotype screening. Tapping was started at the end of the year (S P Withanage, A K Gamage, W A D R Tharanga and Y S L Kumaranayake).

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

This was started with the objectives of studying the role of antioxidant genes on TPD and the effect of exogenous application of antioxidants on TPD affected rubber trees. Using quantitative real time PCR, the expression pattern of antioxidant genes will be analyzed in TPD affected and healthy rubber trees to identify the antioxidant genes express deferentially under TPD condition. This will demonstrate their involvement in TPD and this information will be vital for designing a treatment or future molecular remediation, such as generating transgenic rubber plant overexpressing antioxidant genes, to cope with TPD and in turn to minimize the economic losses caused by TPD.

Quantitative RT-PCR (polymerize chain reaction) was carried out to identify the expression level of above mention genes. qRT-PCR was run with three replicates

for each gene (three biological replicates only for RRISL 2001 clone) and no template control. All the genes selected in three rubber clones, threshold cycles were analyzed to determine the expression levels in TPD affected and healthy trees. The $2^{-\Delta\Delta}$Ct method was used to calculate the relative gene expression.

According to the results, *HbSOD* gene is down regulated in all the TPD affected rubber clones (Table 1) whereas *HbGPX* and *HbCAT* genes are up regulated in all the TPD affected clones except RRIC 121. Three biological replicates were used for RRISL 2001 and qRT-PCR was run with three replicates for each gene. Significant down regulation of *HbSOD* gene was observed in RRISL 2001 whereas significant up regulation of *HbCAT* gene was also observed. Based on the result, it seems that *HbSOD* gene may play a significant role in TPD (Student's t-test was applied to determine the significant difference of threshold cycles of TPD affected and healthy RRISL 2001 clones). Therefore, TPD affected laticifer tissues might run short of antioxidants, mainly *HbSOD* antioxidant enzyme making the clone more prone to TPD.

Table 1. *Fold differences of HbSOD gene expression in TPD affected trees and healthy trees*

Sample		**HbSOD average C_T**	**HbACT average C_T**	**ΔC_T**	**$\Delta\Delta C_T$**	**Fold difference ($=2^{-\Delta\Delta CT}$)**
RRIC 121	Healthy	19.973±0.274	18.653±0.323	1.320±0.423		
	TPD affected	21.470±0.192	20.027±0.060	1.443±0.201	0.123±0.201	0.918
RRISL 217	Healthy	22.437±0.424	20.410±0.130	2.027±0.443		
	TPD affected	22.490±0.140	20.000±0.898	2.490±0.909	0.463±0.909	0.725
RRISL 2001	Healthy	19.837±0.081	21.770±0.325	-1.933±0.335		
	TPD affected	22.997±0.110	23.497±0.075	-0.500±0.133	1.433±0.133	0.370

Ascorbic acid application of TPD affected trees

It is worthwhile to study the effect of exogenous application of antioxidants such as ascorbic acid to compensate this shortage of antioxidants and the potential of ascorbic acid to recover TPD affected clones (third objective of above research).

This experiment was started at two sites at Eladuwa and Payagala with four clones and three levels of ascorbic acid concentrations (5mM, 10mM and 15mM) with control (water with surfactant). Each treatment had five replicates. Around fifty days after the application of ascorbic acid the recovery percentage was recorded while continuing the application and monitoring the recovery percentage. Data were collected in three cycles and statistical analysis was done. It has observed that

considerable recovery percentage from 5% to 20% percent compared to control in all clones in both sites. However, due to a severe cyclone affected a large number of trees were damaged and the experiment was shifted to Payagala Estate (S P Withanage, P K G S S Bandara, B W A N Baddewithana, T M S K Gunasekara and Y S L Kumaranayake).

Hand pollination programme

The annual hand pollination programme was done at Neuchatle Estate and eighty eight new genotypes were raised. Four promising clones were used as female parent where as five clones including one germplasm selection were used as male parent with an aim to develop genetically diverse high yielding vigorous genotypes. Details of new genotypes and crosses made are given in Table 2.

Table 2. *Details of parentage and the number of genotypes obtained in 2017 hand pollination programme*

Cross	No. of genotypes obtained
RRISL 201 x RRISL 2005	04
RRISL 201 x RRISL 2006	03
RRISL 201 x RRISL 203	19
RRISL 201 x Germplasm11-76II	09
RRISL 208 x RRISL 2005	32
RRISL 208 x Germplasm11-76II	09
RRISL 203 x Germplasm11-76II	09
RRISL 2006 x RRISL 203	02
RRISL 2006 x RRISL 201	01
Total	**88**

(S P Withanage, K.K. Liyanage, P V A Anushka, T T D Dahanayake, B W A N Baddewithana, I D M J Sarath Kumara and T M S K Gunasekara)

Developing the *Hevea* breeding garden

A land of 2.88 ha was selected for establishing a *Hevea* breeding garden at Neuchatel estate. Rubber trees were trained by bending branches towards the ground for easy and safe access to flower inflorescences for future breeding programmes. Annual hand pollination programme was conducted with these trees in the year under review. New establishment was done with eight RRIC 100 series clones, 18 RRISL 200 series clones eight RRISL 2000 series clones, five RRISL Centennial clones, eight foreign clones, 20 non-Wickham selections and four hand pollinated selections from 1995 HP evaluation. Two plants from each clone/genotypes were established (S P Withanage, K K Liyanage, P V A Anushka, I D M J Sarath Kumara, T M S K Gunasekara and B W A N Baddewithana).

Multilateral clone exchange programme

Memorandum of understanding has been signed on 2015 by the fifteen member countries of the International Rubber Research and Development Board (IRRDB) to exchange materials under 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 performance of all the exchanged clones in different agro-climatic conditions in the member countries. It is agreed to exchange 49 clones and RRISL has offered five clones namely RRISL 203, RRISL 208, RRISL 211, RRISL 219 and RRISL 2001. We have already sent material to India, Myanmar, Ghana and Thailand. We have received 12 clones from India, Thailand and Myanmar. Details are given in the Table 3. Detailed characteristics for five local clones were prepared and sent to compile the compendium of exchanged clones.

Table 3. *Details of clones received and their bud grafting success*

Country	Clones received	Number of bud grafts done	Number of success plants
India	RRII 422	12	10
	RRII 429	25	24
	RRII 417	5	4
	RRII 414	15	6
	RRII 430	6	6
Myanmar	ARCPC 24/4	26	2
	ARCPC 6/22	43	37
	RRIT 3604	9	9
Thailand	RRIT 251	23	23
	RRIT 408	18	16
	RRIT 3904	23	19
	RRIT 226	18	16

(S P Withanage, K K Liyanage, P V A Anushka, T T D Dahanayake, I D M J Sarath Kumara, T M S K Gunasekara and B W A N Baddewithana).

Evaluation of mother plant nursery

Eighteen genotypes including four out standings from 2011 hand pollinated progeny were selected for planting in 2018. Four years old trees of 2012 hand pollinated progeny were subjected to preliminary evaluation. Girth was measured in individual genotype at the height of 45 cm from the ground level and tapping was done at the same height. Morris - Mann tapping was processed during the cropping months (October - December). Latex from five consecutive tappings done at S2d3 was collected into a single tube and the dry weights were measured. Three such measurements were taken. Overall disease incidences, especially for *Corynespora*

leaf fall disease were recorded with the help of Plant Pathology Department. Top most genotypes are selected for further evaluation under small scale clone level (S P Withanage, P V A Anushka, A K Gamage, B W A N Baddewithana and T M S K Gunasekara).

Evaluation of previous hand pollinated (HP) progenies

Small Scale Clone Trials

The details of the small scale clone trials which maintained and monitored during the year under review are given in Table 4. However, due to heavy rainfall received throughout the year, the yield data collection in most of the trials was not possible.

Table 4. *Details of Small Scale Clone Trials*

HP year	Site	Planting season	Current status
1998	N'kele I, II & III	June 2001	9th year of tapping
	Kuruwita Substation I, II & III	July 2001	9th year of tapping
1999	Kuruwita Substation I, II & III	June 2002	7th year of tapping
2000	Delkeith IV & V	June 2003	7th year of tapping
	Elston VIII & IX	July 2003	7th year of tapping
2001	Paiyagala I	June 2006	5th year of tapping
2002	Pallegoda I	July 2007	3rd year of tapping
2002	Eladuwa II	May 2009	2nd year of tapping
2004	Eladuwa Trial I	July 2009	2nd year of tapping
2004	Neuchatel Trial II	Nov 2009	2nd year of tapping
2007	Kuruwita Sub station (seedlings)	July 2009	1st year of tapping
1995	Yatadola I	July 2011	1st year of tapping
2006	Payagala	July 2012	Immature
2005	Monaragala	Nov 2014	Immature
	Galewatta	May 2016	Immature
2008	Eladuwa	Nov 2016	Immature
2010	Eladuwa	Nov 2016	Immature

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

Evaluation of 1998 HP entries

Girth measurements for sixteen years were analyzed using Duncan's multiple range test for six trials at two sites separately. Yield data were collected only from Kuruwita site (T T D Dahanayake, S P Withanage, K K Liyanage, P V A Anushka, I D M J Sarath Kumara and A K Gamage).

Nivithigalakele Sub station (GPB/BST/HPS/98/01, 02, 03)

Six HP entries 98 HP - 138, 98 HP- 228, 98 HP- 225, 98 HP- 281, 98 HP-133 and 98 HP 269 were selected based on their yield, girth and bark thickness and considering the brown bast incidences. All these selections were taken into further evaluation of early selectable parameters to shorten the *Hevea* breeding and selection cycle (T T D Dahanayake, S P Withanage, K K Liyanage, P V A Anushka, I D M J Sarath Kumara and A K Gamage).

Kuruwita Sub station (GPB/BST/HPS/98/04, 05, 06)

Average yield for six years of genotypes 98-219, 98-105, 98-124, 98-143, 98-236, 98-98, 98-80, 98-68, 98-73 and 98-223 gave more than average 40 g/t/t yield. Genotype 98-80 and 98-219 were recorded highest mean yield of 53.7 g/t/t and 52 g/t/t respectively (P V A Anushka, S P Withanage, K K Liyanage, T T D Dahanayake and H P Peiris).

Evaluation of 1999 HP clones at Kuruwita Substation (GPB/BST/HPS/99/01, 02 & 03)

Girth measurements for fifteenth year and yield data for eighth year were not taken. However, based on the fortieth year girth data (Table 5b) and seventh year yield data (Table 5a), three HP entries (99-73, 99-167 and 99-64) having good yields and vigours growth were selected as Latex-timber clones. Almost all entries performed well and all top ranked HP entries had yielded from 40 g/t/t to 66 g/t/t along with good girth.

Table 5a. *Mean yield values for the 7th year tapping of the best performing 1999 HP progeny planted at Kuruwita Substation in 2002*

Trial 99-01		Trial 99-02		Trial 99-03	
Clone	**Mean yield based on nine TTs * (g/t/t)**	**Clone**	**Mean yield based on ten TTs* (g/t/t)**	**Clone**	**Mean yield based on nine TTs* (g/t/t)**
99-73	47.48^{a}	99-167	66.16^{a}	99-64	61.44^{a}
99-139	46.67^{a}	99-159	57.37^{ab}	99-120	48.79^{ab}
99-41	45.73^{a}	RRISL205	46.05^{bc}	99-189	48.75^{ab}
99-61	44.17^{a}	99-47	44.39^{bcd}	99-166	48.28^{ab}
99-81	42.17^{ab}	99-242	43.30^{bcd}	99-216	47.67^{ab}
99-134	42.14^{ab}	99-135	41.68^{bcd}	99-92	42.15^{bc}
99-80	38.96^{abc}	99-197	40.96^{bcde}	RRIC 121	39.16^{bcd}
99-69	36.78^{abcd}	99-185	39.62^{bcdef}	99-44	38.31^{bcde}
99-65	36.56^{abcd}	RRIC 121	37.63^{bcdef}	99-148	37.38^{bcde}
99-106	35.83^{abcd}	99-187	37.01^{bcdef}	99-138	36.19^{bcde}

Table 5b. *Mean girth values for the 14th year of the best performing 1999 HP progeny planted at Kuruwita Substation in 2002*

Trial 99-01 Mean girth (cm)		Trial 99-02 Mean girth (cm)		Trial 99-03 Mean girth (cm)	
Clone	**Girth**	**Clone**	**Girth**	**Clone**	**Girth**
99-139	85.5[a]	99-157	100.69[a]	99-230	88.37[a]
99-74	82.5[ab]	99-159	81.06[b]	99-156	87.14[ab]
99-73	82.25[ab]	99-167	79.9[bc]	99-216	77.75[abc]
99-67	80.06[abc]	99-47	78.38[bcd]	99-64	76.65[bcd]
99-81	70.9[bcd]	99-236	73-9[bcde]	99-92	76.31[bcd]
99-54	70.68[bcd]	99-161	72.25[bcdef]	99-166	73.56[bcde]
99-55	70.00[bcde]	99-272	71.86[bcdef]	99-63	72.5[cdef]
99-61	69.75[bcde]	99-178	71.63[bcdef]	RRIC 121	72.0[cdefg]
99-52	69.9[bcde]	99-194	70[bcdefg]	99-138	71.0[cdefgh]
99-83	69.33[bcde]	RRISL 205	69.67[bcdefg]	99-78	70.75[cdefghi]

Note. * TTs - test tapings

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

Evaluations at Dalkeith estate (GPB/BST/HPS/2000/04 and 05), Nivithigalakele 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)

In this trial, 112 genotypes derived from two families (RRIC 121 × PB 235 & PB 235 × RRIC 121) (56 from each family) had been planted in a completely randomized block design with three single tree plots per clone. Eleventh year girth and 6th year yield data and bark thickness of individual genotype were analyzed. Four genotypes with promising Latex - Timber properties were selected (Table 6).

Table 6. *Mean girth, yield and bark thicknesses of top most genotypes in trial IV at Dalkith estate, planted in 2003*

Genotype	Mean girth of eleventh year (cm)	Mean yield based on nine TTs * (g/t/t)	Mean bark thickness (mm)
2000HP-935	102[a]	61.44[a]	6.87
2000HP-585	101[ab]	48.79[ab]	7.02
2000HP-875	96[abc]	48.75[ab]	6.7
2000HP-568	93[abcd]	41.45[bc]	9.85

(S P Withanage and A K Gamage)

Dalkeith Estate Trial V, GPB/BST/HPS/2000/05

In this trial, 98 genotypes from two families [BPM 24 × PB 260 (53) and RRIC 121 × PB 260 (45)] were planted in a completely randomized design with three single tree plots per clone. Family mean, of the eleventh year girth and sixth year yield data and bark thickness of individual genotype were analyzed. Two genotypes which would be promising for Latex- Timber purpose were selected.

Table 7. *Mean girth, yield and bark thicknesses of top most genotypes in trial V at Dalkith Estate, planted in 2003*

Genotype	Mean girth of eleventh year (cm)	Mean yield based on nine TTs * (g/t/t)	Mean bark thickness (mm)
2000HP-1198	103[a]	61.44[a]	9.22
2000HP-1141	93[b]	48.79[ab]	7.9

(S P Withanage and A K Gamage)

Evaluation of 2001 HP clones - Payagala Estate (GPB/BST/HPS/2001/01) and Kuruwita Substation (GPB/BST/HPS/2001/02)

The mean girth of clones in eleventh year were grouped using the Duncan's multiple range test and top most promising HP entries are given in Table 8. The control clone RRISL 203 showed poor performance at Payagala estate with compared to Kuruwita Estate. When compared to control clone RRIC 121, five genotypes performed better at Payagala Estate. Top ranked HP entries in Kuruwita Substation (Table 9) had yielded from 50g/t/t to 86 g/t/t along with good girth.

Table 8. *Mean girth of top most HP entries of the 2001 HP progeny planted in 2006*

Payagala Estate		Kuruwita Sub-station	
Clone	**Mean girth (cm)**	**Clone**	**Mean girth (cm)**
2001 HP-110	69.97[a]	2001HP-220	67.82[a]
2001 HP-249	67.89[ab]	RRIC 121	66.75[ab]
2001 HP-199	67.79[ab]	2001HP-185	64.29[abc]
2001 HP-257	67.74[ab]	2001HP-179	61.42[abcd]
2001 HP -224	65.15[abc]	RRISL 203	60.4[abcd]
RRIC 121	62.72[bcd]	HP 205	59.7[abcd]
2001-112	61.74[cde]	2001HP-183	59.08[bcde]
2001-294	61.26[cde]	2001HP-20	58.83[bcd]
2001-92	61.12[cde]	2001HP-227	58.44[bcde]
2001-211	59.67[cde]	2001HP-89	57.18[cdef]

Table 9. *Mean yield of best performing 10 HP entries of the 2001 HP progeny planted in 2006*

Kuruwita Sub-station	
Clone	**yield (g/t/t)**
2001HP-170	86.62[a]
2001HP-87	70.57[ab]
2001HP-179	62.49[abc]
2001HP-205	57.84[abc]
2001HP-220	57.66[abc]
2001HP-185	54.22[abc]
2001HP-183	52.53[abc]
2001HP-89	51.91[abc]
2001HP-115	50.62[abc]
2001HP-159	48.33[abc]

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

Evaluation of 2002 HP clones

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

Tenth year girth measurements were taken and the mean girth of clones were grouped using the Duncan's multiple range test and the results are given in Table 10. Genotype 2002-18 performed better when compared to control clone RRISL 203.

Table 10. *Mean girth of best performing HP entries selected from the 2002 HP progeny planted in 2007*

Clone	Mean girth (cm)
2002-18	70.8[a]
RRISL 203	69.88[ab]
2002-96	69.47[abc]
2002-17	67.55[abcd]
2002-14	66.22[abcde]
2002-11	64.53[abcdef]
2002-24	63.95[abcdef]
2002-77	63.24[bcdef]
2002-67	62.72[cdefg]
2002-69	62.19[defgh]

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

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 block design was used with four replicates per genotype. Replicate size was six. Eighth year girth was taken

at the height of 150 cm from the bud union and mean girth values are shown in Table 11. Although second year yield data collection was started, only two test tappings were possible. However, according to the available data, genotype 2002 HP-138 recorded the highest yield around 52 g/t/t and the second highest was around 40 g/t/t in genotype 2002 HP-66. However, the yield of reference clones RRIC 121 and RRISL 203 were recorded 22 g/t/t and 24 g/t/t respectively.

Table 11. *Mean girth of best performing HP entries selected from the 2000 HP progeny planted in 2009 at Eladuwa*

Clone	Mean girth (cm)
2002HP-138	69.46[a]
2002HP-30	63.27[b]
2002HP-20	62.42[bc]
2002HP-66	62.22[bc]
2002HP-93	59.65[bcd]
RRIC 121	58.87[bcd]
2002HP-139	58.15[bcd]
2002HP-9	58.35[bc]
2002HP-19	55.88[cde]
2002HP-78	54.39[de]
RRISL 203	50.86[ef]

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

Evaluation of 2004 HP clones

Twenty two genotypes from 2004 hand pollination progeny had been planted in two trials at Eladuwa Estate and Nuechatle Estate in the year 2009. RRIC 121 was used as the control clones in Eladuwa Estate and RRIS 203 and PB 260 were used as control clone in Nuechattle Estate. Randomized block design was used with four replicates per genotype. Replicate size was six in both trials.

Neuchatle Estate trial I (GPB/BST/HPS/2004/01)

Eighth year girth was taken. Despite the instructions given to the estate management to take extra care on this trial, the performances of all HP entries as well as control clones were poor and they were not up to the expected level of growth (Table 12). However, it was noticed that the conditions of the surrounding fields established by the estate was also poor in growth possibly owing to substandard ground conditions. However, six HP entries were ranked above control clone PB 260.

Table 12. *Mean girth for 7th year of best performing HP-entries selected from the 2004 HP-progeny at Neuchatle Estate*

Clone	Mean girth of progeny (cm)
2004-298	54.13[a]
2004-115	53.45[ab]
2004-332	51.71[abc]
2004-228	51.62[abc]
2004-10	50.56[abcd]
2004-15	50.35[abcd]
PB 260	49.16[abcde]
2004-341	48.71[abcdef]
2004-346	48.36[abcdefg]
2004-268	48.05[abcdefg]

(P V A Anushka, S P Withanage, K K Liyanage and I D M J Sarath Kumara)

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

Seventh year girth was taken. The HP entry 2004–347 showed significantly higher girth and five entries ranked above the RRIC 121 (Table 13).

Table 13. *Mean girth for 7th year of top most HP-entries selected from the 2004 HP- progeny planted at Eladuwa Estate*

Clone	Mean girth (cm)
2004-347	55.9[a]
2004-107	55.9[a]
2004-48	55.09[ab]
2004-190	54.19[abc]
2004-228	54.1[abc]
RRIC 121	53.82[abcd]
2004-320	53.27[abcde]
2004-50	51.81[abcde]
2004-164	50.87[bcde]
2004-456	49.5[cdef]

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

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

Ninth year girth data were collected for the seedling progeny and family means are given in Table 14. Family **RRIC 130 x GP 1-2** recorded the highest girth. First year tapping data were also collected from the above progeny and family means are given in Table 15. Family RRIC 130 x GP 44 - 24 recorded the highest yield (g/t/t).

Table 14. *Family girth means of 2007 HP - progeny at the Kuruwita Substation planted in 2008*

Clone	Mean girth (cm)
RRIC 130 x GP 1-2	65[a]
RRIC 130 x GP 22- 137	63.60[a]
RRIC 130 x GP 21 - 163	63.35[a]
PB260 x 45/710	59.15[a]
RRIC 130 x GP 10 -154	59[a]
45/710 x PB 260	58.98[a]
RRIC 130 x GP 44 - 24	51.50[a]

Table 15. *Mean yield of 2007 seedling HP progeny planted in 2009*

Clone	Mean girth (cm)
RRIC 130 x GP 44 - 24	41.14[a]
45/710 x PB 260	37.64[a]
PB260 x 45/710	34.28[a]
RRIC 130 x GP 22- 137	31.79[a]
RRIC 130 x GP 10 -154	26.61[a]
RRIC 130 x GP 21 - 163	22.19[a]
RRIC 130 x GP 1-2	19.62[a]

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

Evaluation of 2005 HP progeny planted in 2014 at Monaragala GPB/BST/HPS/2005/01

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. Complete randomized block design was used with 10 replicates per genotype. Screening of genotypes against *Corynespora* leaf fall disease was conducted with the help of Plant Pathology and Microbiology Department. Third year girth was measured (Table 16).

Table 16. *Mean girth of 2005 HP progeny planted in 2014 at Monaragala Substation*

Clone	Girth (cm)	CLF disease incidence
2005 HP 07	8.4^{a}	Moderate
2005 HP 49	7.75^{ab}	Moderate
RRIC 103	7.75^{ab}	Susceptible
2005 HP 10	7.63^{abc}	Resistant
2005 HP 06	7.57^{abc}	Moderate
2005 HP 19	7.5^{abcd}	Resistant
2005 HP 09	7.14^{abcde}	Susceptible
RRISL 201	7^{abcdef}	Moderate

(S P Withanage, K K Liyanage, P V A Anushka, T T D Dahanayake and W A D R Tharanga)

Evaluation of 2005 HP progeny planted in 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 Galewatta division with control clones RRIC 100, RRIC 103, RRIC 52, PB 86 and RRISL 201. Complete randomized block design was used with 10 replicates per genotype. Screening of genotypes against Corynespora leaf fall disease was conducted with the help of Plant Pathology and Microbiology Department. First year girth was measured (Table 17).

Table 17. *First year mean girth of 2005 HP progeny planted in 2016 at Galewatta*

Clone	Girth (cm)	CLF disease incidence
2005HP 17	8^{a}	Resistant
2005HP 32	7.7^{ab}	Resistant
RRIC 100	7.64^{ab}	Resistant
2005HP 13	7.5^{abc}	Moderate
PB 86	7.46^{abcd}	Resistant
2005HP 22	7.13^{abcde}	Resistant
2005HP 49	7^{abcde}	Resistant

(S P Withanage, K K Liyanage, P V A Anushka, T T D Dahanayake and W A D R Tharanga)

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

Sixteen genotypes selected from 2010HP 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, manuaring, off shoots

removing *etc.* were done according to RRISL recommendations (S P Withanage, T T D Dahanayake, P V A Anushka, K K Liyanage and A K Gamage).

Evaluation of 2008 HP progeny planted in 2016 at Eladuwa GPB/BST/HPS/2008/02

Eighteen genotypes selected from 2008 progeny were planted in Eladuwa estate in a complete randomized block design with control clones PB28/59, RRIC 121, and RRIC 100. All agronomical practices such as weeding, manuaring, off shoots removing *etc.* were done according to RRISL recommendations (S P Withanage, P V A Anushka, T T D Dahanayake, K K Liyanage and W A D R Tharanga).

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

Annual girth measurements were taken from all the trials. Table 18a (registered clones) and 18b (unregistered clones) show the girth measurements for the year under review and for the previous two years and the planting sites.

Table 18a. *Mean annual girth measurements for registered clones of ECTs (Estate/RRISL Collaborative Trials)*

Clone	Site	Year of planting	Girth in cm		
			2015	2016	2017
RRISL 201	Dammeria B	2010	26.54	33.2	43.38
RRISL 203	Monaragala	2009	41.6	44.56	46.96
	Wewassa	2011	24.54	32.64	46.42
	Lagos	2011	39.3	47.06	53.23
	Muwankanda	2010	38.27	43.41	48.51
	Dammeria B	2010	29.21	34.2	39.4
	Kamburupitiya (University)	2011	45.9	**52.17**	**58.46**
RRISL 207	Dosert division **	2004	62.5	-	-
RRISL 208	Dartonfield	1994	76.17	77.19	76.94
	Lagos	2013	20.52	31.76	40.19
	Moralioya	2010	42.35	49.06	Not taken
	Dammeria B	2010	25.2	30.0	37.13
RRISL 210	Payagala	2006	62.14	63.51	64.55
RRISL 211	Dartonfield	1994	73.29	75.43	78.92
RRISL 212	Kuruwita	2006	54.92	56.7	57.81
RRISL 214	Dosert division**	2004	52.36	-	-
	Kuruwita	2006	49.97	51.7	53.025
RRISL 216	Dartonfield	1994	79.29	79.56	79.56
RRISL 217	Kuruwita	1995			

Clone	Site	Year of planting	Girth in cm		
RRISL 219	Dartonfield	1994	83.62	85.86	89.25
	Kuruwita	2008	47.46	49.09	50.56 (5')
RRISL 2000	Dosert division**	2004	66.45	-	-
	Kuruwita	2005	65.09	66.9	69.09
RRISL 2001	Dammeria B	2010	39.1	46.6	56.72
	Muwankanda	2010	38.38	45.46	52.22
	Dammeria B (Hanipe Dev.)	2011	26.9	34.6	53.72
	Lagos	2013	19.03	30.08	40.33
	Dosert division**	2004	61.65	-	-
RRISL 2002	Dosert division**	2004	62.02	-	-
RRISL 2003	Dosert division**	2004	58.83	-	-
	Lagos	2013	21.39	35.15	43.71
RRISL 2004	Dosert division	2004	55.63	-	-
RRISL 2006	Dosert division*	2004	67.1	-	-
	Lagos	2013	17.21	25.26	33.26
	Monaragala	2009	47.15	50.28	53.11
	Eladuwa	2009	45.62	-	55.26
	Moralioya*	2010	44.65	51.3	Not taken
RRISL 2100	Payagala**	2006	61.28	62.41	-
	Monaragala	2009	50.47	52.1	53.63
	Edalla	2010	42.08	51.5	52.76
	Kuruwita	2011	31.96	41.77	47.94
RRISL Centennial 3	Kuruwita	2009	52.42	57.58	57.35 (5')
	Monaragala*	2009	44.78	47.2	49.61
	Eladuwa	2010	-	59.86	60.3
	We-oya	2010	48.75	52.66	55.7
	Edalla	2010	46.62	55.55	57.41
	Kuruwita	2010	36.23	46.41	53.21
	Siriniwasa	2011	45.89	-	56.87
	Lagos	2013	23.63	33.3	45.10
RRISL Centennial 4	Pallegoda	2007	64.9	-	-
	Kuruwita	2007	53.95	55.1	56.48(5')
	Eladuwa	2009	46.96	52.02	53.43
	Monaragala	2009	49.48	51.0	52.66
	Lagos	2011	36.72	46.06	53.77
RRISL Centennial 5	Pallegoda	2007	63.5	67.6	-
	Eladuwa	2009	45.46	52.8	56.13
	Kuruwita	2007	54.8	57.66	59.9 (5')

Table 18b. *Mean annual girth measurements of un-registered 2004- entries selected to ECTs (Estate/ RRISL Collaborative Trials)*

Clone	Site	Year of planting	Girth in cm		
			2015	2016	2017
78-140**	Eladuwa	2006	53.25	53.38	
78-198**	Eladuwa	2006	63.5	64.38	
78-150**	Nivitigalakele	2006	73.50	79.43	
78-260**	Eladuwa	2006	56.23	57.24	
78-298	Kuruwita	2006	57.9	60.26	61.42
78-334**	Eladuwa	2006	63.19	63.71	
78-341**	Eladuwa	2006	58.09	58.69	
78-510	Kuruwita	2006	58.64	60.58	63.04
78-534	Kuruwita	2006	54.65	57.37	59.3
78-689**	Eladuwa	2006	56.24	56.71	
78-759	Kuruwita	2006	54.93	56.47	58.09
78-770	Kuruwita	2006	56	57.78	58.92
78-873	Kuruwita	2006	56.16	57.89	60.29
86-10	Kuruwita	2009	42.82	46.65	48.05
86-87	Kuruwita	2009	45.13	49.89	
87-235	Kuruwita	2008	42.76	46.97	50.05
92-129	Pallegoda	2007	60.9	64.8	
	Kuruwita	2007	53.41	55.91	57.53 (5')
92-250	Pallegoda	2007	66.6	74.76	
92-279	Pallegoda	2007	63.38	72.76	
95-33	Kuruwita	2004	53.27	-	
95-55	Kuruwita	2004	56.16	-	
95-55	Lagos	2013	19.96	30.63	43.36
GP 12-93	Kuruwita	2006	53.27	55.12	56.21
GP 22-137**	Payagala	2006	65.35	68.46	
GP 44-24**	Payagala	2006	56.84	58.6	
RRIC 100 seedlings	Kuruwita	2005	64.6	66.5	68.88 (5')

Note :

* Immature trials

**Terminated due to heavy brown bast incidences and low yield

The fields were used to test exogenous application of ascorbic acid which is carried out under NSF project. Details are given under the NSF project.

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

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

The average estate yields obtained from ECT trials are given in Table 19.

Table 19. *Average yield (g/t/t) of the Clones in 14th year of tapping, of ECT trials at Galewatta*

Clone/Selected HP- entry	Average (g/t/t)
RRISL 208	58.64
RRISL 211 (S2/d2) *	66.65
RRISL 211 (S2/d3) *	66.22
RRISL 216	50.5
RRISL 219	39.5

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

Evaluation of clones under smallholder conditions

Smallholder/RRI collaborative clone trial 1

Mean girth values of three clones obtained from two sites planted in year 2001 are given in Table 20.

GPB/BST/SRT/2001 and trial 2 - GPB/BST/SRT/2003

The smallholder trial at Kamburupitiya was terminated due to a change in the ownership as the new owner refused to continue the trials for precise data collection. However, only girth data were taken in other two trials and proper yield data collection is still a problem due to low rubber prices and tapper scarcity.

Table 20. *Mean girth (cm) of the trees of Smallholder/RRI collaborative clone trial 1 planted in 2001*

Site	Clone	Planting year	Girth (cm)
Kegalle	RRISL 201	2001	87.03
	RRISL 203	2001	74.25
Godagama	RRISL 205	2001	77.7
	RRISL 201	2001	74.5
	RRISL 203	2001	69.3

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

Terminations

Three smallholder evaluation trials established at Anamaduwa (SRT - NWP15/1 L A Karunawathie, Uriyawa, Anamaduwa, SRT - NWP 15/2 H M Somalatha, Uriyawa, Anamaduwa, SRT - NWP 15/3 Ven; Dhammananda Tero, Kelegama, Anamaduwa were terminated due to prevailing drought condition and poor support given by the farmers (P V A Anushka, S P Withanage and T B Dissanayake).

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

Multiplication/ Establishment and scientific evaluation of the *Hevea* germplasm collection was started with the aim of enhancement of productivity through genetic improvement and management of genetic resources of *Hevea.* Around 1400 accessions were planted at Nivitigalakele Substation and some accessions are ready to establish in bud wood nurseries at Neuchatle Estate.

One thousand eight hundred and thirty number of accessions were selected for this year multiplication and establishment. All these accessions were preliminary characterized under different categories such as early and late wintering, high girth, dwarf, tall, smooth bark *etc.* Then they were pollarded and established in a seedling nursery for bud grafting. Planting in Nivitigalakele Substation was completed (S P Withanage, K K Liyanage, P V A Anushka, T T D Dahanayake, I D M J Sarath Kumara, B W A N Baddewithana and T M S K Gunasekara).

Testing of promising clones for sub optimal conditions

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

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

Seven experimental plots were established at Padiyathalawa/Maha Oya areas in the eastern province. Their control (reference) plot was established at Bandaragama which belongs to traditional rubber growing region. Details of these trials are given in Table 21.

Table 21. *Details of smallholder/RRI collaborative trials at Eastern Province with their third year girth*

Trial	Smallholder and Location	Agro climatic Region	75% expectancy value of annual rainfall (mm)	Clones planted	Fifth year girth (cm)
SRT-EP 12/1	SM Wirawardana Marawa Padiyathalawa	IL2	> 1600	RRISL 2001	37.45
				RRISL 203	37
				RRISL 2005	36
				RRISL 2006	32.65
SRT-EP 12/2	Indrani Kusumalatha Marawa Padiyathalawa	IL2	>1600	RRISL 203	49.14
				RRIC 121	44.57
				RRISL 2001	45.66
				RRISL 2006	41
SRT-EP 12/3	AM Sumanawathi Helakomana Padiyathalawa	IL2	> 1600	RRISL 203	38.3
				RRIC 100	36.8
				RRISL 2005	38.4
				RRISL 208	33.9
SRT-EP12/4	HM Wimalasena Kudaharasgala Mahaoya	IL2	> 1600	RRISL 208	34.7
				RRISL 2005	34.9
				RRIC 100	33.5
				RRISL 203	32.3
SRT-EP 12/5	YB Thilakarathna Harasgala, Mahaoya	IL2	>1600	RRISL 203	The smallholder expired and trial was abundant
				RRIC 121	
SRT-WP 12/8	Ranjith Thambawita Bandaragama Panadura (Kalutara district – Control Trial)	WL 1a	>3300	RRISL 208	46.5
				RRISL CEN3	47.6
				RRISL 2001	48.5
				95-55	49.0
				RRISL 203	44.3
				RRIC 100	43.4
				RRISL211	43.8
				RRISL 2005	44

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

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

Five experimental plots were established at Ampara area in the Eastern Province. However, one trial was given up due to poor support received from the smallholders (Table 22).

Table 22. *Details of smallholder/RRI collaborative clone trials planted in 2013 at Eastern Province and fourth year of mean girth*

Trial	Smallholder & Location	Agro climatic Region	75% expectancy value of annual rainfall (mm)	Clones planted	Forth year mean girth (cm)
SRT-EP 13/1	HM Jayarathna 17-1 C, Lathugala Warankatagoda	DL2a	> 1300	RRIC 121 (210)	27.35
SRT-EP 13/4	HM Saman Kumara 17/1 B, Lathugala Warankatagoda	DL2a	> 1300	RRISL 203 (210)	25.25
SRT-EP 13/5	M Chandrani Ranasingha 51 B – 2, Lathugala Warankatagoda	DL2a	> 1300	RRISL 203 (210)	21.07

(S P Withanage, K K Liyanage, T T D Dahanayake 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 23 with their third year mean girth.

Table 23. *Details of smallholder/RRI collaborative clone trials planted in 2014 in the Eastern Province with their third year mean girth*

Trial	Smallholder and Location	Agro climatic Region	75% expectancy value of annual rainfall (mm)	Clones planted	Third year of girth (cm)
SRT-EP 14/1	G Senevirathne Mahaoya	IL2	>1600	RRIC 121 (210)	19.55
SRT-EP 14/2	M Senevirathne Mahaoya	IL2	> 1600	RRISL 2001 (210)	17.33
SRT-EP 14/3	AM Jayasekara Mahaoya	IL2	>1600	RRISL 2006 (210)	19.59
SRT-EP 14/4	TM Amarasena Mahaoya	IL2	>1600	RRISL 2005 (210)	19.57

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

Smallholder/RRI collaborative clone trial planted in 2014 - Uva Province

Four experimental plots were established in Monaragala district and their details are given in Table 24. It has observed poor growth in all plots.

Table 24. *Details of smallholder/RRI collaborative clone trials planted in 2014 at Uva Province with their third year of girth*

Trial	Smallholder and Location	Agro climatic Region	75% expectancy value of Annual Rainfall (mm)	Clones planted	Third year of girth (cm)
SRT-UP 14/3	PTG Newton Etiliwewa	DL 1a	>1100	RRIC 121 (210)	8.15
				RRISL 2100 (210)	6.1
				RRISL 203 (210)	8.6
				RRISL 2001 (210)	8.75

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

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

Four experimental sites were established in Bibile area in collaboration with World Vision Organization. One trial was established in Kataragama. Details are given in Table 25. Girth data were not taken due to poor girth performance. In Kataragama trial majority of the first year plants are destroyed due to the heavy dry spell and all the damaged plants were replaced again in 2017.

Table 25. *Details of smallholder/RRI collaborative clone trials planted in 2015 at Uva Province with their second year of girth*

Trial	Smallholder & Location	Agro climatic Region	75% expectancy value of Annual Rainfall (mm)	Clones & the number of plant	Second year of girth (cm)
Bibile (collaborate with World Vision)					
SRT-UP 15/1-WV	HM Punchibanda Ilukpathana	IL1c	>1300	RRISL 2001 (215)	Not taken
SRT-UP 15/2-WV	AM Karunawathie Ilukpathana	IL1c	>1300	RRISL 2001 (215)	Not taken
SRT-UP 15/3-WV	HMW Wijekumara Kudumirisketiya Ilukpathana	IL1c	>1300	RRISL 2001 (430)	Not taken

Trial	Smallholder & Location	Agro climatic Region	75% expectancy value of Annual Rainfall (mm)	Clones & the number of plant	Second year of girth (cm)
SRT-UP 15/4-WV	Chandana Kumara Radaliyagoda Ilukpathana	IL1c	>1300	RRISL 2001-(115)	Not taken
Kataragama					
SRT-UP 15/5	GK Chaminda Diyawaragmmana Junction, Sella Rd	DL 5	>650	RRISL2001 RRISL 203 (215)	NA

Note. NA - Not Available

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

Smallholder/RRI collaborative clone trial planted in 2015 – Central Province

Three experimental trials were established in Matale district and one trial (SRT-CP/15/3) was terminated due to the poor support given by the smallholder. Details on the second year girth are given in Table 26.

Table 26. *Details of smallholder/RRI collaborative clone trials planted in December 2015 at Central Province with their second year of girth*

Trial	Smallholder & Location	Agro climatic Region	75% expectancy value of annual rainfall (mm)	Clones planted	Girth (cm) on June (around 18 months)
SRT- CP 15/1	W Wekunagoda Palapaththla Seelan Estate Koongahamulla Palapathwala	IM3B	>1200	RRISL 2001 (125) RRISL 2005 (125) RRISL 2006 (125) RRISL 2100 (125)	4.34 5.36 4.78 5.00
SRT- CP 15/2	PM Gunasekera Palapaththla Madawalaulpotha			RRISL 2001 (125) RRISL 2005 (125) RRISL 2006 (125) RRISL 2100 (125)	Not taken due to heavy weeds

(T T D Dahanayake, S P Withanage, P V A Anushka and T B Dissanayake)

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 27.

Table 27. *Details of smallholder/RRI collaborative clone trials planted in 2015 at North Central Province with their second year of girth*

Trial	**Smallholder and Location**	**Agro climatic Region**	**75% expectancy value of annual rainfall (mm)**	**Clones planted**	**Girth (one and half year) (cm)**
SRT-NCP 15/1	Army camp Kandakaduwa Polonnaruwa	DL1c	>900	RRISL 2001 (500)	6.51
				RRISL 2006 (500)	5.77

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

PLANT SCIENCE

N M C Nayanakantha

DETAILED REVIEW

Staff

Dr N M C Nayanakantha, Head of the Department, Mr T U K Silva, Mrs S A Nakandala, Miss B M S S Panditharathna, Research Officers, Mrs G A S Wijesekera, Mrs R K Samarasekara, Mr D L N de Zoysa, Mr P D Pathirana and Mr P K W Karunatilaka, Experimental Officers, R Handapangoda and Mrs E U M de Z Dissanayake, Technical Officers, Mrs D E Jayawardena and Mrs P D A H M A de Almeida, Management Assistants were on duty throughout the year.

Mr T U K Silva was promoted to Senior Research Officer with effect from 12.09.2017. Ms S Watawala and Mrs D Madushani were appointed as Technical Officers with effect from 02.01.2017, Mr Dilan Amendra and Ms H Subasinghe were appointed as Technical Officers with effect from 10.07.2017, Mr D Priyadarshana and Mrs U N Udayakumari were appointed as Technical Officers with effect from 24.07.2017 and 27.11.2017 respectively.

Mr M N de Alwis left on 22.10.2017 to attend a training programme in Thailand. Mrs K S D N Senanayake, Research Officer, Mrs Dinesha Madushani, Mr Dilan Amendra and Mr H A U Deshappriya, Technical Officers resigned from RRISL with effect from 29.09.2017, 16.10.2017, 06.10.2017 and 17.02.2017 respectively.

Research students

- Ms K A U Madushani, Eastern University of Sri Lanka, conducted her final year project on "Effect of nitric oxide donor sodium nitroprusside on germination dynamics and seedling attributes of rubber (*Hevea brasiliensis*)" under the supervision of Dr N M C Nayanakantha.
- Mr N D K Gayashan, Uva Wellassa University, conducted his final year project on "Effect of polybag size on growth attributes of rubber (*Hevea brasiliensis*) seedlings" under the supervision of Dr N M C Nayanakantha and Dr P Seneviratne.

Seminars/Training Programmes/Workshops/Exhibitions conducted

Subject/Theme	No. of programmes	Beneficiary/Client	Officers involved
Nursery Management	16	University students NIPM students Agricultural Diploma students Rubber Development Officers Smallholders Animators of STARR Project	NMC Nayanakantha
Tapping	12	Managers of RPCs University students NIPM students Agricultural Diploma students Animators of STARR Project	NMC Nayanakantha
Field Establishment & Immature Upkeep	02	NIPM students Animators of STARR Project	NMC Nayanakantha
Coconut, Rubber, Tea Exhibition (CRT 2017)	01	Rubber stakeholders	NMC Nayanakantha TUK Silva PKW Karunathilaka
Rubber based farming systems	04	Rubber Development Officers, NIPM students, University students	TUK Silva
Tapping	01	University of Jaffna	TUK Silva
Nursery Management (Practical session)	09	University students NIPM students District Agriculture Department Aquinas Institute students Rubber Development Department Officers	DLN de Zoysa R Handapangoda
Field Establishment and Immature upkeep (Practical session)	10	University students NIPM students District Agriculture Department Aquinas Institute students Rubber Development Officers	DLN de Zoysa R Handapangoda
Latex Harvesting (Practical session)	01	University students NIPM students District Agriculture Department Aquinas Institute students Rubber Development Officers	RK Samarasekera PKW Karunathilaka
Tapper training	07	Rubber Development Officers School of Agriculture students Staff and Tappers of some RPCs	PKW Karunathilaka

Seminars/Conferences/Meetings/Workshops attended

Officer	Subject	Organization
NMC Nayanakantha	Workshop/Meetings and Module preparation on introduction of new subject (Plantation Crop Management Technology) for A/L	National Institute of Education, Maharagama
	Workshop on "Seed Act"	Seed Certification Centre, Gannoruwa
	Seminar on "Latest Advances in Sample Preparation"	Hemsons (Pvt.) Ltd. Colombo
	1st International Symposium on Agriculture - 2017	Eastern University, Chenkalady, Batticaloa
	Technical Evaluation Committee for purchasing of polybags for government nurseries	Rubber Development Department
NMC Nayanakantha SA Nakandala TUK Silva DAS Senanayake SS Panditharathna	Scientific Committee Meeting	Rubber Research Institute of Sri Lanka
NMC Nayanakantha SA Nakandala TUK Silva DAS Senanayake SS Panditharathna	Research Reviews (Internal/ External)	Rubber Research Institute of Sri Lanka
TUK Silva W Karunathilaka DE Jayawardana	Laboratory Accreditation Workshop	SLS/Rubber Research Institute of Sri Lanka
MN de Alwis	Training programme on rubber agronomy and technology	Chachongsao Rubber Research Centre, Rubber Research Institute, Thailand
R Handapangoda	Disaster Management	Disaster Management Department, University of Peradeniya

Services

Testing the quality of polythene

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

Supplying of marking plates

About 54 marking plates (d2, d3 and CUT) were issued to stakeholders (N M C Nayanakantha, W Karunathilaka and D E Jayawardana).

Issuing authentic budwood

About 400 meter of budwood were issued to some other departments of RRISL and some 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 15, 16 and 17 (N M C Nayanakantha, B M S S Panditharathna, M N de Alwis, L N de Zoysa and R Handapangoda).

Visits

Advisory	- 85
Experimental	- 430
Nursery inspection	- 42
Total	- 557

LABORATORY INVESTIGATIONS

Tissue culture

No lab work was done at RRISL (N M C Nayanakantha 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)

Wintering and flowering were observed in 26 clones at six estates and one smallholder field (Dompe) during January-February. Majority of the clones completed wintering during 2nd-3rd week of February (N M C Nayanakantha and P D Pathirana).

Seed production (CC/2003/1/b)

Seeds of 26 clones were collected from six estates and one smallholder field (Dompe) (Fig. 1). A slight increase in seed production was recorded for 2017 than for 2016 irrespective of clones and sites. A satisfactory seed production was recorded from RRISL 201 at Salawa and Kuruwita, PB 86 at Dompe, RRISL 217 and RRIC

133 at Kuruwita, BPM 24 at Millewa and RRIC 100 at Dompe. Unfortunately, the clones such as RRIC 121, RRISL 203 and 2001 recommended for the smallholders have recorded a low seed yield in current year similar to that in previous years (N M C Nayanakantha and P D Pathirana).

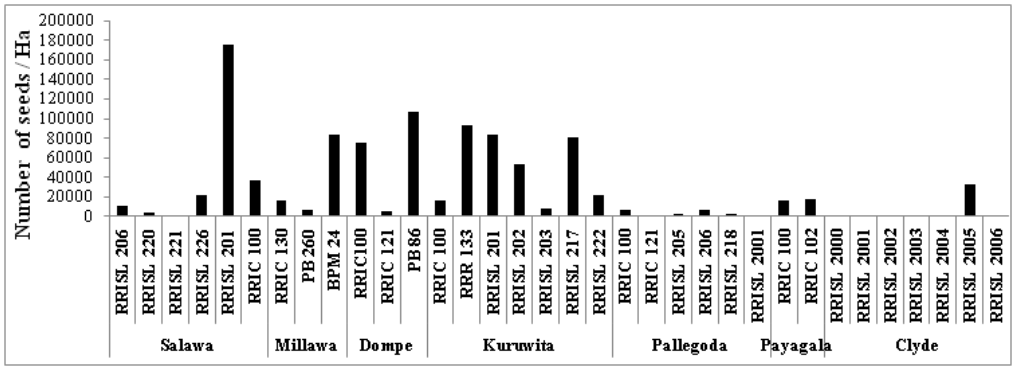

Fig. 1. Total seed production in each clone in different estates

Investigation on alternative and cost-effective sowing media for river sand for germination of rubber seeds (SM/ 2016/Dartonfield)

Rubber seeds (somewhat old and collected 2-3 weeks after falling) brought to the government rubber nursery, Gurugoda, were sown in different sowing media as depicted below;

Control : River sand
Treatment 1 : Elephant dung (dried)
Treatment 2 : Coir dust (leached)
Treatment 3 : Rubber wood chips
Treatment 4 : River sand + coir dust (leached) (1:1)
Treatment 5 : Rubber wood saw dust
Treatment 6 : River sand + Purified sea sand (1:1)
Treatment 7 : Gravel
Treatment 8 : Quarry dust (fine)
Treatment 9 : Purified sea sand

Germination occurred 12-14 days after sowing. After three weeks of sowing, a satisfactory germination was recorded from seeds sown in elephant dung and coir dust as compared to river sand (Fig. 2) (N M C Nayanakantha, B M S S Panditharathna and E U M de Z Dissanayake).

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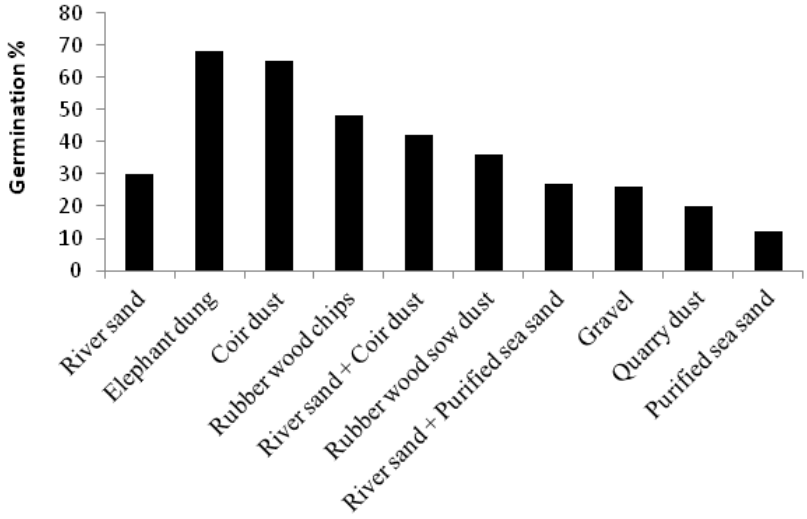


Fig. 2. Effect of sowing media on germination of rubber seeds after 21 days of sowing

Priming of rubber seeds for improved germination dynamics, seedling and budded plant attributes and tolerance to abiotic stresses (ST/2013/DF)

Fresh rubber seeds (about 3500) of clone RRISL 217 were collected and soaked in nitric oxide (NO) donor sodium nitroprusside (SNP) solutions at different concentrations for 24 hours as shown below;

T1 = Control (no soaking)
T2 = Soaked in water
T3 = Soaked in 50µmol SNP
T4 = Soaked in 100µmol SNP
T5 = Soaked in 150µmol SNP

Seeds were sown in a germination bed (according to a randomized complete block design) after storing at room temperature and at different time periods *viz.*, 0, 7, 14, 21 and 28 days, respectively. Each treatment had 140 seeds for each storage interval, 35 seeds in each of 4 blocks. No germination was recorded after 28 days of storage irrespective of priming treatments. At zero day of storage, there was no significant difference in germination percentage. After the 7^{th}day of storage, a significantly ($p \leq 0.05$) higher germination percentage was recorded with SNP at 50 µM [80. 7% (after 7 days) and 99.2% (after 14 days) of sowing] as compared to the control [60% (after 7 days) and 75.7% (after 14 days) of sowing]. After the 14^{th} and 21^{st} day of storage, a significantly ($p \leq 0.05$) higher germination percentage was recorded with SNP at 50 and 100 µM when compared to the control and mock treatment after 21 days of sowing (Fig. 3).

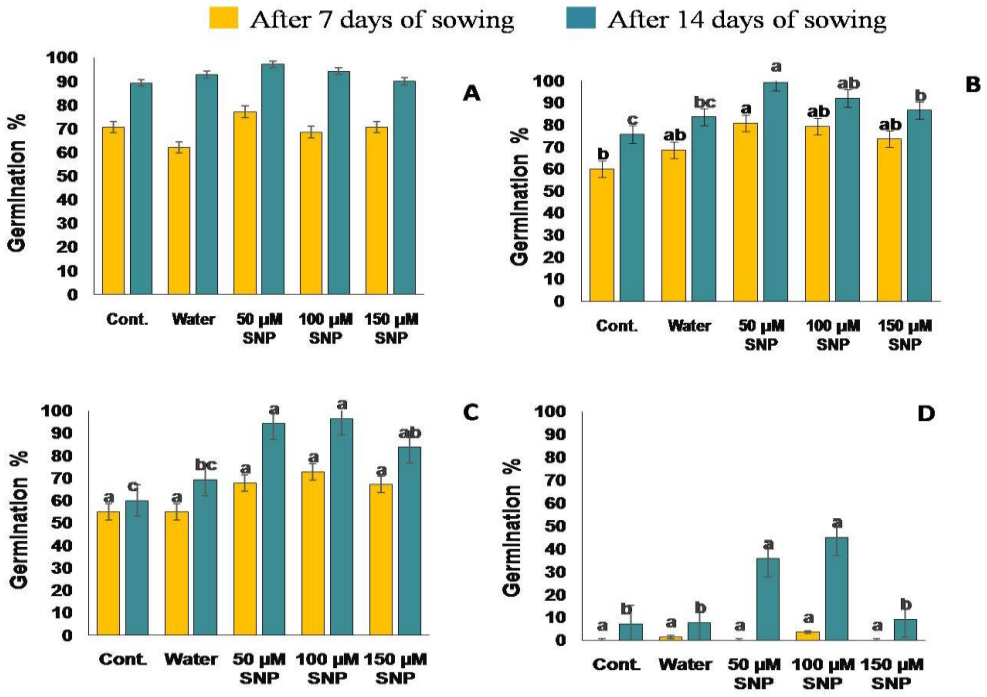


Fig. 3. Effect of NO donor SNP on germination percentage of rubber seeds after 0 day (A), 7 days (B), 14 days (C) and 21 days (D) of storage. Means with same letter are not significantly different at $p \leq 0.05$ according to DMRT

There was no significant difference in growth attributes *viz.*, stem height, stem diameter, leaf area, leaf chlorophyll content, dry weight of shoots and roots of the seedlings raised from seeds primed with SNP as compared to those of control or mock treated seeds after zero day of storage and two months of transplanting. Nevertheless, after 7 days of storage, significantly ($p \leq 0.05$) higher leaf area (380.7 cm^2/ plant) and chlorophyll (50.6) values were recorded from seedlings raised from seeds primed with SNP at 150 µM as compared to those of control seeds (212.6 cm^2/ plant and 47.6) respectively. Further, after 14 days of storage, significantly higher chlorophyll values were recorded from seedlings raised from seeds primed with SNP at 50 (50.3) and 100µM (50.0) as compared to those of control seeds (46.1). After 21 days of storage, a significantly higher shoot dry weight value was recorded from seedlings raised from seeds primed with SNP at 100 µM (2.7 g) as compared to those of control (1.1 g) seeds. After 4 months of transplanting, a significantly higher stem diameter value was recorded from seedlings raised from seeds primed with SNP at

100 µM (6.1mm) as compared to those of control seeds (5.1 mm) (N M C Nayanakantha, K A U Madhushani and E U M de Z Dissanayake).

Priming of rubber seedling/budded plants for improved growth attributes and tolerance to abiotic stresses (PR/2013/DF)

Effect of sodium nitroprusside (nitric oxide donor) as a chemical priming agent or Moringa (Moring aoleifera) leaf extract (MLE) as a biostimulant/botanical for growth improvement and abiotic stress alleviation in rubber plants

Field experiment at Nottinghill Private Estate, Mawathagama

A medium holder's rubber field of clone RRISL 203 (three months old) in Mawathagama (Intermediate Zone) was selected for the study. Plants were spray treated (primed) with SNP or aqueous MLE at different concentrations at monthly intervals for six months as shown below;

T1 - Control
T2 - Water
T3 - 5% MLE
T4 - 10% MLE
T5 - 15% MLE
T6 - 100 µM SNP
T7 - 150 µM SNP
T8 - 200 µM SNP

There were three blocks and each block had 20 plants. Four plants were imposed with each treatment in each block according to a randomized complete block design (RCBD). Girth was recorded before and after 3 months of treatment imposition. Physiological parameters *viz.,* net photosynthesis (*Pr)* and stomatal conductance (g_s) were recorded using a portable photosynthesis system (LI-6400). Leaf water potential (Ψ) was recorded using pressure chamber equipment, after three months of treatment imposition. Chlorophyll content was measured using a SPAD-502 plus Chlorophyll meter.

Significantly higher net photosynthesis and chlorophyll values were recorded from plants primed with MLE at all three concentrations as compared to control after three months from treatment imposition (Table 1). A significantly higher girth was recorded from plants treated with MLE at 15% concentration as compared to control after three months of treatment imposition (Table 1). A significantly higher net photosynthesis values were recorded from SNP treated plants at 100 µM & 150 µM concentrations as compared to control after three months from treatment imposition (Fig. 4). The leaf water potential increased in response to SNP treatments as compared to control (Fig. 5). Interestingly, a significantly higher girth was recorded

from plants treated with SNP at 200 µM concentration as compared to control after three months from treatment imposition (Table 2).

Table 1. *Effect of MLE on net photosynthesis, chlorophyll content and growth of Hevea under sub-optimal climatic conditions in Mawathagama, IZ*

Treatment	Net photosynthesis rate (µmol m^{-2} s^{-1})	Chlorophyll content (SPAD value)	Girth (cm) at day 0	Girth (cm) after 3 months
Control	14.00 ± 2.01^{b}	51.66 ± 0.17^{b}	4.54 ± 0.11^{a}	5.78 ± 0.08^{b}
Water	16.00 ± 0.70^{ab}	52.53 ± 0.49^{b}	4.44 ± 0.07^{a}	6.43 ± 0.48^{ab}
5% MLE	18.53 ± 0.31^{a}	55.83 ± 1.05^{a}	4.27 ± 0.10^{a}	6.66 ± 0.14^{ab}
10% MLE	19.33 ± 0.33^{a}	56.10 ± 1.51^{a}	4.54 ± 0.19^{a}	6.83 ± 0.10^{ab}
15 % MLE	19.53 ± 0.86^{a}	58.36 ± 0.67^{a}	4.45 ± 0.06^{a}	7.00 ± 0.31^{a}
$LSD_{0.5}$	3.641	2.777	0.3205	1.051

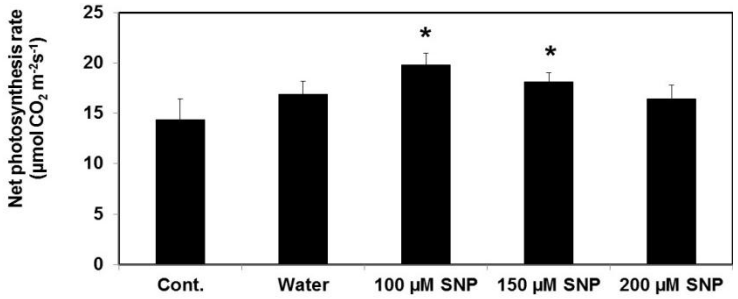


Fig. 4. Effect of exogenous NO donor SNP on net photosynthesis of *Hevea* after three months from treatment imposition. Data presented are the means ± SEs (n = 3). * indicates significant difference at $p \leq 0.05$ according to Dunnett's t test ($LSD_{0.05}$=2.653)

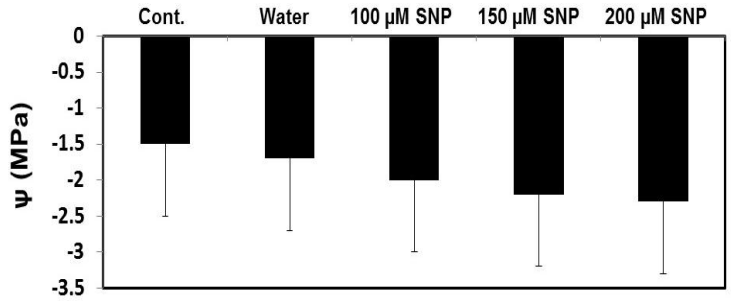


Fig. 5. Effect of exogenous NO donor SNP on leaf water potential (ψ) of *Hevea* after three months from treatment imposition. Data presented are the means ± SEs (n = 2)

Table 2. *Effect of exogenous NO donor SNP on girth of Hevea after three months from treatment imposition*

Treatment	Girth (cm) at day 0	Girth (cm) after 3 months
Control	4.54±0.11	5.78±0.08
Water	4.44±0.07	6.43±0.48
100 µM SNP	4.27±0.10	6.20±0.14
150 µM SNP	4.54±0.19	6.25±0.10
200 µM SNP	4.45±0.06	6.53±0.31*****
$LSD_{0.5}$	0.3205	0.7187

(N M C Nayanakantha, B M S S Pandithrathna, S A Nakandala, K D Madushani and W Karunathilaka)

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

Seeds were collected from eight clones as shown below and their volume and fresh weight were recorded. Growth attributes of seedlings raised from seeds of different clones were recorded after three months from transplanting in polybags.

Control - RRIC 100
T1 - RRISL 226
T2 - RRISL 206
T3 - RRISL 201
T4 - RRISL 217
T5 - RRISL2006
T6 - PB 260
T7 - RRIC 102

The highest volume and fresh weight of seeds were recorded from RRIC 100 (Table 3). The height, diameter and number of leaves of each plant were recorded after 3 months from transplanting in polybags (Table 4).

Table 3. *Volume and fresh weight of seeds of different clones*

Treatment	Volume of a seed (ml)	Fresh weight of a seed (g)
Control	4.66 ± 0.4	6.07 ± 0.3
T2	3.60 ± 0.2	4.40 ± 0.09
T3	2.33 ± 0.2	3.12 ± 0.1
T4	2.05 ± 0.19	3.88 ± 0.08
T5	2.94 ± 0.37	4.75 ± 0.2
T6	2.96 ± 0.18	4.78 ± 0.07
T7	4.45 ± 0.63	5.16 ± 0.25

Table 4. *Shoot attributes of rubber seedlings after three months from transplanting in polybags*

Treatment	Height (cm)	Diameter (mm)	No of leaves
Control	40.15 ± 0.91	4.10 ± 0.07	4.81 ± 0.16
T1	44.10 ± 2.04	4.08 ± 0.12	4.92 ± 0.18
T2	38.87 ± 1.72	3.92 ± 0.06	3.83 ± 0.37
T3	35.57 ± 0.82	3.86 ± 0.10	4.22 ± 0.22
T4	43.06 ± 0.88	3.67 ± 0.09	4.60 ± 0.15
T5	39.03 ± 1.94	4.05 ± 0.26	5.14 ± 0.26
T6	48.21 ± 0.92	4.36 ± 0.11	5.29 ± 0.20
T7	44.26 ± 1.49	4.02 ± 0.11	4.95 ± 0.19

(N M C Nayanakantha, G A S Wijesekera and K D Madushani)

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

An experiment was commenced to study the effect of the height of the germination bed on growth and root characteristics of seedlings. Although RRISL has recommended to collect the germinated seeds at the radical emergence stage, this is not practiced in most government and RPC nurseries. They transplant seedlings at the leaf emergence/expansion stage. Delaying in transplanting causes rapid elongation of the tap root in the germination bed, and unless a sufficient height is provided in the germination bed, the tap root touches the ground and gets distorted or hardened and therefore, they may not elongate further after transplanting in polybags. Fresh rubber seeds were sown in germination beds filled with sand at different heights as depicted below according to a RCBD design;

Control - Height 5cm
T1 - Height 10cm
T2 - Height 15cm
T3 - Height 30cm

Root and shoot attributes of the seedlings obtained from the seeds sown in germination beds at different heights are shown in Tables 5 and 6. Improved root attributes were recorded from seedlings raised in germination beds with increased height as compared to control.

Table 5. *Root attributes of seedlings after two weeks of germination*

Treatment	Length of tap root (cm)	Length of secondary roots (cm)	No. of secondary roots	Dry weight of roots (g)
Control	6.85 ± 0.71	4.33 ± 0.39	13.41 ± 1.18	0.49 ± 0.03
T1	10.74 ± 0.55	3.94 ± 0.49	13.74 ± 1.34	0.52 ± 0.05
T2	13.58 ± 1.83	4.28 ± 0.51	14.09 ± 1.52	0.62 ± 0.05
T3	18.98 ± 1.51	3.85 ± 0.47	15.14 ± 2.41	0.64 ± 0.04

Table 6. *Shoot characteristics of seedlings after three months of transplanting in polybags*

Treatment	Height (cm)	Diameter (mm)	No. of leaves
Control	54.25 ± 0.96	5.94 ± 0.19	5.50 ± 0.51
T1	52.57 ± 1.51	5.58 ± 0.16	5.36 ± 0.09
T2	53.79 ± 0.93	5.65 ± 0.14	5.89 ± 0.54
T3	52.82 ± 1.18	5.88 ± 0.17	5.19 ± 0.22

(N M C Nayanakantha, B M S S Panditharathna and G A S Wijesekera)

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

Experiments were commenced in the government rubber nursery at Egaloya and at Moneragala Substation of RRISL to investigate the effect of polybag colour/ material/size on growth of seedlings. The main objectives were to minimize the soil usage, material cost and optimize the polybag size while arresting the heat stress**.**

Effect of polybag size on growth of seedlings

Different polybag sizes were tested as depicted in Table 7. Germinated seeds were transplanted in each polybag filled with top soil and arranged in a nursery according to a randomized complete block design (RCBD). There were 60 plants for each treatment. Growth and physiological attributes of seedling *viz.*, stem height, stem diameter, number of leaves, chlorophyll content, leaf area, stomatal conductance, tap root length, tap root dry weight, total root dry weight and shoot dry weight were recorded after 8 weeks from transplanting.

There were no significant differences in growth and physiological attributes of seedlings raised in reduced sizes of polybags when compared to the seedlings raised in the standard size polybags in both nurseries.

Table 7. *Different polybag sizes tested in rubber nurseries*

Treatment	Egaloya		Moneragala	
	Polybag size	**Soil volume**	**Polybag size**	**Soil volume**
Control	6" x 15"	344	7" x 18"	562
T1	5" x 15"	239	7" x 17"	531
T2	4" x 15"	153	6" x 17"	390
T3	3" x 15"	86	6" x 16"	367
T4	4" x 13"	132		
T5	5" x 13"	207		
T6	6" x 13"	298		

Effect of polybag colour on growth of seedlings

An experiment was set to compare the growth performances of the polybagged plants raised in black coloured polybags with that of transparent polybags under nursery conditions at Monaragala Substation. Polybags were of 7"× 18" size, gazetted and 500 gauge.

T1 - Black poly bag
T2 - Transparent poly bag

Improved growth attributes and bud grafting successes were recorded from plants raised in transparent polybags as compared to those in black coloured polybags (Tables 8 & 9).

Table 8. *Growth of seedlings after three and five months of transplanting in polybags*

Treatment	3 months		5 months		
	Diameter (mm)	**Height (cm)**	**Diameter (mm)**	**Height (cm)**	**Leaf area (cm^2)**
T1	4.87 ± 0.093	44.68 ± 0.79	6.02 ± 0.29	60.89 ±1.45	642.38 ± 113.7
T2	5.72 ± 0.6	44.315 ± 1.0	6.06 ± 0.15	63.16 ± 2.05	1020.39 ± 197.7

Table 9. *Shoot and root dry weights and bud grafting success after five months of transplanting in polybags*

Treatment	Dry weight of shoots (mg)	Dry weight of roots (mg)	% of Budded plants produced from grafting
T1	7.65 ± 0.91	2.2 ± 0.26	42 ± 3.4
T2	10.53 ± 2.28	3.13 ± 0.48	63.2 ± 3.76

(N M C Nayanakantha, B M S S Panditharathna and E U M de Z Dissanayake)

Clonal propagation

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

The plant of the elite tree of clone 28/59 (Udabage) showed a satisfactory girth increment (16 cm) at a height of 120 cm. Plants of both elite seedlings of Nahalla and Dapiligoda did not show a satisfactory girth increment when compare to the control trees (P Seneviratne and G A S Wijesekera).

Bud grafting

Rejuvenation of budwood plants - Egaloya Nursery

Maintenance was done for the plants produced from 19 successive grafting and established at Galewatta (P Seneviratne and G A S Wijesekera).

Effect of different covering materials on bud grafting success

An experiment was set to study the ways to improve bud grafting success in government nurseries as the bud grafting successes is generally low in the nurseries located in dry areas such as Middeniya, Padiyathalawa and Kumbukkana as compared to those located in wet areas. Budgrafting was done with RRISL 203 at Welikadamulla and Middeniya government rubber nurseries. After wrapping the bud patch with a polythene strip, each area was again covered each with different materials as depicted below;

Control	- Bud patch wrapped with a polythene strip (150 gauge)
T1	- Bud patch covered with a Banana sheath
T2	- Bud patch covered with a rubber leaf (upper surface outside)
T3	- Bud patch covered with a green polythene strip
T4	- Bud patch covered with a rubber leaf (upper surface inside)
T5	- Bud patch covered with an aluminium foil flap
T6	- Bud patch covered with a *Gliricidia* leaf
T7	- Bud patch covered with a black polythene strip
T8	- Bud patch covered with a white polythene strip
T9	- Bud patch covered with a red polythene strip

Bud patches covered with banana sheaths, rubber leaves and aluminum foils showed some improved grafting success in both Middeniya and Welikadamulla nurseries (Tables 10 & 11).

Table 10. *Bud grafting success of rubber plants in Middeniya government rubber nursery*

Treatment	Bud grafting success %
C	72.44 ± 6.74
T1	85.56 ± 3.15
T2	82.44 ± 10.84
T3	73.78 ± 9.44
T4	74.44 ± 11.93
T5	74.22 ± 16.95
T6	70.22 ± 13.62

Table 11. *Bud grafting success of rubber plants in Welikadamulla government rubber nursery*

Treatment	Bud grafting success %
C	66.7 ± 2.9
T1	90.0 ± 2.0
T2	82.0 ± 1.2
T3	74.0 ± 6.4
T4	85.3 ± 1.8
T5	84.0 ± 4.2
T7	52 ± 8.1
T8	84.0 ± 3.1
T9	73.3 ± 4.8

Effect of cello tape as a wrapping material on grafting success

An experiment was carried out to see the effect of cello-tape as a wrapping material on grafting success. The objective was to minimize the water leakages, handling effect and skill factor involved in traditional wrapping technique using polythene strips while improving grafting success. A high grafting success was recorded from plants wrapped with cello tapes as compared to those wrapped with polythene strips (Table 12).

Table 12. *Bud grafting success in plants using cello tape as a wrapping material*

Treatment	Bud grafting success %	Deviation of % success
Cellotape	83.69 ± 2.57	17.03 ± 1.64
Polythene strips (Control)	66.67 ± 2.91	0

Mini-grafting of rubber seedlings

An experiment was commenced at Middeniya nursery to see the effect of mini-grafting using the buds of different maturity stages as depicted below. Seedlings

used were of 2 months old (green colour stem). Percentage bud grafting success was recorded (Table 13).

T1 - Bud stick leaves - Dark green, matured (Control)
T2 - Bud stick leaves - Apple green
T3 - Bud stick leaves - Copper brown
T4 - Bud stick leaves - Before expansion

Table 13. *Bud grafting success percentage after one month from grafting*

Treatment	Bud grafting success %
T1	96.84 ± 0.32
T2	93.10 ± 4.48
T3	84.60 ± 2.89
T4	92.40 ± 1.24

(B M S S Panditharathna, N M C Nayanakantha, M N de Alwis and L N de Zoysa)

Irrigation systems for rubber nurseries

Effect of exogenous application of salicylic acid on physiological and morphological attributes of nursery-gown rubber plants under water stress

A polybag nursery was established at Moneragala substation to optimize the application interval of salicylic acid at a concentration of 0.5 mM with different irrigation systems.

W/o SA – without application of salicylic acid
SA 2 weeks – application of salicylic acid once in two weeks
SA 1 month – application of salicylic acid once a month
SA 3 months – application of salicylic acid once in three months applications

Different irrigation systems *i.e.* sprinkler, drip and manual, were employed at 50% depletion level of available soil moisture and 100ml of 0.5 mM SA was added to each plant as a soil drench one month after planting. Plant stem diameter, stomatal conductance and chlorophyll content were measured as morphological and physiological indicators throughout the nursery period. Figure 6 shows the moisture curves of soil in poly bagged plants under different depletion levels after one irrigation. Depletion pattern shows the days of irrigation interval for next irrigation. Salicylic acid was applied when the depletion level reached at 50% (Fig. 6).

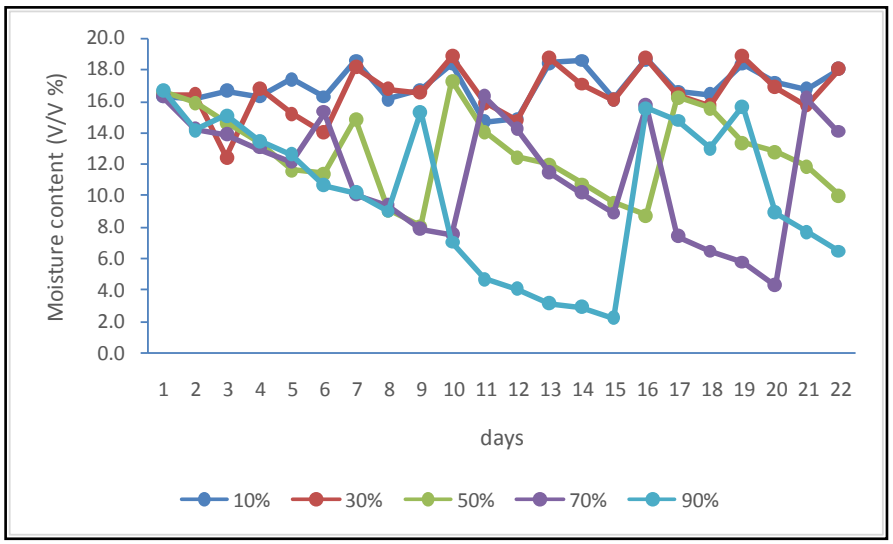


Fig. 6. Soil moisture curves of different depletion levels

Table 14 shows the variations of plant growth under different time of salicylic acid application at different irrigation patterns. Higher diameter values were recorded from plants treated with SA at 0.5 mM concentration and irrigated with a sprinkler system at monthly intervals. Moreover, sprinkler irrigation systems have a greater ability to maintain higher growth rates and bud grafting successes than drip irrigation and manual watering systems (S A Nakandala and P Seneviratne).

Table 14. *Growth, physiological and bud grafting performance of plants after five months of treatment imposition*

Treatments		**Stem diameter (mm)**	**Leaf chlorophyll content (SPAD unit)**	**Stomatal conductance (mm/s)**	**Bud grafting success (%)**
Sprinkler	w/o SA	7.85 ± 0.13^{b}	56.88 ± 1.70^{a}	0.11 ± 0.02^{a}	84.2 ± 0.82^{b}
	SA 2 weeks	7.92 ± 0.10^{b}	56.06 ± 1.36^{a}	0.10 ± 0.03^{a}	84.6 ± 0.90^{b}
	SA 1 month	8.35 ± 0.08^{a}	56.26 ± 1.85^{a}	0.13 ± 0.02^{a}	91.6 ± 0.45^{a}
	SA 3 months	8.00 ± 0.11^{b}	56.44 ± 1.43^{a}	0.11 ± 0.04^{a}	90.0 ± 0.85^{a}
Drip	w/o SA	6.80 ± 0.10^{bc}	52.86 ± 1.29^{ab}	0.05 ± 0.02^{bc}	79.0 ± 0.74^{c}
	SA 2 weeks	7.40 ± 0.10^{bc}	53.08 ± 1.07^{ab}	0.01 ± 0.02^{c}	80.2 ± 0.56^{bc}
	SA 1 month	7.87 ± 0.11^{b}	54.56 ± 1.62^{a}	0.03 ± 0.03^{c}	83.3 ± 0.52^{b}
	SA 3 months	7.53 ± 0.09^{bc}	55.48 ± 1.42^{a}	0.02 ± 0.03^{c}	81.5 ± 0.72^{b}

Treatments		Stem diameter (mm)	Leaf chlorophyll content (SPAD unit)	Stomatal conductance (mm/s)	Bud grafting success (%)
Manual	w/o SA	6.46 ± 0.10^{c}	51.54 ± 1.04^{b}	0.05 ± 0.02^{bc}	82.5 ± 0.90^{b}
	SA 2 weeks	6.55 ± 0.08^{bc}	51.60 ± 0.67^{b}	0.09 ± 0.01^{b}	80.4 ± 0.72^{bc}
	SA 1 month	7.36 ± 0.11^{b}	52.48 ± 0.64^{ab}	0.13 ± 0.02^{a}	85.2 ± 0.65^{b}
	SA 3 months	7.08 ± 0.08^{bc}	51.84 ± 0.60^{b}	0.11 ± 0.02^{a}	85.0 ± 0.59^{b}

Means with the same letter are not significantly different at $p \leq 0.05$

Budwood nurseries

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

Bud wood nurseries at Dolahena, Dartonfield and Gallewatta were regularly visited. Weeding, manuaring, pollarding and application of fungicide were done. The old budwood nursery at Olikanda were uprooted and replanted with 1500 plants of 34 clones. A new budwood nursery was established with 400 plants of 15 clones in the vicinity of Plant Science Department. Authentic bud wood sticks (400m) were issued to other departments of RRISL during the year (N M C Nayanakantha P Seneviratne and R Handapangoda).

Budwood nursery for clone identification purposes (2010/DF)

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

Moneragala Substation

Management of nurseries, upkeep of fields and training programmes were done successfully (P Seneviratne, T U K Silva and V G D N Gunaseela).

Young budding nursery at Monaragala

Nurseries were not established during the year under review (P Seneviratne, T U K Silva and V G D N Gunaseela).

Budwood nursery

Budwood nurseries with 1603 plants were maintained (P Seneviratne, T U K Silva and V G D N Gunaseela).

Monitoring and certification of rubber plants

Monitoring and certification of rubber plants in Government, RPC's and Private nurseries were done during the year and details are given in Tables 15, 16 & 17.

Table 15. *Details of RPC nurseries established in 2017*

Regional Plantation Company	No. of estates	No. of nurseries	No. of plants established in 2016	No. plants certified Y.B. 2017
Kelanivalley	08	08	198,000	113,000
Kegalle	03	03	34,000	20,200
Total	**11**	**11**	**232,000**	**133,200**

Table 16. *Details of government nurseries established in August 2016, January 2017 and August 2017*

Name of the nursery	Season	No. of plants established
Egaloya	2016 Aug.	203,189
	2017 Jan.	154,000
	2017 Aug.	151,000
Gurugoda	2016 Aug.	88,600
	2017 Jan.	
	2017 Aug.	
Karapincha	2016 Aug.	95,000
	2017 Jan.	82,029
	2017 Aug.	100,000
Meerigama	2016 Aug.	150,000
	2017 Jan.	120,000
	2017 Aug.	-
Welikadamulla	2016 Aug.	218,000
	2017 Jan.	185,000
	2017 Aug.	300,000
Middeniya	2016 Aug.	60,723
	2017 Jan.	70,000
	2017 Aug.	100,000
Moneragala	2016 Aug.	150,934
	2017 Jan.	300,000
	2017 Aug.	350,000
Padiyathalawa	2017 Aug.	37,000
Grand total		2,826,875

Table 17. *Details of private nurseries established in 2017*

Region	No. of nurseries	No. of plants established	No. of plants certified
Kegalle	06	44,800	

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

Planting techniques

Selecting plants at the nursery - PT/2001/1 – Nivithigalakele

Table 18. *Correlation among the present girth and the initial girth of the plants*

	Opened in 2008			Opened in 2013		
	Bad	**Moderate**	**Good**	**Bad**	**Moderate**	**Good**
Correlation coefficient (r)	0.39	0.43	0.27	0.43	0.17	0.18
P value	0.01	0.02	0.01	0.002	0.37	0.13
Sample size (n)	39	29	104	49	28	69
STDEV of girth	9.37	12.49	8.21	8.79	9.46	9.58

Table 19. *Correlation among the yield and the initial girth of the plants*

Correlation among the volume and the initial girth of the plants						
	Opened in 2008			**Opened in 2013**		
	Bad	**Moderate**	**Good**	**Bad**	**Moderate**	**Good**
Correlation coefficient (r)	0.35	0.23	0.20	0.26	0.05	0.17
P value	0.08	0.27	0.08	0.05	0.77	0.17
Sample size (n)	27	25	75	56	30	65
STDEV of girth	39.81	64.03	35.60	49.13	54.20	50.06

Table 20. *Mean girth of trees opened for tapping in 2008 and 2013 and grown under three different soil conditions (SEM values are given in brackets)*

Soil condition of the planting hole	**Opened in 2008**	**Opened in 2013**
	Girth (cm)	**Girth (cm)**
Bad	66.10 ± 1.50	66.34 ± 1.26
Moderate	67.98 ± 2.32	67.16 ± 1.15
Good	65.93 ± 0.82	70.66 ± 1.78

(P Seneviratne, G A S Wijesekara and L N de Zoysa)

Stumped budding experiment (SB/2016/Moneragala)

An experimental field was established with RRIC 121 in November 2016 at Moneragala Substation and maintenance, agromanagement practices and recording of girth were done (N M C Nayanakantha, S ANakandala and L N de Zoysa).

Comparison of planting materials - PT/Gallewatta/2007

Yield of young budded plants of both clones were better than bare root plants. D/3 tapping system has shown higher g/t/t and yields in both plantings (Table 21).

Table 21.*Yield values of different planting materials after third year of tapping*

Planting material	Yield (g/t/t)	Yield (kg/ha/yr)
RRIC121, Young budding (D/2)	24.62	1858.46
RRIC121, Young budding (D/3)	26.04	1953.00
RRIC 121, Bare root (D/2)	23.68	1730.77
RRIC 121, Bare root (D/3)	24.61	1846.00
RRISL 201,Young budding (D/2)	37.84	1967.68
RRISL 201,Young budding (D/3)	41.38	2151.50
PB 260, Bare root (D/3)	38.45	2114.75
PB 260, Bare root (D/4)	41.66	2291.67

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

Performances of clones PB 86 and RRIC 100

Weeding, manuring and other agronomical practices were done as recommended. Plastic net cages were fixed around plants to prevent the attack of porcupines. Mean girth values of two clones were given in Table 22.

Table 22. *Mean girth values of two clones after four years*

Clone	Mean girth (cm)
PB 86	34.15±2.06
RRIC 100	38.43±1.06

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

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

Growth and physiological attributes of seedlings and budded plants of different clones in different areas under different agro climatic conditions were different significantly (Tables 23, 24 & 25).

Table 23. *Growth characteristics of stock plants located in different areas*

Clone	Diameter increment (mm) in stock plants to be bud grafted			Height increment (cm) in stock plants to be budgrafted		
	Egaloya	Monera-gala	Ampara	Egaloya	Monera-gala	Ampara
PB 86	3.37^{a}	3.66^{c}	4.07^{ab}	37.20^{abc}	27.51^{a}	43.94^{a}
PB 260	3.63^{a}	3.73^{abc}	4.24^{a}	41.18^{a}	24.39^{b}	43.14^{ab}
RRIC 100	3.59^{a}	3.71^{bc}	4.09^{ab}	37.41^{abc}	27.58^{a}	39.47^{b}
RRIC 102	3.70^{a}	3.81^{abc}	4.30^{a}	37.70^{abc}	26.74^{ab}	41.61^{ab}
RRIC 121	3.53^{a}	3.88^{abc}	3.82^{b}	39.86^{ab}	26.27^{ab}	39.41^{b}
RRISL 203	3.33^{a}	4.08^{a}	4.06^{ab}	36.46^{bc}	27.74^{a}	42.45^{ab}
RRISL 217	3.75^{a}	3.79^{abc}	4.18^{a}	39.35^{abc}	27.71^{a}	41.49^{ab}
RRISL 2001	3.34^{a}	4.04^{ab}	4.12^{ab}	35.18^{c}	26.81^{ab}	45.08^{a}

Northern Province planting

Experimental field at Vavuniya South was visited by the Officers of Plant Science Department and Adaptive Research Unit (N M C Nayanakantha, P Seneviratne and M N de Alwis).

***Kilinochchi* (PT/2015/Kilinochchi)**

Growth data was recorded from plants of three clones *viz.,* RRIC 121, RRISL 203 and RRISL 2001.

Kilinochchi (PT/2017/Kilinochchi)

New experimental fields were established at Malayalapuram, Kilinochchi in four farmer fields. Extent of each field was about 0.5 to 1 acre. Different spacing systems and clones were tested under non - irrigated and irrigated conditions. RRIC 100, RRIC 121, RRIC 102 and RRISL 203 were planted at different spacings of 10'x14', 8'x14', 10'x 15', 13'x13' and 8'x26' (control) (N M C Nayanakantha, S A Nakandala, B M S S Panditharathne, M N de Alwis and D L N de Zoysa).

Cultural practices during immature phase

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

Growth and yield parameters of two clones tested under four different densities are given in Table 26. Tree girth and bark thickness have decreased significantly with the increase in planting density. Also, a similar decrease was shown in the individual tree yield (g/t/t). Although, the interactions were not significant among the treatments, significant differences were recorded between two clones tested. YPH values were not statistically significant among the densities.

Table 26. *Effect of planting density on growth and yield parameters of rubber, (a) plant girth (cm), bark thickness (BT) (mm) at 150cm height and trees in tapping, (b) tree yield (g/t/t) and estimated YPH (kg/ha/year)*

(a)

Density	RRIC 100				RRIC 121			
	Girth (cm)	BT (mm)	% Trees in tapping	Tappable trees/ha	Girth (cm)	BT (mm)	% Trees in tapping	Tappable trees/ha
500	76.77	11.98	64.56	323	91.23	11.23	66.17	331
600	77.93	11.55	63.75	383	85.37	10.15	66.09	397
700	69.22	10.35	54.07	379	79.60	10.81	60.45	423
800	69.79	11.13	61.50	492	78.34	9.96	66.82	535

(b)

Density (tree/ha)	RRIC 100		RRIC 121	
	Yield (g/t/t)	YPH (kg/ha/yr)	Yield (g/t/t)	YPH (kg/ha/yr)
500	35.95	1211	52.52	1914
600	37.85	1358	38.93	1597
700	30.46	898	31.68	1375
800	21.40	914	22.07	1188

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

Low density trial at Galewatta and Nivithigalakele - 2012

Mean girth of RRISL 203 was higher than RRISL 2001 at both spacings and locations (Galewatta and Nivithigalakelle) except for 16' x 16' spacing system at Galewatta (Tables 27 & 28).

Table 27. *Mean girth of rubber clones at different densities at Galewatta*

Clone	No. of plants	Spacing (feet)	Mean girth (cm) ± SEM
RRISL 2001	294	14x15	41.58±0.95
RRISL 203	422	14x15	47.04±0.65
RRISL 2001	314	16x16	44.41±0.72
RRISL 203	391	16x16	43.96±0.30

Table 28. *Mean girth of rubber clones at Nivithigalakelle*

Clone	No. of plants	Spacing (feet)	Mean girth (cm) ± SEM
RRISL 2001	317	16x16	45.72±0.93
RRISL 203	358	16x16	45.95±0.75

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

Low density trail at Kandakadu, Polonnaruwa - 2013

Due to dry weather prevailed in most of the months, plants had been subjected to abiotic stresses and the growth of the plants was poor. Mean girth (cm) of the plants measured at 120cm above ground level and intercropped with banana was 15.14±0.34.

A new clearing was established in the same area with three clones *viz.*, RRIC 121, RRISL 203 and RRISL 2001 at a spacing of 2.5m x 7.75m. 5kg of compost was added to each planting hole before planting (P Seneviratne, N M C Nayanakantha, M N de Alwis and R Handapangoda).

Exploitation

Longer tapping cycle through shorter tapping cuts – Pititakanda Estate

Yield measurements for the period from January to December 2017 are given in Table 29.

Table 29. *Yield measurements for the period from January to December 2017*

Treatments	No. of trees	No. of tapping days	Average g/t/t	Brown Bast %
T_1 : S/4 d3 + 5% E 12/y	42	10	14.6[a]	4
T_2 : S/3 d3 + 2.5% E 12/y	44	10	14.0[a]	-
T_3 : S/2 d3 + 2.5% E 5/y (* BUT up to December 2010)	43	10	13.9[a]	4
T_4 : S/2 d3 + 2.5% E 5/y	39	10	14.9[a]	4

Same yield could be obtained by consuming less bark in T_1 and T_2 as compared to control (T_4) (N M C Nayanakantha, K S D N Senanayake, R K Samarasekera and C Jayawanthi).

Crop estimation experiment – Sapumalkanda Estate (CE/2012/Sapumalkanda)

Girth, bark thickness, bark consumption and yield measurements were recorded and summaries are given in Table 30.

Table 30. *Mean girth, bark thickness, annual bark consumption and yield measurements for the period from January to December 2017*

Girth class (cm)	Girth (cm)	Bark thickness (mm)	Annual bark consumption (cm)	g/t/t
(51-55.9)	63.0	8.1[a]	14.0	67.1[a]
(56-60.9)	68.8	8.6[a]	13.9	53.0[a]
≥(61.0)	72.6	8.5[a]	13.1	65.2[a]

There was no significant difference in g/t/t among the girth classes tested (N M C Nayanakantha, P Seneviratne, K S D N Senanayake, R K Samarasekara and W K S W Watawala).

Crop estimation experiment – Moneragala (CE/2012/Moneragala)

Girth, bark thickness, annual bark consumption and yield measurements were recorded and summaries are given in Tables 31 and32 for RRIC 121 and RRISL 203 respectively.

Table 31. *Mean girth, bark thickness, annual bark consumption and yield measurements of RRIC 121 for the period from January to December 2017*

Girth class (cm)	Girth (cm)	Bark thickness (mm)	Annual bark consumption (cm)	g/t/t
T1 : 45-50.9	58.39	6.98[c]	34.7	27.23[c]
T2 : 51-55.9	64.07	7.75[c]	40.4	32.36[c]
T3 : 56-60.9	70.79	7.88[b]	38.5	41.32[b]
T4 : ≥61.0	80.9	8.99[a]	42.4	56.66[a]

Table 32. *Mean girth, bark thickness, annual bark consumption and yield measurements of RRISL 203 for the period from January to December 2017*

Girth class (cm)	Girth (cm)	Bark thickness (mm)	Annual bark consumption (cm)	g/t/t
T1 : 45-50.9	57.45	7.37[c]	39.1	32.51[c]
T2 : 51-55.9	61.25	8.0[c]	38.92	29.28[c]
T3 : 56-60.9	66.86	8.47[b]	39.5	30.35[b]
T4 : ≥61.0	72.85	8.97[a]	43.5	47.18[a]

There was a significant difference in g/t/t and bark thickness in higher girth classes as compared to the lowest girth class tested irrespective of clones (N M C Nayanakantha, K S D N Senanayke, R K Samarasekera and S Watawala).

A modified stimulation method for rubber – Pitiakanda Estae

Yield measurements were taken during the year and are summarized in Table 33.

Table 33. *Yield measurement for the period from January to December 2017*

Girth class (cm)	Treatment	No. of trees	Average no. of tapping days	g/t/t
55	Panel	100	10	53.8[a]
	Panel + Middle + Neththikanu	119	10	48.0[a]
	Poikanu+Neththikanu	82	10	54.2[a]
60	Panel	104	9	52.7[a]
	Panel + Middle + Neththikanu	101	9	51.1[a]
	Poikanu+Neththikanu	110	9	60.0[a]

There was no significant difference in g/t/t among treatments tested (N M C Nayanakantha, P Seneviratne, K S D N Senanayake, R K Samarasekara and N C Jayawanthi).

Winter rest experiment (WR/2017/Kuruwita)

Objective of this experiment was to investigate the effect of rest during wintering period on yield and brown bark condition.

Three tapping blocks were selected from 1990, 2005 and 2009 clearings at Kuruwita Substation with clone RRIC 100, RRIC 121 and RRISL 203 respectively. 90 trees were selected from each clone and the following treatments were imposed on 30 trees for each treatment;

T_1 - Tapping without a winter rest (Control)
T_2 - A rest is given during wintering period
T_3 - d/6 tapping is practiced only during wintering period.

Daily latex yields were collected and volumetric measurements and metrolac reading of latex samples were recorded for calculating dry rubber content (DRC%) (P Seneviratne, N M C Nayanakantha and R K Samarasekera).

Tapping Panel Dryness

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

Application of chemicals and botanicals having antioxidant properties on rubber trees

Objective of this experiment was to study the effect of bioregulators [chemicals or botanicals (natural plant extracts)] having antioxidant properties on alleviating TPD incidence. Both healthy and TPD affected trees were selected and application of different bioregulators were done on tapping panels.

Dartonfield Estate - Galewatta Division (2017)

A tapping block of RRIC 121 was selected from 1998 clearing at Galewatta and the following treatments were imposed on taping panels;

T1	- Sodium nitroprusside (SNP) 100µM
T2	- SNP 150µM
T3	- 5% Moringa Leaf Extracts (MLE)
T4	- 10%MLE
T5	- Water (Mock treatment)
T6 (Control)	- No treatments

Each treatment was applied on healthy, partially or totally dried trees at monthly intervals. Daily latex samples were collected and recorded (N M C Nayanakantha, K S D N Senanayake, R K Samarasekera, W Karunathilake, W K S W Watawala and U N Udayakumari).

Padukka Estate (2017)

Two tapping blocks of clone RRIC 121 were selected from 2003 clearings at Padukka Estate, Padukka and following treatments were imposed on taping panels;

T1	- Sodium nitroprusside (SNP) 100µM
T2	- SNP 150µM
T3	- 5% Moringa Leaf Extracts (MLE)
T4	- 10%MLE
T5	- Water (Mock treatment)
T6 (Control)	- No treatments

Each treatment was applied on healthy, partially or totally dried trees at monthly intervals. Daily latex samples were collected and recorded (N M C Nayanakantha, K S D N Senanayake, R K Samarasekera, W Karunathilake, W K S W Watawala and U N Udayakumari).

Pitiakanda Estate (2017)

A tapping block of clone RRIC 121 was selected from 2004 clearings at Pitiakanda Estate, Mawathagama and following treatments were imposed on tapping panels;

T1 (Control)	- 2.5% Ethrel 4 times a year + No antioxidant treatments
T2	- 2.5% Ethrel 4 times a year + 5% Moringa Leaf Extracts (MLE)
T3	- 2.5% Ethrel 4 times a year + Sodium nitroprusside (SNP) 100µM
T4	- 2.5% Ethrel 4 times a year + 5% Banana Leaf Extracts (BLE)

T5 - 2.5% Ethrel 4 times a year + 10% Moringa Leaf Extracts (MLE)
T6 - 2.5% Ethrel 4 times a year + SNP 150µM
T7 - 2.5% Ethrel 4 times a year + 10% Banana Leaf Extracts (BLE)

Botanical and Chemical treatments were applied on healthy trees at monthly intervals. Ethrel was applied four times a year. In case when ethrel application and chemical and botanical application coincide, application of botanical and chemical was done 48 hours before ethrel application. Daily latex samples were collected and recorded for calculating DRC % (N M C Nayanakantha, K S D N Senanayake, R K Samarasekera and W K S W Watawala).

Introduction of a d3 tapping system for RRISL 203 (TS/2017/Padukka)

Objective of this experiment was to investigate on d3 tapping system on growth and yield of RRISL 203. Consensus among some smallholders and the managers of RPCs are that RRISL 203 is more prone to TPD under d2 tapping system and hence it should be tapped at d3 frequency, considering it as a high latex yield clone. 60 trees were selected from a 2007 clearing at Menerigama Division in Padukka Estate, Padukka and a S/2 d3 tapping system (without ethrel) was introduced along with the normal S/2 d2 (control) tapping system. There were three blocks, each containing 10 trees so that the total number of trees per treatment was 30. Latex volumes were measured and metrolac readings were taken to calculate DRC % (N M C Nayanakantha, K S D N Senanayake, R K Samarasekera, W K S W Watawala and U N Udayakumari).

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

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

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

On station experiment to assess the overall impact of selected tapping systems representing different bark consumption rates using representative set of clones

Growth parameters, *i.e.* tree girth at 1.5 m height, thickness of bark, length of the tapping cut, shaving thickness of the tapped bark were measured. Yield and yield determinants, *i.e.* daily latex yields in terms of latex volume and metrolac reading (% dry rubber content), census of tapping panel dryness were recorded. Initial flow rates were measured and plugging indices were calculated based on the initial flow rates. Rainfall and the distribution of tapped and wet days were recorded. Assessments on wounds and bark deformation on tapping panel were done as visual observations.

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

Treatment four was stimulated by using 2.5% Ethrel (1.6g per tree) at three months interval.

Bark anatomical studies were done to investigate on the development of latex vessel system in response to different bark regeneration rates associated with treatments and clones tested.

Development of latex vessels among treatments and clones was affected significantly by different harvesting systems indicating clonal specific responses for the different bark consumption patterns four years after tapping (Figs. 7 & 8). High level of recovery tapping (T3) and daily tapping (T5) resulted in significantly a lower yield per tree as compared to T4 (Fig. 9). Yield per tree per annum for different treatments and clones are shown in Figure 10.

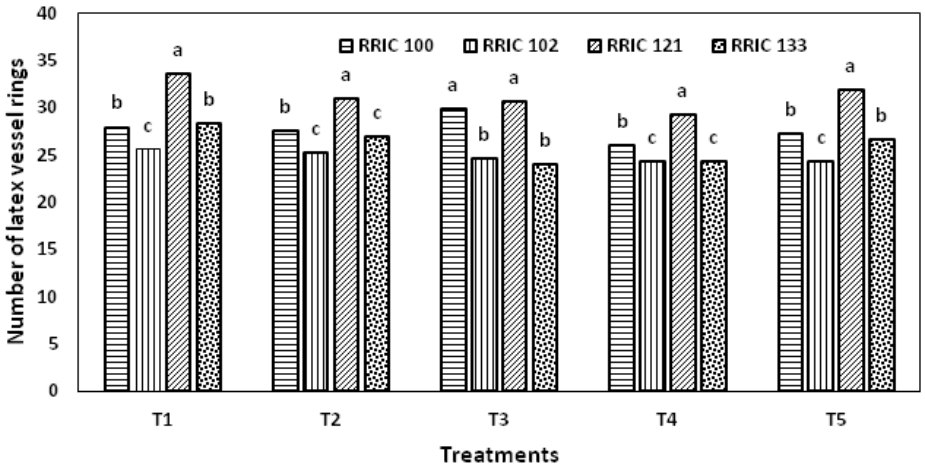


Fig. 7. Number of latex vessel rings in untapped bark of rubber trees at 150 cm height from the ground in response to different treatments and clones. Means of each category (clone) with the same letter within the treatment are not significantly different at $P>0.05$.

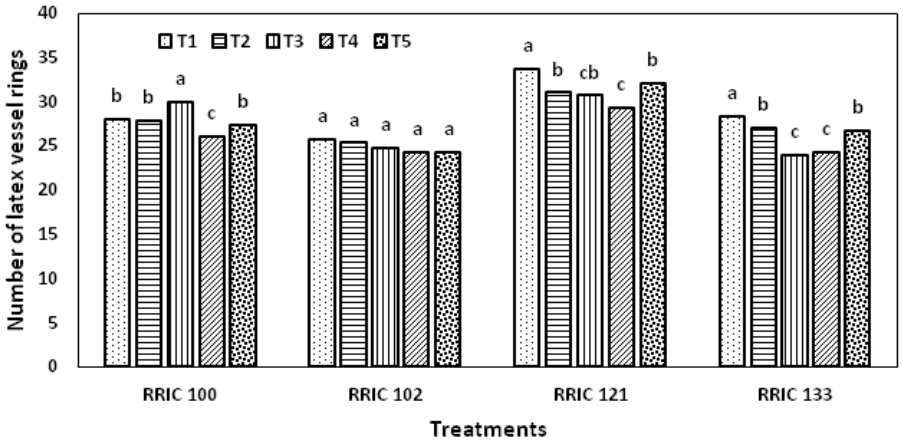


Fig. 8. Number of latex vessel rings in untapped bark of rubber trees at 150 cm height from the ground in response to different treatments and clones. Means of each category (treatment) with the same letter within the clone are not significantly different at $P \leq 0.05$

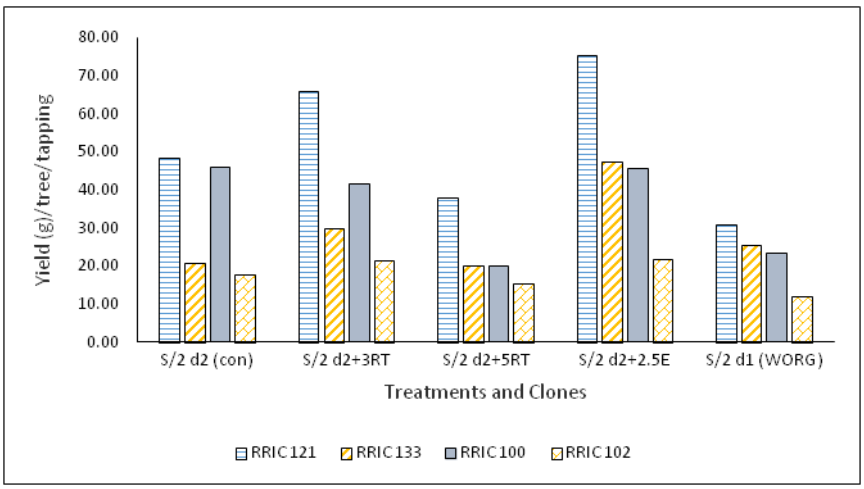


Fig. 9. Dry rubber yield (g) per tree per tapping for five treatments and four clones tested

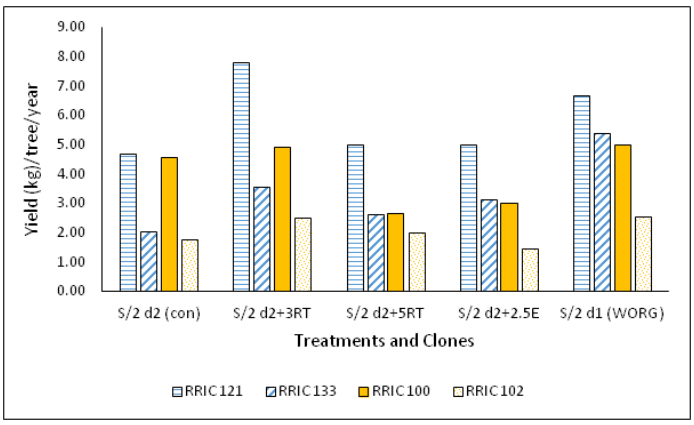


Fig. 10. Dry rubber yield (kg) per tree per annum for different treatments and clones

Multi location panel data assessments under different tapping systems practiced by the growers

Five sites from Regional Plantation Companies (RPCs) and five smallholdings were selected for the study. Three sites from Kalutara, Ratnapura and Kegalle representing major rubber growing districts whilst another two sites from Kurunegala and Moneragala districts representing low country intermediate zone where the rainfall is comparatively low (higher number of tapping days) were selected. The survey conducted clearly showed that the bark utilization rate in most of the rubber fields had been increased at an alarming rate. In most of the rubber fields, actual panel duration to finish the panel is higher than the estimated time. The higher rate of bark consumption has resulted in shifting to another panel before the scheduled time and therefore, harvesting being done on comparatively smaller trees and partially renewed bark.

Latex vessels development in virgin and renewed panels was studied in terms of number of latex vessel rings found in bark of rubber trees. Number of latex vessel rings in both RRIC 100 and RRIC 121 in different fields at Bibile Estate in Moneragala district are shown in Figures 11 &12 respectively. Results of the similar assessments done in Payagala Estate in Kalutara district for the same clones are shown in Figures 13 &14 respectively.

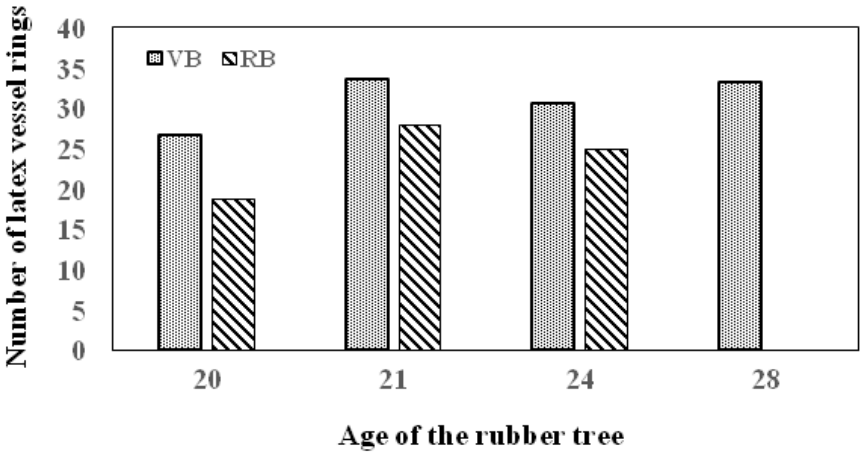


Fig. 11. Number of latex vessel rings in cross sections of barks (both virgin and untapped) of rubber trees of RRIC 100 at different ages and bark positions in Bibile Estate, Moneragala

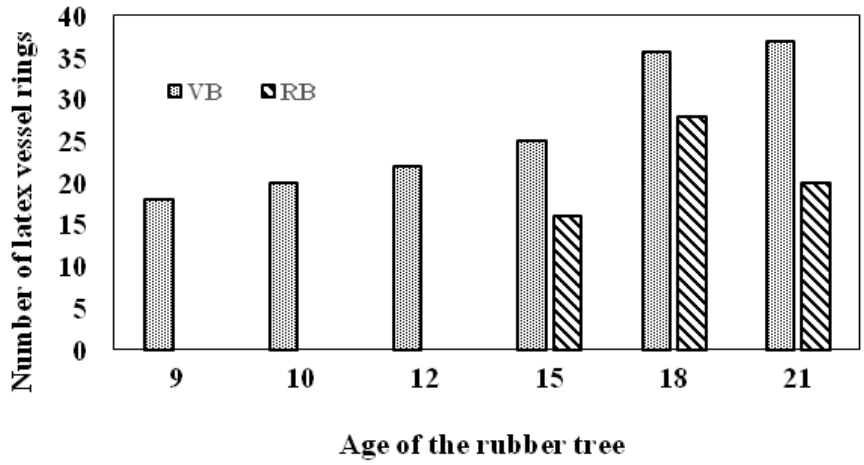


Fig. 12. Number of latex vessel rings in cross sections of barks (both virgin and untapped) of rubber trees of RRIC 121 at different ages and bark positions in Bibile Estate, Moneragala

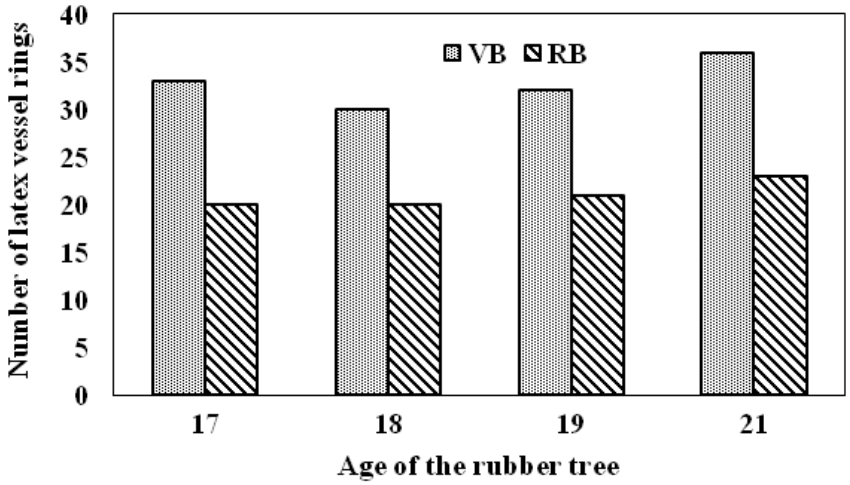


Fig. 13. Number of latex vessel rings in cross sections of barks (both virgin and untapped) of rubber trees of RRIC 100 at different ages and bark positions in Payagala Estate, Kalutara

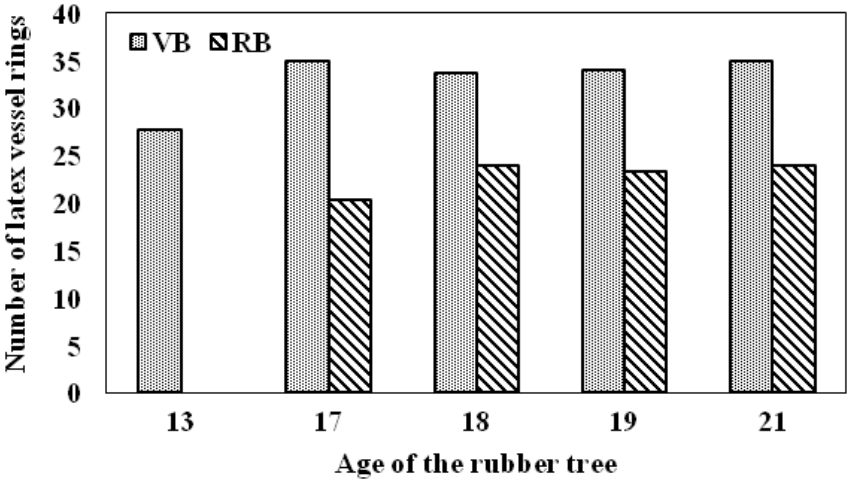


Fig. 14. Number of latex vessel rings in cross sections of barks (both virgin and untapped) of rubber trees of RRIC 121 at different ages and bark positions in Payagala Estate, Kalutara

(T U K Silva, P Seneviratne and H Subasingha)

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

Considering the challenges faced by both smallholder and plantation sector at present, this study was planned to address some issues such as daily tapping, high wage rates to be paid for tappers and imposition of high stress on middle aged rubber trees for obtaining more crop. Therefore, the objective of this study was to find ways and means to increase the productivity of rubber plantations by minimizing bark consumption rates during tapping. A rubber field (2 ha of RRIC 121) established in 2005 at Sirikandura Estate, Kalutara was selected. Initial growth and yield measurements were taken before imposing treatments as shown below;

Treatment	Tapping system
T1	S/2 d2 + Recommended No. of Recovery Tapping (Control)
T2	S/2 d1 + without rainguard, no recovery tapping (Smallholder practice)
T3	S/4 d1 + With RG (No RT)
T4	S/2 d2 (RG) No RT + Supplementary Holiday tapping (S/4 U d7)
T5	S/4U d3 2.5% ET + S/2 D d3 2.5%ET (12M alternatively)
T6	S/2 D d6 5%ET (Monthly)

(T U K Silva, P Seneviratne and H Subasingha)

Intercropping

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

Growth of rubber with respect to the girth and thickness of virgin bark was measured at 150 cm height (Table 34 and 35). Growth of trees under T3 and T4 was significantly higher. Percentage trees in tapping was comparable among treatments (Table 36). Daily records were monitored for latex volume and % dry rubber content was estimated using a metrolac. Individual tree yield in terms of g/t/t was not significantly different among treatments or clones (Table 37). Tea yield was higher in rehabilitated experimental plots than un-rehabilitated plots (Table 38).

Growth and establishment rates of rambutan and jackfruits were satisfactory. The growth of bud grafted (bg) and seedlings (s) durian (Table 39) were comparatively low and no commercial yields from fruit crops was recorded during this year.

Table 34. *Mean girth (cm tree^{-1}) of rubber in different treatments. Measurements were taken 150 cm height*

Main trts.	Sub treatments				
	Tea	Cinnamon	Durian/Jak	Rambutan	Sole rubber
T1 (3m×3m)-15m	75.53	72.45	73.82	73.88	77.30
T2 (3m×3m)-18m	80.84	72.26	72.41	71.66	77.25
T3 (3.5m×3.5m)-15m	79.78	81.05	79.10	76.79	76.57
T4 (3.5m×3.5m)-18m	84.67	78.04	82.55	76.57	81.64

Table 35. *Summary of the bark thickness of rubber (mm tree^{-1}). Measurements were taken at 150 cm height*

Main trts.	Sub treatments				
	Tea	**Cinnamon**	**Durian**	**Rambutan**	**Sole rubber**
T_1	9.59	9.36	8.85	8.03	10.32
T_2	9.72	9.70	9.75	9.24	10.26
T_3	9.92	9.75	10.06	10.26	10.63
T_4	10.55	9.87	10.12	10.00	10.17

Table 36. *Mean percentage trees in tapping (%TIT) and trees in tapping per hectare (TIT_{ha}) of rubber under different planting systems*

Trt	**Tea**		**Cinnamon**		**Durian**		**Rambutan**		**Sole rubber**	
	%TIT	TIT_{ha}	%TIT	TIT_{ha}	%TIT	TIT_{ha}	%TIT	TIT_{ha}	%TIT	TIT_{ha}
T1	94.23	349	68.52	254	63.84	236	60.25	223	87.22	323
T2	54.35	172	62.42	198	81.26	258	53.15	168	58.57	186
T3	81.08	251	88.69	274	80.39	248	92.31	285	90.48	280
T4	74.58	198	75.00	200	98.15	261	83.89	223	96.30	256

Table 37. *Mean yield per tree per tapping (g/t/t) and yield per hectare (YPH) of rubber under different planting systems*

Trt	**Tea**		**Cinnamon**		**Durian**		**Rambutan**		**Sole rubber**	
	g/t/t	YPH	g/t/t	YPH	g/t/t	YPH	g/t/t	YPH	g/t/t	YPH
T1	53.32	1885	70.63	1707	66.43	1566	75.03	1660	72.12	2231
T2	70.62	1236	90.59	1649	67.92	1785	98.88	1697	76.88	1416
T3	67.02	1692	69.17	1934	89.71	2207	66.44	1859	103.07	3003
T4	97.24	1814	92.76	1808	79.57	2123	74.31	1701	86.13	2283

Table 38. *Summary of the growth and yield performance of rehabilitated and unrehabilitated Tea under different planting arrangements of rubber*

Main treatments	**Tea growth**		**Tea yield (green fresh leaves)**			
	Basal girth (cm)		**Tea (unrehab.)**		**Tea (rehab.)**	
	Tea (unrehab.)	**Tea (rehab.)**	**g/bush/ year**	**kg/ha/ year**	**g/bush/ year**	**kg/ha/ year**
T1	18.79	19.24	179	816	489	2420
T2	20.27	19.24	197	1214	410	1764
T3	18.03	18.77	214	1082	658	2466
T4	18.94	16.59	247	1094	499	2187

Table 39. *Summary of the growth performance of Rambutan, Jak, bud grafted Durian (bg) and Durian seedlings (s) in different planting arrangements of rubber*

Main treatments	Basal girth (cm) at 10 cm height			
	Rambutan	**Jak**	**Durian (bg)**	**Durian (s)**
T1	81.25	69.00	43.00	33.00*
T2	86.56	100.11	101.50	38.00
T3	77.72	66.17	77.25	47.50
T4	79.31	82.20	-	76.88

*Plant were re-established in 2007 due to the damage of rabbits

(T U K Silva, P D Pathirana and D Priyadarshana)

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

Five species, *i.e.* cinnamon, areca, rattan, dracaena and cane palm were established along the fence in year 2010. The plant basal girth and height of different crops are given in Table 40. Cinnamon showed better performance and was harvested for fourth time for this year. Growth of dracaena was satisfactory and therefore, reasonable number of cut leaves could be harvested.

Table 40. *Crops planted along the rubber fence, spacing (m), girth (cm) and their overall plant height (m) at the seventh year after planting*

Crop	**Spacing (m) along the fence**	**Basal girth (cm)**	**Plant height (m)**
Cinnamon (*Cinnamomum verum*)	0.6 x 0.6 paired rows	11.05	2.61
Rattan (*Calamus rotang*)	2.5	nm	0.82
Messengiana (*Dracaena messengiana*)	0.9	26.53	Nm
Cane palm (*Dypsis lutescens*)	0.9		
Arecanut palm (*Areca catechu*)	2.0	39.11	4.58
Main crop	**Spacing (m)**	**Girth at 120 cm**	
Rubber	2.5m x 7.75m	53.63	Not measured

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

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

Out of the four species tested teak has recorded better growth and 100% survival. Therefore, teak seems to be more suitable for the boundary of rubber plantations provided a reasonable gap between rubber and teak (T U K Silva and D Priyadarshana).

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

The field was established as an intercropping demonstration field at RRISL Substation, Moneragala. Growth of rubber under different planting systems is given in Table 41. Plant basal girth and heights of different intercrops under two spatial arrangements of rubber are given in Table 42. A satisfactory plant height was recorded in each crop at seventh year after planting (Table 42). Mango, guava and pomegranate showed a higher growth rate and a reasonable yield of guava and mango could be harvested. Flowering and fruit setting were observed on some pomegranate trees.

Table 41. *Plant girth (cm) of rubber with different systems of intercrops planted under three different rubber spatial arrangements*

Intercropping system	Rubber spacing (m)	Girth of rubber (cm)
Rubber x Pineapple	Single row system	44.64
Rubber x Banana	2.5m x 7.75m	46.35
Rubber x Pomegranate/Guava	Single row system	26.98
Rubber x Pomegranate/Guava*	2.5m x 12m	23.5
Rubber x Cinnamon	Paired row system	44.74
Rubber x Mango/Rambutan	(3m x 3m) – 18m	41.32

Table 42. *Plant basal girth and height (cm) of different intercrops planted under two different rubber spatial arrangements*

Intercropping system	Year established	Intercrop spacing (m)	Basal girth (cm)	Tree height (m)	Canopy width (m)
Pomegranate	2010	3m x 3m	26	1.82	0.91
Guava			46.36	3.65	3.35
Pomegranate	2012		32.17	2.38	1.54
Guava			30.0	3.27	2.43
Cinnamon		0.6m x 1.2m	11.05	3.46	
Mango	2010	10m	70.9	4.53	4.9
Rambutan*		10m	-	-	-

***Plants were resupplied**

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

Intercropping Agarwood with Rubber (IC/AW/2015)

Girth data was recorded at two months intervals from January to December 2017 (Table 43). The highest girth and girth increment were recorded from *A. crassna* and the lowest was recorded from *G. walla* in both double and single row systems under full sun light condition. Under the natural shading system, the highest girth was

recorded from *A. crassna* and girth increment was as same in *A. crassna* and *A. subintegra*.

Table 43. *Growth attributes of three agarwood species after 28 months from planting*. Gyrinops walla *(GW),* Aquilaria crassna *(AC) and* Aquilaria subintegra *(AS) grown as intercrops with rubber under three planting system*

Planting system of rubber	Agarwood species	Girth at planting (cm)	Girth increment (cm)
Double row	AC	29.90 ± 0.62	2.59±0.32
	GW	9.64±0.51	0.94±0.08
	AS	26.70±0.88	1.93±0.30
Single row	AC	27.61± 1.26	2.44±0.37
	GW	7.16±0.66	0.86±0.12
	AS	26.53±1.16	2.54±0.32
Under natural shade	AC	14.74± 0.99	0.83±0.31
	GW	7.06±0.91	0.52±0.10
	AS	13.08±1.36	0.83±0.34

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

Rubber - Rattan intercropping trial – IC/RR/1996 - Kuruwita Substation

Data was not collected during the year under review and also the data collected so far are being analysed (P Seneviratne).

Possibilities of intercropping Cinnamon under Rubber – IC/RC/1998 - Kuruwita Substation

Data was not collected during the year under review and also the data collected so far are being analysed (P Seneviratne).

Table 24. *Bud grafting and budded plant attributes in different areas*

Time taken for bud braking (days)			Scion diameter increment (mm)			Scion height increment (cm)		
Egaloya	**Moneragala**	**Ampara**	**Egaloya**	**Moneragala**	**Ampara**	**Egaloya**	**Moneragala**	**Ampara**
6.14^{a}	7.22^{b}	8.45^{a}	1.87^{abc}	1.41^{ab}	1.66^{a}	14.65^{abc}	9.76^{a}	14.23^{b}
6.71^{a}	7.44^{a}	8.38^{ab}	1.93^{abc}	0.97^{c}	1.42^{a}	18.54^{ab}	9.18^{ab}	13.73^{bc}
6.07^{a}	6.95^{c}	8.40^{ab}	1.75^{abc}	1.18^{bc}	1.32^{a}	15.9^{abc}	7.65^{ab}	11.99^{bc}
5.97^{a}	7.17^{b}	8.38^{ab}	1.18^{c}	1.16^{bc}	1.44^{a}	12.15^{c}	9.55^{a}	17.87^{a}
5.97^{a}	6.92^{c}	7.50^{b}	1.27^{bc}	1.17^{bc}	1.63^{a}	13.93^{bc}	9.27^{ab}	10.14^{c}
6.37^{a}	6.89^{c}	8.11^{ab}	1.94^{abc}	1.53^{a}	1.68^{a}	11.30^{c}	10.06^{a}	13.49^{bc}
6.84^{a}	7.18^{b}	8.18^{ab}	2.42^{a}	1.16^{bc}	1.67^{a}	19.56^{a}	8.11^{ab}	14.49^{b}
6.37^{a}	6.85^{c}	8.42^{a}	2.08^{ab}	0.95^{c}	1.32^{a}	20.03^{a}	6.81^{b}	12.70^{bc}

Table 25. *Shoot attributes of budded plants*

Clone	**Scion Angle**			**Number of leaf whorls**			**Chlorophyll content (SPAD) values**		
	Egaloya	**Moneragala**	**Ampara**	**Egaloya**	**Moneragala**	**Ampara**	**Egaloya**	**Moneragala**	**Ampara**
PB 86	41.09^{a}	38.30^{a}	40.82^{ab}	2.64^{a}	2.66^{a}	2.52^{a}	52.31^{bc}	50.36^{b}	51.78^{b}
PB 260	35.36^{bc}	33.36^{bc}	43.90^{a}	2.40^{a}	2.32^{a}	2.25^{bcd}	53.85^{b}	54.70^{a}	51.00^{b}
RRIC 100	24.23^{e}	22.23^{d}	28.93^{d}	2.28^{a}	2.34^{a}	1.98^{e}	47.28^{c}	49.76^{b}	67.54^{a}
RRIC 102	30.57^{cd}	32.79^{c}	37.00^{abc}	2.48^{a}	2.28^{a}	2.14^{d}	52.57^{bc}	46.49^{c}	48.40^{b}
RRIC 121	35.86^{abc}	34.40^{bc}	34.44^{bcd}	2.76^{a}	3.24^{a}	2.55^{a}	53.87^{b}	53.84^{a}	48.95^{b}
RRISL 203	25.92^{de}	33.38^{bc}	31.73^{cd}	6.55^{a}	2.41^{a}	2.18^{cd}	54.41^{b}	52.52^{a}	54.11^{b}
RRISL 217	39.77^{ab}	36.75^{ab}	43.53^{a}	4.34^{a}	2.71^{a}	2.34^{bc}	58.05^{ab}	53.02^{a}	52.44^{b}
RRISL 2001	31.94^{c}	32.23^{c}	30.10^{cd}	6.84^{a}	2.58^{a}	2.41^{ab}	61.11^{a}	52.95^{a}	53.42^{b}

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

PLANT PATHOLOGY AND MICROBIOLOGY

T H P S Fernando

DETAILED REVIEW

Staff

Dr (Mrs) T H P S Fernando was promoted to Principal Plant Pathologist with effect from 01st February 2017 and covered up the duties of the Head of the Plant Pathology and Microbiology Department. Mrs M K R Silva and Mrs L H S N Gunerathne Research Officers were on duty throughout the year. Experimental Officers, Mrs B I Tennakoon, Mrs E A D D Siriwardene and Mr S C P Wijayaratne worked throughout the year. Mr E A D N Nishantha, Experimental Officer was on no-pay leave from the 1st of November 2016. Mr P W Balasooriya and Miss J Wijesinghe assumed duties as Technical Officers of the department with effect from 2nd of January 2017. Miss J Wijesinghe resigned from duties with effect from 22nd of February 2017. Miss S A D T L Wijesundara and Miss W R N M Gunawardhana assumed duties as Technical Officers of the department with effect from 10th July & 13th July 2017 respectively. Miss R D N Sewwandi assumed duties as a Technical Officer with effect from 27th November 2017. Mrs K A D Y Madushani Lanka, Management Assistant was on maternity leave with effect from 22nd November 2017. Mr P L P B Nishantha and Miss B V A Umesha worked as Temporary Research Assistants under the Development Project 23/1/15 and Ms K G M Sakunthala assumed duties as a Technical Assistant under the NSF Project RG/2016/AG/01.

Research grants received

Source & grant No	Duration	Title of the project	Allocation	Status
Ministry of Plantation Industries **Development Project – 23/1/15**	May 2016 - 2020	Identification of the Potential Pest and Disease Problems of Rubber in Non-Traditional Areas to Develop Improved Management Strategies	20 Rs. Mn.	In progress
National Science Foundation **NSF Project: RG/2016/AG/01**	May 2016 - 2019	Investigations on biological control measures for WRD of rubber to improve integrated disease management strategies	2.071 Rs. Mn.	In progress

Research students

Dr (Mrs) T H P S Fernando and Mrs M K R Silva supervised the final year research projects of the following undergraduate students.

Name	Duration	University	Project title
BVA Umesha	April - September 2017	University of Rajarata	Effectiveness of several antagonistic botanicals against white root disease of rubber
BDNP Aberatne	July - October 2017	University of Uva Wellassa	Production of toxic metobolites by antoganistic *Trichorderma* spp. against White root disease of rubber

Committees attended

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

Training programmes attended (Foreign)

Officers	Training Programme	Duration
MKR Silva	Molecular Biological Techniques for Research in Agriculture and Biomedical Sciences	2 - 28 February 2017
BI Tennakoon	Training programme in Thailand	22 Oct. 2017 - 13 January 2018

Training programmes conducted

Dr (Mrs) T H P S Fernando and Mrs M K R Silva served as the resource personnel 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 P Balasooriya covered the practical aspects of the above programmes while all the staff members extended their fullest cooperation in educating students from Universities and Technical Colleges on departmental activities.

Experimental/Advisory visits

Purpose	No of visits
Experimental	239
Advisory	46
Other	45
Total	**330**

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 litres per each tree) and hexaconazole (50g/l) at the concentrations of 1%, 2%, 2.5% and 5% (4 litres per each tree) were tested for the efficacy having an initial disease index of each tree. The experiment was conducted at the Talgaswala Estate, Elpitiya (T H P S Fernando and S C P Wijayaratne).

Another trial was conducted at a smallholding in Baduraliya to test different chemical concentrations as given below. The curative effect was assessed. The fungicide, tebuconazole was effective at the 1% concentration and hexaconazole showed less effectiveness on curative effects. Higher concentrations of the chemical were effective in checking the disease. The experiment is in progress to monitor the effectiveness of the chemical.

teboconazole (Folicur 25 EW)
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 B I Tennakoon)

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

With the collaboration of the Adaptive Research Unit, a new trial was initiated in Polgahawela to evaluate the adaptability of the repellent chemical for the small holder conditions in the intermediate zone. The repellent chemical with the new adhesive was applied in three locations. The objective is to adjust the timing and the frequency of application with respect to the rainfall pattern of the area (M K R Silva, T H P S Fernando and B I Tennakoon).

Tree injection against white root disease –* I *Vogan Estate

In the experiment conducted to test the effectiveness of tree injection using tebuconazole against white root disease, three concentrations *i.e.* 8, 12, 15% were tested using chem.-jet injectors. As a control, the recommended concentration (1%) tebuconazole drenching was done. The trees were monitored for the disease severity level of the collar and foliar symptoms. The plants treated with 8% tebuconazole showed promising results. This trial is to be done in several other experimental sites to make conclusions (T H P S Fernando and S C P Wijayaratne).

Alternative chemicals for the management of the bark cracking disorder

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

Screening of effective chemicals to control Brown root disease

Three fungicides, tebuconazole, hexaconazole and propiconazole were subjected to poisoned food technique *in vitro*. The fungus could not grow at very low concentrations *i.e.* 0.1ppm with all the three fungicides.

The field trial established to screen the effectiveness of the two systemic fungicides: tebuconazole and hexaconazole on the control of the brown root disease was further monitored. This experiment was in a four year-old clearing at Galagedara. The initial infectious level was assessed and a rank was given for each tree prior to the application of the fungicides. The treatments used were tebuconazole (Folicur 250 EW) in 1% concentration, hexaconazole (Hayzole 50 EC) in 1% concentration and hexaconazole (Hayzole 50 EC) in 2% concentration. All the 40 trees under the three treatments did not exhibit any brown root disease symptom after one fungicide application (M K R Silva, T H P S Fernando, R L C Wijesundera and B I Tennakoon).

Management of secondary leaf fall disease of rubber

Experiments were continued to test the application of chemicals to control Secondary leaf fall diseases caused mainly by *Oidium heveae*. Soluble sulphur and sulphur dusting were performed. Five rounds of chemical spraying were completed at the selected sites in Pussella and Mirishena Estates (T H P S Fernando, M K R Silva, S C P Wijayaratne and B I Tennakoon).

Biology of pests (23/P/02)

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

White root disease survey to establish the spread of the disease on the cover crop, *Mucuna bractiata* the incidence of White Root Disease on the cover crop, *Mucuna bractiata* was revealed (Table 1). The gaps of knowledge in view of improving the management strategies of white root disease were also reported.

Table 1. *WRD survey with reference to Mucuna, cover crop*

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

Report of symptoms to identify White Root Disease

Common symptoms of the disease were reported to facilitate disease diagnosis (Fig. 1). Furthermore, it was noted that similar symptoms are shown by various other diseases (Fig. 2). Hence, growers usually adopt wrong chemical treatments and end with negative results.

Fig. 1. Characteristic symptoms to identify white root disease: **a.** & **b.** Foliar symptoms, **c.** infected roots to show characteristic rhizormorphs, **d.** Fruit bodies produced at late stages

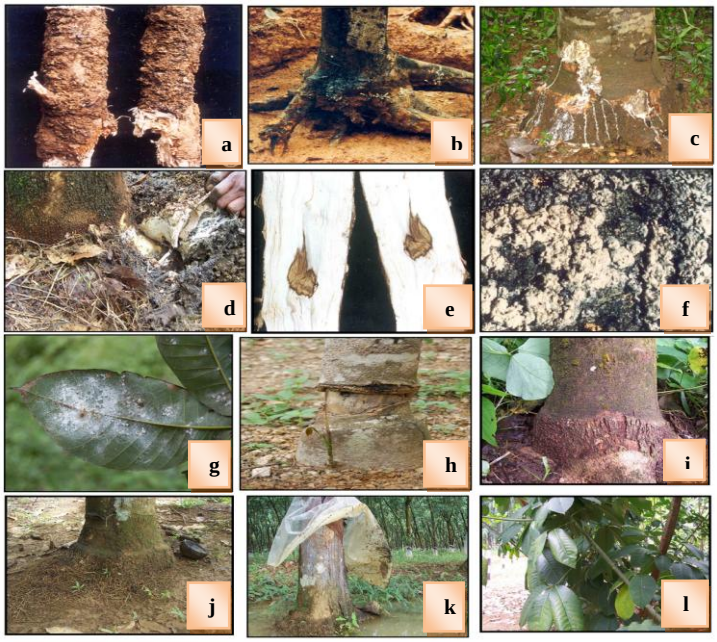


Fig. 2. Similar symptoms are shown by various other diseases: **a.** Brown root disease caused by *Phellinus noxius* **b.** Black root dsease caused by *Xylaria thwatsii* **c.** Wild boar/Porcupine attacks **d.** Patch canker disease caused by *Pythium* spp. **e.** Fusarium wilt disease caused by *Fusarium solani* **f.** Ustulina stem rot caused by *Ustulina deusta* **g.** Mites or mealy bug infestations **h.** Ring bark due to physical damages i**.** Mal planting practices like exposure of bud union **j.** Silt formation conditions **k.** Water logging conditions **l.** Genetical characters of some clones showing foliar yellowing and buckling *eg*: RRISL 226

Collection of pathogen isolates from different hosts from Sri Lanka

R. microporus was isolated from different alternative hosts from Sri Lanka (Table 2).

Table 2. *Collection of* R. microporus *isolates under investigation*

Isolate	Host plant	Common name of the host	Region
Rm 1	*Hevea brasiliensis*	Rubber	Dartonfield
Rm 2	***Mucuna bractiata*	Mucuna	Deraniyagala
Rm 3	*Cinnamomum zeylanicum*	Cinnamon	Kuruwita
Rm 4	*Hevea brasiliensis*	Rubber	Monaragala
Rm 5	*Cammelia sinensis*	Tea	Kuruwita
Rm 6	***Artocapus nobilis*	Wal del	Mathugama
Rm 7	***Murraya koenigii*	Curry leaves	Matugama
Rm 8	*Salix babylonica*	Weeping Willow	Matugama
Rm 9	*Alastonia*	Ginikuru	Padukka
Rm 10	*Artocarpus heterophyllus*	Jak	Kegalle

** First world records

Based on the literature survey, the alternative hosts *Mucuna bractiata, Murraya koenigii, Artocapus nobilis* are reported as the first world records.

Studies on the cultural and reproductive characteristics

Different pathogen isolates showed high variability in colony morphology (Fig. 3). Factors (temperature - Fig. 4/media/light conditions/PH - Fig. 5) affecting the growth of the pathogen isolates were investigated. Significant variations were revealed among the different isolates.

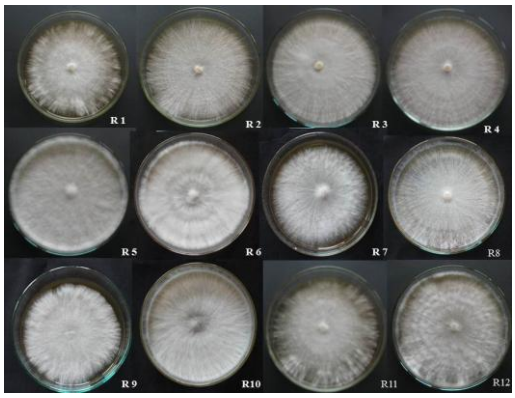


Fig. 3. Variation in the colony morphology

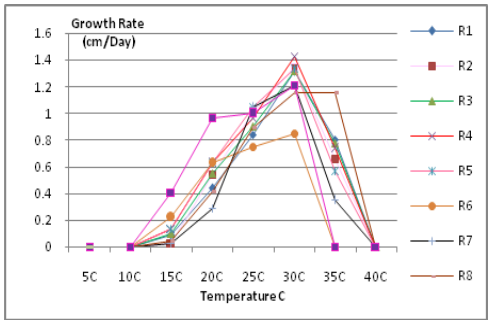


Fig. 4. Effect of temperature on growth

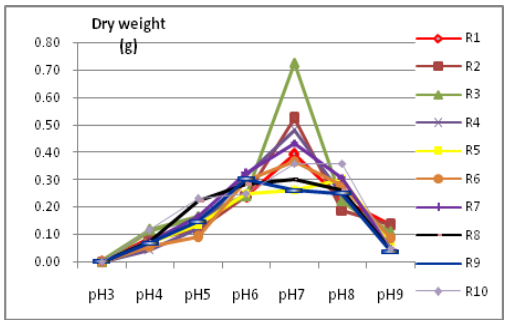


Fig. 5. Effect of PH on growth

Variability in pathogenicity among *Rigidoporus* isolates from different hosts

A pot experiment was done to assess the pathogenicity levels of different isolates. Inocula were prepared under laboratory conditions using root pieces and rubber seedlings from a single clone were raised for artificial inoculation. After two months of incubation, rubber seedlings showed established rhizormophs. All the isolates tested were pathogenic on *H. brasiliensis*. Re isolation trails revealed that the isolated fungi from diseased plants were identical with those used for artificial inoculations. The twelve isolates tested were grouped into two clusters from 0.8 similarity. Isolates of R1, R4, R11 and R12 which were from the host plant *Hevea brasiliensis* have been clustered in to both sub clusters from 0.8 similarity level (Fig. 6). R10 and R6 were isolated from genus of *Artocarpus* were grouped alone as a main cluster. Isolate R2, R8 and R11 are in higher virulent. Isolate R6 & R10 isolates are less virulent and R1, R3, R4, R5, R7 and R9 isolates are moderate virulent. Virulence of R12 isolates is laid between moderate and less virulence.

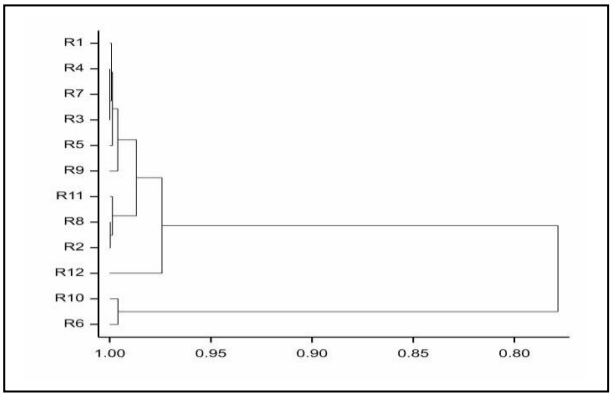


Fig. 6. Dendogram showing the clusters of *R. microporus* isolates (R1-R12) based on the pathogenicity

Production of cell wall degrading enzymes by *Rigidoporus microporus*

Growth in the liquid media

Growth of the seven *R. microporus* isolates in KAT liquid medium with citrus pectin, carboxy methyl cellulose and glucose as the main sources of carbon showed a more or less similar pattern with an initial short lag phase, and with an exponential phase followed by a leveling off growth rate (Fig. 7).

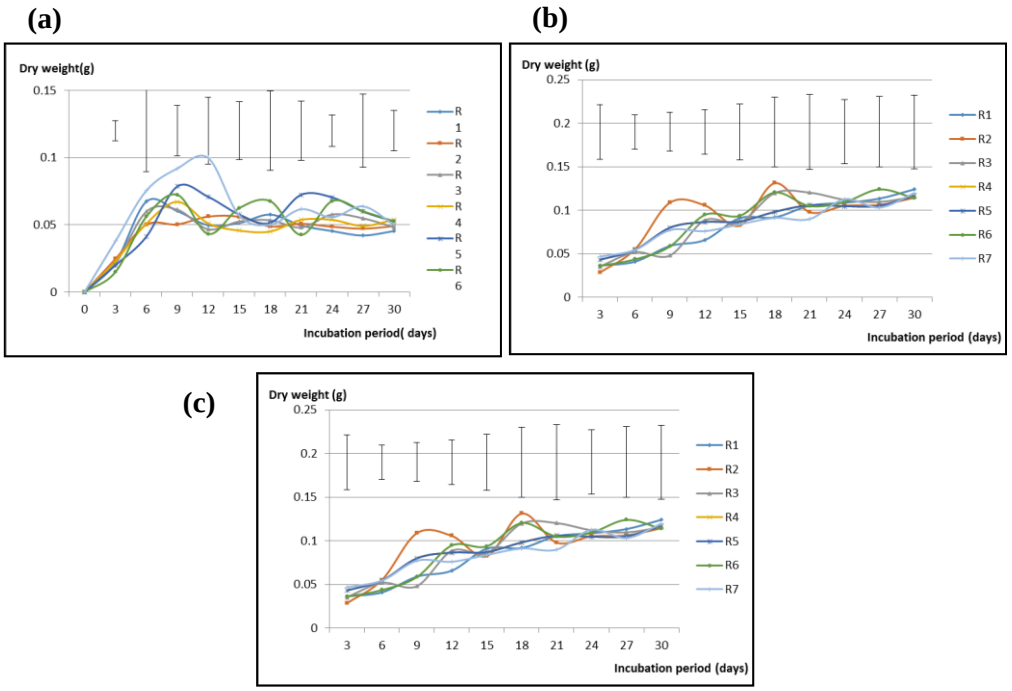


Fig. 7. Growth pattern of *R. microporus* in culture with citrus-pectin **(a)** or Carboxy-methyl-cellulose **(b)** or glucose **(c)** as the main sources of carbon

Enzymes production in liquid culture

Pectin Layase - All isolates under investigation, except the isolate R6 produced comparatively lower PL levels. The enzyme production was significantly higher in the R6 isolate (Fig. 8).

Polygalacturonase enzyme - Polygalacturonase enzyme activity was detected only in isolate R6.

Cellulolytic enzymes - Cellobiase and B glucosidase

The *Rigidoporus microporus* produces celluloses; cellobiase and B glucosidase. These cellulolytic paly a nutritional role.

Determination of molecular weight

Molecular weight of PL and PG of the isolate R6 showed 30.167 ± 2.021 kDa and 42.833 ± 0.764 kDa respectively. Molecular weights of laccase ranged from 57.167 kDa to 69 kDa for all isolates in their 1st peak.

Table 3. *Molecular weights of the laccase and pectinolytic enzymes* R. microporus *isolates grown in culture media*

Isolate	Molecular weights (KDa)		
	Laccase	**PG**	**PL**
R1	65.5 ± 2.765	-	-
R2	57.167 ± 4.311	-	-
R3	62.167 ± 3.403	-	-
R4	66.5 ± 2.947	-	-
R5	61.167 ± 4.646	-	-
R6	61.333 ± 3.512	30.167 ± 2.021	42.833 ± 0.764
R7	69.0 ± 3.50	-	-

Fungicide sensitivity of *R. microporus*

On tebuconazole, R1, R2, R4 and R6 isolates reached EC 100 (total inhibition) from 25ppm but resumed the growth after transfer to the MEA plates. Other isolates reached EC 100 from 50ppm and above. For hexaconazole, R1, R2, R4, R5 and R7 isolates inhibited radial expansion of growth up to 100 ppm above and all the other isolates stopped their radial expansion at 50 ppm.

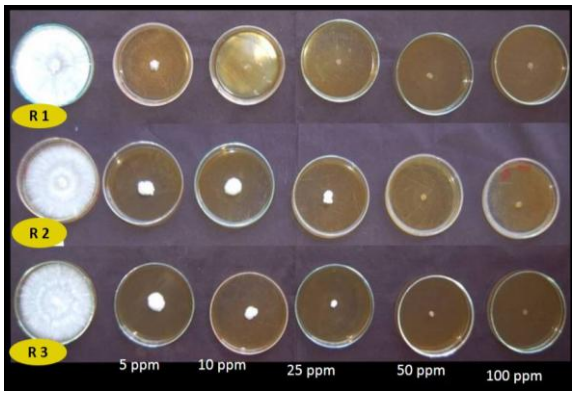


Fig. 8. Variability of fungicide sensitivity against tebuconazole by three isolates of *R. microporus* isolates

(T H P S Fernando, E A D D Siriwardene, S C P Wijayaratne and I Madushani, This project was funded by National Research Council, Sri Lanka: Grant No. 11-39)

Studies on the biology of the associated organisms of patch canker disease of rubber

Collection of disease specimens from different locations of the country and isolation of the pathogen is continued in a specifically developed medium in order to evaluate the associated organisms. P10VP medium was used as the specific medium. In addition, molecular diagnosis of organisms will be done through gene sequencing. As the first step of molecular diagnosis, fungal DNA was extracted using Norgen Biotek Plant/fungi DNA isolation kit.

The experiment is continued to gene sequencing of isolated pathogens and identification through homology search (NCBI). Pathogenicity tests are carried out in a field experiment.

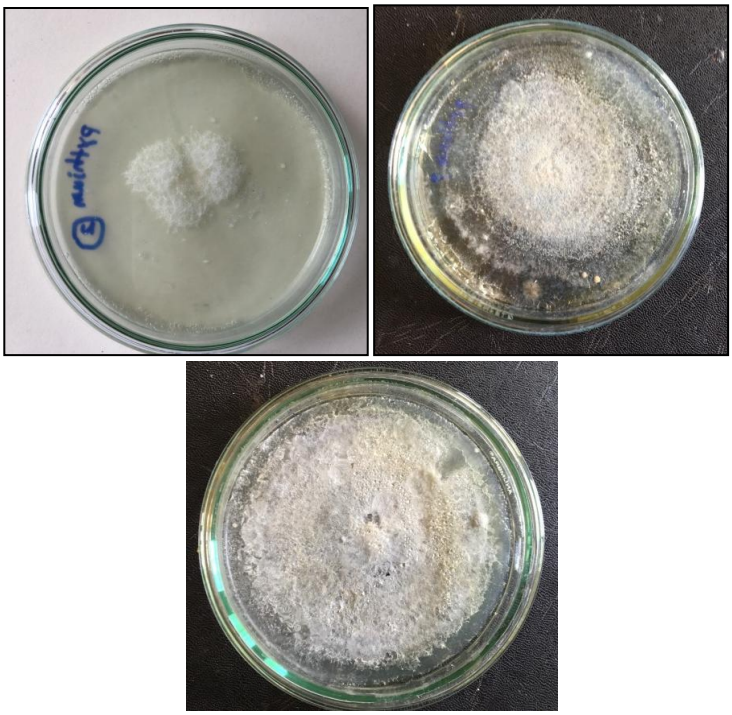


Fig. 9. Isolated causal organisms for Patch Canker disease in the selective medium (L H S N Gunarathne, T H P S Fernando and N Nishantha)

***Morphology and physiology of the brown root disease-causing fungus,* Phellinus noxius**

Studies on the morphological characteristics of the newly collected isolates of the pathogen were carried out. The fluffiness and the density of the cultures and the

development of coloration with time by different isolates were tested in the petri plate.

The pot trial established at Dartonfield to investigate the pathogenicity of the different isolates of the fungus wasre-inoculated with the brown root disease-causing fungus, *Phellinus noxius* (M K R Silva, T H P S Fernando and B I Tennakoon).

***Fungicide sensitivity of* Phellinus noxius**

On both the fungicides, tebuconazole, hexaconazole and propiconazole, all the 24 isolates of *Phellinus noxius* reached EC_{100} (Total inhibition) at 0.1ppm at the poisoned food technique. Moreover, all the isolates didn't resume the growth at this concentration. Therefore, soil fungicide screening test is being carried out to test the differential reaction of the fungal isolates to the three fungicides (M K R Silva, T H P S Fernando and B I Tennakoon).

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

Current disease distribution in different agro-climatic regions is being further investigated. A trial is being carried out at Dartonfield to investigate the influence of different moisture levels on the survival of the fungus in the soil. In order to identify the mode of disease spread, the origin of the pathogen innoculum and the species history of the land were investigated in the reported disease incidences. It was observed that in all disease incidences, the initially diseased rubber tree had a root contact with a diseased root of some other species. Moreover, at all seventy incidences studied, the land had been previously either under the forest or abandoned for years with trees and shrubs of forest origin. The isolates obtained from seven alternative hosts showed a variation in their morphological and physiological characteristics. However, they showed cross infection ability among them and with rubber.

Field trials established at Moneragala investigate the influence of agro-climatic conditions on the spread of the disease were re-inoculated with the brown root disease-causing fungus, *Phellinus noxius* (M K R Silva, T H P S Fernando and B I Tennakoon).

Screening of clones for leaf and panel diseases (23/P/03)

Screening of clones against Corynespora leaf fall disease (CLFD)

The incidence of Corynespora leaf fall disease was mild during the year 2017. The pathogen isolates were obtained from non-traditional rubber growing areas (T H P S Fernando, E A D D Siriwardena and E A D N Nishantha).

Table 4. *Results of the survey on Corynespora leaf fall disease conducted in 2017*

Clone	ADSI *	Clone	ADSI *
RRIC 121	0	RRISL 221	0
RRIC 102	0	RRISL 222	0
RRIC 130	0	RRISL 202	2.0
RRISL 203	0	RRISL 200	3.5
PB 260	0	RRISL 2000	0
RRIC 133	1.0	RRISL 2002	0
RRISL 201	1.2	RRISL 2004	0
RRISL 205	0	RRISL 2005	0
RRISL 206	0	RRISL 2006	0
RRISL 210	0	GPS 1	0
RRISL 211	0	PB 255	1.0
RRISL 215	0	PR 255	0
RRISL 216	0	PR 305	0
RRISL 217	1.0	RRII 105	1.0
RRISL 219	0	PB 235	0
RRISL 2001	0	BPM 24	0
RRISL 2003	0	RRISL 200	3.0
RRISL 218	1.4	Centennial 2	0
RRISL 204	0	Centennial 3	1.2
RRISL 202	2.3	Centennial 4	0
RRISL 208	1.6	Centennial 5	0
RRISL 220	0		

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

Maintenance of nurseries for screening purposes – Ratnapura District

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

Establishment of a nursery for screening purposes - Moneragala

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

Establishment of a nursery for screening purposes - Padiyathalawa

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

Establishment of a nursery for screening purposes - Dartonfield

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

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

The WRD survey – Government nurseries

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 2018 (T H P S Fernando, M K R Silva, L H S N Gunaratne, B I Tennakoon, E A D D Siriwardena, S C P Wijayaratne and P W Balasooriya).

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

Activities done under this project are listed below.

- Rubber growing areas in different mega zones of non-traditional areas were traced.
- Two Research Assistants were recruited and trained.
- A questionnaire was prepared to carry out the survey in Uva province to find potential Pests and Diseases.
- Sites have been selected for clonal screening nurseries in Padiyathalawa/ Monaragala & Dartonfield and preparation of planting materials were completed.
- Disease samples were collected from rubber and other intercrops in non-traditional rubber growing areas, Symptoms were recorded.
- Establishment of disease clonal clearings consisting of ten clones (six clearings); each clone consisting with 50 replicate trees.

Selected sites

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

(T H P S Fernando, P Senevirathne, M K R Silva, B I Tennakoon, E A D D Siriwardena, S C P Wijayaratne P Balasooriya and Sasitha Sandaruwan)

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

Identification of indigenous soil microflora as biological control measures for white root disease of rubber

An effective biopesticide to control Hevea root diseases

A medium is being tested for the combinations of identified native bio control agents. Different compounds such as rubber serum, sugar, molasses, etc. were used in a liquid broth culture in order to test the *in vitro* combination effects of antagonist bacteria. Rubber serum was found as the best medium for the liquid bio pesticide.

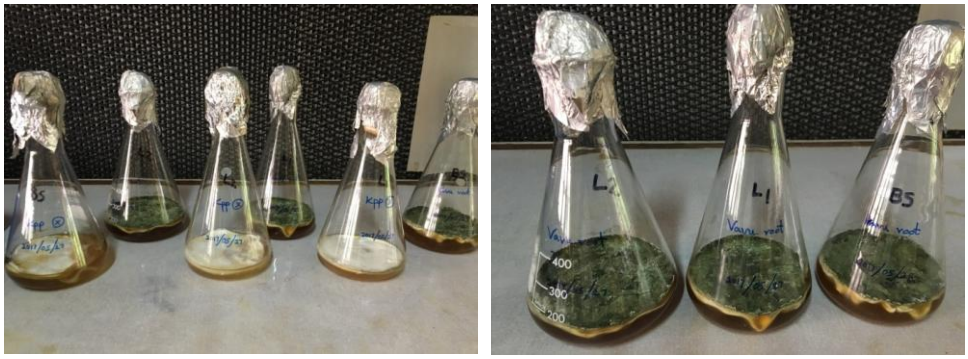


Fig. 10. *In vitro* combination of bacteria in order to prepare an effective biopesticide

Table 5. *Possible combinations of liquid media in order to prepare a biopesticide*

Combination	Type of the medium	Degree of making a biofilm	Bacterial colony count 3 days after inoculation
1	Rubber Serum+ Triptone Soy Broth	Significantly higher	
2	Sugar solution + Triptone Soy Broth	Moderate	0.6 x10^5 CFU/ml
3	Rubber Serum	Moderate	0.2 x10^4 CFU/ml

Pathogenicity tests are carried out in a field experiment. Further investigations are carried out to modify and develop the biopesticide (T H P S Fernando, Samudra Gunarathne, Poorna Balasooriya and E A D D Siriwardene: This project is partially funded by National Science Foundation - Project NSF 03.30x).

Developing and modifying a national level bacterial culture collection

The national level culture collection will be used for industrial and bioremediation applications such as Rubber waste water treatments, Cadmium degradation, Glyphosate degradation, Polythene and petroleum oil degradation *etc.*

Bacteria were isolated from natural rubber serum, rubber latex, processed rubber samples, polluted aquatic bodies (marine environments and freshwater environments) and contaminated soil rhizosphere (Table 6 and Fig. 11). Screening of effective bacteria was carried out based on results of various biochemical and physical parameters (COD, Total Dissolved Solids, pH, Turbidity, Atomic absorption *etc*).

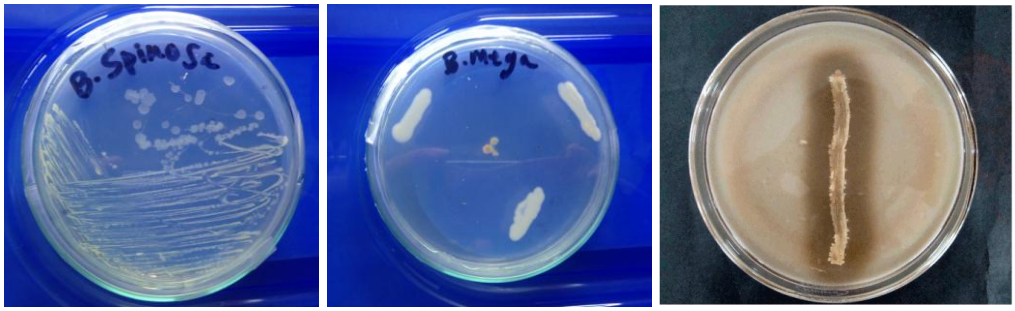


Fig. 11. Isolated bacteria from different habitats (Pure cultures)

Table 6. *Isolated bacteria with their potential applications*

Label	Origin of isolate	Application
A	Marine environment	Rubber waste water treatment/Cadmium degradation
B	Marine polluted environment	Rubber waste water treatment
C	Crepe rubber sample	Rubber waste water treatment
D	Crepe rubber sample	Rubber waste water treatment
E	Rubber serum	Rubber waste water treatment/Cadmium degradation
F	Rubber serum	Rubber waste water treatment

The experiment is continued to gene sequencing of effective bacteria and identification through homology search (NCBI). Successful cultures are maintained as a culture bank and will be commercialized according to the needs of the industries.

The potential use of plant growth-promoting rhizobacteria (PGPR) as antagonists and biocontrol agents in* Hevea *diseases

This experiment was initiated to identify effective PGPR bacteria in rubber soils of Sri Lanka to determine the potential use as antagonists and biocontrol agents to control economically important *Hevea* diseases in nurseries, and to identify effective novel inoculant formulations. Among 13 selected PGPR bacterial species, three bacteria showed significant antagonism towards *Rigidoporous microporus*. (Percentage growth inhibition by 51.2%, 46.8% and 44.3% respectively) *Fusarium sp*. was controlled by seven PGPR species. *Pythium sp*. was controlled by two PGPR (Percentage growth inhibition by 41.6% and 38.7% respectively) five types of combinations of bacteria were tested. Among five types, two types were highly effective in controlling *Rigidoporous microporus* (Percentage growth inhibition by 79.8% and 72.6% respectively). All five combinations were moderately effective in controling *Fusarium sp.* and one type was highly effective in controlling *Pythium sp.* (Percentage growth inhibition by 67.8%).

Table 7. *Isolated PGPR bacteria with their potential applications*

PGPR strain	Antagonism	P solubilizing	IAA producing	Lipase producing	Pectinase producing	Amylase producing
PGPR1	+	+	-	+	-	-
PGPR2	+	+	+	+	-	+
PGPR3	+	-	-	-	-	-
PGPR4	+	+	+	+	+	+
PGPR5	+	-	+	-	-	+
PGPR6	+	+	-	+	-	+

PGPR strain	Antagonism	P solubilizing	IAA producing	Lipase producing	Pectinase producing	Amylase producing
PGPR7	+	+	+	-	-	-
PGPR8	+	+	-	-	-	+
PGPR9	+	+	-	+	+	+
PGPR10	+	+	+	+	+	+
PGPR11	+	+	+	-	+	+
PGPR12	+	+	-	-	-	-
PGPR13	+	+	-	+	-	-

Table 8. *Combinations of PGPR bacteria with their mean values of antagonism*

Combination type	PGPR strains	*R. microporus*	*Fusarium sp.*	*Pythium sp.*
Combination 1	PGPR4, PGPR7, PGPR11	13.32^{de}	51.34^{b}	46.46^{c}
Combination 2	PGPR1, PGPR9, PGPR13	40.25^{c}	58.32^{b}	38.64^{c}
Combination 3	PGPR4, PGPR10, PGPR11	71.45^{a}	61.25^{b}	79.46^{a}
Combination 4	PGPR7, PGPR8, PGPR13	68.34^{a}	60.44^{b}	64.22^{b}
Combination 5	PGPR10, PGPR11, PGPR12	60.16^{b}	52.68^{b}	66.68^{b}

A solid medium for biological control agents

Compost was identified as a suitable medium for the introduction of *Trichoderma* inocula in to the soil. The studies revealed that the medium should be slightly modified to enhance the establishment and also it was noted that the composition of compost from different agents were not consistent and this influenced the propagation of the micro-organism (T H P S Fernando, L H S N Gunarathne, Poorna Balasuriya and E A D D Siriwardene: This project is partially funded by National Science Foundation - NSF Project 03.30x).

Identification of antagonistic plants to control WRD

Antagonistic effect of some locally available plant spp. on *Rigidoporus microporus*, which causes White root disease was tested *in vitro*. As the aqueous extracts of these plant species have been tested previously, it was aimed to test the effect of the same in organic solvents, as the solubility of a compound mainly depends on the polarity it and the solvent.

Di ethyl ether extract of four potential antagonistic plant species which had shown proven results under the previous studies were tested. The freshly uprooted rhizomes were used to prepare solvent extracts and the presence of the white root-inhibiting compounds in the extracts was tested in different concentrations using the Poison Food Technique (PFT), Soil Fungicide Screening Test (SFST) and colony growth in liquid medium. Di ethyl ether was substituted for the extract in the control

experiments. In each test, the percent inhibition of growth in each of the treatment with respect to the control was calculated using a standard equation. Analysis of variance was carried out for the percentage inhibition over the control and the means were compared.

Among the four species used, three species namely *Alpiniagalanga* L. (Galangale), Wild ginger (*Curcuma xanthorrhiza)* and Ginger (*Zingiber officinale)* showed a significant inhibitory effect at all three tests, while Garlic (*Allium cepa*) didn't show a significant inhibitory effect in any test.

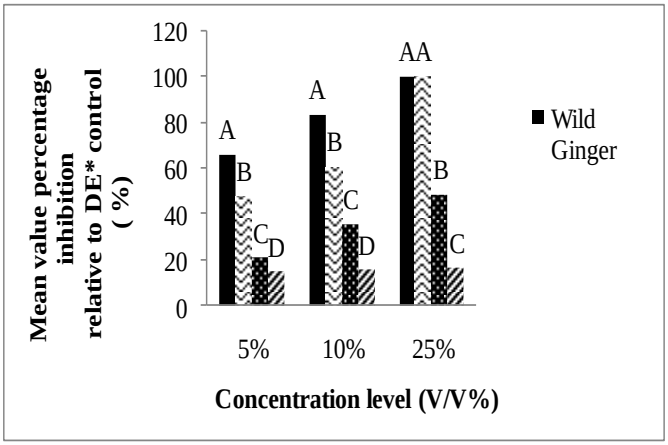


Fig. 12. PFT results of percentage inhibition of selected plant species at different concentration levels % (V/V) (Diethyl ether as the control)

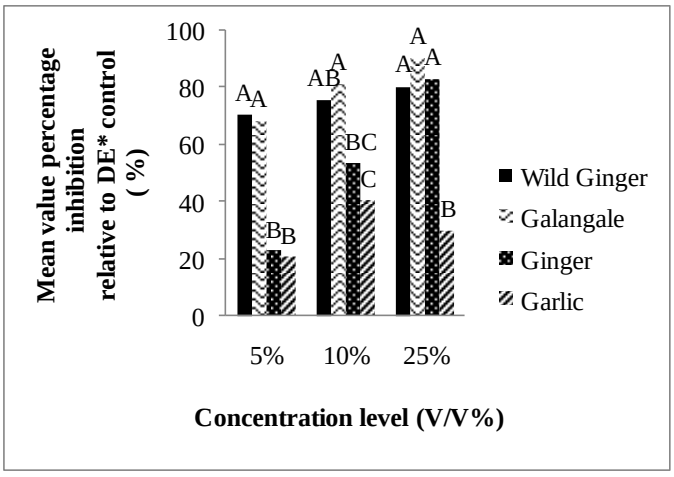


Fig. 13. SFST results of percentage inhibition of selected plant species for selected concentration levels (Diethyl ether as the control)

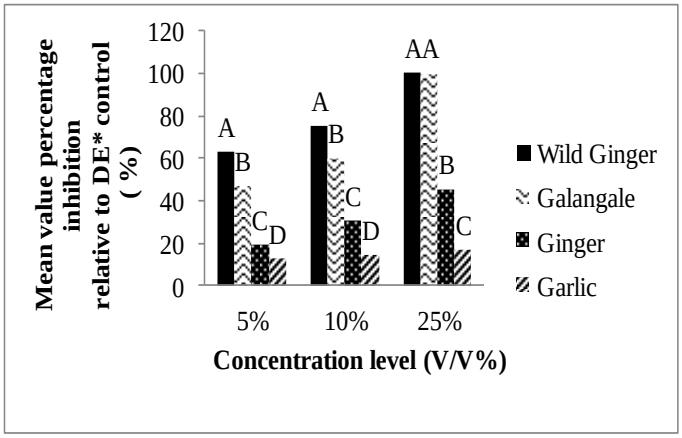


Fig. 14. Percentage inhibition results of mycelial dry weight test of selected plant species for selected concentration levels (Diethyl ether as the control)

The results confirm the presence of effective compound/(s) in above-mentioned species and suggest the potential of using diethyl ether extract of these plant species for the identification of effective botanical compound/(s) against white root disease (M K R Silva, T H P S Fernando, B I Tennakoon and Prof. R L C Wijesundera).

Identification of antagonistic fungi to control brown root disease

With preliminary *in vitro* tests, six fungal species in rubber rhizosphere were identified as potential antagonistic species against *Phellinus noxius* (M K R Silva, T H P S Fernando and Prof. R L C Wijesundera).

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

In association with the roots of the diseased tuber trees, two more species showing similar symptoms as rubber were identified as alternative hosts to the brown root disease. They were *Mangifera indica* (mango) and *Cinnamomum zeylanicum* (cinnamon). The fungal isolates showed a variation in their morphological and physiological characteristics. The trials were carried out to test the cross infection ability of seven alternative hosts and all the seven were having the cross infection ability among themselves and rubber (M K R Silva, T H P S Fernando and Prof. R L C Wijesundera).

Developing a national level fungal culture collection

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

The collection mainly consists of *Colletotrichum acutatum/Colletotrichum gloeosporioides/Corynespora cassiicola/Phytophthora spp./Rigidoporus microporus/ Phellinus noxius/Xylaria thwatsii/Fusarium solani/Nattrassia mangiferae/ Thanetephorus cucumeri/Rhizoctonia solani/Pestalotiopsis spp./Phomopsis spp./ Botrodiploidea theobromae*/*Trichoderma* spp./*Aspergillus* spp./*Penicillium* spp.

(T H P S Fernando, Samudra Gunarathne, M K R Silva and P W Balasooriya)

Advisory visits and training programmes (PP- 08)

The staff of the department made 46 advisory visits mainly to handle complicated disease problems. Majority of these visits were for the estate sector while the others were directed to the department by the Extension staff (T H P S Fernando, M K R Silva, B I Tennakoon, E A D D Siriwardene and S P Wijayaratne).

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

SOILS AND PLANT NUTRITION

R P Hettiarachchi

DETAILED REIVEW

Staff

Dr (Mrs) R P Hettiarachchi, Senior Soils Chemist and Mrs H A R K Jayawardana, Research Officer were on duty throughout the year. Experimental Officer, Miss V Edirimanna, successfully conducted her training programme at Thailand with effect from 23rd September to 13th January 2018. Experimental Officers, Miss A Thevarapperuma, Mr T Gunathileke, Mr J A S Chandrasiri, Technical Officers Mrs K E de Silva, Mr G C Malawaraarachchi, Mrs K M M E K Kulatunga and the English Stenographer Mrs L Rupasinghe were on duty throughout the year. Six Technical Officers Mrs P D S D O Rathnasooriya and Miss R M Baddevithane with effect from on 03.01.2017, Mr M W H Gayan, with effect from 02.02.2017. Mr S L N S L Madusanka and Mrs N S Siriwardena with effect from 10.07.2017 joined the Dept. Miss K A M Y C Jayatissa assumed duties on 17.07.2017 as a Technical Officer but resigned from the Institute on 12th December 2017.

Research students

Student name	University	Research topic
DNM Gunathilake	University of Rajarata	"Assessing the effect of arbuscular mycorrhizal fungi on the phytoremediation potential of *Eichhornia crassipes* on cadmium uptake"

Seminars/Trainings/Workshops/Conferences/Meeting conducted

Officer	Subject	Beneficiary/Client
RP Hettiarachchi	Presentation on "Biofertilizers for rubber"	Scientific Committee Meeting, RRISL
	Presentation on "Soil fertility management"	Agrarian Development District Office
	Presentation on "Cost effective applications of GAP in crop lands"	IRRDB training programme

Seminars/Training Programmes/Workshops/Exhibition attended

Officer	Subject	Organization
RP Hettiarachchi	Seminar on "Soil & Water conservation and dryland farming for developing countries" 18th April to 10th May - Yangling, China	International Exchange Center of Yangling Demonstration Zone Yangling, China
	Scientific Committee Meetings	RRISL
	Executive Committee Meeting	Soil Science Society of Sri Lanka
	Training Program on "Data Management"	Ministry of Disaster Management, in collaboration with Ministry of Mahaweli Development & Environment
	National Inception Workshop on Land Degradation Neutrality Target Setting Program (LDN-TSP)	Ministry of Mahaweli Development & Environment
	Meeting of the working group on Land Degradation Neutrality Target Setting Program (LDN-TSP)	Ministry of Mahaweli Development & Environment
	National Work shop on Land Degradation Neutrality Target Setting Program (LDN-TSP)	Ministry of Mahaweli Development & Environment
	Technical Coordinating Committee Meeting on Implementation of National Action Programme (NAP) 2015-2024 for combating land degradation in Sri Lanka	Ministry of Mahaweli Development & Environment
	National Steering Committee (NSC) Meeting for the implementation of Revised and Aligned National Action Programme (NAP) for Combating Land Degradation in Sri Lanka 2015-2024	Ministry of Mahaweli Development & Environment
	Annual General Meeting	Sri Lanka Association of Testing Laboratories (SLATL)
	Meeting on "Relaxing Glyphosate Ban"	Parliament of Sri Lanka Committee Office

Officer	Subject	Organization
	National Conference on Biofertilizers and Biopesticides	Wayamba University of Sri Lanka
	CRT Trade fair	Ministry of Plantation Industries
HARK Jayawardana	General awareness on Laboratory Accreditation	RRISL
	Use of Global Positioning System and Google Earth Tools in research	PGIA, Peradeniya
	Scientific Committee Meetings	RRISL
	Land Degradation Neutrality Target Setting Program (LDN-TSP)	Development & Environment Ministry of Mahaweli
	CRT Trade Fair	Ministry of Plantation Industries
	Workshop on writing a winning research proposal	SLCARP

Visits

Advisory	4
Experimental	163
Others	97

LABORATORY AND FIELD INVESTIGATIONS

Soil fertility management

Mass production of* Mucuna bracteata *plants

Mucuna nurseries were established in RRISL substations in Nivithigalakele and at Payagala Estate and 800 polybagged *Mucuna* plants were produced and issued for smallholders and plantations at Rs.25.00 per plant (Table 1).

Table 1. *Details of issuing Mucuna plants at different nurseries*

Name of the Nursery	Number of plants	Recipient
Payagala	500	Neuchattle Estate, Ekerella Estate, Geekiyanakande Estate and seven smallholders
Nivitigalakele Substation	300	Ganapalla Estate, Panawatta Estate and five smallholders

(R P Hettiarachchi, A Thewarapperuma and T Gunathilake)

Biofilm biofertilizers (BFBF) for rubber

Evaluate the effectiveness of BFBF on nitrogen fixation

This experiment was conducted in root trainers. Soil was filled and two weeks old one germinated rubber seed was planted in each. Two weeks after the experiment treatments were initiated (Table 2). Throughout the experimental period of six weeks different biofilm biofertilizers (BFBF) and inorganic fertilizers were applied biweekly. Soil and plant samples were analyzed for nutrients at the end of the experimental period.

Table 2. *Treatment combinations of the experiment*

Treatments	Combination
Zero	No fertilizer of BFBF
50% fertilizer	50% recommended fertilizer dosage
B6F2 + 50% fertilizer	B6F2 + 50% recommended fertilizer
B12F2 + 50% fertilizer	B12F2 + 50% recommended fertilizer
B19F2 + 50% fertilizer	B19F2 + 50% recommended fertilizer
B23F2 + 50% fertilizer	B23F2 + 50% recommended fertilizer
B25F2 + 50% fertilizer	B25F2 + 50% recommended fertilizer
B6F2	Biofilm biofertilizer B6F2 only
B12F2	Biofilm biofertilizer B12F2 only
B19F2	Biofilm biofertilizer B19F2 only
B23F2	Biofilm biofertilizer B23F2 only
B25F2	Biofilm biofertilizer B25F2 only

There was no significant difference between treatments related to the nitrogen fixation and seedling dry weights of the above mentioned treatments. However, higher mean values for nitrogen fixation and seedling dry weights were observed with B6F2 + 50% fertilizer and B25F2 + 50% fertilizer treatments compared to others (Table 3).

Table 3. *Nitrogen fixation capacity and plant dry weight of rubber seedlings of different treatments*

Treatment	Nitrogen fixation capacity (g/pot)	Seedling dry weight (g)
Zero	0.27[a]	3.52[a]
50% fertilizer	0.03[a]	3.507[a]
B6F2 + 50% fertilizer	0.032[a]	3.789[a]
B12F2 + 50% fertilizer	0.03[a]	3.551[a]
B19F2 + 50% fertilizer	0.03[a]	3.541[a]
B23F2 + 50% fertilizer	0.03[a]	3.558[a]
B25F2 + 50% fertilizer	0.031[a]	3.859[a]
B6F2	0.028[a]	3.622[a]

Treatment	Nitrogen fixation capacity (g/pot)	Seedling dry weight (g)
B12F2	0.029[a]	3.610[a]
B19F2	0.03[a]	3.593[a]
B23F2	0.03[a]	3.526[a]
B25F2	0.031[a]	3.525[a]

Quantitative response of inorganic fertilizers to young budding nursery plants with biofilm biofertilizers at field conditions

One experiments was started at Dartonfield using different inorganic fertilizer applications and Biofilm biofertilizers to evaluate the effectiveness on nursery plants. Different treatments were tested according to the details reported in 2015 Annual Review. Growth assessments were done throughout the before and after budgrafting periods at monthly intervals. At the end of before budgrafting stage, randomly selected plants were removed from each treatment and analyzed their nutrient contents. The treatment 50%F+BFBF gave significantly higher diameter values compared to recommended fertilizer application (100%F) at four months after planting. The highest diameter increment was observed with 50%F+BFBF treatment compared to other treatments (Table 4). No significant differences could be observed among plant height values, but the highest height value and height increment could be observed with 50%F+BFBF treatment compared to other treatments (Table 5).

Table 4. *Effect of different combinations of inorganic fertilizer and BFBF applications on diameter of seedling plants*

Treatments	Plant diameter (mm)				Diameter increment
	1st month	2nd month	3rd month	4th month	
100%F	4.75[a]	5.84[ab]	7.55[ab]	9.9[b]	5.15
50%F	4.82[a]	5.83[ab]	7.75[a]	10.8[b]	5.98
100%F+BFBF	4.77[a]	5.91[a]	7.41[b]	10.3[b]	5.53
50%F+BFBF	4.81[a]	5.71[b]	7.43[b]	12.4[a]	7.59

Table 5. *Effect of different combinations of inorganic fertilizer and BFBF applications on height of seedling plants*

Treatments	Plant height (mm)				Height increment
	1st month	2nd month	3rd month	4th month	
100%F	41.2[a]	53.7[a]	69.1[a]	96.3[a]	55.1
50%F	41.3[a]	54.1[a]	69.8[a]	95.4[a]	54.1
100%F+BFBF	41.9[a]	56.8[a]	71.5[a]	95.7[a]	53.8
50%F+BFBF	42.0[a]	56.0[a]	72.5[a]	100[a]	58.0

Plant analysis data showed that there is no significant difference in the nutrient contents of root samples in biofilm biofertilizer (BFBF) treatments and their respective non BFBF treatments. In comparison to 100% fertilizer only treatment, combine use of fertilizer with BFBF treatments (50% fertilizer + BFBF/ 100%F+BFBF) gave higher N and K nutrient contents in root samples (Table 6).

Table 6. *Effect of different combinations of fertilizer applications on root nutrient contents of rubber seedlings*

Treatments	Tap root nutrient contents (%)		
	N	P	K
0% fertilizer	0.373[b]	0.057[a]	0.427[b]
50% fertilizer	0.550[a]	0.100[a]	0.830[ab]
100% fertilizer	0.613[a]	0.103[a]	0.840[ab]
BFBF	0.380[b]	0.085[a]	0.640[ab]
50% fertilizer + BFBF	0.663[a]	0.107[a]	0.910[a]
100% fertilizer + BFBF	0.675[a]	0.105[a]	0.890[a]

Quantitative response of inorganic fertilizers to immature field plants with biofilm biofertilizers

This experiment was conducted at Millawa estate to study the effectiveness of BFBF (B25F2) with reduced amount of chemical fertilizers for immature rubber plants at field conditions. Different treatments were tested according to the details reported in 2015 Annual Review. Plant diameter was measured throughout the year and are given in Table 7. At the end of 2½ years period, BFBF treatments, 50%F+BFBF and 75%F+BFBF gave significantly higher girth values compared to inorganic fertilizer only control treatment (100%F). At the end of 3 years all BFBF treated with 50%F+BFBF, 75%F+BFBF and 100%F+BFBF plants gave significantly higher girth values compared to control treatment. Moreover, all BFBF treated plants gave higher girth increments compared to inorganic fertilizer only applied control treatment (Table 7).

Table 7. *Plant girth and girth increment of different combinations of inorganic fertilizer and BFBF applications of immature rubber plants*

Treatments	Plant girth (cm)		Girth increment
	2½ years	3 years	
100%F	23.9[b]	30.7[c]	6.8
100%F+BFBF	24.7[ab]	33.7[ab]	9.0
50%F+BFBF	25.4[a]	34.4[a]	9.0
75%F+BFBF	25.1[a]	33.2[b]	8.1

At the end of 3 years soil samples were collected and analyzed for the determination of soil fertility parameters; organic carbon, available P and total N. These data showed that enhancement of soil fertility parameters could be observed with 100%F+BFBF and 75%F+BFBF treatments compared to control treatment (Table 8). Therefore, it can be concluded that there is a possibility of enhancement of plant growth and soil fertility parameters with BFBF treatment compared to non BFBF treatment.

Table 8. *Effect of different combinations of inorganic fertilizer and BFBF applications on soil fertility parameters*

Treatments	Organic carbon	Available P	Total N
100%F	0.6^{b}	20.29^{ab}	1.03^{b}
100%F+BFBF	0.72^{ab}	20.8^{b}	1.44^{a}
50%F+BFBF	0.62^{b}	16.87^{b}	0.98^{b}
75%F+BFBF	0.79^{a}	21.67^{a}	1.06^{b}

Vermicompost application for rubber nursery plants

Vermicomposting is a biotechnological process that converts organic materials into compost through the activities of red worms and microorganisms. Kitchen waste, cow dung, grass cuttings *etc*. were used with earthworm *Eudrilus* for the preparation of vermicompost. Throughout the process, nutritionally enriched solution, named vermiwash was collected and their effectiveness were evaluated using rubber nursery plants. This included three treatments and were arranged in a completely randomized block design with fifty replicates per treatment and one polybag as a replicate (Table 9).

Table 9. *Treatment combinations of the experiment*

Treatment	Combination
1	Soil + compost + recommended inorganic fertilizers
2	Soil + compost + recommended inorganic fertilizers + Vermi wash
3	Soil + compost + Vermi wash

Plant height and diameter were measured throughout the before bud grafting period. Data showed that the application of vermi wash with recommended fertilizer application (T2) and vermi wash only treatment (T3) gave significantly higher plant diameter values compared to recommended fertilizer only control treatment (T1) at the end of four months period. Enhancement of plant height was also observed with T2 and T3 treatments but it was not significant compared to control treatment (T1). Moreover, vermi wash only application plants (T3) showed yellowish colorization of

leaflets compared to other treatments. Therefore, totally organic manuring is not practicable and combined use of organic and inorganic as integrated plant nutrient system is more beneficial than application of organic or inorganic manure only (Table 10) (R P Hettiarachchi and K M M E K Kulatunga).

Table 10. *Effect of different fertilizer applications on growth of rubber nursery plants*

Treatments	Combination	Plant diameter (mm)	Plant height (cm)
T1	Soil+compost+recommended inorganic fertilizer	9.93[b]	96.34[a]
T2	Soil+compost+recommended inorganic fertilizer+ vermiwash	10.91[a]	99.14[a]
T3	Soil+compost+ vermiwash	10.87[a]	100.96[a]

Rehabilitation of degraded lands

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

This experiment was started in 2015 at Panawatta and Ekerella Estates. The effect of combine use of environmental friendly agro management practices for the enhancement of soil fertility in degraded rubber lands were evaluated in this study. Soil fertility parameters and plant girth were measured at six months intervals. Eighteen months after the establishment of the treatments, significant enhancement of all measured soil fertility parameters such as; pH, organic carbon, total N, ammonium, available P, exchangeable K, Mg, Ca and cation exchange capacity (CEC) could be observed with the combine use of agro management practices compared to normal estate practices. Therefore, this type of integrated plant nutrient system (IPNS) could have a possibility to reverse deteriorated soil fertility in most of the traditional rubber growing soils in Sri Lanka (Table 11). Moreover, higher plant girth measurements could be observed with combine use of agro management practices compared to estate practices (Table 12) (R P Hettiarachchi, V Edirimannne, T Gunathilake and G C Malawaraarachchi).

Table 11. *Soil fertility parameters after eighteen months of the establishment of combined use of agro management practices compared to normal estate practices at Panawatta Estate*

Assessment	Combined use of agro management practices	Normal estate practices
pH	5.8[a]	5.07[b]
Organic carbon (%)	1.4[a]	1.01[b]
Total N (%)	0.19[a]	0.15[b]

Assessment	Combined use of agro management practices	Normal Estate practices
Ammonium N (ppm)	198.5[a]	125.6[b]
K (ppm)	199[a]	152[b]
Mg (ppm)	71[a]	25[b]
Ca (ppm)	183[a]	119[b]
Available P (ppm)	27.22[a]	2047[b]
Cation exchange capacity (cmol+/Kg)	3.95[a]	2.77[b]

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

Table 12. *Effect of combine use of agro management practices and estate practices on the girth of immature Hevea plants*

Treatments	Girth (cm)
Combine use of agro management practices	13.0[a]
Normal estate practices	12.5[a]

Organic manure application for rubber nursery plants

Evaluation of the effectiveness of compost on rubber nursery plants

This experiment was started in 2016 and the experimental designed was explained in same Annual Review. Growth parameters; plant diameter and height were measured throughout the before bugrafting period. At the end of three months after planting significantly higher plant diameter measurements could be observed with 100g compost applied (T2) treatment compared to other treatments (T1 and T4) had 50 g and 200 g of compost respectively. There is no significant differences between T2 and T3 treatments which had 100g and 150g of compost respectively. Moreover, T1, T2 and T3 treatments which had 50g, 100g and 150g of compost showed significantly higher plant height compared to T4 treatment which had 200g of compost. Similar results were observed in 2016, the highest plant diameter and height values were observed with 100 g compost application (T2) at the end of the experimental period of three months (Table 13) (R P Hettiarachchi and T Gunathilake).

Table 13. *Effect of different compost applications on plant height and diameter of rubber nursery plants before bud grafting period*

Treatments	Combination	Plant diameter (mm)	Plant height (cm)
T1	Soil + 50g compost	7.52[b]	71.56[a]
T2	Soil + 100g compost	7.84[a]	72.96[a]
T3	Soil + 150g compost	7.59[ab]	72.8[a]
T4	Soil + 200g compost	7.37[b]	64.89[b]

The effect of half burned paddy husk and paddy husk ash on rubber nursery plants

An experiment was started in August 2016 to investigate the effect of soil media amendment with half burned paddy husk (HBPH) and paddy husk ash (PH ash) on the growth of poly bagged nursery plants. There were five treatments as below (Table 14).

Table 14. *The treatment combination of the experiment*

T1	Soil + HBPH (4:1) media + recommended inorganic fertilizer and compost
T2	Soil + HBPH (4:1) media + recommended inorganic fertilizer without compost
T3	Soil + PH ash (4:1) media + recommended inorganic fertilizer and compost
T4	Soil + PH ash (4:1) media + recommended inorganic fertilizer without compost
T5	Soil + recommended inorganic fertilizer and compost

It was revealed that paddy husk incorporation into growing media enhances plant diameter compared to the control plants (data reported in annual review 2016). Moreover, leaf and soil samples collected at the end of 4 months after planting were analyzed for their properties. However, plant dry matter weight (leaf dry weight, stem dry weight, root dry weight), leaf N, P, K content, soil pH and soil organic carbon have not been significantly affected by the treatments compared to the control (Table 15).

Table 15. *Effect of different paddy husk amendments on plant and soil parameters at 4 months after planting*

Parameter	Control	T1	T2	T3	T4
Leaf N (%)	2.00[a]	2.07[a]	2.12[a]	2.10[a]	2.02[a]
Leaf P (%)	0.244[a]	0.222[a]	0.224[a]	0.242[a]	0.212[a]
Leaf K (%)	0.95[a]	1.03[a]	1.03[a]	1.12[a]	1.08[a]
Leaf dry weight (g)	6.1[a]	6.0[a]	5.9[a]	6.1[a]	6.8[a]
Stem dry weight (g)	10.6[a]	9.2[a]	9.6[a]	10.1[a]	11.2[a]
Root dry weight (g)	6.5[a]	6.2[a]	6.1[a]	6.1[a]	7.0[a]
Soil pH	4.3[a]	4.1[a]	4.2[a]	4.5[a]	4.2[a]
Soil OC (%)	0.81[a]	0.93[a]	0.96[a]	1.02[a]	0.96[a]

Mean values followed by same superscript letter in each row are not significantly different at $p < 0.05$ as determined by Duncan's multiple range test

Since there was no significant difference between the results obtained from half burned paddy husk and paddy husk ash treatments, it can be concluded that use of half burned paddy husk would be better as it requires less burning and less time taken.

The findings open path for future investigations on the effect of different forms of paddy husk for enhancing performance of different plants (H A R K Jayawardana, J A S Chandrasiri, T Gunatilleke, P D S D O Rathnasooriya and R M Baddevidana).

Soil amendment with half burned paddy husk in different ratios on the growth of poly bagged nursery plants

A new experiment was begun in 2017 to investigate the effect of soil amendment with half burned paddy husk in different ratios on the plant growth and soil parameters of poly bagged nurseries. The treatments were arranged in a completely randomized block design with ten replicates. There were four treatments as below (Table 16).

Table 16. *The treatment combination of the experiment*

T1	Soil + HBPH (3:1) media + recommended inorganic fertilizer
T2	Soil + HBPH (2:1) media + recommended inorganic fertilizer
T3	Soil + HBPH (1:1) media + recommended inorganic fertilizer
T4	(Control) Soil only + recommended inorganic fertilizer

The same trial was conducted in two sites: Welikadamulla RDD nursery and Dartonfield. There was no significant difference in plant height among the treatments at the end of first three months after planting at Dartonfield experiment site. However, plant diameter values of the control (T4) plants were higher than the other treatments during the above period at Dartonfield. T3 treatment showed higher plant diameter than T1 and T2 during the same period (Table 17).

Table 17. *Effect of different HBPH applications on diameter and height of rubber nursery plants at Dartonfield*

Parameter	Treatment	Months after planting		
		1	2	3
Height (cm)	T1	46.68^{a}	62.72^{a}	69.20^{a}
	T2	47.22^{a}	61.16^{a}	67.16^{a}
	T3	47.90^{a}	62.54^{a}	67.74^{a}
	T4	47.12^{a}	62.78^{a}	69.96^{a}
Diameter (mm)	T1	4.97^{a}	6.18^{b}	7.50^{b}
	T2	5.04^{a}	6.17^{b}	7.53^{b}
	T3	5.09^{a}	6.28^{b}	7.75^{ab}
	T4	5.12^{a}	6.69^{a}	7.94^{a}

Means with the same letters in a column under each parameter are not significantly different at $p< 0.05$.

The data taken from Welikadamulla site showed that plant diameter values were significantly different at the end of 3 months after planting showing the highest diameter in control plants. However, plant height showed significant differences among the treatments from 1-3 months of planting (Table 18).

Table 18. *Effect of different HBPH applications on diameter and height of rubber nursery plants at Welikadamulla*

Parameter	Treatment	Months after planting		
		1	**2**	**3**
Height (cm)	T1	37.72^{ab}	56.64^{a}	76.68^{ab}
	T2	34.42^{c}	51.78^{b}	70.40^{c}
	T3	35.64^{bc}	50.80^{b}	72.30^{bc}
	T4	38.89^{a}	57.58^{a}	78.84^{a}
Diameter (mm)	T1	5.18^{a}	7.03^{a}	10.01^{ab}
	T2	5.05^{a}	6.66^{a}	9.50^{b}
	T3	4.87^{a}	6.70^{a}	9.68^{ab}
	T4	5.10^{a}	6.70^{a}	10.21^{a}

Means with the same letters in a column under each parameter are not significantly different at $p< 0.05$. (H A R K Jayawardana, T Gunatilleke, J A S Chandrasiri P D S D O Rathnasooriya, R M Baddevidana, N W H Gayan, S L Madushanka and N Siriwardana)

Organic and inorganic mulching for weed control in immature rubber plantations

In this study, paddy straw, oil palm refuse, polythene cover and a 50% shade net were tested for weed control around the plant in comparison to normal estate weed management practices. Experiment was conducted in immature rubber plantation of 2 years of age. Experiment was conducted in Kalutara District (Geekiyanakanda and Raigam Estates). Four different mulching materials were tested on weed control and weed regeneration compared to normal estate practices *i.e.* allow naturals and manual weeding at fertilizer application (Table 19).

Table 19. *Treatment combinations of the experiment*

Treatment	Combination
T1	Shade net
T2	Polythene sheet
T3	Oil palm refuse
T4	Paddy straw
Control	Normal estate practices

Treatments were arranged in randomized complete block design (RCBD) with 4 replicates consisting 5 plants per replicate.

Percentage weed death was checked at 2 weeks intervals and once 100% of weeds are dead, weed regeneration was observed at 2 weeks intervals. Soil samples were collected at 6 months after treatments and are being analyzed for soil N, P, K, Mg nutrient status, soil pH, CEC and organic C level.

Oil palm refuse mulch showed a quicker weed control compared to the other treatments which killed all the weeds under the mulch at 2 weeks after treatment application and the weed percentage remained zero for eight weeks period. Polythene and shade net mulch treatments also showed a higher weed control showing almost 0% of weeds from 4 – 12 weeks period (H A R K Jayawardana, T Gunatilleke and A Thewarapperuma).

Plant nutrition and fertilizer use

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

This experiment was started in 2016 and the experimental design was explained in the Annual Review 2016. At the beginning four sites in Moneragala, Vauniya, Padiyathalawa and Mahaoya areas were selected. In 2017 another three sites in Mahaoya, Padiyathalawa and Moneragala were included to evaluate the effectiveness of different fertilizer treatments on immature rubber plants. Plants at Padiyathalawa and Mahaoya sites showed significant enhancement of plant girth with R/SA 7:9:9:3 mixture and modified new fertilizer mixture compared to other treatments *i.e*. R/SA 7:9:9:3 + 2K and R/U 12:14:14 at the end of first year (Table 20). Moreover, plants in Padiyathalawa area showed significantly higher girth parameters compared to those in Mahaoya area (Table 21) (R P Hettiarachchi, U Mitrasena, V Edirimannne, J A S Chandrasiri and T Gunathilake).

Table 20. *Effect of different fertilizer mixtures on diameter of immature plants*

Treatment	Diameter (mm)
R/SA 7:9:9:3	16.58[a]
New mixture	14.53[ab]
R/SA 7:9:9:3 +2K	13.84[b]
R/u 12:14:14	13.6[b]

Table 21. *Growth pattern of immature plants in different nontraditional areas*

Nontraditional site	Diameter (mm)
Padiyathalawa	16.47[a]
Mahaoya	12.8[a]

Slow release fertilizer application

An experimental was started to evaluate the effectiveness of commercially available slow release fertilizers for rubber nursery plants. Based on the results of 2015 and 2016, two slow release fertilizers (SRF) were selected for rubber nursery plants. Instead of conventional fertilizer application procedure of biweekly application, one application of SRF was done at the beginning of the experiment at bag filling stage and the effect was evaluated throughout the nursery stage. Plants were treated according to the treatments in Table 22 and were arranged in a completely randomized block design with 50 replicates.

Table 22. *Treatment combination of the experiment*

Treatment	Combination
T1	Basal HERP application + Recommended fertilizer application biweekly
T2	Basal HERP application + 10g of slow release fertilizer type1
T3	Basal HERP application + 15g of slow release fertilizer type1
T4	Basal HERP application + 10g of slow release fertilizer type2
T5	Basal HERP application + 15g of slow release fertilizer type2
T6	No Basal HERP application + 15g of slow release fertilizer type1
T7	No Basal HERP application + 15g of slow release fertilizer type2

This experiment was conducted in Dartonfield and RDD rubber nursey at Karapincha to re-confirm the data. Plant diameter and height were measured throughout the before budgrafting period. Experiment at Dartonfield showed significant enhancement of plant diameter values with some SRF treatments; T2, T3, T4 and T5 compared to conventional fertilizer application control treatment (T1). Treatment numbers 3, 5, 6 and 7 included 15g of SRF and they gave higher plant height values compared to control treatment (T1) (Table 23). However the experiment at RDD nursery at Karapincha did not give significant differences among treatments for all growth parameters throughout the before budgrafting period (Table 24). According to the fertilizer recommendation for rubber nursery plants, fertilizer should be applied throughout the period at biweekly intervals and it is a laborious practice. Moreover, the common problems such as preparation of fertilizer solution for nursery plants, application of fertilizer with continuous stirring and unavailability of the correct fertilizer mixtures at correct time are some of the practical problems associated with conventional fertilizer application. Therefore, application of SRF at bag filling stage totally cut down labour cost associated with regular fertilizer applications and solve the problems mentioned with conventional fertilizer application (R P Hettiarachchi and J A S Chandrasiri).

Table 23. *Diameter and height of the nursery plants at the end of four months period at Dartonfield trial*

Treatment	Diameter (mm)	Height (cm)
T1	9.56b[c]	80.36[bc]
T2	10.28[a]	80.56[bc]
T3	10.33[a]	81.12[bc]
T4	10.06[a]	79.14[c]
T5	9.95[ab]	81.4[bc]
T6	9.39[c]	88.06[a]
T7	9.19[c]	85.58[ab]

Table 24. *Diameter and height of the nursery plants at the end of four months period at Karapincha trial*

Treatment	Diameter (mm)	Height (cm)
T1	8.86[a]	77.12[a]
T2	9.37[a]	77.81[a]
T3	9.31[a]	72.67[a]
T4	9.33[a]	75.88[a]
T5	9.41[a]	76.16[a]
T6	8.76[a]	74.56[a]
T7	9.18[a]	75.21[a]

Coir and latex based slow release fertilizers

Coir based slow release fertilizer application for immature rubber plants

This experiment was started in 2016 and the experimental design was explained in the annual review 2016. The immature plants at Millewa estate showed significant enhancement of girth parameters with SRF treatments (T2, T3) compared to conventional fertilizer application treatment (T1) at the end of first year period (Table 25). This experimental area in the estate was selected for industrialization zone by the government and therefore the trial was terminated at the end of 2017. However immature plants in Raigama Estate did not show significant differences between SRF treatments (T2, T3) or conventional fertilizer application treatment (T1) at the end of seven months after planting (Table 25). Therefore, it could be observed that there is a possibility to apply SRF against conventional fertilizers without affecting immature plant growth.

Table 25. *Girth of immature plants at Millewa and Raigama Estates*

Treatment	Immature plant (girth/cm)	
	Millewa Estate (after 12 months)	Rigama Estate (after 7 months)
T1	10.1[b]	5.06[a]
T2	11.12[a]	5.05[a]
T3	11.94[a]	5.04[a]

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

Ten and eight different soil units were identified and mapped in Galle and Matara districts respectively (Figs.1 and 2). Sampling sites were randomly selected in main soil units and samples were collected for analysis of fertility parameters. Moreover, field parameters such as yield, growth, topography of the land, fertilizer application history and soil management practices were collected from same sites to determine fertility levels of the lands very correctly (Tables 26 & 27).

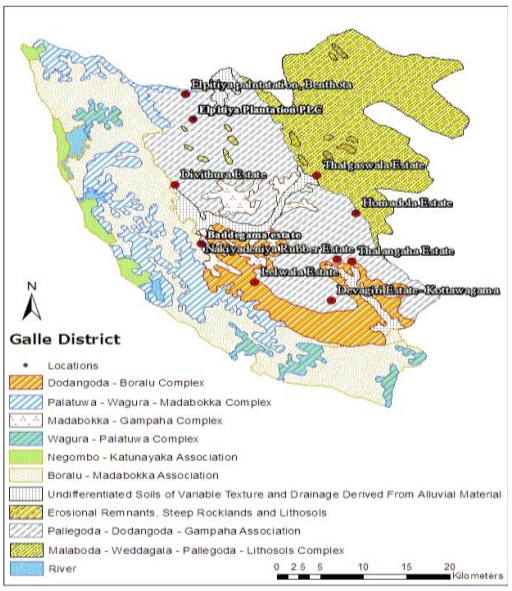


Fig. 1. Identification of different soil units in Galle district

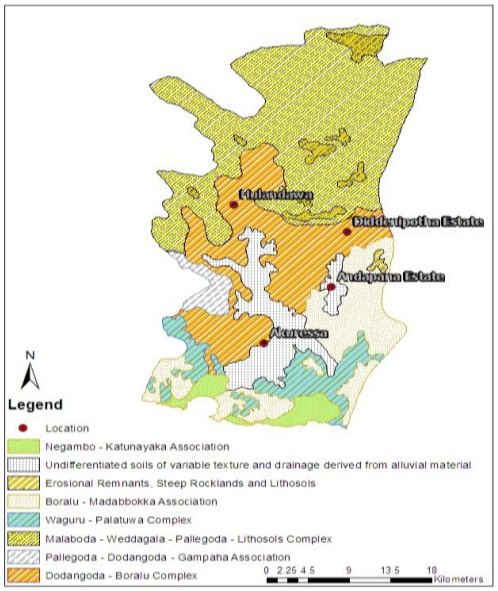


Fig. 2. Identification of different soil units in Matara district

Table 26. *Identified sampling units in Galle district and details of sample collection*

Sample unit	Site (Estate)	Extent (ha)	Data collection		Parameters analyzed
			Soil	Leaf	
Dodangoda-Boralu Complex	Lelwala	44	14	14	196
Boralu-Madabokka Association	Baddegama	58	11	10	150
Pallegoda-Dodangoda-Gampaha Association	Elpitiya	120	42	19	286
Malaboda-Weddagala-Pallegoda-Lithosols Complex	Thalgaswala	78	19	19	266

Table 27. *Identified sampling units in Matara district and details of sample collection*

Sample unit	Site (Estate)	Extent (ha)	Data collection		Parameters analyzed
			Soil	Plant	
Dodangoda-Boralu Complex	Hulandawa	17	6	6	84
	Diddenipotha	73	9	9	126
Malaboda-Weddagala-Pallegoda-Lithosols Complex	Thennahena	78	19	19	266

Services

Site-specific fertilizer recommendation by soil and foliar survey programme

Under this programme 6,500 hectares of mature rubber fields were surveyed and 43 fertilizer recommendations were given for the next three years. Details of the survey are given in Table 28 (R P Hettiarachchi, A Thewarapperuma and all the staff of the department).

Table 28. *Detailed report of the site specific fertilizer recommendation programme in 2017*

Estate	Extent surveyed (ha)	Estate	Extent surveyed (ha)
Alupola	230	Vincit	130
Etana	230	Parambe	160
Elpitiya	200	Higgoda	170
Chesterford	73	Miyanawita	35
Sunny croft	101	Talduwa	107
Glenesk	27	Lavant	200
Pimbura	50	Nottinghill	160
Clyde	155	Kappetigala	165

Estate	Extent surveyed (ha)	Estate	Extent surveyed (ha)
Pitiyakande	155	Hapugastenna	90
Muwankanda	250	Hathbawa	120
Kobowela	23	Weniwella	110
Ambadeniya	270	Atale	300
Ederapola	375	Pallegama	150
Dammaria B	205	Pallegoda	45
Adawatta	121	Eheliyagoda	220
Shawland	50	Keragala	120
Yatawatta	10	Doloswela	200
Hopton	117	Sapumalkanda	250
Tagaswela	70	Udabage	850
Ketandola	90	Yatadola	115
Citrus	30	Sanquhar	25
Moralioya	150		

Land selection and suitability for rubber cultivation

Under the routine land selection program 205 hectares of land were surveyed for the suitability of rubber cultivation and eight land suitability reports were issued. Details of the surveys are given in Table 29 (R P Hettiarachchi and all the staff of the department).

Table 29. *Details of the land selection program in 2017*

Place (GS Division)	Extent surveyed (ha)
Chankaladi (Batticaloa)	150
Mahaoya (Batticaloa)	45
Sevanagala (Moneragala)	10

Analytical services

Under this programme various samples which were received from estates, small holders, universities and other private organizations were analyzed according to the SLS methods. The Department analyzed approximately 1,050 samples (4,500 parameters) including 400 fertilizer samples form rubber growers to assure application of good quality fertilizers to their rubber lands (R P Hettiarachchi and all the staff of the department).

BIOCHEMISTRY AND PHYSIOLOGY

K V V S Kudaligama

DETAILED REVIEW

Staff

Dr (Mrs) K V V S Kudaligama, Senior Research Officer, covered the duties of the Head of the Department whilst managing the research and development work. Research Officer, Miss N P S N Karunarathne, Experimental Officer, Mr M K P Perera, Technical Officer, Mrs P D T L Madushani and Management Assistant, Mrs H A M E Hettiarachchi were on duty throughout the year. Miss N N Nadeeshani assumed duties as a Technical Officer with effect from 02.01.2017. Mr L T B K Fernando was appointed as a Temporary Research Assistant for the National Science Foundation funded research project RG/2017/AG/1 with effect from 25.09.2017.

Research students

- Ms K K Thanuja Lakmali trainee from Sri Lanka School of Agriculture, Bibile completed her one month practical training at the department.

Seminars/Conferences/Workshops/Exhibitions attended

Officer/s	Subject/Theme	Organization
KVVS Kudaligama	Scientific Committee Meetings	RRISL
	IRRDB Conference 2017	IRRI, Indonesia
NPSN Karunarathne	Scientific Committee Meetings	RRISL
	Training workshop	Hyles Pvt Ltd
	Workshop on project proposal writing	SLCARP
	Training workshop on water quality management	Hemsons Pvt Ltd

Training Programmes conducted

Officer/s	Subject/Theme	Beneficiary/Client
KVVS Kudaligama	Low intensity harvesting and Temperature corrected Ready Reckoner chart	Two knowledge upgrading programmes for RDOs/REOs of in Kalutara and Ratnapura districts
	Low intensity harvesting and Temperature corrected Ready Reckoner chart	17 awareness programmes for growers in Kalutara and Ratnapura districts
	02 training programmes	NIPM

Field visits

Advisory - 12 visits
Experimental - 222 visits
Miscellaneous - 18 visits

Sample testing

% Dry rubber content of latex - 254 samples

LABORATORY AND FIELD INVESTIGATIONS

Research, development and commercial scale adaptation of low frequency harvesting (LFH)/Low intensity harvesting (LIH) systems (BCP/01)

Identification of cost effective Low frequency/Low intensity harvesting systems to reduce cost of production, increase economic lifespan of trees and wage of harvesters whilst securing the health of rubber tree (BCP/1/a)

Commercial scale testing of low intensity harvesting systems have been tested in 2002 replanted field with RRIC 121 genotype at Kuruwita Substation. Systems being tested were S/2 d4, S/4 d3 and S/2 d1 2d7.

Dry rubber content of latex S/2 d4 systems was comparable with S/2 d2 system. 3.4% increase in daily latex yield (GTT) in S/2 d4 system has led to increase the productivity of LIH system by 18kg over that of S/2 d2 system (Table 1).

Table 1. *Performance of commercial scale S/2 d4 low intensity system with ethephon stimulation*

Tapping system	Actual tapping days	DRC (%)	GTT (g)	IPH (kg)	YPT (kg)	YPH (kg)
S/2 d2	149	36.51	29.12	8.74	4.34	1736
S/2 d4	74	37.01	59.24	17.77	4.38	1754

The commercial scale testing of S/4 d3 system started in 2010 was continued at Kuruwita Substation with application of 2.5% oil based commercial ethephon mixture as the yield stimulant at every two weeks interval. Dry rubber content of latex in low intensity system was comparable with S/2 d2 system. Productivity of S/4 d3 system observed in 2017 (Table 2) is 49kg higher than that of S/2 d2 system.

Table 2. *Performance of commercial scale S/4 d3 low intensity system with ethephon stimulation*

Tapping system	Actual tapping days	DRC (%)	GTT (g)	IPH (kg)	YPT (kg)	YPH (kg)
S/2 d2	149	36.51	29.12	8.74	4.34	1736
S/4 d3	99	35.61	42.61	12.78	4.22	1687

Testing of the weekend harvesting system with two consecutive tappings per week was continued in commercial level with application of 2% ethephon at every two weeks interval. Yield levels in terms of yield per tree (YPT) and yield per hectare per year (YPH) of S/2 d1 2d/7 was more or less similar to that of S/2 d2 system (Table 3).

Table 3. *Performance of commercial scale S/2 d1 2d/7 low intensity system with ethephon stimulation*

Tapping system	Actual tapping days	DRC (%)	GTT (g)	IPH (kg)	YPT (kg)	YPH (kg)
S/2 d2	149	36.51	29.12	8.74	4.34	1736
S/2 d1 2d/7	80	38.33	53.41	16.02	4.27	1709

Commercial scale adaptation of recommended LFH/LIH systems with liquid stimulation

Commercial scale adoption of S/2 d4 system has been started with 04 tapping blocks in Gallewatta division of Dartonfield estate replanted in 2008 with RRIC 121 genotype in January 2016 with 2.5% oil based ethephon as the yield stimulant. According to the tapping days of the estate, expected tappings under d4 system was 70 days. However, this has not been met due to absenteeism of harvesters. Yield per tree per year varied from 2.70 kg to 3.47 kg in four blocks. Average dry rubber content of latex was more or less similar in four tapping blocks (Table 4).

Table 4. *Performance of S/2 d4 system under commercial scale plantation*

Tapping block	Actual tapping days	DRC (%)	GTT (g)	IPH (kg)	YPT (kg)	YPH (kg)
Block - 1	67	39.77	45.20	13.56	3.01	1203
Block - 2	61	39.56	56.92	17.08	3.47	1389
Block - 3	63	39.53	47.08	14.13	2.97	1187
Block - 4	62	39.64	43.63	13.09	2.70	1082

Mature rubber field replanted in 2010 with RRIC 121 and RRISL 203 in Nivithigalakele division of Dartonfield Estate was also selected to investigate the adaptability of S/2 d4 system at commercial scale with the commencement of tapping (K V V S Kudaligama, N P S N Karunarathna, V H L Rodrigo, M K P Perera and P D T L Madushani).

Research & development on biochemical & physiological aspects of rubber tree/plant, latex and wood for sustainable rubber industry (BCP/02)

Research & development on biochemical & physiological aspects of rubber plant/tree to screen best genotypes for sustainable rubber cultivation (BCP/02/a)

Experimental fields established in 2014 and 2016 in Nedunkulama, Vauniya with four clones had to discontinue as Mr Jayantha, owner of the cultivation passed away in 2017. Experimental fields established with different clones in Kandakaduwa, Meerigama and Dartonfield has been monitored for growth and physiological performances of the trees. Physiological, biochemical and growth data collection was started at newly established experimental fields in Namalgama, Kandakaduwa, Hambegamuwa and Padiyathalawa with 10 clones in collaboration with Plant Pathology and Microbiology Department.

One year after planting stem diameter and height of RRIC 121 in Kandakaduwa site showed higher growth rate whilst PB 260 clone showed the least growth in plants. After 2nd year of planting best growth performances was shown by RRIC 121 and RRISL 2001 clones in Dartonfield site. At Meerigama site RRISL 203 was the best out of four clones planted (Tables 5 & 6).

Table 5. *Average diameter of plants of different clones at Kandakaduwa, Dartonfield and Meerigama sites*

Site	**Diameter (cm)**				
	RRIC 100	**RRIC 121**	**RRISL 203**	**RRISL 2001**	**PB 260**
Kandakaduwa (DZ) 1st year	17.1	19.4	15.2	15.8	12.3
Dartonfield (WZ) 2nd year	31.4	42.2	41.8	42.3	-
Meerigama (IZ) 2nd year	-	17.3	21.1	17.0	12.7

Table 6. *Average height of plants of different clones at Kandakaduwa, Dartonfield and Meerigama sites*

	Height (cm)				
Site	**RRIC 100**	**RRIC 121**	**RRISL 203**	**RRISL 2001**	**PB 260**
Kandakaduwa (DZ) 1st year	187	236	161	154	139
Dartonfield (WZ) 2nd year	316	487	456	451	-
Meerigama (WZ) 2nd year	-	242	267	164	158

In general epicuticular wax content of all clones planted in Dry zone site was considerably higher than that in Wet zone sites. Out of five clones RRIC 121 showed the highest epicuticular wax content whilst RRIC 203 showed the least values in Dry zone. Out of two sites in Wet zone, epicuticular wax content of all clones were higher in Dartonfield site (Table 7).

Table 7. *Epicuticular wax content of plants of different clones at Kandakaduwa, Dartonfield and Meerigama sites*

	Epicuticular wax content (g/cm^2)				
Site	**RRIC 100**	**RRIC 121**	**RRISL 203**	**RRISL 2001**	**PB 260**
Kandakaduwa (DZ) 1st year	131.7840	261.8835	122.3877	151.3397	172.0184
Dartonfield (WZ) 2nd year	0.0244	0.0164	0.0400	0.0252	-
Meerigama (WZ) 2nd year	-	0.0046	0.0038	0.0041	0.0038

(K V V S Kudaligama, N P S N Karunarathne and M K P Perera)

Research and development on biochemical, physiological and mechanical aspects of rubber wood (BCP/02/c)

Physical properties of green wood of RRIC 121 genotype under different age classes were analysed in order to investigate the quality of rubber wood to use it as an alternative to forest timber. Samples were collected initially from randomly selected trees in different age classes at Dartonfield, Gallewatta and Nivithigalakele.

Density of wood was observed to be increased with the age of the tree. Specific gravity and moisture content of wood was more or less similar within the different age classes (Table 8).

Table 8. *Moisture content, density and specific gravity of wood of RRIC 121 genotype under four different age groups*

Physical property	RRIC 121 genotype Age groups			
	26 - 30	**21 - 25**	**16 - 20**	**11 - 15**
Moisture content (w/w%)	65.75	65.96	65.14	66.19
Density (kgm^{-3})	634.58	625.04	624.42	619.08
Specific gravity	0.63	0.63	0.62	0.62

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

Miscellaneous experiments to increase the production and productivity of rubber plantations (BCP/04)

Development of a rapid method to estimate leaf chlorophyll content of rubber plants (BCP/04/a)

Rapid method has been developed to estimate actual leaf chlorophyll content with SPAD – 502 leaf chlorophyll meter. Chlorophyll content per biomass (mg g^{-1}) leaf tissue and per area (mg cm^{-2}) of leaf tissue was regressed with appropriate SPAD units and fitted for each *Hevea* genotype *i.e.* RRIC 100, RRIC 121, RRISL 203 and RRISL 2001 separately. Second order polynomial curves showed the highest accuracy level in the equations obtained for estimation of leaf chlorophyll content in all genotypes tested.

Investigating biochemical aspects of latex that effect on quality of raw rubber (BCP/04/b)

Investigations were started to identify variation of major biochemical components of latex that affect the colour of raw rubber of five clones. Amongst the clones tested, highest polyphenol and carotenoid contents were observed in RRISL 203 whereas RRISL 2001 and Centennial 4 had the highest protein and thiol contents, respectively (Table 9). Raw rubber properties of unfractioned unbleached crepe of these clones are to be tested to investigate the effect of biochemical components on quality of raw rubber.

Table 9. *Composition of different biochemical components in rubber latex*

Clone	Biochemical components (µg/g)			
	Polyphenol content	Protein content	Carotenoid content	Thiol content
RRISL 203	545.10	393.03	1.14	169.51
Centennial 3	393.86	751.62	0.78	98.05
Centennial 4	432.83	900.04	0.31	184.85
RRISL 2001	324.15	1365.51	0.42	83.96
RRISL 2006	410.30	724.08	0.43	136.19

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

Development of in-country ethephon formulations to promote low cost harvesting systems for rubber plantations in Sri Lanka (RG/2017/AG/1)

National Science Foundation of Sri Lanka funded to develop ethephon formulation that suits to use as the yield stimulant in rubber plantations in Sri Lanka. Main objective of this project was to develop cost effective stimulant with locally available ingredients as base materials.

Initial investigations had been done to investigate suitable thickener for the formulation. Cellulose derivatives, gums and starch available in the market were tested for mixing properties and convenience to apply with different viscosity levels (K V V S Kudaligama, T H P S Fernando, V H L Rodrigo, P Seneviratne, N P S N Karunarathna and L T B K Fernando).

ADVISORY SERVICES

A Dissanayake

DETAILED REVIEW

Staff

The Head of the Department, two Regional Advisory Officers (RAOo), twenty one Rubber Extension Officers (REOo) and the Assistant Training Officer were on duty throughout the year. Mr W D C Munirathana and D Weerasekara Rubber Extension Officers retired with effect from 2017.11.20 and 2017.8.17 respectively, after providing an outstanding services for the betterment of the rubber smallholder sector.

Mr Sameera Gayanath Hewanambikanda and Mr Buddika Jayasianghe, Mr Lalange Siriwardana, Miss Kalani Indrachapa Jayasundara and Miss Rangika Thennakoon and Mr Dimanta Dissanayaka assumed duties as Rubber Extension Officers with effect from 2017.1.2, 2017.2.2, 2017.3.1 and 2017.7.10 respectively.

Conferences/Meetings/Seminars/Workshops/Foreign tours attended

Officer/s	Subject/s	Organization/s
Anura Dissanayake	Progress Review Meetings	Ministry of Plantation Industries
Anura Dissanayake PKKS Gunaratna RAD Ranawake	Scientific Committee Meetings Technology update programmes Research Meetings	Rubber Research Institute of Sri Lanka

PROGRESS OF PROJECTS AND SERVICES

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

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

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

To demonstrate the value of adopting RRISL recommendations to increase the land use efficiency of rubber smallholdings, the extension strategy focused on

farmer participatory development of selected rubber holdings as "Model rubber holdings" was continued successfully (Table 1).

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

Region	No. of developed holdings	
	Mature	**Immature**
Colombo/Gampaha	7	4
Kegalle	25	25
Kalutara	20	21
Ratnapura	15	15
Galle/Matara	10	10
Total	**77**	93
		152

Project 2 (ASD/01/B) Participatory development of Rubber Processing Centers as models

Advisory and extension support services were provided to maintain 37 "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).

Table 2. *Number of model rubber processing centers developed*

Region	No. of model centers maintained
Colombo/Gampaha	3
Kegalle	11
Kalutara	8
Ratnapura	7
Galle/Matara	8
Total	**37**

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

To popularize the rainguard technology as a short term strategy to increase the productivity of rubber smallholders, 40 rainguard demonstrations were established under supervision of Rubber Extension Officers (Table 3).

Table 3. *Details of rain guard demonstration holdings*

Region	No. of demonstrations established
Colombo/Gampaha	9
Kegalle	7
Kalutara	5
Ratnapura	4
Galle/Matara	15
Total	**40**

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 47 new RSS Production Centres and rehabilitation of 20 substandard processing centers, as per to the requests of owners to maintain them as cost effective units (Table 4).

Table 4. *The number of rubber processing centers constructed, rehabilitated & modified in different regions*

Region	No. of RSS production centers	
	Constructed	Rehabilitated
Colombo/Gampaha	3	3
Kegalle	26	4
Kalutara	6	5
Ratnapura	9	4
Galle/Matara	3	4
Total	**47**	**20**

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, 20 intercropping demonstration plots were established (Table 5).

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

Region	No. of demonstrations plots	Intercrops/cropping system
Colombo/Gampaha	3	Pineapple, Banana
Kegalle	5	Pineapple, Banana
Kalutara	7	Banana
Ratnapura	3	Banana
Galle/Matara	2	Banana
Total	**20**	

Project 6 (ASD/01/F) Rehabilitation of substandard immature and mature rubber holdings

Advisory and extension support services were provided to rehabilitate 80 immature and 84 mature substandard rubber holdings respectively (Table 6).

Table 6. *Number of immature, mature substandard rubber holdings rehabilitated in each region*

Region	Immature holdings rehabilitated	Mature holdings rehabilitated
Colombo/Gampaha	7	10
Kegalle	28	29
Kalutara	20	20
Ratnapura	15	15
Galle/Matara	10	10
Total	**80**	**84**

Project 7 (ASD/01/G) Participatory development of "Forward march" model rubber villages

The concept of establishment of "forward march rubber villages" is widen with the selection of 22 new villages to up-grade as model villages. Basic data and information were collected and action plans were prepared. The project is in progress.

Project 8 (ASD/01/H) Projects related advisory visits in traditional rubber growing areas

Two thousand five hundred and thirty one 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 7).

Table 7. *Number of advisory visits made under different projects in different regions*

Region	Nature of advisory visit							
	Model farm development	Rehabilitation of substandard rubber holdings	Introduction of Intercropping Systems	Introduction of rain guard technology	Maintenance of model RSS centers	Construction of new RSS centers	Rehabilitation of substandard RSS centers	**Total**
Colombo/Gampaha	76	94	24	34	16	18	19	**281**
Kalutara	316	211	48	69	97	21	17	**779**
Kegalle	315	175	21	43	40	67	26	**687**
Rathnapura	203	169	35	48	31	36	30	**552**
Galle/Matara	79	68	21	14	31	12	7	**232**
Total	**989**	**717**	**149**	**208**	**215**	**154**	**99**	**2531**

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

Project 9 (ASD/2/A) Individual advisory visits on requests of rubber smallholders

Six hundred and forty seven advisory visits 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 8).

Table 8. *Number of individual advisory visits conducted by REOo, on requests of stakeholders*

Region	No. of advisory visits conducted by REOo
Colombo/Gampaha	65
Kegalle	284
Kalutara	126
Ratnapura	85
Galle/Matara	87
Total	**647**

Project 10 (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, 29 "Vihidum Sathkara" group advisory programmes were conducted for the benefit of 580 rubber smallholdings in traditional rubber growing areas (Table 9).

Table 9. *The "Vihidum Sathkara" special group advisory programmes conducted for rubber smallholders*

Region/District	No. of programmes conducted	No. of mature holdings inspected	No. of immature holdings inspected
Colombo/Gampaha	1	2	5
Kegalle	12	183	101
Kalutara	5	102	53
Ratnapura	7	26	40
Galle/Matara	4	22	46
Total	**29**	**335**	**245**

Project 11 (ASD/02/C) "Vihidum Sathkara" Centrally planned special group advisory and Extension programmes for medium scale rubber estate owners in traditional rubber growing areas

Four "Vihidum Sathkara" centrally planned special group advisory and extension programmes were conducted to increase the productivity of 6 medium scale Rubber estates in traditional rubber growing areas (Table 10).

Table 10. *"Vihidum Sathkara group advisory and extension programmes conducted for improvements of medium scale rubber estate*

Region	No. of programmes conducted	No. of medium scale estates benefitted
Kegalle	3	4
Ratnapura	1	2
Total	**4**	**6**

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

Project 12 (ASD/03/A) Awareness raising programmes

Sixty six awareness programmes were conducted to educate 1,768 rubber growers in traditional area on general aspects of rubber cultivation and immature up keep (Table 11).

Table 11. *Awareness raising programmes conducted*

Region /District	No. of programmes conducted	No. of rubber farmers benefitted
Colombo/Gampaha	6	130
Kegalle	27	933
Kalutara	12	412
Ratnapura	13	164
Galle/Matara	8	129
Total	**66**	**1768**

Project 13 (ASD/03/B) Mobile tapper training schools

As a solution to the tapper shortage in rubber growing areas, 11 mobile tapper training programmes were conducted and 226 new harvesting assistants were introduced to the rubber industry (Table 12).

Table 12. *Number training programmes conducted and number of harvesting assistants introduced through Mobile Tapper Training Schools conducted in traditional rubber growing areas*

Region/District	No. of training programmes	No. of new harvesting assistants introduced
Kegalle	6	120
Kalutara	3	67
Galle/Matara	2	39
Total	**11**	**226**

Project 14 (ASD/3/C) Skills development of rubber tappers

To upgrade the knowledge and skill levels of semi-skilled harvesting assistants, 42 skill development training programmes were conducted to improve the quality of tapping of 673 selected harvesting assistants (Table 13).

Table 13. *Skill development programmes conducted for semi-skilled rubber tappers*

Region	No. of programmes	No. of Semi-skilled tappers trained
Colombo/Gampaha	2	35
Kegalle	14	261
Kalutara	15	252
Ratnapura	6	55
Galle/Matara	5	70
Total	**42**	**673**

Project 15 (ASD/3/D) Quality improvement of RSS

To improve the product quality of RSS produced by rubber smallholders, 29 one day training programmes were conducted for the benefit of 378 selected RSS producers (Table 14).

Table 14. *Training programmes conducted for quality improvement of RSS*

Region	No. of training programmes	No. of RSS producers benefitted
Colombo/Gampaha	1	12
Kegalle	10	140
Kalutara	9	168
Ratnapura	7	48
Galle/Matara	2	10
Total	**29**	**378**

Project 16 (ASD/03/E) Training programmes on identification, control and eradication of white root disease

Forty three farmer training programmes were conducted to educate 638 rubber growers on identification, control and preventive measures of white root disease (Table 15).

Table 15. *Details of Training programmes conducted on identification, control and prevention of white root disease*

Region	No. of training programmes conducted by REOo	No. of farmers benefitted
Colombo/Gampaha	2	29
Kegalle	11	209
Kalutara	13	207
Ratnapura	11	111
Galle/Matara	6	82
Total	**43**	**638**

Project 17 (ASD/03/F) "Nipunatha Saviya" special training programmes to avoid/prevent in-discriminatory exploitation of rubber trees by smallholders

Twenty five full day workshops were conducted to educate selected rubber smallholders and their harvesting assistants totaling 636 on importance of adhering to RRI tapping recommendations to avoid in-discriminatory exploitation of rubber trees (Table 16).

Table 16. *Details of "Nipunatha Saviya" special programmes conducted*

Region	No. of training programmes	No. of owners and tappers benefitted
Colombo/Gampaha	1	39
Kegalle	13	284
Kalutara	5	174
Ratnapura	4	81
Galle/Matara	2	58
Total	**25**	**636**

Project 18 (ASD/03/G) "Erambumata Athwalak"- Training for village youth on land preparation, contour lining, planting and value addition

A workshop was conducted to train five selected youth from Homagama REO range in pre planting activities including lining, holing and soil conservation methods.

Project 19 (ASD/03/H Rubber value addition training programme for medium scale rubber farmers

One day workshop was conducted on rubber value addition for the medium scale rubber farmers in collaboration with the Rubber Technology and Development Department. Forty eight medium scale entrepreneur farmers participated, in this programme from Colombo and Gampaha districts.

Project 20 (ASD/03/I) Special training programmes and exhibitions

On request of different organizations following servicers were provided.

Organization	Service
Rubber Development Department	REOo participated as resource persons for 3 tapping training schools
Thurusaviya Fund	REOo participated as resource persons for 3 training programmes of quality improvement of RSS processing, two general awareness programmes, one tapping skill development programme and three tapper training schools
Kalawana National School	Establishment of the exhibition stall on rubber cultivation and other relevant aspects
University of Rajarata	Training workshop on rubber farming for the undergraduates of Faculty of Agriculture

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

Preliminary works to establish two technology transfer centres as noval approach in effective extension were attended. The Regional Office premises of Kegalle, Kalutara and Ratnapura were selected for this purpose and some renovations were planned and instruments needed for these centers were received.

Data collection was carried out in relation to all field training and advisory programmes and GIS based mapping was used for effective planning of extension programmes.

A new project was started on "Introduction and establishment of new fuelwood growing rubber in selected lands of smallholder rubber farmers" funded by the Food and Agriculture Organization of the United Nations. Under this project awareness programmes were conducted with the aim of selection of suitable farmers,

in addition to educate the rubber extension officers. Eight different growing models were introduced for rubber smallholders and details given in Table 17.

Table 17. *Establishment of new fuelwood growing lands of smallholder rubber farmers*

Model	No. of farmers	Area (ha)
G Only	3	1.6
G-P (8'x8')	45	46
R-G-P (8'x27')	21	23
R-G-P (8'x40')	9	9.3
R-G-P (8'x60')	2	2.8
R-G (8'x27')	2	0.8
R-G (8'x40')	1	2.8
R-G (8'x60')	0	0
Total	83	86.3

R – Rubber **G - Gliricidia** **P - Pepper**

RUBBER TECHNOLOGY AND DEVELOPMENT

Dilhara Edirisinghe

DETAILED REVIEW

Staff

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

Mr P L Perera, Mrs S I Yapa, Mr S L G Ranjith and Mrs Priyanthi Perera, Experimental Officers and Mr D G M J Abeywardena, Miss Gayathri Bhagyawedha and Mr K I D P Perera, Technical Officers were also on duty throughout the year. Miss Ishani Jayaratne and Mr Pavithra Gunasekera were recruited to the Post of Technical Officer with effect from 14th July 2017 and 1st August 2017, respectively. Miss S M D Shashee Rekha De Alwis Wijerathne, Management Assistant was on duty throughout the year.

Research students

Postgraduate students

- Mr Vinod Silva, a MSc (Polymer Technology) student from the University of Moratuwa conducted his research project on "Development of a PAH comply black tread compound" under the supervision of Dr (Mrs) D G Edirisinghe.

- Mr Nadun Perera, a MSc (Polymer Science and Technology) student from the University of Sri Jayewardenapura initiated his research project on "Effect of particle size of antioxidants on properties of natural rubber latex films" under the supervision of Dr (Mrs) D G Edirisinghe.

Undergraduate students

- Miss K C Samaraweera, a BSc (Palm and Latex Technology) undergraduate student from the Uva Wellassa University of Sri Lanka conducted her research project on "Silica extracted from rice husk ash as effective reinforcing filler for natural rubber composites" under the supervision of Dr (Mrs) D G Edirisinghe.

- Miss M K C L Chathushani, BSc (Chemical Science and Technology – Special) undergraduate student from the Sabaragamuwa University of Sri Lanka completed her research project on "Evaluation of suitability of methanol extracted *Moringa oleifera* leaves as a natural antioxidant for dry rubber composites" under the supervision of Mr W D M Sampath.

Seminars/Training/Conferences/Workshops/Meetings attended

Officer/s	Subject/Theme	Organization
DG Edirisinghe & WDM Sampath	Scientific Committee Meetings	Rubber Research Institute of Sri Lanka
DG Edirisinghe	Meetings - CRT Trade Fair 2017	Ministry of Plantation Industries
DG Edirisinghe	Meeting in regard to the National Exhibition, "Thirasara Yugayake Haritha Udanaya"	Presidential Secretariat & Ministry of Plantation Industries
DG Edirisinghe, WDM Sampath & DGMJ Abeywardena	NSF Awards Ceremony	National Science Foundation
DG Edirisinghe and WDM Sampath	Meeting on "Development of NR/bitumen masterbatches for road construction"	Road Development Authority (RDA), Ratmalana
DG Edirisinghe	Meeting in regard to setting up the Finite Element Analysis (FEA) Centre	Ministry of Plantation Industries
DG Edirisinghe	Training program in regard to evaluation of inventions	Sri Lanka Inventors Commission (SLIC)
DG Edirisinghe & WDM Sampath	IRRDB Fellowship Program	IRRDB and RRISL
DG Edirisinghe	Cluster Finance Workshop	Sri Lanka Export Development Board in collaboration with Asian Development Bank
DG Edirisinghe	Meetings regarding formulation of a development plan for the G.C.E. Advanced Level "Technology Stream"	Ministry of Education & National Institute of Education
DG Edirisinghe	Awareness seminar on rubber testing facilities available in Sri Lanka	Sri Lanka Export Development Board
DG Edirisinghe, WDM Sampath & KIDP Perera	International Symposium on Polymer Science & Technology, IIUPST 2017	University of Sri Jayewardenepura
DG Edirisinghe	Meeting regarding the exhibition in connection with "40th Anniversary of the Open Economy"	Ministry of Plantation Industries
DG Edirisinghe	Seminar on "Solid waste management in Sri Lanka: Highlights, suggestions and solutions"	Science & Technology Steering Committee (STAC) of SLAAS
DG Edirisinghe	Meeting of the Rubber Sector Review Committee	Ministry of Plantation Industries

Officer/s	Subject/Theme	Organization
DG Edirisinghe	Awareness seminar for exporters on "Available testing facilities in Sri Lanka"	Sri Lanka Export Development Board
DG Edirisinghe	Stakeholder meeting on "Certification issues for selected export products"	Sri Lanka Export Development Board
WDM Sampath	"Open day" program	Industrial Technology Institute (ITI)
Priyanthi Perera	Training program on "Agricultural products circulation technology for developing countries"	Hunan Agricultural Group, China
PL Perera and SLG Ranjith	Three day workshop for inventors at Kukuleganga	Sri Lanka Inventors Commission (SLIC)

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

Officer/s	Subject/Theme	Beneficiary/Client
DG Edirisinghe	Latex technology	MSc Students (Polymer Science & Technology) - University of Sri Jayewardenepura
WDM Sampath	Compounding ingredients for latex and dry rubber	Students of the Certificate Course in Rubber Technology - PRISL
Priyanthi Perera	Structure – property relationship of polymers	Students of the Certificate Course in Rubber Technology - PRISL
WDM Sampath	Rubber product manufacture as a cottage industry	Rubber Development Officers – Rubber Development Department
WDM Sampath	Composition of NR latex and stability Value addition to raw rubber	Induction Course for Planter Trainees - NIPM
DG Edirisinghe	Introduction to natural rubber latex characteristics	National Diploma in Plantation Extension Management-NIPM
DG Edirisinghe	NR latex, composition and its characteristics	National Diploma in Plantation Management - Rubber Agronomy & Processing - NIPM
DG Edirisinghe	Natural rubber latex characteristics	Professional Programme in Rubber Manufacture & Factory Practices - NIPM
DG Edirisinghe	Home-made rubber products Value addition at farmer level	IRRDB and RRISL
Staff of the department	Field training on "Value addition to rubber products"	Undergraduate students of Faculty of Agriculture, Rajarata University
Staff of the department	Field training on "Rubber technology"	Undergraduate students of Plantation Agriculture - Sabaragamuwa University of Sri Lanka

Officer/s	Subject/Theme	Beneficiary/Client
Staff of the department	Practical training on "Rubber technology"	MSc Students (Polymer Science & Technology) - University of Sri Jayewardenepura
Staff of the department	Field training on "Rubber product manufacture"	Undergraduate students of Palm & Latex Technology and Value Addition - Uva Wellassa University
WDM Sampath, SLG Ranjith, PL Perera, SI Yapa, DGMJ Abeywardena & KIDP Perera	Educational Exhibition	C W W Kannangara Central College, Matugama
WDM Sampath	Judging panel member - IRSUWU 2017, International Research Symposium of Uva Wellassa University	Uva Wellassa University
Staff of the department	Educational Exhibition – Centennial Celebrations	Visakha Vidyalaya, Colombo 4
SLG Ranjith, PL Perera, SI Yapa, Priyanthi Perera, DGMJ Abeywardena and KIDP Perera	"Senasee" Golden Jubilee Educational Exhibition - 2017	D.S. Senanayake College, Colombo 7
SLG Ranjith	The first exhibition commemorating the 40th Anniversary of the Open Economy	Prime Minister's Office & Ministry of Plantation Industries
DG Edirisinghe & KIDP Perera	"Thirasara Yugayaka Haritha Udanaya – 2017" - National exhibition	Presidential Secretariat & Ministry of Plantation Industries
DG Edirisinghe	Participated in the "Sara Prabha Gira" radio Programme	Ministry of Plantation Industries & SLBC
SLG Ranjith & PDA Gunasekera	Workshop on "Rubber based products manufacture" in Kandy District, Hataraliyadda	National Institute of Plantation Management & Thurusaviya Fund
SLG Ranjith and KIDP Perera	Workshop on "Rubber based products manufacture" in Dankotuwa	National Institute of Plantation Management & Thurusaviya Fund
Priyanthi Perera	Workshop on "Rubber based products manufacture" in Ratnapura	National Institute of Plantation Management & Thurusaviya Fund

Officer/s	Subject/Theme	Beneficiary/Client
DG Edirisinghe, WDM Sampath, SLG Ranjith, PL Perera & DGMJ Abeywardena	CRT Trade Fair 2017	Ministry of Plantation Industries
Staff of the department	Training program on rubber based products manufacture	Advisory Services Department of RRISL
Staff of the department	Practical demonstrations on rubber based products manufacture	BSc (Agri. Sp.) undergraduates of the Department of Plantation Management, Wayamba University of Sri Lanka

Industrial visits

The following Institutes/Industries were visited during the year for development /trouble shooting work.

Officer	Industry/Organization
DG Edirisinghe and SI Yapa	Lalan Eco Latex (Pvt.) Ltd., Katunayake
DG Edirisinghe, WDM Sampath and DGMJ Abeywardena	Road Development Authority, Ratmalana
WDM Sampath, D G M J Abeywardena and K I D P Perera	Irradiation Unit of the Atomic Energy Authority, Biyagama

LABORATORY INVESTIGATIONS

Latex technology

Development of a non-toxic natural rubber latex based adhesive for paper

A non-toxic natural rubber latex based adhesive for paper was developed using neem oil as a preservative and other non-toxic ingredients in collaboration with a group of final year undergraduate students of the Faculty of Management, University of Colombo. The product which was named by the students as "Glamour Kohomba Glue" was introduced to the market at the launching ceremony organized by the faculty (D G Edirisinghe and S I Yapa).

Dry rubber technology

Evaluation of suitability of methanol extraction of Moringa oleifera leaves as a natural antioxidant for dry rubber composites

Antioxidants are added in compounding of natural rubber to protect against thermal oxidation. Amine type antioxidants are widely used in dry rubber compounding. However, these antioxidants have been found to be toxic. Hence,

replacement of these antioxidants with natural materials having antioxidant activity would be advantageous.

Among the plants which are rich in antioxidant activity, *Moringa oleifera* is special because its leaves, bark and roots also show good antioxidant ability and leaves are rich in phenolic constituents. Methanol extraction of the *Moringa oleifera* leaves was selected as a natural antioxidant replacement. Also, ascorbic acid has the highest antioxidant ability in respect to other chemicals. Therefore, adding ascorbic acid into the crude would also increase its antioxidant activity.

The methodology of the research is given in Table 1.

Table 1. *Methodology of the research*

Stage	**Steps**
Extraction	• Extraction of *Moringa oleifera* leaves with methanol • Evaporation of methanol using a rotary evaporator • Modification of the crude with ascorbic acid • FTIR analysis of the *Moringa oleifera* crude and modified crude • Evaluation of DPPH scavenging ability of ▪ IPPD ▪ *Moringa oleifera* crude (MCE) ▪ *Moringa oleifera* modified crude (MME)
Compounding	• Six NR based dry rubber compounds were prepared by using different antioxidants such as TMQ, IPPD, WSP, MCE and MME. The Control compound was prepared without any antioxidant.
Testing	• Evaluation of cure characteristics • Evaluation of physico-mechanical properties • Tensile properties after 3,7 and 10 days ageing • Hardness after 3 days ageing • Tear strength after 3 and 7 days ageing • Resilience • Resistance to abrasion • Analysis of chemical properties ▪ Swelling index ▪ Gel content ▪ Resistance to ozone • Analysis of morphology • Analysis of resistance to UV rays

Mechanical and ageing properties of the vulcanizates

Tensile strength of the six rubber vulcanizates is given in Table 2 and the values vary in the range 8-20 MPa. The vulcanizate, which contains IPPD as the antioxidant (AO – amine type) shows the highest tensile strength. The vulcanizate, which contains WSP (phenolic type) as the AO shows the lowest tensile strength

among the vulcanizates containing AOs. Elongation at break (%) of all the vulcanizates is greater than 200 and vulcanizates containing modified *Moringa* oleifera crude as AO and TMQ (quinone type antioxidant) shows more or less equal values. Modulus at 100% elongation is highest in the Control, however there is no marked difference between the modulus values of the six vulcanizates.

Results (Tables 2 and 3) indicate that the vulcanizate containing methanol extracted *Moringa oleifera*, modified with ascorbic acid has the highest resistance to ageing or in other words highest thermal stability. This could be attributed to the high content of phenolic substances present as antioxidants.

Table 2. *Tensile properties of vulcanizates before and after ageing*

	Unaged values			**Values after ageing**								
				Aged for 3 days			**Aged for 7 days**			**Aged for 10 days**		
Sample	Tensile strength (MPa)	Modulus at 100% (MPa)	Elongation at break (%)	Tensile strength (MPa)	Modulus at 100% (MPa)	Elongation at break (%)	Tensile strength (MPa)	Modulus at 100% (MPa)	Elongation at break (%)	Tensile strength (MPa)	Modulus at 100% (MPa)	Elongation at break (%)
Control	8.06	5.19	226	4.46	3.06	153	3.05	2.33	159	2.80	-	116
TMQ	16.34	2.28	281	13.97	2.43	238	10.62	3.35	173	3.31	1.90	23
IPPD	19.29	3.61	252	13.32	2.96	227	4.29	2.88	20	3.97	2.21	243
WSP	13.17	3.03	245	2.24	-	82	2.33	-	70	2	-	117
MCE	16.98	2.63	279	14.13	3.01	236	9.81	3.18	194	3.84	2.83	167
MME	16.01	2.99	232	13.85	2.41	238	13.48	3.24	213	11.23	3.44	189

Table 3. *Percentage retention of tensile properties of vulcanizates after ageing*

Sample	Tensile strength (%)			Elongation at break (%)		
	Aged for 3 days	Aged for 7 days	Aged for 10 days	Aged for 3 days	Aged for 7 days	Aged for 10 days
Control	24.7	16.9	15.5	67.6	70.1	51.1
TMQ	85.5	65.0	20.3	84.6	61.3	84.3
IPPD	69.0	22.2	20.6	90.0	71.4	96.4
WSP	17.0	17.7	15.2	33.0	28.7	47.9
MCE	83.7	57.8	22.6	84.5	69.6	59.9
MME	86.5	84.2	70.1	102.4	91.8	81.2

The vulcanizate containing WSP as the AO shows the lowest tear strength before ageing (Table 4). Unaged tear strength of the vulcanizate consisting of modified *Moringa oleifera* crude and that of the Control are higher than that of the other vulcanizates.

Table 4. *Tear strength of vulcanizates before and after ageing*

Sample	Unaged value	Aged for 3 days	Aged for 7 days
Control	28.77	24.91	18.34
TMQ	27.86	20.39	24.55
IPPD	25.96	20.45	21.79
WSP	22.04	21.66	27.40
MCE	22.88	28.59	20.47
MME	28.49	26.65	24.87

After 3 days ageing, percentage retention of tear strength of the vulcanizates containing MCE and MME are more than 90% and also higher than that of the other four vulcanizates (Table 5). After 7 days ageing, the five vulcanizates containing antioxidants show higher tear strength in comparison to the Control. In overall, highest retention of tear strength in respect to three days ageing is shown by the vulcanizate, MCE followed by MME. However, the latter shows a higher retention value after 7 days ageing in comparison to the former.

Tensile strength of the UV treated MME containing vulcanizate was higher than its original tensile strength value. Also, elongation at break of UV treated vulcanizates was higher than their original value. Best performance in respect to stability towards UV rays was shown by MCE and MME vulcanizates (W D M Sampath and M K C L Chathushani (BSc Chemical Science & Technology Special), an undergraduate student from the Sabaragamuwa University, Sri Lanka).

Table 5. *Percentage retention of tear strength of vulcanizates after ageing*

Sample	Tear strength (%)	
	Aged for 3 days	Aged for 7 days
Control	86.5	63.7
TMQ	73.2	88.1
WSP	78.8	83.3
IPPD	77.3	87.7
MCE	102.6	73.4
MME	93.5	87.3

Development of environmental friendly natural fibre filled rubber composites

Development of surface treated pandanas fibre filled rubber composites

Natural fibers become important reinforcement materials for commercial rubber composites as these fibers are abundant, renewable, easy processing, biodegrade and exhibit high specific strength. In this study, Pandanus Amaryllifolius Fiber (PAF) was treated with different chemicals namely, ethanol, silane coupling agent (Si 69) and potassium hydroxide (KOH). Thereafter, composites were produced by mixing 15 phr of the chemically treated PAF with virgin NR according to a middle layer solid tyre formulation and properties were evaluated. The results obtained are given in Table 6.

Table 6. *Physico-mechanical properties of chemically treated PAF filled rubber vulcanizates*

Property	Treatment			
	Control	Ethanol	Silane	KOH
Hardness (IRHD)	78	77	70	61
Modulus at 100% elongation (MPa)	7.1	7.2	9.6	7.1
Resilience (%)	49	48	52	47
Tensile strength (MPa)	10.3	11.3	13.3	13.1
Elongation at break (%)	145	161	146	176
Tear strength (N/mm)	54.2	65.5	41.0	48.7
Compression set (%)	16.6	13.9	18.1	24.1
Abrasion volume loss (mm^3)	117	105	99	100

Hardness of the Control is higher compared to chemically treated PAF filled rubber vulcanizates. However, modulus at 100%, resilience, tensile strength and abrasion volume loss of silane treated PAF filled rubber vulcanisate are superior to those of the other three vulcanisates. Further, tear strength and compression set of ethanol treated PAF filled rubber vulcanisate are superior to those of other vulcanisates.

Table 7 indicates the percentage retention of properties of the vulcanisates after ageing at 100 ^{0}C for 22 hrs. The compound prepared with KOH treated PAF shows good ageing properties or in other words good thermal stability. In overall of physico-mechanical and aging properties, the compound prepared with silane treated PAF was selected for further studies.

Table 7. *Percentage retention of properties of the vulcanisates after ageing*

Treatment	Modulus at 100% (%)	Tensile strength (%)	Elongation at break (%)	Tear strength (%)
Control	74	111	68	67
Ethanol	85	125	70	62
Silane	63	-	53	80
KOH	87	126	74	81

(D G Edirisinghe, W D M Sampath, Gayathri Baghyawedha and Ishani Jayaratne)

Development of rubber compounds with modified rubber waste

(a) Development of rubber-bitumen masterbatches with modified rubber waste

Crumb rubber or ground rubber tyre (GRT) produced from automotive and truck scrap tires was used as a waste material to produce rubberized bitumen. A series of 50/50 rubber/bitumen masterbatches was formulated by varying the natural rubber (RSS-5) and crumb rubber ratios (Table 1). Three Controls were prepared as given below. The rubber/bitumen masterbatches were prepared using a Brabender Plasticorder at 70 ^{0}C. Thereafter, rubberized bitumen compounds were prepared by mixing 5% masterbatch and 95% bitumen (60/70 grade). Physical and mechanical characteristics were evaluated at the laboratory of the Road Development Authority (RDA).

Control I - *The masterbatch was prepared without rubber*
Control II - *The masterbatch was prepared with 50% natural rubber (RSS-5) and 50% bitumen*
Control III - *The masterbatch was prepared with 50% crumb rubber and 50% bitumen*

Table 8. *RSS : crumb rubber ratios of the rubber/bitumen masterbatches*

Sample No.	A	B	C	D	E	F
RSS	20	25	30	35	40	45
Crumb	30	25	20	15	10	5

Control I shows the highest penetration value compared to the other two controls and rubber/bitumen blends. Generally, high penetration value indicates low hardness. Hence, the masterbatch prepared with pure bitumen shows the lowest hardness. Sample E indicates high hardness compared to the others. Control II represents the highest softening point, which is the critical temperature at which the bitumen softens and it indicates good thermal stability. Further, there is no significant difference in the softening point of rubber/bitumen blends. Control I shows the lowest percentage of recovery and indicates low elastic property. The master batch prepared with 50% crumb rubber shows the highest viscosity and it is the reason for poor dispersability of crumb rubber in bitumen. 35/15 RSS/crumb rubber masterbatch was selected for further studies.

Table 9. *Physical and mechanical characteristics of rubber/bitumen compounds*

Sample No.	Penetration at 25 ^{0}C	Softening point ^{0}C	Recovery (%)	Viscosity (Pas)
Control I	62	50	8	0.35
Control II	55	62	25	0.53
Control III	47	54.5	18	1.74
A	40	56	24	0.58
B	43	56	27	0.48
C	43	52.5	29	0.60
D	42	56	26	0.55
E	39	55	26	0.48
F	41	56	28	0.49

Crumb rubber was modified according to the following three techniques. The Control was prepared without modification.

Technique A – Crumb rubber was mixed with 6 phr TMTD and milled for 5 minutes around ambient temperature using a laboratory two-roll mill (6" x 13") at a friction ratio of 1:1.1.

Technique B – Crumb rubber was mixed with 6 phr TMTD and kept in an oven at 80 ^{0}C for 24 hours. Thereafter, it was milled for 5 minutes around ambient temperature using a laboratory two-roll mill (6" x 13") at a friction ratio of 1:1.1.

Technique C – Crumb rubber was mixed with 6 phr TMTD and 2 phr aromatic oil. Thereafter, it was milled for 5 minutes around ambient temperature using a laboratory two-roll mill (6" x 13") at a friction ratio of 1:1.1.

The physical and mechanical characteristics of 35:15:50 RSS/crumb rubber or modified crumb rubber/bitumen masterbatches were evaluated and the results obtained are given in Figures 1-4. Masterbatch produced with crumb rubber modified according to Technique B showed the highest penetration value (Fig. 1) and it indicates greater softness. However, all modified crumb rubber-bitumen masterbatches show high penetration property than the Control. Further, the Control has high hardness, which is confirmed by viscosity (Fig. 4).

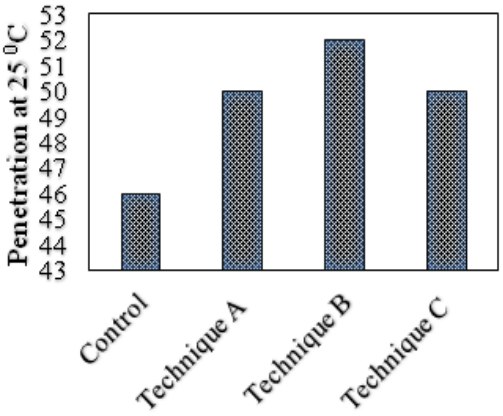


Fig. 1. Penetration of rubberized-bitumen masterbatches

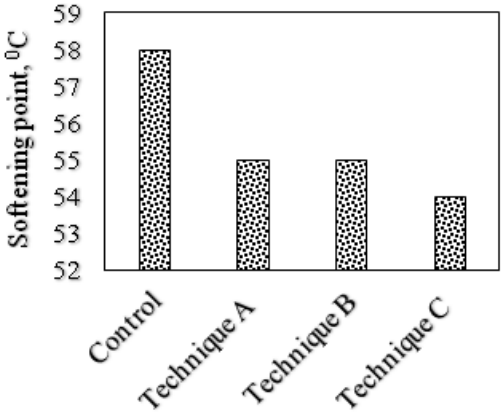


Fig. 2. Softening point of rubberized-bitumen masterbatches

Softening point of all rubberized-bitumen masterbatches is greater than 54 ^{0}C (Fig. 2). However, the Control shows the highest softening point and indicates high hardness (Fig. 1). Generally, crumb rubber is a vulcanized material and it contains non-rubber materials such as fillers. Hence, rubberized-bitumen masterbatches prepared with non-modified crumb rubber would not flow in a homogeneous manner. This could be the reason for the highest softening point of the Control in comparison to that of the masterbatches containing modified crumb rubber. The masterbatch produced with crumb rubber modified according to technique A showed better recovery than the others. This indicates good resilience and flexibility for road surface application.

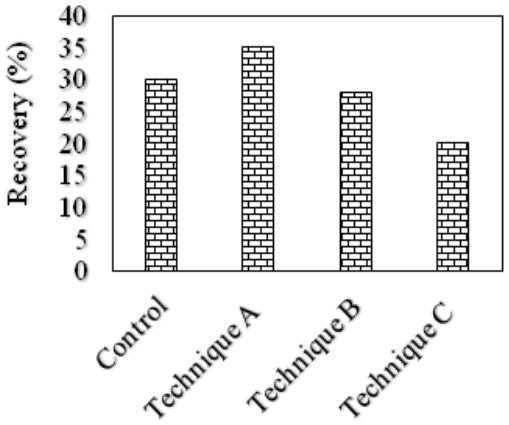


Fig. 3. Recovery of rubberized - bitumen masterbatches

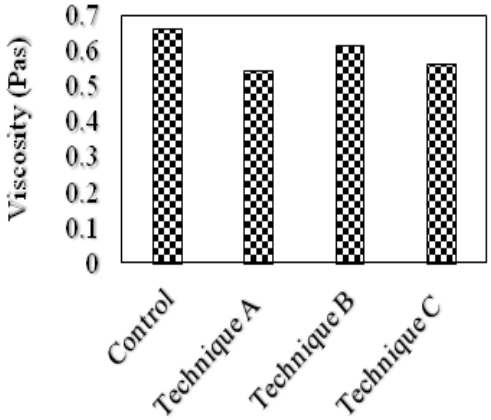


Fig. 4. Viscosity of rubberized - bitumen masterbatches

Figure 4 shows the variation of viscosity of rubberized bitumen masterbatches. The Control indicates the highest viscosity in comparison to technically modified rubberized bitumen masterbatches. The modified crumb rubber may not disperse properly in bitumen and it would aggregate in the bitumen mixture. Further, the compound prepared according to Technique A showed the lowest viscosity and it may be at the acceptable level for road surfaces. Further work on this project is in progress (D G Edirisinghe, W D M Sampath and D G M J Abeywardhana).

(b) Development of rubber composites with modified nitrile rubber glove waste

A request was made by Dipped Products Plc. to modify nitrile rubber (NBR) glove waste to use as a rubber component in blends with virgin NBR to manufacture rubber products such as oil resistant mats/carpets, oil seals, *etc.* Seven NBR based rubber composites were prepared using the following rubber compositions according to an oil seal formulation.

Table 10. *Rubber compositions used in the rubber composites*

Compound No.	Rubber composition
SC	100% virgin NBR (Control)
SM	90% virgin NBR 10% mechanically reclaimed rubber
ST0	90% virgin NBR 10% mechano - chemically reclaimed rubber with 6 pphw* amino compound

Compound No.	Rubber composition
ST25	90% virgin NBR 10% mechano - chemically reclaimed rubber with 4.5 pphw* amino compound and 1.5 pphw* TMTD
ST50	90% virgin NBR 10% mechano - chemically reclaimed rubber with 3 pphw* amino compound and 3 pphw* TMTD
ST75	90% virgin NBR 10% mechano - chemically reclaimed rubber with 1.5 pphw* amino compound and 4.5 pphw* TMTD
ST100	90% virgin NBR 10% mechano - chemically reclaimed rubber with 6 pphw* TMTD

*pphw – parts per hundred parts of waste (glove waste)

Table 11. *Cure and processing characteristics of virgin NBR and reclaimed rubber composites*

Sample No.	Scorch time (sec.)	ML (dN.m)	MH (dN.m)	MH-ML (dN.m)	T90 (min.)	Initial plasticity (P_o)	Mooney viscosity ML (1+4)100^oC
SC	144	8.95	98.52	89.57	432	50.2	64.22
SM	131	12.26	106.34	94.08	326	64.3	83.45
ST0	122	11.89	112.18	100.29	391	60.7	79.69
ST25	116	11.88	103.4	91.52	327	64.4	82.09
ST50	128	11.57	106.23	94.66	341	66	77.17
ST75	122	11.52	109.46	97.94	339	68	79.1
ST100	128	12.16	112.85	100.69	337	62.6	81.71

Table 11 indicates that compounds SM to ST100 are scorchy and cures faster in comparison to the Control compound SC. This could be attributed to the presence of active crosslinking sites in the former compounds. This results in a higher crosslink density for the same as indicated by MH and MH-ML values given in Table 11. As expected, composites containing reclaimed rubber show higher minimum torque (ML), initial plasticity (P_o), Mooney viscosity (Table 11), hardness and modulus at 100% elongation (Table 12) in comparison to the Control due to the presence of crosslinked structures.

Table 12. *Physico-mechanical properties of virgin NBR and reclaimed rubber blend vulcanizates prepared by varying the ratio of TMTD and amino compound*

Sample No.	Hardness (IRHD)	Resilience (%)	Abrasion volume loss (mm^3)	Compression set (%)	Tensile strength (MPa)	Mod. at 100% elongation (MPa)	Elongation at break (%)	Tear Strength (N/mm)
SC	68.7	31.6	72.9	14.1	17.5	5.0	279	54.7
SM	72.1	30	80.7	11.6	16.9	6.0	253	55.2
ST0	72.4	30.3	77.2	11.7	16.7	6.0	248	45.6
ST25	73.7	30	84.2	8.3	16.7	9.9	171	52.5
ST50	73.2	30.7	73.5	7.6	16.0	9.2	179	51.3
ST75	73.9	30	68.9	6.4	17.5	10.7	173	51.2
ST100	74.1	30	74.8	11.3	14.9	8.3	173	45.2

Higher hardness reflects lower resilience for the composites containing reclaimed rubber. Tensile strength of composites containing reclaimed rubber prepared with the amino compound is not markedly different from that of the Control. Further, elongation at break of SM and ST0 is closer to that of the Control. Abrasion resistance and tear strength vary according to a cyclic pattern. It is interesting to note that the compression set of composites containing reclaimed rubber prepared with both the amino compound and TMTD are much lower than that of the Control and the composites SM, ST0 and ST100 indicating a synergistic action in reclaiming (D G Edirisinghe and K I D P Perera).

Industrial extension

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

Hardness of sole crepe samples	Physico-mechanical properties of rubber compounds	Physico-mechanical properties of rubber products
Kegalle Plantations, Pallegama Estate	Associated Motorways Polymer Products Impex (Pvt.) Ltd. Tiran Tyre (Pvt.) Ltd. Ceytra (Pvt.) Ltd.	Textrip (Pvt.) Ltd. Bogawantalawa Tea Estate

Hardness of sole crepe samples	Physico-mechanical properties of rubber/plastic compounds	Physico-mechanical properties of rubber/plastic products
Kegalle Plantations, Atale Estate Elpitiya Estate Panawatta Estate Dewalakanda Estate	US Lanka Rubber Solutions (Pvt.) Ltd. Dharmasiri Tyre House Samson Reclaim Rubber Ltd. Industrial Development Board Unicorn Tyre Retreading (Pvt.) Ltd	

The following compound developments were conducted on request.

Compound development	Client
• Non-toxic NR latex based adhesive for paper	Undergraduate students of Management Faculty, University of Colombo
• Non-toxic NR latex based paint for toys	DSL Toy Company
• Synthetic rubber based sliding shoe of crawlers	Road Development Authority
• NR based toy item	Green Rubber Toy Company (Pvt.) Ltd.
• NR latex foam based ear plug	Textrip (Pvt.) Ltd.
• NR latex/dry rubber based inner lining for storage tanks of sodium hydroxide	Paranthan Chemicals
(a) NR latex based soft robotic gripper to handle eggs, tomatoes, *etc*. (b) NR latex based endometrial ablation device, a special balloon to treat internal wounds in female reproductive system (c) Five NR latex based balloons with different thicknesses to use in a robot	Undergraduate students of Dept. of Mechanical Engineering, University of Moratuwa

POLYMER CHEMISTRY

Y R Somarathna

DETAILED REVIEW

Staff

Mrs I H K Samarasinghe, Research Officer was in charge of overall activities of the department throughout the year. Mr Y R Somarathna, Research Officer was on duty throughout the year. Mrs Nirmala Jayawardena, Experimental Officer and Mrs H M H Dhanukamalee, Technical Officer were on duty throughout the year. Miss P S V Rupasinghe, Mr D V D Mallikaarachchi and Miss H L Thilini Tharaka assumed duties as Technical Officers on 02.02.2017, 10.07.2017 and 04.12.2017 respectively. Mr M A D W K Thilakarathne, Management Assistant was on duty throughout the year.

Research students

Undergraduate students

- Miss A H D M N Gunawardana, BSc undergraduate student from the University of Uva Wellassa completed her research project on "Nanotechnological approach for preservation of natural rubber latex and its properties" under the supervision of Mr Y R Somarathna.
- Miss K P R E Ratnasekara, BSc undergraduate student from the University of Uva Wellassa completed her research project on "Performance analysis of Skim/Natural Rubber Latex blends for manufacture of Ribbed Smoked Sheets" under the supervision of Ms I H K Samarasinghe.

Lectures/Seminars/Training/Workshops/Conferences attended

Officer/s	Subject/Theme	Organization
IHK Samarasinghe YR Somarathna	Scientific Committee Meetings	Rubber Research Institute of Sri Lanka
	Workshop on DSC, FTIR and TG-coupled FTIR	Techno Solutions Pvt Ltd
	Workshop on Micro-digestion techniques	Hemsons International (Pte) Ltd
	IRRDB International Conference and Fellowship Program	Rubber Research Institute
	Third Biennial International Symposium on Polymer Science and Technology	University of Sri Jayewardenepura

Officer/s	Subject/Theme	Organization
IHK Samarasinghe	Cluster Finance Workshop	Sri Lanka Export Development Board
YR Somarathna	Open Day Program and Workshop	Industrial Technology Institute, Sri Lanka
N Jayawardena	Agricultural products circulation technology for developing countries	Hunan Agricultural Group, China

Lectures/Seminars/Training/Workshops/Conferences conducted

Officer/s	Subject/Theme	Beneficiary/Client
IHK Samarasinghe	Manufacture of centrifuged latex	Students of Advance Certificate Course in Plantation Management from National Institute of Plantation Management
YR Somarathna	Certificate Course in Rubber Technology	Students of the certificate course in rubber technology from Plastics & Rubber Institute
Staff of the Department	Analytical Techniques on Polymer Characterization (FTIR, DSC and DMA)	Batch of students of National Diploma in Technology, University of Moratuwa
Staff of the Department	Field training program on Polymer Technology	Undergraduate students of Palm & Latex Technology and Value Addition - Uva Wellassa University
Staff of the Department	MSc Practicals on polymer characterization techniques	Students of MSc in Polymer Science and Technology, University of Sri Jayewardenepura

LABORATORY INVESTIGATIONS

Effect of skim content on raw rubber, cure characteristic and physico-mechanical properties of skim/NR latex blended RSS

This study was conducted using six different ratios of natural rubber latex and skim latex blends as treatments (Table 1). Complete Randomized Design (CRD) was used as the experimental design. Each treatment was replicated 03 times. Data was analyzed using ANOVA (One way) and Minitab 17 statistical software.

Table 1. *Volume ratios used to prepare the skim/NR latex blends*

Treatments	SNR 00	SNR 20	SNR 40	SNR 60	SNR 80	SNR 100
Natural Rubber Latex (V/V %) (DRC-32%)	100	80	60	40	20	0
Skim Latex (V/V %) (DRC - 4%)	0	20	40	60	80	100

Latex mixtures of SNR 00, SNR 20, SNR 40 and SNR 60 samples were diluted to 10% DRC adding fresh clean water prior to coagulation. Formic acid was added until pH reach to isoelectric point in order to achieve proper coagulation. It was observed that formic acid consumption was gradually increased due to the increase amount of skim latex. Soft coagulum which is suitable to manufacture RSS sheets were obtained for all samples expect SNR 100 which contained only Skim rubber latex. Each coagulum sheets were processed in to RSS following the standard manufacturing procedure of RSS.

According to the Table 2, Ash Content, Volatile Matter Content, Acetone Extraction, Nitrogen Content, and Initial Plasticity of SNR 20 and SNR40 blends were not significantly different from the control. In SNR 60, Ash Content, Volatile Matter Content and Nitrogen Content were not significantly different from the control.

Table 2. *Raw rubber properties of different skim/NR latex blends*

Sample	PRI (%)	Ash (%)	Density (d)	Volatile Matter (%)	Acetone Extract (%)	Nitrogen (%)	Cu^{+2} (ppm)	Plasticity No(Po)
SNR 00 (Control)	80.54[a]	0.2[a]	0.9[a]	0.52[a]	1.63[a]	0.17[a]	0.9[a]	45.33[a]
SNR 20	54.78	0.21[a]	0.89	0.45[a]	2.32[a]	0.24[a]	2.39	48.27[a]
SNR 40	38.97	0.2[a]	0.91	0.6[a]	2.86[a]	0.3[a]	3.51	47.23[a]
SNR 60	34.39	0.22[a]	0.92	0.58[a]	3.29	0.31[a]	4.36	50
SNR 80	38.03	0.33	0.9[b]	0.78	3.74	0.5	4.7	55.33
SNR 100	45.15	0.44	0.93	2.48	5.4	1.26	7.21	53.83
P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Means not labeled with the letter 'a' are significantly different from the control level mean

Figure 1 illustrates the effect of skim content on Mooney viscosity and Mooney Stress Relaxation of skim/NR latex blends. Results show that resistance to flow has gradually increased with increasing skim latex content up to 80% in the

blend while Mooney viscosity of the rubber made out of 100% NR latex has decreased.

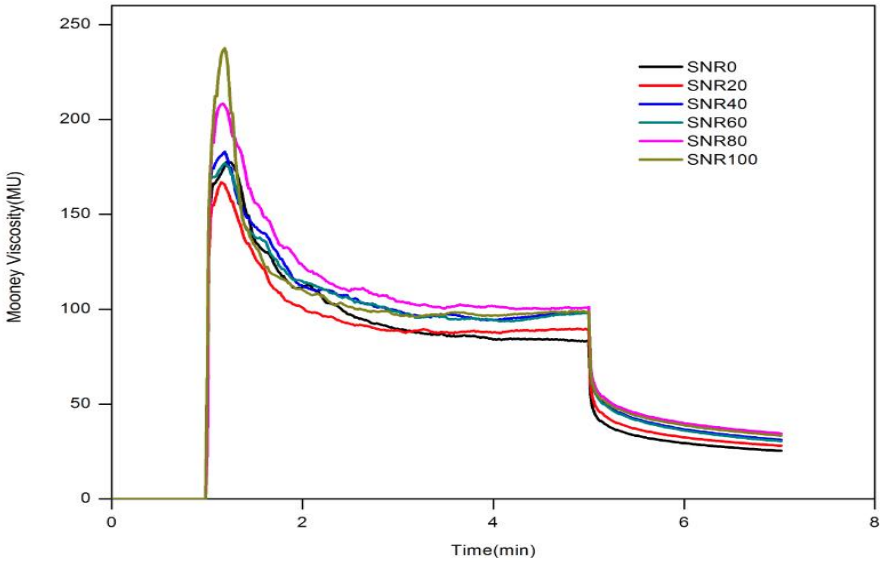


Fig.1. Mooney Viscosity and Mooney Stress-Relaxation curves of Skim/NR latex blends

Cure characteristics of skim/NR latex blends are tabulated in Table 3. SNR 20 and SNR 40 both show comparable cure behavior as the typical RSS (SNR 00) compound. This indicates that content of non-rubbers in these blends have no effect on the curing behavior.

Table 3. *Cure characteristics of SNR 20 and SNR40 latex blends*

Curing properties	Maximum torque (NM)	Minimum torque (NM)	tS2 (min)	t90 (min)
SNR 00	0.59[a]	0.023[a]	3.2[a]	7.08[a]
SNR 20	0.61[a]	0.023[a]	3.2[a]	7.17[a]
SNR 40	0.67[a]	0.027[a]	3.1[a]	7.23[a]
P - Value	0.393	0.058	0.178	0.912

Means labeled with the letter "a" are not significantly different from the control level mean

Physico-mechanical properties of SNR 20 and SNR 40 blends showed (Table 4) that there is no considerable difference with SNR 00. Therefore, it is evident that,

the network structures formed during vulcanization in both SNR 20 and SNR 40 blends is independent from the skim content present in the blend.

Table 4. *Comparison of vulcanization properties of skim/NR latex blends*

Samples	Tensile Strength (Mpa)	Rebound resilience (%)	Hardness (IRHD)	Modulus @100% elongation (MPa)	Compression set (%)	Tear Strength (N/mm)	Elongation @ break (%)
SNR 00	14.42[a]	62.67[a]	34.18[a]	1.38[a]	35[a]	14.71[a]	300.78[a]
SNR 20	14.32[a]	61.67[a]	34.39[a]	1.42[a]	41[a]	16.16[a]	283.41[a]
SNR 40	13.50[a]	58.33[a]	34.77[a]	1.45[a]	41[a]	16.49[a]	281.86[a]
P - Value	0.115	0.180	0.875	0.821	0.381	0.141	0.356

Means labeled with the letter "a" are not significantly different from the control level mean

Analyzing the above results, it could be concluded that, 40% (V/V %) of skim latex can be blended with natural rubber latex to produce conventional type RSS without a significant effect on curing and physico-mechanical properties of the dry rubber compounds developed out of them (I H K Samarasinghe, S Siriwardena and K P R E Ratnasekara).

Development of a nitrosamine safe accelerator system for sulfur vulcanization of dry rubber compounds

Systematic investigations on the performance of nitrosamine safe accelerators and their combinations have not been carried so far. Therefore a study was initiated to focus on the performance evaluation of nitrosamine safe combined accelerator systems for sulfur vulcanization of natural rubber, and to propose such systems to compete with the conventional accelerator systems used in the rubber industry (I H K Samarasinghe, D G Edirisinghe, S Walpolage and S M Egodage - Senior Lecturer, Dept. of Chemical and Process Engineering, University of Moratuwa).

In-situ filler incorporated natural rubber latex

A novel method has been developed to incorporate filler by *in-situ* incorporation in natural rubber latex. The main objective of this study is to improve the dispersion of fillers in the latex matrix and to increase of value addition of both rubber and dolomite in Sri Lanka.

In this study, several trials have been made to incorporate fillers in the centrifuged latex matrix. Latex films were prepared and characterized by TGA to ensure the filler formation. Green strength of those films were evaluated and it was found that there was no deterioration of properties of filler incorporated latex films. Further characterization of latex films and improvement of the incorporation process are in progress (Y R Somarathna, S Siriwardena and D V D Mallikaarachchi).

Nanotechnological approach for preservation of Natural Rubber Latex (NRL)

In low ammonia preservative system (LATZ), tetramethylthiuramdisulphide (TMTD) and Zinc oxide (ZnO) act as the conjugated secondary preservatives. The LATZ system, however has its own disadvantages due to the presence of TMTD, which produces carcinogenic nitrosamines during the latex processing. Therefore, finding an alternative preservative system or the modification of LATZ is timely needed.

After characterizing conventional ZnO and the commercial nano-compound using XRD and SEM, the current LATZ system was modified by replacing ZnO from a commercially available nano-compound. Centrifuged latex samples with the conventional TMTD/ZnO system (Control) and different quantities of TMTD/nano compound [(Sample A- 6.25/8.0%), (Sample B- 6.0/6.25%), (Sample C- 4.0/6.25%), and Sample D (2.0/6.25%)] were prepared. Characterization of each centrifuged latex sample was done in terms of DRC (dry rubber content), TSC (total solid content), alkalinity, VFA Number (volatile fatty acid number) and MST (mechanical stability time). Latex was analysed for VFA Number after a storage period of 03, 10 and 17 days. MST was measured after a storage period of 20 and 27 days. Physico-mechanical properties of preserved latex samples were evaluated using vulcanized cast films made out of latex, treated with different combinations of TMTD/nano compound and TMTD/ZnO.

Overall results indicated that the novel commercially available nano compound could be used as an effective preservative agent with reduced amount of TMTD (with 50% reduction). Moreover, the results indicated that the physio-mechanical properties of latex films were not affected with the introduction of novel compound. Further work on optimization of systems is in progress (Y R Somarathna, A H D M N Gunawardana, Nirmala Jayawardena, P S V Rupasinghe, A M W K Senevirathna, H G I M Wijesinghe - Department of Export Agriculture, Uva Wellassa University).

Plant base antioxidant for natural rubber compounding

Antioxidants are very important chemicals in rubber compounding and they protect the product from oxidation in different ways. At present, phenolic and amine base antioxidants are used although they are hazardous to human. The main intention of this research was to study the effect of plant base antioxidant (lignin type) in

thermal oxidation of natural rubber and to replace toxic antioxidants by this plant extract.

A series of natural rubber samples were compounded separately with amine base and phenolic base antioxidants incorporated with the plant extract (PLEX) in different ratios. N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine (6PPD) was used as amine base antioxidant and 2,2,4-trimethyl-1,2-dihydroquinoline (TMQ) was used as the phenolic base antioxidant. Cure characteristics of those compounded samples were analysed using rheographs recorded at 150 $^{\circ}$C for 30 min. Physico-mechanical properties such as hardness, tensile strength, tear strength compression set and abrasion volume loss were studied at ageing and non-ageing conditions.

The results revealed that the physico-mechanical properties of those rubber compounds with PLEX were very much similar to those properties of typical rubber compounds with either amine or phenolic base antioxidants. According to ageing properties, it was observed that the compounds were thermally stable with PLEX as with typical rubber compounds. Therefore, this lignin base plant extract (PLEX) could be used as an antioxidant replacing either amine or phenolic type antioxidants without affecting their physical properties (A M K S P Adhikari and R A P R Kumara).

Industrial extensions

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

- National Water Supply & Drainage Board
- Ansell Textile Lanka (Pvt) Ltd
- AMW (Pvt) Ltd
- Elastomeric Technologies (Pvt) Ltd
- Dipped Products Ltd
- ATG Lanka (Pvt) Ltd
- Ceylon Electricity Board
- Sri Lanka Railways
- Samson Industries (Pvt) Ltd
- Textrip (Pvt) Ltd
- Polymer Products Impex (Private) Limited
- Sri Lanka Institute of Textile Apparel
- Samson International PLC
- Samson Rubber Product (Pvt) Ltd
- DSL Lanka (Pvt) Ltd
- Phoenix Industries Ltd
- Microcells (Pvt) Ltd

- Associated Specialty Rubbers (Pvt) Ltd
- Samson Compounds (Pvt) Ltd
- Sierra Constructions (Pvt) Ltd
- Jefferjee Brothers Export (Pvt) Ltd
- University of Ruhuna (Department of Chemistry)
- Fantasia Erastics (Pvt) Ltd
- University of Sri Jayewardenepura

RAW RUBBER AND CHEMICAL ANALYSIS

A P Attanayake

DETAILED REVIEW

Staff

Mrs A P Attanayake, Research Officer completed her PhD degree at the University of Sri Jayewardenepura and was awarded the degree with effect from 31st October 2016. She was promoted to the post of Senior Research Officer with effect from 12th September 2017 while on duty throughout the year as the Officer In-Charge. Mr A M K S P Adhikari, Research Officer was on duty throughout the year.

Mrs H V K Gamage, Mr L P P Vitharana, Mrs C Lokuge and Miss M Wijesekera, Experimental Officers were on duty throughout the year. Miss S P Wijewardana, Technical Officer was on duty throughout the year. Technical Officers Miss N C Y Kithmini, Miss M U D S Weerasinghe, Miss L K Inosha Madhushani assumed duties on 01stof January 2017 and Mr H D M S Wijewardana, Mr K A S T Koswatta assumed duties on 07th July 2017. Technical Officer, Miss L K Inosha Madhushani resigned from RRISL with effect from 29.09.2017. Management Assistant Miss W D D Samanmali, was on duty throughout the year.

Research students

- Miss H R S P Gunarathne and Miss E N N Nanayakkara, BSc students from Faculty of Animal Science and Export Agriculture, Uva Wellassa University, completed their final year research projects on "Study on latex, raw rubber and physico-mechanical properties of RRISL 203 cultivar of *Hevea brasiliensis*" and "Effect of Ethephon Stimulation on Physico - Mechanical Properties of Carbon Black Filled Natural Rubber Vulcanizates" respectively under the supervision of Dr (Mrs) Anusha Attanayake.

Seminars/Training Programmes/Workshops/Exhibitions conducted

Officer/s	Subject	Beneficiary/Client
Staff of the department	Latex and dry rubber testing	Undergraduate students from Department of Palm & Latex Technology and Value Addition, University of Uva Wellasa, Badulla
Staff of the department	Practical Demonstration on latex & raw rubber testing	Undergraduate students from Department of Plantation Management, Wayamba University of Sri Lanka

Officer/s	Subject	Beneficiary/Client
Staff of the department	Theoretical & Practical session on latex testing	Miss T M Wathsala Nimanthi Lak Latex (Pvt) Ltd
Staff of the department	Theoretical & Practical session on raw rubber testing	Mr A T Rajakaruna, Camso Loadstar (Pvt) Ltd

Lectures/Seminars/Workshops/Meetings attended

Officer/s	Subject	Organization
AP Attanayake	Waters Technology Forum 2017	Hemsons International (Pvt) Ltd (Hotel - Galadari, Colombo)
AP Attanayake Kasun Adhikari	Research Review Meeting 2017	Dartonfield, RRISL
AP Attanayake Kasun Adhikari	Technology Update on rubber plantation	Dartonfield, RRISL
Kasun Adhikari	Workshop on “driving the nation through technology”	ITI, Colombo 07
Kasun Adhikari	Workshop on "Analytical Research"	Analytical Instruments (Pvt) Ltd (Hotel - Galadari, Colombo)
AP Attanayake Kasun Adhikari	Polymer Symposium - 2017	University of Sri Jayewardenepura (Golden Rose Hotel, Borelasgamuwa)
AP Attanayake	Hands on training on advanced scientific Instruments for material characterization	ITI, Colombo 07
KasunAdhikari	Workshop on AFF Programme	SLIDA - Colombo
AP Attanayake	Seminar on micro digestion	Hemsons International (Pvt) Ltd Taj Samudra Hotel, Colombo
AP Attanayake	Project Review	Dartonfield, RRISL
AP Attanayake	IRRDB fellowship training Programme	Dartonfield, RRISL
AP Attanayake	International Rubber Conference - 2017, Jakarta, Indonesia (IRC)	International Rubber Research & Development Board (IRRDB)

LABORATORY INVESTIGATIONS

Quality analysis of latex, raw rubber and rubber processing chemicals (RR&CA/2017/01)

Testing and Certification services were provided to all sectors in the rubber industry and they are summarized below:

Sample analysis	No. of samples
Raw rubber	2,009
Latex	1,015
Chemicals	12
Gloves	23
Polythene	39
Certificates of analysis issued	386

Development of new test methods (RR & CA/2017/02)

Development of a new test method to estimate dry rubber content in field latex was continued. This was designed as a replacement for metrolac. Further developments are being carried out to achieve more precise results (S Siriwardena, A P Attanayake, C Lokuge, P L Perera and H D M S Wijewardana).

Two new test methods were developed for the determination of purity of sulphur and the volume change in a vulcanized rubber product (A M K S P Adhikari).

Raw rubber quality related projects (RR & CA/2017/05)

Investigation on factors affecting the green strength of natural rubber

Green strength is one of the most important parameter of natural rubber latex. The objective of the present study is to investigate the effect of latex particle size distribution (bimodality) on strength properties of NR latex film. Skim latex composed of small rubber particles in the range of 0.04 µm - 0.4 µm while the size of those large rubber particles available in concentrated latex vary from 0.1µm to 3µm (Fig.1). A series of blends of centrifuged latex and skim latex were prepared in order to increase the packing volume of latex film (Table 1). Latex casting films were prepared from each blend and the films were tested for tensile green strength. The work is being continued to achieve the optimum strength properties with NR/Skim blends. It was observed that the blend of skim/NR ratio 1:1 has the highest strength, however it is lower than that of the control (A P Attanayake and N C Yashika Kithmini)**.**

Table 1. *Green strength of NR/skim latex blends*

Reference No:	Amount of centrifuge latex (ml)	Amount of skim latex (ml)	Ratio	Green strength (Mpa)
1	40	0	Control	1.34 ± 0.15
2	35	5	7:1	1.23 ± 0.11
3	30	10	6:2	1.12 ± 0.13
4	25	15	5:3	1.18 ± 0.34
5	20	20	1:1	1.27 ± 0.31
6	15	25	3:5	0.90 ± 0.1

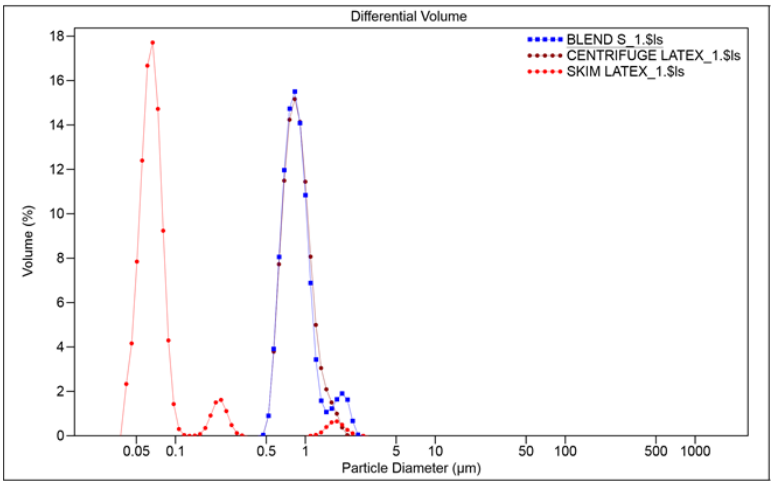


Fig. 1. Particle size distribution of skim latex, centrifuged latex and 1:1 blend of skim latex and centrifuged latex

Short term projects

Effect of ethephon stimulation for latex exploitation on physico-mechanical properties of carbon black filled natural rubber vulcanizate

Low intensity harvesting systems (LIH) with ethephon stimulation were introduced to rubber plantations due to the shortage of skilled latex harvesters. The objective of this research study was to identify the effect of ethephon stimulation on physico-mechanical properties of the natural rubber vulcanizates. The study was conducted with the RRIC 121 clone using half spiral, once in three-day harvesting system. Experiments were laid out in Randomized Complete Block Design with six treatments with three blocks. Each treatment composed of 25 trees. Each block was treated with 1 to 5% (1, 2, 3, 4, 5%) ethephon by keeping non stimulated trees as the control. Latex collected from each treatment was processed into un-fractioned, unbleached (UFUB) crepe rubber. Carbon black filled vulcanizates were produced according to the general compounding formula and vulcanization was carried out at 150°C for 10 minutes. Rebound resilience, tensile strength and tensile strain at break reduced with high ethephon concentrations while hardness, compression set and tear strength increased (Fig. 2). Results revealed that elastic properties reduced and reinforcement of rubber matrix achieved through filler incorporation increased with high ethephon concentrations. LIH systems with ethephon stimulation does not have any adverse effect on physico-mechanical properties up to 3% ethephon concentrations. However, such properties were negatively affected with the application of higher ethephon concentrations beyond 3%.

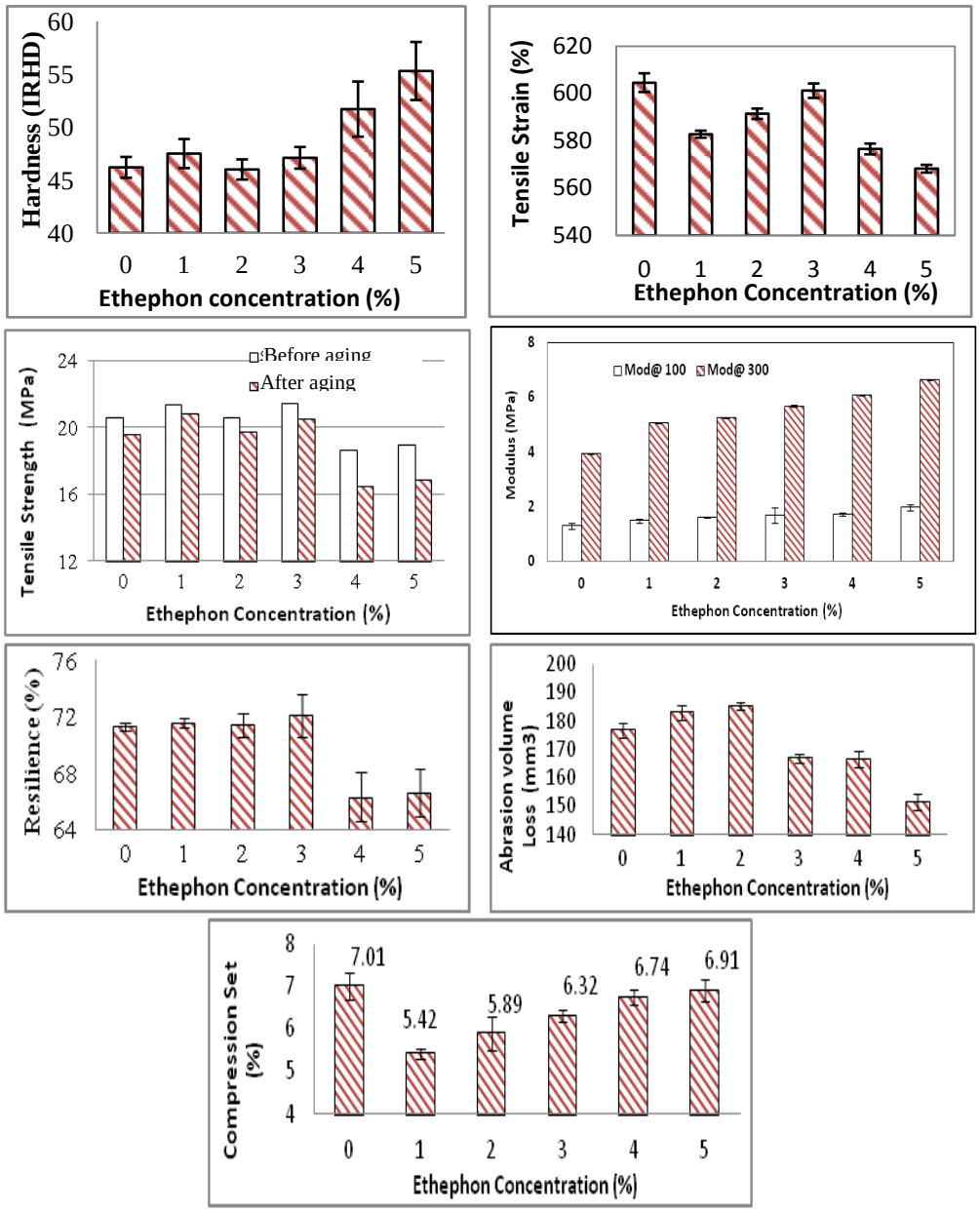


Fig. 3. Physico – Mechanical properties of rubber made out of stimulated latex, treated with 1 - 5% ethephone

(A P Attanayake, C Lokuge, L P Vitharana and N N Nanayakkara)

Study on latex, raw rubber and physico-mechanical properties of RRISL 203 cultivar of *Hevea brasiiensis*

RRISL 203 and RRIC 121 are among the recommended high yielding clones to be planted up to a maximum of 10% of the total extent of an estate; and their annual potential yields are expected to be 3,000 kgs and 2,650 kgs per hectare, respectively. RRISL 203 clone is relatively a new clone to rubber plantation sector in Sri Lanka. However, there is no in-depth study carried out on the latex characteristics and the physico-mechanical properties of the latex films of this clone. Therefore, this study was carried out in order to characterize latex, raw rubber and physico-mechanical properties of RRISL 203 genotype. The experimental design was Completely Randomized Design with two treatments and three replicates. Latex was harvested and unfractioned-unbleached (UFUB) crepe rubber and Carbon-Black filled compounds were prepared. Volatile Fatty Acid (VFA), Dry Rubber Content (DRC), Total Solid Content (TSC), Magnesium content, Mooney viscosity, Colour, Nitrogen content, Plasticity Retention Index (PRI), Compression set, Hardness, Rebound resilience, Abrasion, Tensile and Tear strength properties were measured. All the properties were tested according to the ISO standard test methods and each property was compared with those of RRIC 121 clone.

Among all properties studied only Mooney viscosity of rubber was significantly higher in RRISL 203 clone while Magnesium content registered a significantly low value compared to RRIC 121. All other properties showed no significant variation between RRISL 121 and RRISL 203 clone. However, this study will be continued further for a long-term to study the overall performance as this clone is highly sensitive for environmental stress conditions (A P Attanayake, C Lokuge, L P Vitharana and R Gunarathne).

RAW RUBBER PROCESS DEVELOPMENT AND CHEMICAL ENGINEERING

Y Sudusingha

DETAILED REVIEW

Staff

Mr Y C Y Sudusingha, Research Officer was on duty throughout the year. Messrs Chandrika Nalini, U M S Priyanka, A K D Warnajith, C Rohanadepa, Experimental Officers and Mrs A R Melani de Alwis, Management Assistant were on duty throughout the year. Technical Officers, Mr R D Illeperuma, Ms P K N Sandamali and Mr W R U de Silva assumed duties with effect from 02.01.2017, 02.02.2017 and 10.07.2017, respectively.

Research students

Postgraduate students

- Messrs Oshintha Sandaruwan and Pathum Fernando, MSc students (Polymer Science and Technology) commenced their research projects on "use of fly ash as filler in solid tyre middle rubber compound" and "Accelerated vulcanization of thick walled rubber article" respectively under the supervision of Dr S Siriwardena and Dr (Mrs) Shantha Egodage (Senior Lecturer, Dept. of Chemical and Process Engineering, University of Moratuwa).

Undergraduate students

- Mr W H U S Dharmasena, BSc student from Uva Wellassa University of Sri Lanka, completed his research project titled "Preparation and characterization of creamed and centrifuged natural rubber latex to reduce protein levels" under the supervision of Dr S Siriwardena.

- Mr H P Pathirage, BSc student from Sabaragamuwa University of Sri Lanka, completed his research project titled "Preparation of creamed latex and studies on creaming characteristics and properties of crepe compounds made out of creamed skim latex" under the supervision of Dr S Siriwardena.

- Messrs H N Demuni and H W K Prabhashana, BSc students from University of Peradeniya, completed their industrial training project titled "Economic use of water in sole crepe and pale crepe manufacturing factories" under the supervision of Dr S Siriwardena.

- Messrs J A S S Jayawardana, M A G A Mudannayake and W A C S Muthukumarana, BSc students from University of Moratuwa, completed their group research project titled "Modeling and Optimization of Biomass Stove-Dryer System for Small Scale Indirect Heating Applications" under the supervision of Mr Yohan Sudusinghe.

- Mr A W I D Madusanka, BSc student from University of Sri Jayewardenepura, completed his industrial training project titled "Study the potential of Ribbed Smoked Sheets/Styrene Butadiene/Skim Crepe Rubber Blends for Solid tyre applications" under the supervision of Mr Yohan Sudusinghe.

- Ms K P T M Wijerathne and Ms R H L Kodithuwakku, BSc students from University of Sri Jayewardenepura, completed their industrial training project titled "Further improvement of quality of treated effluent water discharged from crepe rubber and Technically Specified Rubber Processing Factories" under the supervision of Mr Yohan Sudusinghe.

Seminars/Training programs/Workshops/Conferences/Meetings attended

Officer/s	Subject	Organization
YCY Sudusingha	Scientific Committee Meeting	Rubber Research Institute
	Certificate course on "Advanced Rubber Technology"	Cochin University, Kerala, India
	IRRDM International Conference and Fellowship Program	Rubber Research Institute
	Research Review Meeting	Rubber Research Institute
UMS Priyanka	Workshop on HPLC Instrument	Hemsons International (Pvt) Ltd at Hotel Taj Samudra.
	Workshop on "Polymer Characterization"	University of Sri Jayewardenepura
R.D Illeperuma	International Research Symposium	UvaWellassa University, Badulla
YCY Sudusingha RD Illeperuma	International Research Symposium	Sri Jayawardenapura University, Nugegoda
YCY Sudusingha PKKN Sandamali RD Illeperuma WRU de Silva	Work Shop on rubber compounding	Plastics and Rubber Institute of Sri Lanka, Rajagiriya
YCY Sudusingha PKKN Sandamali	Seminar on Analytical Instruments	Analytical Instrument Pvt Ltd at Taj Samudra Hotel, Colombo

Seminars/Training programs/Workshops/Exhibitions conducted

Officer/s	Subject	Organization
YCY Sudusingha	Certificate course in Rubber and Plastic technology-Monomers for polymers	Plastic and Rubber Institute
	Raw rubber processing	National Institute of Plantation Management
AKD Warnajith	Six workshops on "Manufacture of sheet rubber and single day smoke drying system"	Thurusaviya fund
	Field training program on crepe rubber manufacture- planter trainees	National Institute of Plantation Management
Staff of the RDD	Training program on "Raw rubber processing" for Rubber Development Officers	Rubber Development Department
UMS Priyanka & VC Rohanadeepa	Factory training on Raw rubber Manufacturing	BSc (Palm & Latex Technology & value Addition) undergraduates of the UwaWellassa University

Special training

Mrs U M S Priyanka, Experimental Officer participated in a foreign training program jointly organized by the Rubber Authority Thailand and Rubber Research Institute Sri Lanka on "Rubber agronomy and technology" under the Human Resource Development Programme launched by the RRISL for Technical Officers and Experimental Offices.

Advisory visits

Services provided

Services provided	No. of factories/visits
Process and quality improvements	05
Waste water treatment	03
Waste water sample collection for testing	43
Plans issued for construction of new SS drying systems with Capacity less than 100kg	14
Miscellaneous advisory and troubleshooting	06

Waste water analysis

Raw rubber processing and allied industries were visited throughout the year for collection of waste water samples for analysis and issue of certificates on requests.

Samples tested and certificates issued:

Sample tested	No. of samples/ Certificates
Waste water- rubber related	144/92
Waste water- Non rubber Related	35/23
Processing water	2/2
Miscellaneous Sample (Metal ions, ZnO *etc*.	3/3
Analysis of Extractable proteins	26/12
No of "certificates of epidemic prevention" issued for sole crepe	51

Technical assistance to Thurusaviya Fund

Extending technical assistance was continued to Thurusaviya annual programs by providing the services of resource personal and technical expert panels for evaluating quotations, issuing smoke house plans, inspection of construction and operation activities of sheet Rubber Processing Centers and Single Day Smoke Drying Units.

LABORATORY AND FIELD INVESTIGATIONS

Adaptation of simple and small scale (SS) tank

Design of a user friendly simple and small scale latex coagulation tank with 10kg capacity was completed after evaluating few designs with rubber smallholders and in consultation with rubber extension officers of the Advisory Services Department of RRISL. Few pilot scale tanks were constructed. Movability, built in facilities for latex standardization and prevention of dirt contamination, convenient acid addition into latex, uniform acid distribution, less froth formation, easy handling of wet coagulum and prevention of dirt contamination are some of the special features of these tanks compared to the conventional coagulating pans. Labour productivity could be increased while reducing the space requirement for coagulation operations. Field experiments will be continued to evaluate farmer level field performance of the tank (S Siriwardena, Y Sudusinghe and A K D Warnajith).

Solar assisted smoke drying of sheet rubber

Construction work of a solar flat plate air collectors assisted greenhouse type dryer funded by Sri Lanka Climate Pvt. Ltd. was completed at Bangalagoda Grameeya Rubber Sanwardhana Sansadaya (Bangalagoda Rural Rubber Development Society), Badalkumbura, Moneragala who is also a collaborator of the project. This unit was used for pre-drying of sheets. Preliminary trials have shown that smoke drying period of twenty four hours in a Single day Smoke drying unit (SS drying unit) could be reduced by 50% when the sheets are pre-dried in the green house for two days. Lighter colour sheets fetching higher prices in the market could

easily be manufactured using this system while being able to reduce the firewood consumption. Raw rubber properties of the sheets dried using this system were also not adversely affected as they all are in the recommended ranges. However, Po seems to be higher which may be a disadvantage as far as energy consumption in compounding is concerned and which will be further studied. Average raw rubber properties of solar assisted smoked sheets are given in the Table 1 below.

Table 1. *Raw rubber properties of Solar assisted smoked sheets*

Raw rubber property	Solar assisted smoke sheet	Reference sample (Conventionally smoked sheets)	Test method
Plasticity (Po)	63	44	ISO 2930
Plasticity Retention Index (PRI)	86	89	ISO 2930
Volatile matter (Vm) % (w/w)	0.57	0.38	ISO 248
Mooney viscosity (ML(1+4) @ 100	97.5	83	ISO 289-1
Dirt (%) (w/w)	0.024	0.067	ISO 249
Ash (%) (w/w)	0.219	0.38	ISO 247

(S Siriwardena, Y Sudusinghe and A K D Warnajith)

Physio-mechanical and curing characteristics of rubber vulcanizates filled with used tea waste

A large quantity of Used Tea Waste (UTW) is daily generated and discharged to the environment as a waste material. The possibility of using this readily available cellulose and water extractable organic constituents rich material as filler in rubber composites has not been explored. Therefore, this study was focused to study the preparation and performance evaluation of natural rubber (NR) composites filled with UTW. UTW was first processed into particulate filler form with moisture content less than 1%. A series of UTW incorporated natural rubber compounds was prepared. Another NR composite filled with semi-reinforcing carbon black namely N550 was also prepared for the purpose of comparison. Curing characteristics and Physico-mechanical properties of the composites were studied. It was found that both maximum torque (M_H) and minimum torque (M_L) values showed an increase with the UTW loading indicating the contribution of tea waste in increasing stiffness and the viscosity of the compounds. The processability of UTW filled composites was also similar to the commercially available filler incorporated NR composites without registering significant processing problems. An accelerating effect on the vulcanization process has been shown by UTW probably due to the high heat generation during the compounding process or presence of naturally occurring accelerators in UTW. However, carbon black filled NR composites showed a comparable curing time to the UTW filled composites with higher loading suggesting an adequate scorch safety of the latter composites.

Table 2. *Curing characteristics of rubber composites*

Filler type and loading (phr)	Maximum torque (M_H) (MPa)	Minimum torque (M_L) (MPa)	M_H- M_L (MPa)	t_{90} (Minutes)	ts_2 (Minutes)
CB -75	32.16	11.63	20.53	2.51	1.72
UTW- 60	31.55	4.38	27.17	4.10	1.80
UTW -75	31.93	7.08	24.85	3.47	1.60
UTW -90	31.94	7.70	24.24	2.41	1.57

Addition of UTW showed an increase in hardness and modulus at 100% elongation of the vulcanizates. But, the composite showed a gradual decrease in the mechanical properties of tensile strength, tear strength and elongation at break with UTW loading. Abrasion volume loss also increased with UTW loading. The comparison with the mechanical properties of CB filled composites has showed that CB composites exhibit higher performance than UTW filled composites. However, in term of ageing properties as assessed based on the tensile properties, all the composites yielded a retention percentage of more than 75%. Therefore, considering the processability and the mechanical properties registered, UTW also has a potential to be used as diluents filler in certain class of rubber product manufacture.

Table 3. *Physico- mechanical properties*

Compound	Hardness (IRHD)	Modulus at 100% elongation (MPa)	Tensile strength (MPa)	Elongation at break (%)	Tear strength (MPa)	Retention (%)	Abrasion volume loss (cm^3)
CB 75	71.64	7.92	11.20	158.03	40.75	88.21	9.05
UTW 60	63.74	2.57	4.74	503.1	24.21	78.27	14.31
UTW 75	64.75	2.76	4.43	487.49	23.96	75.17	16.62
UTW 90	70.00	2.98	3.40	331.29	19.73	98.53	19.66

(S Siriwardena, Y Sudusinghe and R D Illeperuma)

A study on feasibility of recycling of processing water generated in crepe rubber factories in Sri Lanka

Crepe rubber is the purest form of the raw rubber produced in the world and Sri Lanka is the major manufacturer and exporter of crepe rubber including pale crepe and sole crepe in the global rubber market. At present, most of the crepe rubber manufacturing factories have faced a severe problem in finding adequate good quality water for processing of natural rubber latex into crepe rubber and other activities.

Therefore, this study was carried out to explore the feasibility of recycling of processing water used for simultaneous rubber washing during milling and mill cooling processes in the crepe rubber manufacturing process at a selected pale and sole crepe rubber manufacturing factory in Sri Lanka. Water quality parameters namely Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Total Ammoniacal Nitrogen (TAN), metal ions and pH of feeding and discharging water at each stage of coagulum breaking, intermediate milling and smooth milling processes were tested. It was found that quality and quantity of washing water used at the smooth mill is sufficient to provide the entire quantity of water required for the maceration and diamond mill operations which are the first two milling operations carried out prior to the smooth mill operation in the manufacturing process of crepe rubber. It was also found that mill cooling water could be completely recycled repeatedly for the same purpose without using fresh water. Results of one of the pale crepe factory located in Kalutara district is described in this report. A new protocol was proposed based on the quantitative and qualitative analysis of present water use pattern of the factory, to recycle the processing water generated from rubber washing while milling and mill cooling processes. According to the proposed protocol, it could be saved 4,907 liters and 17,130 liters of fresh water used for rubber washing and mill cooling respectively per 1000 kg of dry pale crepe produced. In other words, the factory would be able to save 63% of daily fresh water consumed during milling operations at this particular factory by adopting the proposed protocol for water recycling.

Water consumption for washing and cooling for each mill to process 826kg of rubber, are shown in Table 4.

Table 4. *Fresh water consumption for washing and mill cooling*

Mill No	Mill type	Time (min)	Total washing water (ℓ)	Total cooling Water (ℓ)	Average washing flow rate (ℓ/h)	Cooling average flow rate (ℓ/h)
1	Macerator	178	2,281	796	-	-
2	Diamond	103	1,773	1,054	-	
4	Smooth	287	5,259	2.876	1,099	601
7	Smooth	375	5,502	6,244	804	1,056
6	Dry blanket	497	-	5,029		

Table 5 presents the values of quality parameters of collected waste water sample during the milling process and fresh water sample from source. In addition, it also contains tolerance limits for effluents from rubber factories being discharged into inland surface waters stipulated by Central Environmental Authority (CEA) Sri Lanka. It was revealed that except the TAN which has slightly higher value compared to

feeding water (source water), all water quality parameters of discharging washing water at smooth mill is similar to feeding water (source water) supply.

Table 5. *Water quality parameters at different mills*

Parameter	Macerator	Diamond	Smooth	Cooling	Source	CEA tolerance limits
COD (ppm)	2,15	600	60	20	20	400
TAN (ppm)	12.6	4.9	1.05	0.7	0.1	40
TSS (ppm)	444	100	72	104	72	100
Copper ions (ppm)	0.30	0.00	0.00	0.00	0.00	3.0
Iron ions (ppm)	2.62	0.86	0.94	0.00	0.00	0.0
P^H	5.92	6.82	6.94	7.24	7.65	6.5-8.5

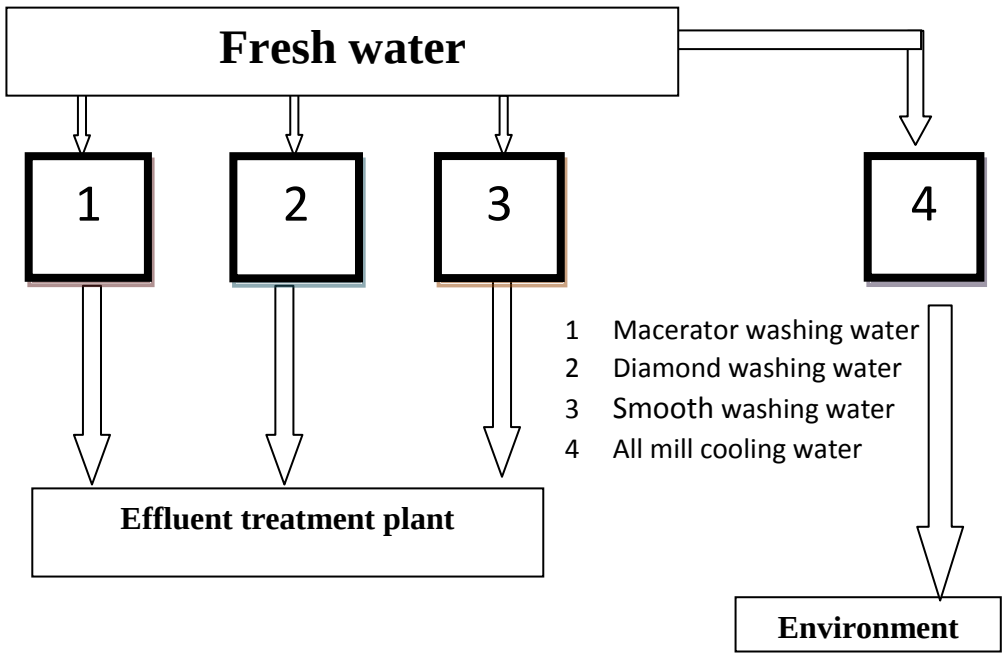


Fig. 1. Present water consumption system

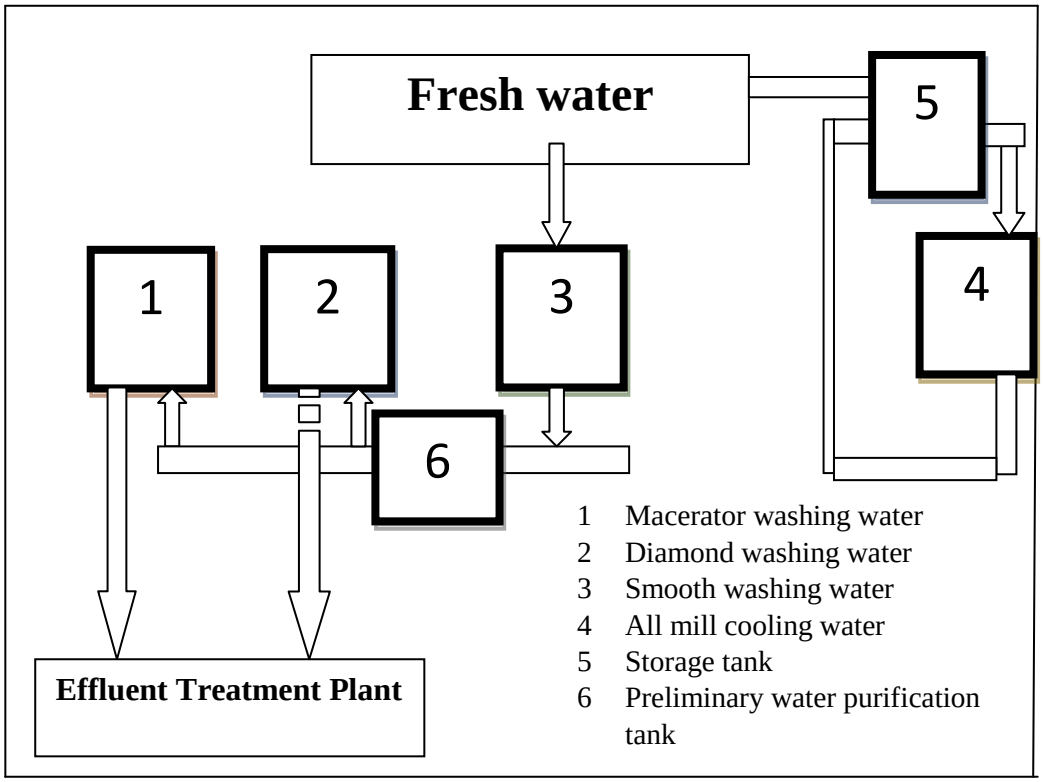


Fig. 2. Proposed water recycle system
(S Siriwardena, Y Sudusinghe, A K D Warnajith, C Rohanadepa, R D Illeperuma, P K N Sandamali and W R U de Silva)

Preparation and characterization prevulcanized natural rubber latex with prolong shelf life time

Prevulcanized natural rubber latex (PVNRL) are convenient materials for the manufacturers of latex goods, especially dipped goods. But PVNRL latex have a short shelf life due to vulcanization process in system is continuing even after it comes to required swelling index value or crosslinking density. Therefore, the main objective of this research was to develop PVNRL with prolong shelf life time by inhibiting the action of accelerators of PVNRL. Firstly, suitable retarder was identified and 25% (w/w) dispersion of the retarder was prepared. Two sets of PVNRL compounds (with filler and without filler) were prepared using a standard formula with addition of different concentrations of retarder. A control counterpart was also prepared. Each sample was then kept undisturbed at room temperature. Change of cross linking density of samples with time taken was then measured using Swelling Index (SI) test and chloroform test. Results are shown in Table 6. Results show sample 2 and 3 of

compounds with filler take 2 days to achieve SI of 80 and sample 4 and 5 take 5 and 17 days to achieve SI of 80 respectively. The control reaches to SI of 75 within 2 days. As shown in Table 7, sample 2 and 3 of compounds without filler take 8 and 30 days to achieve SI of 80 respectively. The control reaches to SI of 80 within 8 days.

Table 6. *Swelling Index (SI) of pre-vulcanized filled (30 phr) latex samples incorporated with different PVI concentrations*

Date	PVI concentration				
	Sample 1 (Control)	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**
	0.0	**0.5**	**1.0**	**1.5**	**2.0**
11/8/2017	90	90	90	90	90
11/9/2017	85	85	85	85	85
11/11/2017	75	80	80	85	85
11/13/2017	75	75	80	80	85
11/15/2017	70	70	75	80	85
11/17/2017	70	70	75	80	85
11/19/2017	70	70	75	80	85
11/21/2017	70	70	75	80	85
11/23/2017	65	65	75	75	85
11/25/2017	65	65	70	80	80
11/27/2017	65	65	70	80	80
11/29/2017	60	60	70	75	80
12/1/2017	60	60	70	75	75
12/3/2017	60	60	70	70	75
12/5/2017	60	60	70	75	80
12/7/2017	60	60	70	75	80
12/9/2017	60	60	70	75	80
12/11/2017	60	60	70	75	80
12/13/2017	60	60	70	75	80
12/15/2017	60	60	70	75	80
12/17/2017	60	60	70	75	80
12/19/2017	60	60	70	75	80
12/21/2017	60	60	70	75	80
12/23/2017	-	-	-	-	-
12/25/2017	-	-	-	-	-
12/27/2017	60	60	70	75	80
TSC - 30%	Viscosity - 11 Sec				

Table 7. *Swelling Index (SI) of pre-vulcanized filled (0 phr) latex samples incorporated with different PVI concentrations*

Date	*PVI phr*		
	Sample 1 (Control) 0.0	**Sample 2 0.5**	**Sample 3 1.0**
11/15/2017	110	110	110
11/17/2017	90	90	90
11/19/2017	85	85	85
11/21/2017	80	80	85
11/23/2017	75	75	85
11/25/2017	70	75	85
11/27/2017	65	70	85
11/29/2017	65	70	85
12/1/2017	65	70	85
12/3/2017	65	70	85
12/5/2017	65	70	85
12/7/2017	65	70	85
12/9/2017	65	70	85
12/11/2017	65	70	85
12/13/2017	65	70	80
12/15/2017	65	65	80
12/17/2017	65	70	80
12/19/2017	65	70	80
12/21/2017	60	70	80
12/23/2017	-	-	-
12/25/2017	-	-	-
12/27/2017	65	70	80

TSC - 58% Viscosity - 16 Sec

(S Siriwardena, Y Sudusinghe, A K D Warnajith and R D Illeperuma)

Study of DMA properties of different types of natural rubber composites

Dynamic Mechanical Analysis (DMA) is used to measure visco-elastic properties of polymeric materials and it is a widely used tool for selection of materials for different dynamic applications and performance evaluation. A series of polymer composites was prepared with 15 phr whiting loading using four types of natural rubber containing different levels of non-rubbers. They were Ribbed Smoked Sheet

rubber (RSS), Fractioned and Bleached Crepe rubber (FBC), Standard Lanka Rubber (SLR-20) and Skim Crepe rubber. They were vulcanized at a temperature of 150 ^{o}C for their respective cure times. Dynamic mechanical properties *i.e.* Storage modulus (E'), loss modulus (E'') and damping factor (tan δ) were studied in the temperature range between -90 and 150 ^{o}C at 1Hz oscillating frequency. Typical S- shaped curves for storage modulus were obtained for all four types of vulcanized rubber composites. There were no β and ɤ transitions observed in the glassy region studied confirming that there were no detectable local, bend and stretch; and side group motions occurred in this region. However, E' of the SLR-20 composite exhibited a significantly higher value (21 MPa) compared to other three types, E'' of which lie between 3.5-5.0 MPa. This suggests that stiffness of the former is remarkably higher than that of the other types below the glass transition temperatures. As the material reached the rubbery stage, E' of the composite reached almost a similar value irrespective of the types of the raw rubber used. Comparison of the E'' values showed the same pattern obtained for E' below the glass transition temperature. However in the rubbery region, skim crepe rubber based composite showed a higher value. E'' of the other composites followed the order; SLR-20>RSS> FBC. Higher E'' value confirms a higher heat dissipation for the skim crepe rubber composite. The gap between storage and loss modulus curves is higher in the skim crepe rubber composite, in the rubbery region. This may be due to the presence of higher cross link density of the skim composites compared to the crosslink densities of other composites. However, the skim crepe rubber composite registered the lowest damping coefficient. The Tg values taken from tan δ curves of all composites were similar. It was revealed that E' and E'' of SLR -20 composites were significantly higher than that of other rubber composites studied in the glassy region. In the rubbery region, SLR-20, RSS and crepe rubber composites showed similar dynamic properties while skim crepe rubber composite recorded higher E'' values and lower tan δ peak value indicating the need for careful selection of skim crepe rubber for dynamic applications.

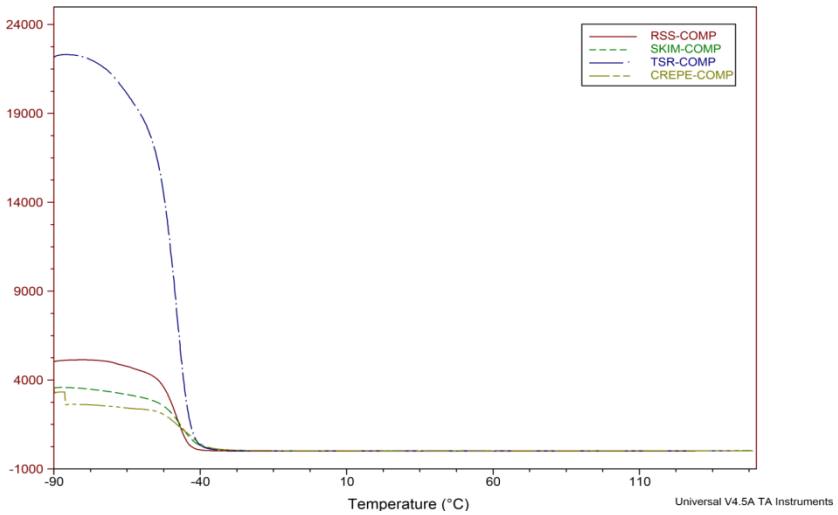


Fig. 3. Storage modulus of rubber composites

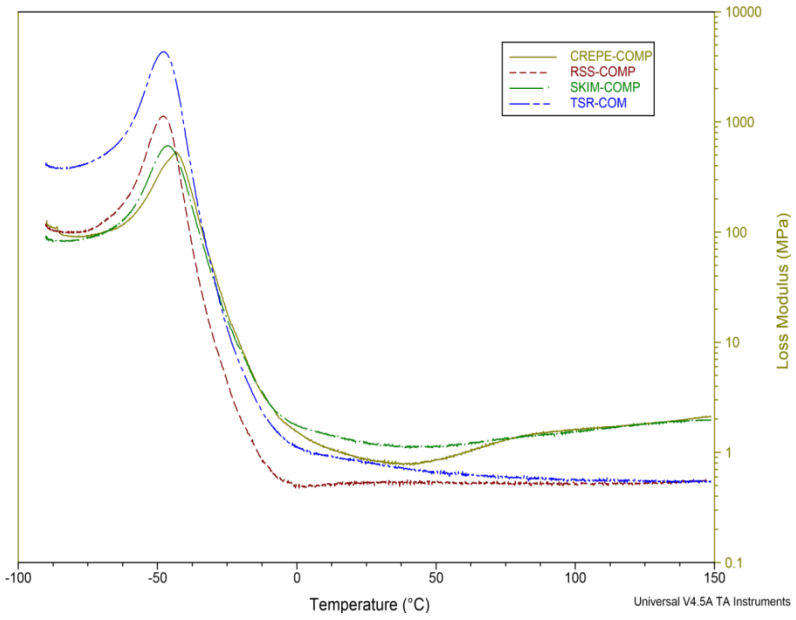


Fig. 4. Loss modulus of rubber composites

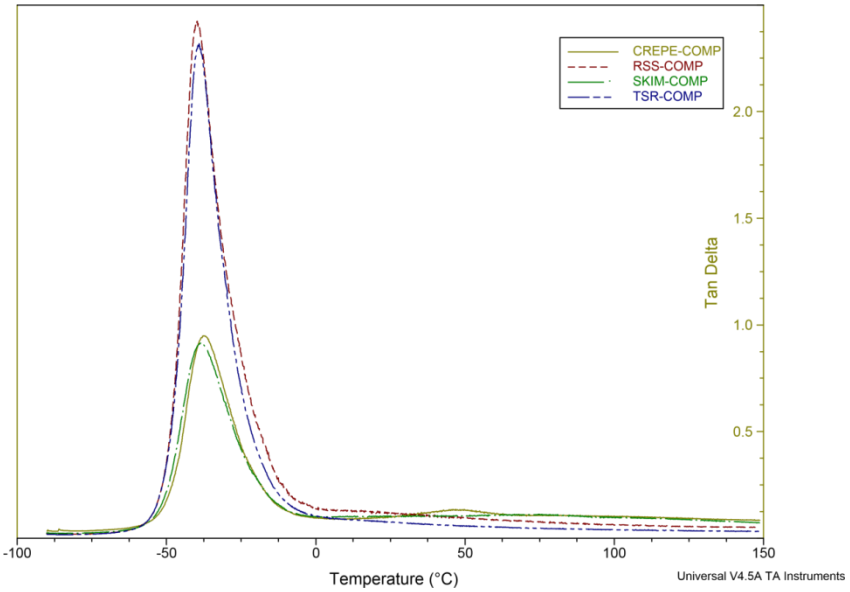


Fig. 5. Tan delta of rubber composites
(Y Sudusinghe)

Development of environmentally friendly and an economical sludge management technique for natural rubber latex tank sludge

A series of NR composites were prepared with different loadings of the surface treated sludge with stearic acid using a laboratory scale internal mixer to study the performance of the treated sludge on curing and mechanical properties of the filled NR compounds. A series of untreated sludge filled NR composites was also prepared for the purpose of comparison. Curing characteristics as measured with low shear strain rheological characterization have shown that surface modification improves the processing safety without a significant impact on the curing time.

Mechanical properties of surface treated sludge filled NR vulcanizates have shown an improvement in tensile properties, especially strength and elongation at break in comparison to untreated counterparts. However, on the other hand, stiffness as measured with hardness was reduced at higher loadings of surface treated sludge filled NR vulcanizates. Results have been explained with improved degree of dispersion of surface treated sludge as a result of the surface modification and availability of free fatty acids in the NR matrix.

Studies carried out on compositions and structural characterization reveal that sludge is a crystalline material known as struvite. In addition to phosphates, it contains rubber and other inorganic materials trapped within the sludge. Unmodified

sludge accelerates the vulcanization reaction resulting in early onset of vulcanization and reduction of optimum cure time. Coating of sludge with stearic acid increased the processing safety and kept the cure time constant at all loading levels.

Surface coating of NR/sludge compound increased the mechanical properties such as tensile strength and elongation at break. No considerable effect on hardness and resilience was observed. But abrasion resistance decreased with increase of sludge loading levels. Therefore, this material could be used for applications where abrasion property is not a major important product performance factor.

As an another economic route to dispose the sludge generated at the centrifuging plants, the sludge collected in the field latex storage tanks was directly coagulated using Sulphuric acid. According to preliminary studies, 70ml of Sulfuric acid (5% by weight) required to complete coagulation of 1kg of tank sludge. Sludge coagulated with sulfuric acid was then passed through the smooth mills for three times without washings and then passed through the macerator three times. Sludge containing laces thus prepared were dried in the loft for three days. Dry laces were passed through dry blanket mill. Composition the sludge based rubber was studied. Composition of the sludge rich rubber are given in Table 8.

Table 8. *Composition of the sludge rich rubber*

Ash (%)	VM content (%)	Total nitrogen content (%)	PRI	Dirt content (%)	Rubber content (%)
26.21	22.911	3.1747	Melted	39.8	37.3

According to above results, sludge rich rubber contains 37.3% natural rubber and the total nitrogen content is around 3.17%. Dirt content of the rubber sample represent the sludge and metal quantity trapped within the rubber sample.VM value of the sample is 22.91 which includes crystalline water and ammonia in the sludge material. Ash represents the metal ions and the remaining sludge ($Mg_2P_2O_7$) after de-composition at 550 ^{0}C in muffle furnace. Ash was analysed for several important metal ions and phosphates and the results are tabulated in Table 9.

Table 9. *Analysis of ash derived from the sludge rich rubber*

Sample	Copper content (µg/g)	Iron content (µg/g)	Chromium content (µg/g)	Nickel content (µg/g)	Lead content (µg/g)	Zinc content (µg/g)	Phosphate content (µg/g)
Sludge containing rubber	6.61	334.9	5.05	nil	nil	49.2	3571

According to above results modified sludge rubber contains Copper, chromium and iron in excess while nickel and lead ions are undetectable. Total ion content is also considerably high. As can be expected Zn content was found to be high due to the presence of ZnO added with TMTD as a preservative into field latex. Phosphate content too was found to be obviously very high since the main component of the sludge is precipitated $MgNH_4$ PO_4, $6H_2O$. High metal ion content, especially copper has resulted in very low Plasticity Retention Index of the modified sludge rubber manifested by melting of the pellets on aging.

Mooney viscosity of sludge rich rubber is 148 at ML (1+4). Mooney graph of the sludge containing rubber compound showed an irregular shape (Fig. 10). This may be due to the simultaneous degradation of rubber during the testing as rubber contains higher content of metal ions and the presence of high content of non rubber materials. Combination of non deformable sludge with deformable rubber has reduced the deformability of rubber leading to increasing of Mooney viscosity (S Siriwardena and U M S Priyanka) (consider revising this explanation. High Mooney may be due to low rubber content with high loading of non rubbery sludge and the Mooney value may have been lowered with time due to the softening effect).

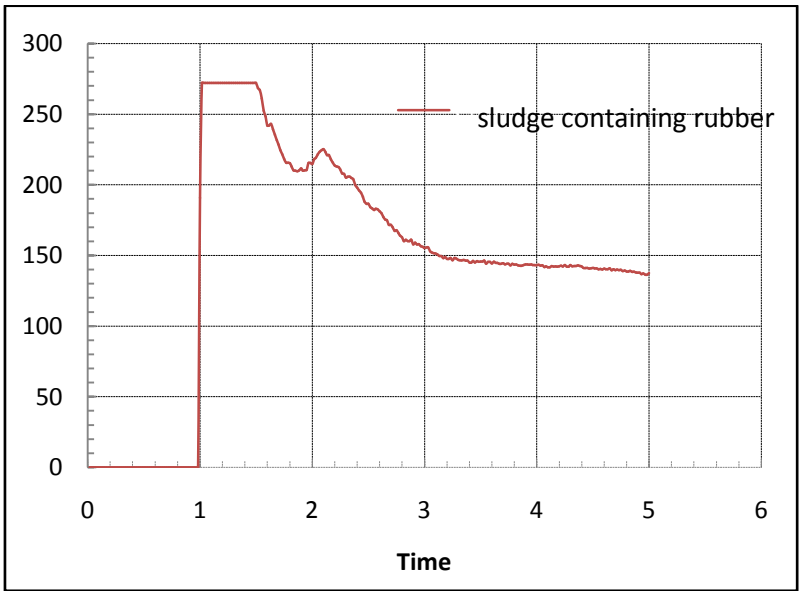


Fig. 6. Mooney viscosity cure *vs* time

Preparation and characterization of creamed and centrifuged natural rubber latex

Latex Concentration is a process by which the Dry Rubber Content (DRC) of NRL is increased. This study focused on the combination of Creaming and Centrifuging in concentrating NRL. In one method, NRL was creamed for ten hours, latex cream was separated out and was then subjected to centrifugation to produce Short-term Creamed Centrifuged Latex (SCCL). In the other method, NRL was creamed for 22 days until the DRC reached 60% and the separated latex cream was re-diluted to 30% and it was subjected to centrifugation to produce Long-term Creamed and Centrifuged Latex (LCCL). In both procedures, NRL was creamed using Sodium Alginate as a creaming agent. Variation of DRC of creamed latex with time was recorded. Total Solid Content (TSC), DRC, Volatile Fatty Acids number (VFA No), Mechanical Stability Time (MST), Nitrogen (N) content, and Extractable Protein content (EP) were determined. A batch of Normal Centrifuged Latex (NCL) was also prepared for comparison. It was found that the creaming rate as determined by the increasing DRC, started to decline after an period of ten hours. NRL with initial DRC of 30% reached 42% at this point. Also the TSC and DRC values of SCCL are slightly below such values of other two samples. Creaming prior to centrifugation has resulted in lowering the VFA and N-Content of the centrifuged latex. EP of NCL was 168.53 ppm while creamed and centrifuged latex recorded un-detectable levels of EP. MST of SCCL, LCCL and NCL after 21 days of maturation has recorded as 820, 522 and 782, respectively. Thus, LCCL do not meet the minimum MST standards required to qualify LCCL for Latex industry. Creaming NRL for ten hours followed by centrifugation (SCCL) could be an industrially viable method to produce low protein concentrated latex for special applications (W H U S Dharmasena, S Siriwardena and Y Sudusinghe).

ADAPTIVE RESEARCH

E S Munasinghe

DETAILED REVIEW

Staff

Dr (Mrs) E S Munasinghe, Principal Research Officer, Mr P M M Jayathilake, Technical Officer and Mrs M A R Srimali, Management Assistant were on duty throughout the year. Mrs B M D C Balasooriya, Research Officer was transferred to Polgahawela Sub station to commence her postgraduate studies with effect from 25th April 2017. Mrs N M Piyasena assumed duties as a Technical Officer with effect from 10th July 2017.

Dr (Mrs) E S Munasinghe was promoted from the position of Senior Research Officer to Principal Research Officer with effect from 1st February 2017. Dr S M M Iqbal, Principal Agronomist retired on 21st April 2017 after 26 years of service at RRISL. He deserves special appreciation for the contributions made in developing Moneragala and Polgahawela Sub-stations and introducing and popularising rubber in non-traditional areas, particularly in the dry climates of Eastern and Northern Provinces.

Mrs C Weeramanthree, Accounts Clerk of Polgahawela Substation retired on 9th December 2017 after 29 years of commendable service at RRISL.

Seminars/Training/Workshops/Exhibitions conducted

Officer/s	Subject/Theme	Beneficiary/Client
ES Munasinghe BMDC Balasooriya PMM Jayathilake	CRT exhibition	Stakeholders in plantation sector

Seminars/Training/Workshops/Meetings/Conferences attended

Officer/s	Subject/Theme	Organization
SMM Iqbal	Annual Symposium on Minor Export Crops	Ministry of Minor Export Crop Production
	Workshop on GPS	Postgraduate Institute of Agriculture, Peradeniya
ES Munasinghe	Expert Consultation Meeting of Climate Change Adaptation & Disaster Risk Management in Agriculture Sector	Institute of Policy Studies

Officer/s	Subject/Theme	Organization
ES Munasinghe	Cabinet Committee Meeting on Economic Development	Ministry of Development Strategies and International Trade
	Programme Advisory Committee Agriculture	Higher National Diploma in Technology (Agriculture)
	Australian Award Fellowship programme	Department of Foreign Affairs & Trade, Australia
	Consultative Committee Meeting on non-traditional rubber cultivation	RRB
ES Munasinghe & BMDC Balasooriya	Scientific Committee Meeting	RRISL
BMDC Balasooriya	International Stingless bees Conference and Workshop	IRRDB

Research students

- Mr G N S Premarathna, an undergraduate student of Faculty of Agriculture, Rajarata University of Sri Lanka, carried out his final year research project on 'Identification of socioeconomic, cultural and agronomic limitations for adaptation of rubber cultivation in Northern province of Sri Lanka' under the supervision of Dr (Mrs) E S Munasinghe and Dr V H L Rodrigo.

Visits

Experimental Visits 93

FIELD INVESTIGATIONS

Expansion of rubber cultivation to non traditional areas (ARU/01)

Assessments on socioeconomic impact of rubber cultivation in the Eastern province

The study was conducted to characterize and quantify the impact of rubber cultivation on the peasant community in the Eastern province through the assessments on major livelihood capital assets. The study was carried out in Padiyathalawa Divisional Secretariat area of Ampara District where rubber was initially introduced to the Eastern Province. Major livelihood capital assets; human, natural, physical, financial and social capital prevailed with 33 rubber farmers were compared with similar number of non-rubber farmers in the area.

Findings of the study showed rubber cultivation has significantly contributed to increase the livelihood capital assets of rubber farmers in terms of household income, quality of roof and walls of house, electric appliances at house, money lending and borrowing capacity of farmers, interaction with relatives, involvement in religious activities and expenditure on children's education, family healthcare and charity than those of non-rubber farmers (Table 1). This implies rubber cultivation in

the Eastern Province positively contribute to uplift the livelihood standards of households and ultimately to alleviate the rural poverty in Sri Lanka.

Table 1. *Statistical significance in the impact of rubber cultivation on livelihood assets of rubber farmers in the Eastern Province*

Livelihood asset	Co efficient	SE	P>[t]
Total household income	0.565*	0.145	0.000
Total household expenditure	0.383*	0.171	0.029
Expenditure on health	0.054*	0.013	0.000
Expenditure on education	0.059*	0.018	0.002
Expenditure on charity	0.039*	0.006	0.000
Floor type of house	1.380*	0.553	0.013
Wall type of house	1.345*	0.555	0.015
Electric appliances of house	2.339*	0.655	0.000
Money borrowing capacity	1.757*	0.805	0.004
Money lending capacity	1.577*	0.602	0.003

Significant* at $p < 0.05$

(E S Munasinghe, V H L Rodrigo, S M M Iqbal, P M M Jayathilake and N M Piyasena)

Assessments on yield potential and seasonal variation of rubber yield in the Eastern Province

In order to identify the yield potential and seasonal variation of yield at smallholder condition, daily yield records of 20 rubber farmers in Padiyathalawa Divisional Secretariat area have been monitored throughout the year. The highest yield was observed in the month of January and the lowest in August (Fig. 1). Accordingly, average annual latex yield was recorded as 1,320 kg/ha at early stage of harvesting (Panel A) and average number of tapping days as 167 per year.

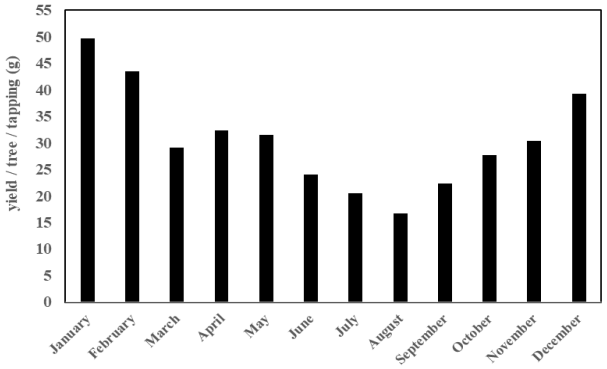


Fig. 1. Seasonal yield variation under smallholder condition at Padiyathalawa (E S Munasinghe, V H L Rodrigo, S M M Iqbal and P M M Jayathilake).

Improving the protocols available to cultivate rubber in Dry Zone

With the aim of improving suitable protocols available to cultivate rubber in dry zone, adaptive research trials were conducted in Northern Province of the country. Growth performance of rubber plants of sites in Vavuniya (in terms of tree girth at 120 cm height of the trunk) was assessed (Table 2).

Table 2. *Growth of rubber plants in Dry zone*

		Extent (Ac)	**Average girth (cm) (at 120 cm height)**
Site 1	2010 Planting	2	45.8
	2011 Planting	10	42.7
Site 2	2010 Planting	2	42.5
	2011 Planting	8	35.8

As a new approach of attracting Tamil community to rubber cultivation, four farmer participatory adaptive research plots (each 0.5 Ac) were established in Malayalapuram, Kilinochchi in 2017.

(E S Munasinghe, V H L Rodrigo, S M M Iqbal, P M M Jayathilake and N M Piyasena in collaboration with all Agronomy Departments)

Identification of socio economic, cultural and agronomic limitations for rubber cultivation in the Northern Province

Despite the evidence for acceptable climatic conditions in the region, rubber cultivation has been successful only in Vavuniya district of the Northern Province. Therefore, this study was conducted to identify possible socio economic, cultural and agronomic limitations affecting the adoption of rubber cultivation in rubber growing areas in Vavuniya, Mullaithivu and Kilinochchi districts of the Northern Province. Further, it was expected to identify farmer perceptions on the promotion of expansion process. All farmers with successful rubber cultivation along with similar numbers of unsuccessful farmers and farmers who willing to cultivate rubber were considered for the study.

The results revealed, being Sinhalese, proficiency in Sinhala language, affiliation to social organizations, availability of water source and usage of mulch at early growth stage of rubber plants have significantly contributed to the success of rubber cultivation in Northern Province (Table 3). Although many farmers failed in rubber cultivation, their perception on cultivating rubber are still optimistic, demanding organizational support for initial establishment at first priority. Further, all categories have highly been demanded continuous and effective extension service, uninterrupted water supply, improved transportation system and introduction of

suitable agronomic practices to enhance soil properties and moisture conservation in the expansion process.

Table 3. *Statistical significance of sociocultural and agronomic parameters towards the success of rubber cultivation in Northern Province of Sri Lanka*

Parameter	Number of farmers (%)	Pr > ChiSq
Language skills (proficiency in Sinhala)		0.0145*
Yes	22 (65)	
No	12 (35)	
Ethnicity		0.0145*
Sinhala	22 (65)	
Tamil	12 (35)	
Membership in social organization		0.0011*
Yes	23 (68)	
No	11 (32)	
Water source		0.0366*
Agro well	24 (71)	
Irrigation cannel	10 (29)	
Mulch usage for rubber plants		0.0029*
Yes	19 (56)	
No	15 (44)	

Significant* at $p < 0.05$

(E S Munasinghe, G N S Premaratne, V H L Rodrigo and S M M Iqbal)

Increase land productivity through technology adoption (ARU/02)

Impact of late planting on growth and development of rubber plants in the Intermediate Zone

This experiment was commenced as a rubber/sugarcane intercropping demonstration plot at Moneragala sub-station in 2009 together with an objective of assessing the impact of late planting on growth and development of rubber plants in the intermediate zone. Experiment comprises six main treatments of planting time points beginning onset of Maha season and thereafter in every two weeks. As sub treatments two types of planting materials, *i.e.* one and two leaf whorl rubber plants were planted with split plot arrangement in four experimental blocks. The experiment was replicated with a rubber/banana demonstration plot in 2011.

Girth (at 120 cm height) of rubber plants were measured. No significant difference observed among average girth values of rubber plants with the delay in planting (Table 4).

Table 4. *Mean growth of rubber plants*

	Girth (cm) - at 120 cm height Rubber/Sugarcane intercrop (8 years after planting)		Girth (cm) - at 120 cm height Rubber/Banana intercrop (6 years after planting)	
	one leaf whorl plants	**two leaf whorl plants**	**one leaf whorl plants**	**two leaf whorl plants**
Onset of rain	48.9	49.1	38.1	38.3
2 weeks after	48.6	49.0	36.8	37.8
		48.9	36.3	37.3
4 weeks after	48.2			
6 weeks after	46.7	48.0	36.1	37.2
8 weeks after	46.6	47.5	35.9	37.1
			34.6	36.8
10 weeks after	44.9	45.9		

(E S Munasinghe, V H L Rodrigo, S M M Iqbal, P M M Jayathilake, N M Piyasena and V G D N Gunaseela)

Adaptability of new animal repellent under smallholder conditions

Damage from mammalian pest has become a serious issue in some rubber growing areas of the country. Wild boar and porcupine are the most threatening animals to rubber plantations. They damage the bark of the rubber tree which finally affects to the growth of plants.

Rubber Research Institute has recommended several mechanical protection methods (*i.e.* physical barriers) for rubber plants and an animal repellent, a chemical protection method to apply on bark of the rubber tree. Most of the time, farmers are reluctant to use mechanical methods. Some of them tend to apply locally prepared mixtures on the tree bark.

Animal repellent which was introduced by the Plant Pathology and Microbiology Department successfully protects rubber trees from wild boars and porcupines. But the major limitation with this method is washing off the repellent due to rain and the retention time is generally considered as three months. Nevertheless, the retention time can vary with the climatic zone. Therefore, an adaptive research trial was started with the collaboration of Plant Pathology and Microbiology Department to identify the suitable application time and frequency of application. In the initial stage, five sites were selected from Polgahawela and Alawwa RDO Divisions and one site from the Polgahawela Sub-station. Three sites out of the six sites, are at the commencement of tapping and therefore these sites were selected to study whether wild boar attack is reduced at the beginning of tapping. Other three sites were selected for the animal repellent application. Around 60 trees were selected

for animal repellent application in each field and same number of trees kept as the control (without applying the repellent). Pre assessment was done in all the six sites and the results are given in the Table 5.

Table 5. *Pre damage assessment in selected smallholder sites*

Category	Site	Planting year	Clone	Damage %
Smallholder sites at the commencement of tapping	Smallholder site 1	2009	RRIC 121	95%
	Smallholder site 2	2010	RRIC 121	87%
	Smallholder site 3	2011	RRIC 121	75%
Smallholder sites treated with animal repellent	Smallholder site 5	2015	RRISL 203	12%
	Smallholder site 6	2014	RRIC 121	39%
	Sub-station field	2012	RRIC 121	89%

(B M D C Balasooriya and N M Piyasena in collaboration with Plant Pathology and Microbiology Department)

BIOMETRY

Wasana Wijesuriya

DETAILED REVIEW

Staff

Dr (Mrs) Wasana Wijesuriya (Principal Research Officer) and Experimental Officers; Mrs Chintha Munasinghe and Mr Vidura Abeywardene were on duty throughout the year. Mrs W W L S Sashikala, Management Assistant attached to the Biometry Section was on duty until 11th August 2017 and was on maternity leave afterwards.

Seminars/Trainings/Workshops addressed/conducted

Mrs Wasana Wijesuriya conducted the following trainings.

Subject/Theme	Beneficiary/Client
Use of MS EXCEL for data entry in experiments and surveys	Research/Experimental/Technical Officers of RRISL
Climatic conditions and rainfall distribution in rubber growing areas	Participants of the Advanced Certificate Course in Plantation Management
Climatic conditions and rainfall distribution in rubber growing areas	Officers of Rubber Development Department

Seminars/Conferences/Meetings/Workshops attended

Mrs Wasana Wijesuriya attended the following Meetings/Conferences.

Subject/Theme	Organization
Climate change and sustainable development - Are we ready?	Sri Lanka Council for Agricultural Research Policy (SLCARP)
Present status of research and development activities on climate change mitigation and future needs	Sri Lanka Council for Agricultural Research Policy (SLCARP)
Disaster management in Plantation Sector	Ministry of Plantation Industries
Scientific Committee Meetings of Rubber Research Institute of Sri Lanka (RRISL)	RRISL
Conference on recognizing climate change risk of Dry Zone farmers in Sri Lanka	Ministry of Disaster Management/National Building and Research Organization
Research Coordination Committee Meetings of NSF National Thematic Research Programme (NTRP) on food security	National Science Foundation (NSF)

Subject/Theme	Organization
Research Coordination Committee Meetings of the project "Assessment of Spatial Impacts of Climate Change on the Plantation Sector in Sri Lanka"	National Science Foundation (NSF)
Review meetings of the project on "Introduction and establishment of new fuel wood growing models in selected lands of smallholder rubber farmers"	FAO/RRISL
XVIth Monsoon Forum	Department of Meteorology
Climate Change Adaptation Strategies	Singapore Cooperation Programme Training Award/Small Island Developing States Technical Cooperation Programme

Mr Vidura Abeywardene attended the following Workshops

Subject/Theme	Organization
World Metrological Day - 2017	Department of Meteorology
CRT Exhibition	Ministry of Plantation Industries
Review Meetings of the project on "Introduction and establishment of new fuel wood growing models in selected lands of smallholder rubber farmers"	FAO/RRISL
Workshop on INFORM data collection	SLCARP
Meteorological data recording and reporting	Department of Meteorology/CRI
Training programme on operation of meta data portal	Ministry of Disaster Management

Seminars/Conferences/Workshops addressed

Mrs Wasana Wijesuriya addressed the following Seminars/Conferences/Workshops.

Subject/Theme	Target group
Management of impacts of climate change on plantation crop production : Rubber Sector	Policy makers and plantation sector personnel
Alumni Speech of the Annual Congress 2017 of PGIA - Contribution of Postgraduate Institute of Agriculture to the Plantation Sector Research	Policy makers, Academics, Researchers and Postgraduate students
Agro-climatic conditions in rubber growing areas of Sri Lanka	Participants of IRRDB Fellowship Programme

Research students

The following students are registered for postgraduate studies under the guidance of Dr (Mrs) Wasana Wijesuriya.

- Mr M W H Gayan – Working on "Suitability of different drought indices under Sri Lankan conditions based on statistical considerations and practical use" for his MSc degree at the Faculty of Agriculture, University of Ruhuna.

- Mr L A T S Liyanaarachchi - Registered for a MPhil in the Wayamba University based on a study titled "Indicator based identification, forecasting and mapping of droughts in Sri Lanka"

RESEARCH

Developments, modifications and applications of statistical techniques for the rubber sector

The objective of this activity is to familiarize the statistical techniques among the researchers and to encourage use of these methods in the proper manner. This activity has been continued from last year and pertinent research material to produce guidelines for the following areas of Statistics is being continued. The areas covered; a) Design and analysis of on-farm trials, b) Statistical process control and c) Multivariate statistical methods in relation to the research in the rubber sector. It is expected to document and publish the guidelines in 2019 (Wasana Wijesuriya).

Research on climate change and variability

Comparing drought indices and forecasting

Analysis of Drought Indices was focused further during this reporting period. SPI and SPEI have been focused during the last year and the method, Deciles suggested by Gibbs and Maher has been focused during the reporting year as a potential drought index. Attempt was also made to forecast SPI values employing the rainfall values for Ampara.

In forecasting of SPI it is important to forecast both mean and variance of SPI for better decision making about expected droughts. In time series literature, application of Box-Jenkins type stochastic methods are common as forecasting models of the mean of a time series which is useful to understand the future trends in long term trends in drought incidences. Model fitting on both conditional mean and variance is in progress and results of the models fitted for monthly SPI values of Ampara, one of the areas to which rubber has been introduced recently, are reported below.

Based on the results, the SARIMA model can be identified as the best fit class of models for SPIs computed for Ampara area. Forecasts of SPI for the months of 2017 were obtained using the selected models. There appeared an increasing trend in SPIs indicating above-average rainfall (Fig. 1).

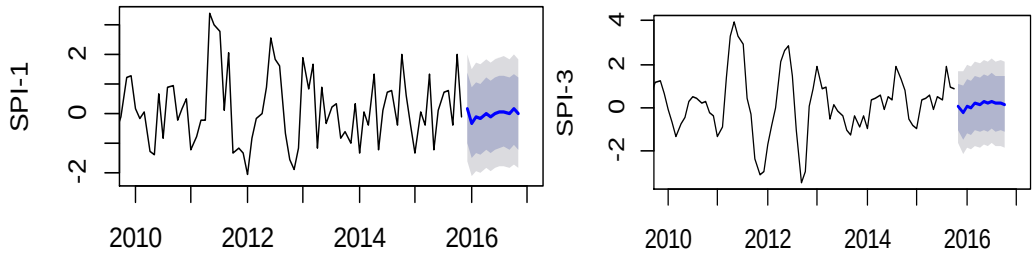


Fig. 1. Forecasts of SPI (Scale 1 & 3) at different scales for next twelve months for Ampara

It was found that an ARMA-GARCH hybrid model would be more appropriate for studying SPIs rather than fitting a GARCH model separately on the innovations from SARIMA models. The development of the hybrid model is still under progress.

This work is carried out under the project "Indicator based identification and forecasting of droughts in Sri Lanka".

Preparedness of the natural rubber sector against adverse impacts of climate change and variability

Present status of research and development activities related to climate change focused on national adaptation strategy for 2016 - 2025 have been studied and discussed and a document is prepared titled "*Preparedness of the natural rubber sector against adverse impacts of climate change and variability".* This document highlights that research on rubber have been focused on combating adverse environmental impacts even before identifying the threats of climate change. Moreover, Rubber is a crop which has its own adaptive capacity to withstand adverse environmental impacts. In addition, a monoculture of rubber has been reported to be a relatively efficient converter of solar energy into dry matter production. As a consequence, the rubber growers have contributed to the sustenance of an environmentally friendly, ecologically sustainable crop with dual economic potentials of both rubber (latex) and timber production for world consumption, while simultaneously contributing to maintenance of the global carbon balance in the atmosphere.

Obviously there are some identified gaps in the research and development programmes of RRISL although it address the adaptation needs, options and activities of the National adaptation plan for climate change of Sri Lanka. The necessity to look into economic aspects before recommendation of new technologies and promoting more collaborative research have been identified to be practiced in future (Wasana Wijesuriya).

Collaborative research

1. Indicator based identification and forecasting of droughts in Sri Lanka
   This study is funded by NRC which was commenced in September 2015. It is a collaborative study with 2 Universities; Peradeniya and Wayamba and 2 Institutions; Natural Resources Management Centre (NRMC) and Department of Meteorology (DoM). This study is in progress and will continue up to August 2018 (Wasana Wijesuriya and J K S Sankalpa from RRISL, B L Peiris from University of Peradeniya, Keminda Herath from Wayamba University, B V R Punyawardene from NRMC and S Premalal from DoM – Research Assistant : Sangeeth Liyanaarachchi).

2. Introduction and establishment of new fuel wood growing models in selected lands of smallholder rubber farmers
   This project is funded by 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 fuel wood species in smallholder rubber lands which assure a sustainable biomass energy production system while improving the livelihoods of smallholder rubber farmers. Biometry section is involved in this project in designing and carrying out of socio-economic surveys and constructing indices for combined benefit and monetary advantage. This is a collaborative project between Advisory Services Department, Agricultural Economics Unit and the Biometry Section.

3. 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". This project is a collaborative one including Wayamba University, Department of Meteorology, Department of the Environment and Energy, the Government of Australia, Canberra, Australia, Tea Research Institute and the Coconut Research Institute. 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.

SERVICES

Statistical consultancy (BM/03/a)

Statistical consultancy is provided on designing of 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 O V Abeywardene).

Developments in meteorological and agro-meteorological stations (BM/02/b)

Database management

The database with daily meteorological data collected at Dartonfield meteorological station was properly maintained. Reports were prepared from this daily database and sent to the Department of Meteorology. Rainfall records received at the Dartonfield Station are sent to National Building and Research Organization (NBRO) for issuing warnings on landslides. Rainfall records of substations, *viz.* Moneragala, Kuruwita, Nivitigalakele and Polgahawela were also maintained in a database. These data were made available to researchers and organizations on request. Data pertaining to the current year appear in the Meteorological Review.

A database is maintained on rainfall experienced in rubber growing areas of Sri Lanka. Monthly rainfall values experienced in rubber growing areas is given in Table 1 (W Wijesuriya, C Munasinghe and V Abeywardene).

Maintenance and establishment of Meteorological & Agro-meteorological Stations

Maintenance and data recording is being done in the meteorological stations owned by RRISL by visiting and inspection of these sites and by providing instruments when necessary. New recording type rain gauges were installed at the meteorological stations in the premises of Kuruwita and Moneragala Sub-stations where data collection was started in 2016 (W Wijesuriya and V Abeywardene).

Table 1. *Monthly rainfall in rubber growing areas in 2017*

Month	Location										
	Hanwella	**Ratnapura**	**Agalawatte**	**Galle**	**Kekanadura**	**Nittambuwa**	**Kurunegala**	**Moneragala**	**Uhana**	**Matale**	**Badulla**
	WL 1a	**WL 1a**	**WL 1a**	**WL 2a**	**IL 1a**	**WL 3**	**IL 1a**	**IL 1c**	**DL 2a**	**WM 3b**	**IM 1a**
January	85	39	218	225	102	78	76	169	406	137	177
February	41	33	61	37	31	38	55	91	72	56	122
March	363	264	149	82	154	250	288	198	43	224	283
April	117	201	275	179	161	62	128	117	32	46	60
May	919	983	749	351	312	411	151	188	22	157	95
June	281	376	304	94	61	211	171	8	5	113	64
July	125	184	211	137	87	53	26	99	38	14	28
August	192	353	383	179	148	89	83	90	70	60	89
September	660	612	611	239	200	552	176	22	87	163	133
October	611	512	529	286	214	472	367	263	46	264	262
November	428	509	512	549	496	350	115	240	124	183	265
December	248	243	245	75	73	151	156	240	68	56	346
Total rainfall (mm)	4072	4308	4248	2433	2037	2716	1794	1723	1015	1473	1925
No. of rainy days	182	237	220	184	106	186	157	132	73	137	142

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

Mr Sankalpa attended the following during the year under review.

Activity	Organization
Scientific Committee Meeting	Rubber Research Institute of Sri Lanka
International Rubber Research Conference, Kuala Lumpur, Malaysia	International Rubber Research Development Board (IRRDB)
Socio-economic Committee Meetings in Agriculture Sector	Sri Lanka Council for Agricultural Research Policy, Ministry of Agriculture
International Statistical Conference, Colombo, Sri Lanka	Institute of Applied Statistics Sri Lanka, University of Moratuwa, University of Maryland Baltimore County, USA & National Science Foundation
World GIS day celebration	Survey Department Sri Lanka
Workshop on Factor Analysis	Institute of Applied Statistics Sri Lanka

Mrs P G N Ishani attended the following during the year under review.

Activity	Organization
Scientific Committee Meeting	Rubber Research Institute of Sri Lanka
Policy advocacy group meeting on eliminating South Asian Association for Regional Corporation (SAARC) Non-Tariff barriers to trade with Sri Lanka	Federation of Chambers of Commerce and Industry of Sri Lanka
INFORM 2nd quarter data collection evaluation program	Sri Lanka Council for Agricultural Research Policy, Ministry of Agriculture
Conference on "Recognizing climate change risk of Dry Zone farmers"	National Building Research Organization (NBRO)

Activity	Organization
Workshop on Factor Analysis	Institute of Applied Statistics Sri Lanka
Seminar on Next Generation Weather Services Focusing on Rainfall Disaster Mitigation	JICA (Japan International Cooperation Agency) and Department of Meteorology
Capacity building program on Greenhouse Gas Inventory Preparation	Ministry of Mahaweli Development and Environment and United Nations Development Program (UNDP)
17^{iti} Monsoon Forum	Department of Meteorology

Services

Research support

Various cost-benefit and economic analyses were carried out on the request of other researchers.

Database management

A database on auction prices of rubber in Sri Lanka and International rubber prices were updated throughout the year. Agricultural Economics Unit analyzed the rubber price and rubber products exports performance in quarterly basis and presented the information to the industry and also to the Plantation Sector.

Rubber marketing in Sri Lanka

Colombo auction is the main mode of disposal of rubber manufactured in Sri Lanka. Number of auctions conducted by Ceylon Chamber of Commerce under Colombo Rubber Traders' Association (CRTA) accounted for 95 during this year. Details of all these were updated and recorded in a database.

Prices of Ribbed Smoked Sheets (RSS)

Monthly average of RSS 1 and RSS 3 are given in Figures 1(a) and 1(b), respectively. The highest average price of RSS 1 was Rs.351, recorded in July. Prices of all grades of RSS were higher than that of the previous year (2016). Price difference of RSS 1 against the previous year was around Rs.100 for the first and third quarters during the year. Yearly average RSS 1 price has increased by 40% when compared to year 2016. This was mainly due to higher demand prevailed at the international market.

(a) (b)

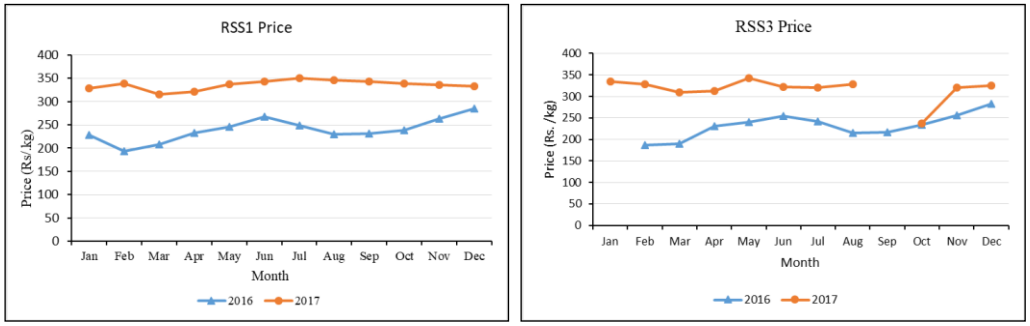


Fig.1. Monthly average prices of RSS 1 **(a)** and RSS 3 **(b)** in 2016 & 2017

Prices of Latex Crepe (LC)

Prices of Latex Crepe1X for 2016 and 2017 are shown in Fig. 2. LC1X prices has remarkably increased during the latter part of 2017. However, the gap between LC prices were low until the month of June. The average LC1X price ranged from Rs.296 (April) to Rs.415 (November) during 2017. The average price of LC1X was Rs.350 which was a 34% improvement compared to the previous year.

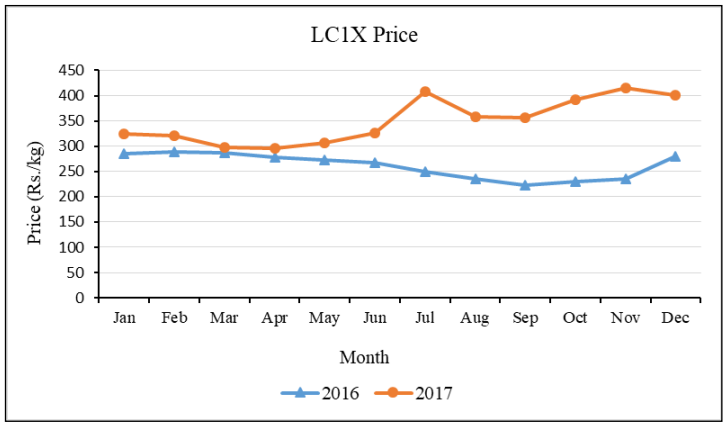


Fig. 2. Monthly average of nominal price of LC1X in 2016 and 2017

Monthly averages of auction prices for different rubber grades in year 2017 are given in Table 1.

Monthly changes of RSS 1 and LC1X from 2014 to 2017 are depicted in Fig. 3. Monthly average of RSS1 reached the highest in July 2017 (351 Rs./kg) and the LC1X price was highest in November 2017 (415 Rs./kg). The price differences between the LC1X and RSS1 were higher in year 2015.

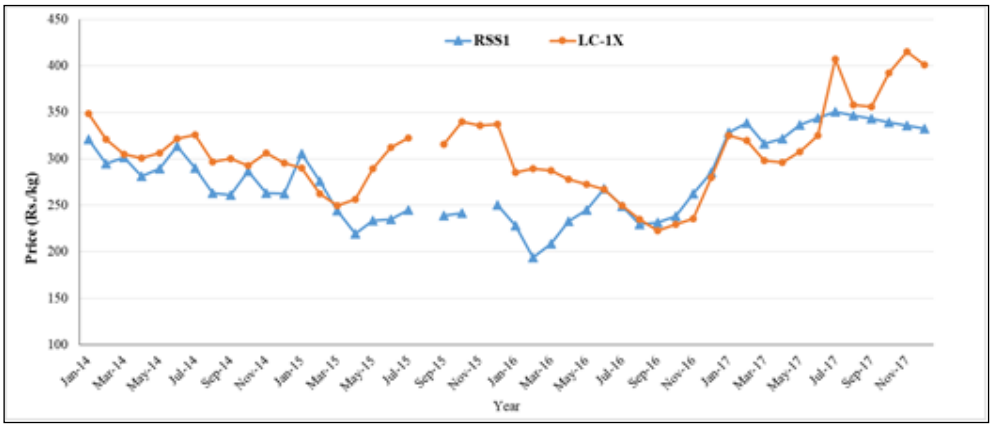


Fig. 3. Monthly nominal average prices of LC1X and RSS 1

RESEARCH

The following studies were conducted in the year 2017.

Analysis of income diversification of rubber farmers (AE/01/a)

The goal of this study was to analyze and characterize the rubber based farming systems which play a significant role in income generation. Characterization is critical for precise technological intervention and formulating informed policy support for rubber-based farming systems. This study has been completed in the Moneragala district and being continued in the Kalutara district. It attempts to categorise rubber farmers based on their respective socio-economic status at household level which corresponds to the particular farming system they have employed in agriculture. Socio-economic characteristic based multivariate analysis is used for delineation of rubber based farming systems. Multivariate statistical techniques like Factor Analysis of Mixed Data (FAMD) and Cluster Analysis (CA) are used for a wide variety of situations associated with farm typology delineation. Data collected from 220 farm households through a questionnaire survey could identify four predominant cluster types with different socio-economic implications.

Clusters as well as the Weighted Sum of Ranking (WSR) based on the individual factor scores in each components identified from FAMD are characterized by different levels of socio-economic conditions while each category is discriminated at different levels. Stratified sample selected from the Moneragala district is given in Table 2.

Table 2. *Number of farmers selected by DS Division*

Divisional Secretariat Division	Number of farmers
Bibile	6
Madulla	27
Medagama	54
Siyambalanduwa	28
Moneragala	43
Badalkumbura	20
Wellawaya	32
Buttala	10
Total	**220**

According to the results obtained for the Moneragala district, education, experience of farming, income from rubber based farming systems, societal involvement and access to credit were the dominant factors in the most common farming clusters in Moneragala District. Existing socio-economic status of each farm household including farming systems was presented and thereby, parameters to be improved were identified for each system in the District. Thereby, this approach ensures an applied, holistic, and cross-disciplinary approach for priority setting and targeting. Analyzed Minimum (Min.) and Maximum (Max.) weighted sum of rank (WSR) values of farming systems are presented in the Fig. 4. Farming systems with lowest Min. value and lowest Max. value are comparatively better than the others with respect to the defined socio-economic parameters in the study. Lowest WSR values were recorded by the cocoa and pepper farming systems followed by banana, maize and cattle. Highest WSR values were recorded for Banana and Maize farming systems.

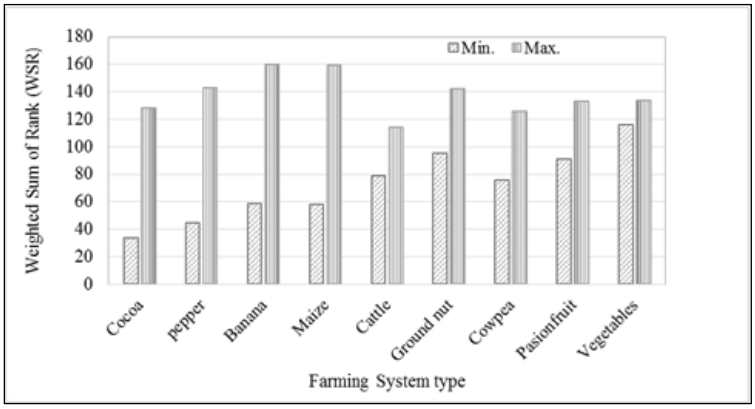


Fig. 4. Weighted Sum of Rank (WSR) values of farming systems

Clustering is the most convenient method in multivariate statistics to identify similar characters among the survey sample through grouping of individuals. While ranking of individual farming systems in the sample helps to characterize and identify farmers' deviation in the selected socio-economic variables, clustering has done a great job in dividing them into groups which are having similar characteristics. Although ability of spending on health services was used as a variable in factor analysis, it wasn't a significant variable in clustering.

36 farmers with Maize (39%), Banana (26%) and Ground nut (6.5%) were included in C1. Also 63 farmers including Banana (41%) Cocoa (13.2%) Pepper (12%) based farming systems were found in C2. 115 number of farmers were found in C3 including Banana (40%), Cocoa (18%) and Maize (13%). Only 6 farmers were identified in cluster 4 with Cowpea (17%), Banana (33%) and Cattle (8%) based farming systems.

Net return of farming systems is given in Table 3 and the geographical distribution of farming systems clusters in Moneragala district is shown in Fig. 5. Survey on farming system is in progress in Kalutara district.

Table 3. *Net return from rubber-based farming system*

Net return category (Rs./Acre/yr)	**Percentage (%)**	
	Without family labour	With family labour
Net return < 0	4	13
0-50,000	32	42
50,000-100,000	29	20
100,000-150,000	15	10
150,000-200,000	7	5
200,000-300,000	8	5
300,000-500,000	3	3
500,000-700,000	1	1
Net return >700,000	1	1

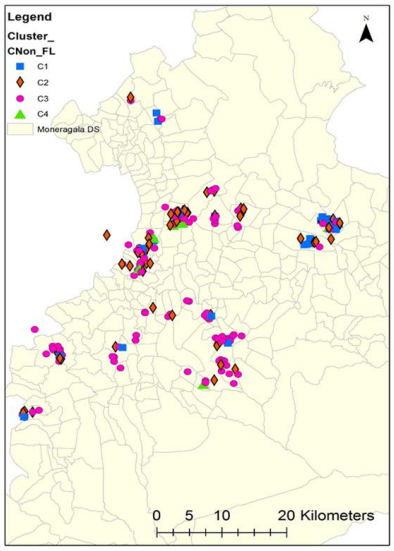


Fig. 5. Geographical representation of farm clusters in Moneragala District
(J K S Sankalpa, P G N Ishani, Wasana Wijesuriya and O V Abewardana)

Use of GIS in rubber plantation management (AE/03)

Type of interpolation and data computation in developing yield maps of Natural Rubber for precision crop production (A case study from smallholder rubber lands in Kalutara District of Sri Lanka) (AE/03/a)

Yield monitoring and mapping are the main technological advances in precision agriculture. It provides an outlook on farming efficiency and it is related

outputs provide basic guidelines for extension personnel and decision makers to serve the target groups in a systematic way to achieve high productivity. To serve the same purpose in the Natural Rubber sector, this study was conducted to analyze the average yield variation in smallholder rubber lands in the Kalutara district in the Wet Zone of Sri Lanka. Special emphasis was made to compare different statistical interpolation techniques available in ArcGIS geostatistical analyst in developing spatial maps. In this study, we coupled yield data with Geographic Information System (GIS) and generated spatial variation of Natural Rubber (NR) yield in smallholder rubber lands in Kalutara District. Scientists and practitioners have reported the use of multiple interpolation techniques to process yield data. Hence, the influence of the different interpolation methods on the quality of the resulting thematic yield maps was investigated in this study. Three interpolation techniques including ordinary Kriging, Inverse Distance (ID) and Inverse of squared distance (IDS) were used as the interpolation techniques to develop yield maps. Upon the comparison of 3 interpolation techniques, ordinary Kriging performed better than the inverse distance and inverse squared distance interpolation methods. Lowest values for the Mean Error (ME) and Standard Deviation of Mean Error (SDME) were recorded as 1.02 and 122 for the Kriging interpolation. Standardized Mean Error (SME) and Standard Deviation of Reduced Mean Error (SDRME) were used to compare the variogram generated in kriging interpolation and values for the SME and SDRME (0.008, 1.034) indicated that exponential kriging was better than Spherical and Gaussian types. As per the case study, the average yield of smallholder rubber lands in Kalutara District varied from 1,008 to 1,347 kg ha-1 year-1 according to the Kriging exponential interpolation. Mean absolute difference of yield was 40.61 and 38 kg/ha in Kriging interpolation with reference to the ID and IDS while it was 13.85 for the ID with reference to IDS. Corresponding relative deviation of Kriging was 3.44% and 3.22% while it was 1.19% for the ID.

Table 4 shows the results of interpolating field collected yield data which include the three variogram models. Variogram parameters observed during the variogram modelling process indicated that the exponential variogram model consistently out-performed the Gaussian and spherical variogram models. Estimate yield using three variogram modelling was unbiased since the SMEs of three variogram models were approximately zero. Since the SDRME values of three estimated variograms were little higher than one, estimated yield less estimated the true errors. Spatial dependency which is explained by the percentage of nugget effect is comparatively high in exponential variogram while all models exhibit moderate to strong spatial dependency. Nugget effect due to short scale variability and measurement error are common for all three types of variogram models. Spatial auto-

correlated region is comparatively high in exponential model while it was approximately closer to each other in Gaussian and spherical models (Table 4).

Table 4. *Parameter estimates and fit statistics for three variogram models used in the kriging interpolation techniques*

Variogram model	Nugget	Sill	Range (km)	Percentage nugget effect	SME	SDRME
Gaussian	0.5702	1.0244	7.3	55	0.028	1.050
Spherical	0.4569	0.9889	7.2	46	0.026	1.057
Exponential*	0.3783	1.0478	9.6	36	0.008	1.034

SME - Standard Mean Error; SDRM - Standard Deviation of Reduced Mean Error; * best model using SDRME and SME criteria; *Best model based on SDRME & SME criteria

Comparison of three methods used to interpolate crop yields using the mean error (ME) and standard deviation of mean errors (SDME) obtained as part of a cross validation used to evaluate the predictive performance of the models are given in Table 5. Kriging recorded ME of 1.02 while it was 2.05 and 2.45 for the IDW and IDS respectively.

Table 5. *Comparison of three methods of interpolation used to prediction of crop yields*

Interpolation method	ME	SDME
IDW	2.05	123
IDS	2.45	126
KRG	1.05	122

(J K S Sankalpa, W Wijesuriya, P G N Ishani and S Karunaratne)

Analysis on impact of plantation sector policy changes (AE/05)

Impact of CESS rate changes on rubber industry in Sri Lanka (AE/05/a)

This study mainly focused on analysis of structural changes in CESS tax on rubber industry and thereby to identify the significant changes throughout the past.

Analysis of Structural changes in CESS: CESS tax on rubber industry was imposed with the purpose of expansion of cultivation, modernisation factories with the aim of providing support for smallholder rubber growers in Sri Lanka. CESS tax System in Sri Lanka came into effect from 1946. At the beginning, this tax was implemented only on exports of natural rubber. In 1998, CESS tax on natural rubber exports was imposed and thereafter, some fluctuations were observed in the CESS rate. CESS on

natural rubber exports was abolished with effect from 5th of August 1998. However, CESS was imposed again with effect from 15th October 2004 for both exports of raw rubber and imports of rubber related products. It was observed a few significant changes of CESS income on exports during the period of 2004 to 2015. There were 10 significant changes reported in the figure including Dec 2005, May 2010, Sep 2010, Mar 2011, May 2012, Sep 2012, Apr 2013, Aug 2013, Apr 2014 and Jul 2015 under the 95% confidence level. Further analyses is on progress to identify the reasons of generated significant changes with respect to the CESS rate (P G N Ishani, J K S Sankalpa, W Wijesuriya and O V Abewardana).

Rubber industry analysis (AE/04)

Shift share analysis of Sri Lanka rubber product exports (AE/04/b)

Rubber export sector in Sri Lanka is growing over the years despite the recent decrease between 2014 and 2016. Strategies are required to attain global competitiveness by Sri Lankan rubber industry. This analysis aimed to analyze the shift-share as an ex-post analysis technique, which is widely used in regional economies. This study intended to identify potential export markets and challenges of rubber export industry in Sri Lanka using Dynamic Shift Share Analysis (DSA). Information on rubber export status from 2009 to 2016 using 25 selected major export destinations. Shift-Share methodology was employed to estimate the relative shift of export share value by country of imports. Export performance was measured using absolute growth (AG), Percentage Growth (PG) and Net Percentage Shift-Share (NPSS) by country. The average export values of the period from 2009-2012 were compared against the average export values of the period from 2013-2016.

For raw rubber exports, Netherlands had the highest AG of LKR 33 million followed by South Africa which exhibited an AG of LKR 6.28 million. For PE, Netherlands had the highest PE of 51% followed by South Africa which had a PE of 2.5% compared to the previous period. Except Netherlands and South Africa, rest of the countries in the selected group of countries showed negative values for PE. The market opportunities based on the percentage net shift, Japan showed the highest market opportunity and attained the percentage net shift of 10.5%. It is followed by Vietnam at 8.9% and South Africa at 7.1%.

When the finished rubber exports are considered, USA exhibited the highest imports from Sri Lanka with an average growth of LKR 14,560 million. Other major importers were Germany at LKR 5,324 million and Brazil at LKR 2083 million. In terms of percentage growth, Brazil showed better market opportunity of 140.2%, followed by Canada and China at 133.2% and 119%, respectively. According to the results of NPSS, USA had the highest value, *viz.* 16.9% followed by Brazil, Canada and Germany with respective NPSS values of 8.3%, 8.0% and 7.4%. Hence these

results imply that most of the European countries have maintained their finished products market share while most of the Asian countries opted for raw rubber exports.

Table 6 lists information on Absolute Growth, Percentage Growth and Net Percentage shift share values of raw rubber products of selected importing countries and Table 7 shows the values for finished rubber products.

Table 6. *Raw rubber products for the period of 2009 - 2012 and 2013 - 2016*

Country name	Absolute growth (Mn)	Percentage growth (%)	Net percentage shift share (%)
Japan	-236	-32	10
Vietnam	-58	-14	8
South Africa	6	2	7
Germany	-472	-51	6
Italy	-258	-50	3
China	-213	-48	3
Netherlands	33	50	3
France	-36	-26	2
U.K.	-68	-45	1
Bangladesh	-21	-37	0
Kenya	-52	-54	0
Belgium	-76	-59	0
Taiwan	-35	-50	0
Mexico	-43	-56	0
Spain	-57	-62	0
Poland	-39	-59	0
Egypt	-60	-70	-0
Pakistan	-1,656	-69	-0
Hong Kong	-202	-76	-0
South Korea	-161	-83	-1
Turkey	-218	-90	-1
Singapore	-312	-90	-2
U.S.A.	-934	-83	-6
India	-2,241	-82	-14
Malaysia	-3,265	-84	-22

Table 7. *Finished rubber products for the periods of 2009-2012 and 2013-2016*

Country name	Absolute growth (Mn)	Percentage growth (%)	Net percentage shift share (%)
U.S.A.	14,559	71	**16**
Germany	5,323	73	**7**
Belgium	1,801	46	-3
Italy	1,531	43	-3
U.K.	1,510	50	-1
India	-199	-7	-12
Sweden	-546	-25	-12
France	842	40	-2
Australia	937	56	-0
Canada	2,078	133	**7**
Brazil	2,083	140	**8**
Spain	286	23	-2
U.A.E.	51	5	-3
Japan	806	86	1
Netherlands	985	106	**3**
Malaysia	-150	-17	-4
Mexico	624	76	0
Turkey	371	45	-0
South Africa	312	47	-0
Ireland	371	57	-0
South Korea	400	62	0
China	669	118	**2**
Saudi Arabia	462	89	1
Singapore	219	43	-0
Russia	314	63	0

(P G N Ishani, J K S Sankalpa, W Wijesuriya and O V Abeywardana)

Table 1. *Monthly Auction Prices of Rubber in year 2017*

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	329	321	334	323	-	325	324	320	317	317	308	283	297	-	-
Feb	339	329	329	325	319	320	311	309	305	301	303	303	296	291	-
Mar	316	313	309	305	300	298	295	289	284	279	276	282	279	274	268
Apr	322	319	312	305	-	296	292	284	274	265	259	-	259	251	255
May	337	321	343	316	300	308	302	294	290	287	283	264	255	248	232
Jun	344	328	323	282	279	325	321	309	289	279	264	250	245	236	222
Jul	351	344	320	-	-	408	394	372	333	281	264	253	244	235	222
Aug	346	335	329	-	287	358	356	343	332	272	260	252	245	238	225
Sep	344	338	-	325	290	356	354	345	332	267	268	251	241	236	200
Oct	339	339	237	-	-	392	390	377	356	292	255	244	245	235	215
Nov	336	336	320	-	290	416	414	400	380	269	259	253	241	235	226
Dec	333	332	325	295	-	401	400	389	363	262	247	243	236	229	218
2016 Average	336	330	316	310	295	350	346	336	321	281	271	261	257	246	228

LIBRARY AND PUBLICATION

N C D Wijesekera

DETAILED REVIEW

Mrs R M Amaratunga, Library Assistant and Assistant Publication Officer, Mr P M Prema Jayantha, Management Assistant and Mr N W E C Maduranga, Management Assistant (Colombo Library) were on duty throughout the year. Mr S U Amarasinghe, Librarian resigned from RRISL on 15th May 2017, after serving 17 years to the Institute.

Mrs D N C Amarathunga was appointed as a Library Assistant & Publication Assistant (Ratmalana) with effect from January 2017.

Publications

RRISL Annual Report 2015 in trilingual was submitted to the Parliament on 07.09.2017 and RRISL Annual Report 2016 was submitted to the Ministry of Plantation Industries for approval on 22.08.2017.

The following RRISL regular publications and Advisory Leaflets were published during the year.

- Annual Report 2015
- RRISL Journal Vol.95 (2015)
- IRRDB Programme Book – International Training Fellowship Programme on Sustainable Rubber Cultivation 9th - 14th October 2017
- Advisory Circular Folder – 500 copies

List of books purchased during the year

No	Title	Publisher	Year of publication
01	විශිෂ්ටත්වය උදෙසා ඵලදායීතා වර්ධනය තුලනාත්මක පාලන සටහන්	අධ්‍යාපන අමාත්‍යංශය	2010
02	ලොව පතල ප්‍රස්වා පිරුළු	ඇම්.ඩී. ගුණසේන සහ සමාගම	2015
03	ප්‍රත්‍යාර්ථනාම	ඇම්.ඩී. ගුණසේන සහ සමාගම	2016
04	විභක්ති	ඇම්.ඩී. ගුණසේන සහ සමාගම	2017
05	අව්‍ය පද	ඇම්.ඩී. ගුණසේන සහ සමාගම	2017
06	සමාස	ඇම්.ඩී. ගුණසේන සහ සමාගම	2016
07	සන්ධි	ඇම්.ඩී. ගුණසේන සහ සමාගම	2016
08	අක්ෂර වින්‍යාසය	ඇම්.ඩී. ගුණසේන සහ සමාගම	2016
09	ප්‍රස්ථාව පිරුළු	ඇම්.ඩී. ගුණසේන සහ සමාගම	2016

No	Title	Publisher	Year of publication
10	Statistical Information on Plantation Crops – 2015	Ministry of Plantation Industries	2015
11	Clinical Medicine 9th edition	Elsevier – Print	2017
12	හරිත ඵලදායීතාව	ජාතික ඵලදායීතා ලේකම් කාර්යාලය	2016
13	Business Pena Shathakaya පැන ශතකය	ජාතික ඵලදායීතා ලේකම් කාර්යාලය	2015
14	දැනුම කළමණාකරණය	ජාතික ඵලදායීතා ලේකම් කාර්යාලය	2016
15	The Australian Native Bee Book	Sugarpag Bees Penerbit UMT	2016
16	Repositor Kalulut Indo - Malaya Sekaya	Sugarpag Bees Penerbit UMT	2017
17	B.C. Sekhar – Malaysia's Man or Seasons	Academy of Sciences Malaysia	2010
18	Efficient Weed Management to enhance Rubber Production	Academy of Sciences Malaysia	2014
19	අම්ල සිතක රැඳි මතක (Two copies)	පියසිරි අම්ලසිත් යාපා	2017
20	BNF 72 September 2016 March 2017	Bnf.Org	2017
21	Recent Economic Development – 2016	Central Bank of Sri Lanka	2016
22	Directory of Synonyms and Antonyms	Wasana Book Publishers	2011
23	ශ්‍රී ලංකාවේ මදුරු ආශ්‍රිත රෝග - වැලකීම සහ පාලනය	කේ.ඩී.පී. ජයතිලක	2014
24	Brilliant Budgets and Forecasts	Pearson Education Limited	2010
25	Ranil Weckramasinghe – A Political Biography	Denesh Weerakkody	2017
26	In Search of Bawa – Master Architect of Sri Lanka	Talisman Publishing Ltd.	2016
27	Biological Science 3rd ed.	Cambridge University Press	2016
28	උපාය මාර්ගික කළමණාකරණය	සීමාසහිත ඇස්. ගොඩගේ සමාගම	2017
29	සංවිධාන වර්යාව	සීමාසහිත ඇස්. ගොඩගේ සමාගම	2010
30	ඉංග්‍රීසි - සිංහල සත්ව සහ ශාක නාම ශබ්දකෝෂය	සීමාසහිත ඇස්. ගොඩගේ සමාගම	2010
31	ජීව විද්‍යාව 11 (ශාක) ශබ්දකෝෂය	සීමාසහිත ඇස්. ගොඩගේ සමාගම	2005
32	ශ්‍රී ලංකා පරිපාලන සේවා සීමිත/විවෘත සහ උසස් තරඟ විභාග සඳහා	ගිහාන් පොත්හල	2016
33	යහපාලන ආණ්ඩුවේ කවුරුත් නොදත් රාජ්‍ය රහස්	අකීෂා ප්‍රින්ට් ඇන්ඩ් පබ්ලිකේෂන්	2017
34	කෝපය ජයගන්නේ මෙහෙමයි	විජේසූරිය ග්‍රන්ථ කේන්ද්‍රය	2017
35	මධුචිත අතහරින්නේ මෙහෙමයි	විජේසූරිය ග්‍රන්ථ කේන්ද්‍රය	2017
36	Technical Bulletin : Engineering Design with Rubber	A Publication of the Tun Abdul Razak Research Centre	2015

DARTONFIELD GROUP

P A Lukshaman

DETAILED REVIEW

Mr P A Lukshaman Senior Estate Manager, Mr T D Harsha, Mr M N S Pavinda Management Assistants, Mr Dinesh Achinda Acting Rubber Factory Officer, Mr B M Siriwardena Field Officer and Mr K A Sarath Kumara, Mr Jagath Nakandala, and Mr N L D Premechandra Junior Assistant Field Officers were on duty throughout the year. Mr K A S D Kumara Field Officer resigned on 2017.

The Group cadre stood as follows at the end of the year.

Senior staff	01
Assistant staff	09
Minor staff	03
Total	**13**

Hectarage summary - Dartonfield group

Hectarage summary of the Dartonfield Group is given in Table 1.

Table 1. *Land distribution (ha.) of Dartonfield group*

	Dartonfield Division	Gallewatta Division	Nivitigalakele Division	Total
Mature area	32.21	121.26	27.81	176.05
Immature area	4.14	28.18	15.13	45.02
Cinnamon under power line	0.80	-	-	0.80
State land take in	0.27	-	-	0.27
Nurseries	7.27	2.62	2.00	11.89
Paddy/Deniya land	0.75	1.22	1.22	3.19
Waste land	0.19	0.18	-	0.37
Earth slipped area	4.88	1.26	-	6.14
Jungle	0.80	0.50	1.03	2.33
Rocky areas	2.14	7.02	3.04	12.20
Roads	2.92	6.86	0.36	10.14
Building	16.92	5.43	7.79	30.14
Play ground	1.00	-	-	1.00
Proposed replanting area	-	9.82	12.69	22.51
Streams	-	-	2.17	2.17
Grand total	**74.29**	**184.35**	**73.24**	**331.88**

Rainfall

The annual rainfall recorded for the year was 4,068.1 mm. with 188 wet days.

Table 2. *Annual rainfall and wet days of the group for last five years*

	2013	2014	2015	2016	2017
Rainfall (mm)	3,565.4	4,568.6	4,014.5	2,682.1	4,068.1
Wet days	207	199	210	181	188

Crop

A total crop for 161,455 kg have been harvested against the estimated crop of 185,606 kg (86.9%) which is a decrease of 24,151 kg.

Table 3. *The crop and YPH (kg) Dartonfield group from 2013to 2017*

Hect.	2013		2014		2015		2016		2017	
	169.03		179.32		181.28		181.28		181.28	
Division	Crop	YPH	Crop	YPH	Crop	YPH	Crop	YPH	Crop	YPH
Dartonfield	29,451	770	28,885	897	26,878	834	23,635	734	19,124	649
Gallewatta	130,425	1,043	115,248	952	109,247	901	123,207	1,016	106,531	938
N'kele	24,720	1,355	28,682	1,101	25,545	919	29,294	1,053	35,800	1,086
Group total	184,596	1,016	172,815	964	161,670	892	176,136	972	161,455	917
Group estimate	190,000	1,046	199,296	1,111	200,688	1,107	197,474	1,089	185,606	1,054

Tappers productivity

The average IPT during the last five years are given in Table 4.

Table 4. *The average IPT (kg.) of Dartonfield group from 2013 to 2017*

	2013	2014	2015	2016	2017
Dartonfield	6.2	5.5	5.6	5.7	6.4
Gallewatta	8.7	6.9	7.2	7.9	7.6
Nivitigalakele	7.6	7.0	7.2	7.3	8.4
Group average	**8.0**	**6.6**	**6.9**	**7.4**	**7.6**

Tapping days

Annual break down of Normal tapping (NT), Late tapping (LT), double tapping (DT) and No tapping of Dartonfield estate is given in Table 5.

Table 5. *Average number of tapping days of Dartonfield group during last five years*

	2013	2014	2015	2016	2017
Normal tapping	216	219	204	258	224
Late tapping	28	11	12	07	02
Cash/Double tapping	(18)	(21)	(23)	(29)	(18)
No tapping	56	55	70	39	69
Rainguard tapping	61	80	79	62	69
Slight rain	01	-	-	-	01

Total number of tapping days have decreased over the previous year.

Rainguard

Total of 174.85 hectares were rainguarded during the year and an additional crop of 27,129 kg was harvested which amounts to 17% of total harvested crop. Additional tapping days done due to rainguard during the year from D/F 55, G/W 78 & N/K 74 respectively. Profit generated due to rainguard Rs.2,585,122.41 and profit per hectare Rs.14,784.80.

Table 6. *Additional income generated by fixing rainguards (Rs/kg)*

	Dartonfield Division	Gallewatta Division	Nivithigalakale Division	Total
Hectare	29.42	113.60	31.83	174.85
No. of rainguards fitted	5,948	36,839	11,892	54,679
Additional crop (kg)	3,184	16,272	7,673	27,129
Rainguard cost per kg.	59.61	78.78	43.23	66.47
Tapping cost per kg.	122.77	122.77	122.77	122.77
C.O.M. Rs/kg	34.47	34.47	34.47	34.47
Total cost Rs/kg	216.85	235.72	200.47	223.71
N.S.A. Rs./kg	319	319	319	319
Additional profit Rs./kg	102.15	83.28	118.83	95.29
Additional profit from rainguards (Rs.)	*325,245.6*	1,355,132.16	911,782.59	2,585,122.41
Additional profit per hectare (Rs.)	11,055.25	11,928.98	28,645.38	14,784.80

Total profit and profitability per hectare

The total profit and profit per hectare were Rs.6,207,944.75 and Rs.35,262.40 for the year under review.

Table 7. *Comparative statement of the revenue profit per kg and profit per hectare*

	Years				
	2013	**2014**	**2015**	**2016**	**2017**
Mature area (ha)	169.03	179.32	181.28	181.28	181.28
Total profit (Rs.)	15,071,788.05	1,987,373.99	(2,475,167.70)	(1,107,895.44)	6,207,944.75
Profit per ha. (Rs.)	89,166.35	11,082.83	(13,653.84)	(6,111.52)	35,262.40

Cost of production and productivity

Table 8. *Labour rates and break down of cost of production from 2013 to 2017 (Rs./kg.)*

	2013	**2014**	**2015**	**2016**	**2017**
1. Labour wages	572.00	687.50	687.50	687.50 up to Sept. 805 from Oct.	805
2. Cost of production	262.39	245.06	270.57	241.13	280.55
2.1 Tapping	100.94	118.61	113.94	116.46	122.77
2.2 Manufacture	35.68	35.82	36.43	32.35	34.47
2.3 General charges	102.26	74.49	103.07	74.43	97.29
2.4 M/area upkeep	23.51	16.14	17.13	17.89	26.02
3. N.S.A.	348.74	256.56	255.26	234.84	319.00
4. Profit per kg	86.35	11.50	(15.31)	(6.29)	38.45

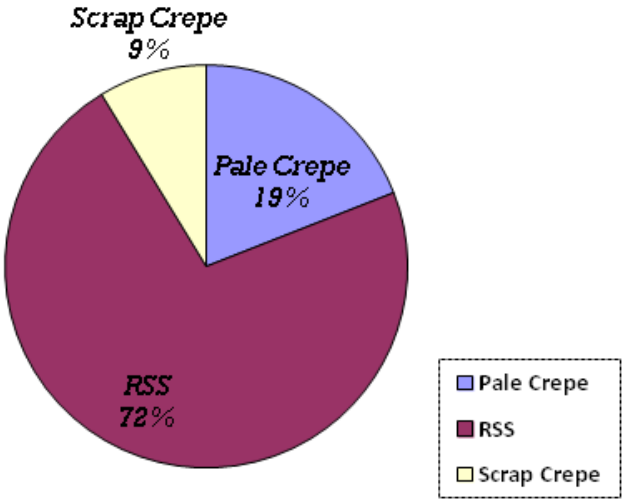
Manufacture

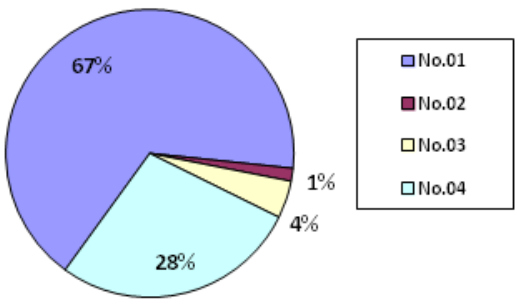
Out of the latex crop of 161,455 kg harvested, 20,485 kg has been sent as Latex Crepe No.1 which is 67% and 106,613 kg as RSS No. 01 which is 91%. Details are given in Table 9.

Table 9. *Summary of grades manufactured during the year*

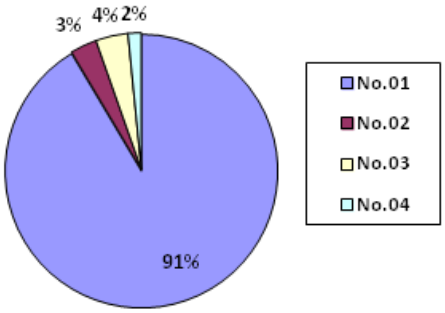
Grade	**Quantity (kg.)**	**Percentage %**
Latex crepe No.1	20,485	67
Latex crepe No.2	441	01
Latex crepe No.3	1,296	04
Latex crepe No 4	8,510	28
Total	**30,732**	**100**
RSS No.01	106,613	91
RSS No.02	3,687	03
RSS No.03	4,463	04
RSS No.04	1,844	02
Total	**11,6607**	**100**

Grade	Quantity (kg.)	Percentage %
Scrap crepe No. 1	10,498	75
Scrap crepe No.2	2,512	18
Scrap crepe No.3	1,046	07
Total	**14,056**	**100**
Grand total	**161,455**	**-**





Pale crepe manufacturing percentage



RSS manufacturing percentage

SUB STATION - KURUWITA

P A Lukshaman

DETAILED REVIEW

Staff

Mr S A R Samarasekara, Manager (Estate), Mr D S Jayasinghe, Mr K D P Senarathne, Management Assistants, Mr K K S Dinesh and Mrs E P S L Erawwala Field Supervisors were on duty throughout the year.

The estate cadre stood as follows at the end of the year.

Intermediate Staff	- 01
Assistant Staff	- 02
Minor Staff	- 02

Hectarage

A summary of the hectarage is given in Table 1.

Table 1. *Land distribution (ha.) in Kuruwita Sub station*

Land type	Extent (ha.)
Mature area	77.66
Immature area	4.50
Nurseries	2.25
Tea area	3.49
Paddy	1.00
Buildings, Gardens and Road	10.23
Water Tank	0.01
Unsuitable for planting	0.86
Total	**100.00**

Crop

A total crop of 84,391 kg was harvested during the year, recording a decrease of 20,260 kg on previous year's crop.

The actual yield per hectare (YPH) was 1,086.67 kg which is a decrease of 296.5 kg when comparing with previous year's crop.

The yield per hectare (YPH) for the past five years are given in the Table 2.

Table 2. *Yield per hectare for the past five years*

YPH (Kg)	Year				
	2013	**2014**	**2015**	**2016**	**2017**
Estimated	1,366.26	1,419.82	1,378.65	1,339.54	1,318.57
Actual	1,410.77	1,378.34	1,367.32	1,383.17	1,086.67

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	147.59
February	92.40
March	90.20
April	54.10
May	66.30
June	83.00
July	115.60
August	93.99
September	77.50
October	57.70
November	96.50
December	111.30

Tapper productivity

The average intake per tapper at the end of the year was 9.0 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				
	2013	**2014**	**2015**	**2016**	**2017**
Intake per tapper	8.7	8.9	8.9	9.1	9.0

Rainfall

The annual rainfall recorded during the year was 4,768.4 mm with 246 wet days (Table 5).

Table 5. *Annual rainfall figures and the number of wet days of the estate for the past 5 years*

	Year				
	2013	**2014**	**2015**	**2016**	**2017**
Rainfall (mm)	3,817.80	5,093.10	4,002.14	3,342.80	4,768.40
Wet days	174	239	251	222	246

Tapping days

There were 321 tapping days recorded during the year (Table 6). This was possible merely due to the use of rainguards.

Table 6. *The Average number of tapping days of the Kuruwita Sub Station for the past five years*

	Year				
	2013	**2014**	**2015**	**2016**	**2017**
01.Total tapping days	**338**	**335**	**348**	**352**	**321**
1.1 Normal	232	151	174	260	203
1.2 Late	11	38	32	08	00
1.3 Rain interference	-	15	02	-	40
1.4 Rainguarded tapping	95	131	140	84	78
02. Recovery tapping	(12)	(08)	(08)	-	-
03. No tapping	27	30	17	14	44

When compared with the last year there was a decrease in normal tapping days from 260 to 203 days during the year.

Rainguards

Due to the use of rainguards an additional 78 tapping days were recorded during the year. This contributed to 22% of the total crop yielding an additional profit of Rs.2,916,889.00

An analysis of the use of rainguards for the years 2014, 2015, 2016 and 2017 are given in Table 7.

Table 7. *An analysis of the use of rainguards (Rs/kg)*

	Year			
	2014	**2015**	**2016**	**2017**
Hectarage (ha)	62.34	71.00	73.41	63.46
No. of raiguards fitted	18,421	21,890	22,262	19,904
Additional tapping days	131	140	84	78
No. of kilos harvested	36,275	36,837	20,454	18,710
Raiguard cost per (kg)	27.65	25.65	43.41	39.20

	Year			
	2014	**2015**	**2016**	**2017**
Tapping cost (Rs./kg)	87.81	87.77	89.65	99.08
Total cost (Rs./kg)	115.46	113.42	133.06	138.28
N.S.A (Rs./kg)	251.92	207.86	217.11	294.18
Additional Profit (Rs./kg)	136.46	94.44	84.05	155.90
Additional profit from rainguards (Rs.)	4,950,086.50	3,478,886.28	1,719,158.70	2,916,889.00
Additional profit per hectare (Rs.)	79,404.65	48,998.39	23,418.59	45,964.21

Total profit and profitability per hectare

The total profit and profit per hectare were Rs.3,727,550.47 and Rs.47,998.33 respectively for the year 2017. This is a decrease of Rs.232,443.37 and Rs.4,341.00 respectively when compared with the last year.

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				
	2013	**2014**	**2015**	**2016**	**2017**
Mature extent (ha.)	74.29	71.84	73.26	75.66	77.66
Total profit (Rs.)	15,975,578.58	5,339,158.40	1,667,830.50	3,959,993.84	3,727,550.47
Profit per hectare (Rs.)	215,043.46	74,320.13	22,765.91	52,339.33	47,998.33

Cost of production and profitability

The cost of production has increased by Rs.70.74 per kg when comparing with the previous year (Table 9).

Labour rate and the breakdown of the cost of production (Rs./kg) for the past five years are given in Table 9.

Table 9. *Labour rate (Rs.) and the break down of the cost of production from 2013 to 2017 (Rs./kg)*

	Year					
	2013	**2014**	**2015**		**2016**	**2017**
Labour rate	687.50	687.50	687.50	Jan. - Nov.	687.50	805.00
				From December	805.00	
Cost of production	187.19	198.00	191.21		179.27	250.01
Tapping cost	90.44	96.70	87.77		89.65	99.08
Manufacturing	-	-	22.14		21.49	32.65
General chargers	74.55	79.58	64.72		54.48	92.38
Field & cultivation cost	22.20	21.72	16.58		13.65	25.90
N.S.A	339.62	251.92	207.86		217.11	294.18
Profit per kg	152.43	53.92	16.65		37.84	44.17

Other crops

Cinnamon

Cinnamon were sold during the year from Rubber/Cinnamon inter cropping area and the total income and the profit were Rs.552,000.00 and Rs.401,071.21 respectively.

POLGAHAWELA SUB STATION

P A Lukshaman

DETAILED REVIEW

Mr P A Lukshaman, Senior Estate Manager overlooked the activities of the Sub station and Mrs Chandrani Weeramantrie, Management Assistant was on duty until and retired.

Crop

A total crop of 7,661kg have been harvested against the estimated crop of 11,756 kg which is a decrease of 4,095 kg. The total crop, YPH and IPT for 2015, 2016 and 2017 are given in Table 1.

Table 1. *Total crop (kg), YPH (kg) and IPT (kg) for the years of 2015, 2016 & 2017*

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

Fields at Polgahawela were not tapped during the following periods during the year under review due to seven drought condition prevailed. This is the main reason for the poor crop.

Period	No. of days not tapped
➢ 30.01.2017	44 days
➢ 30.03.2017	32 days
Total	**76 days**

Meteorological Summary

Dartonfield Station

Wasana Wijesuriya

During the last 18 years, an average annual rainfall of 4,079 mm was observed in the Dartonfield meteorological station located in the Agro Ecological Region, WL_{1a}. Out of the 18 years since 2000, a total rainfall of less than 3,000 mm has been recorded only during 2016 (Fig. 1) which was 2,966 mm. The rainfall recorded in 2017 was 4,248 mm, which accounted for an increase of 43% compared to the previous year.

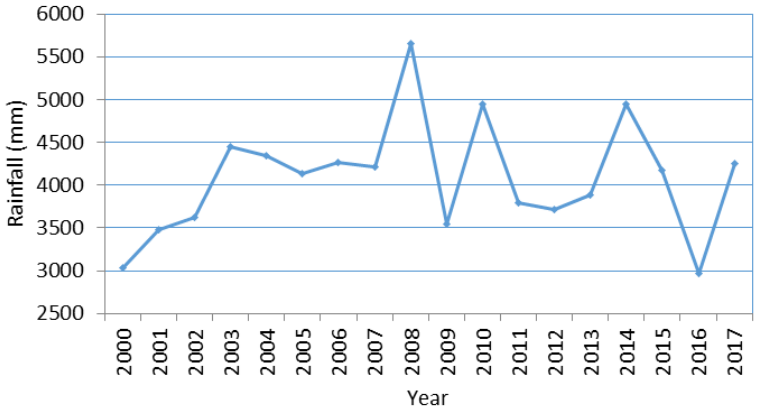


Fig. 1. Variation in annual rainfall at Dartonfield from 2000 to 2017

As indicated in Fig. 2 the rainfall distribution at Dartonfield during this year closely followed the usual rainfall pattern during the latter half of the year but departed from the usual pattern with less rainfall during the first half of the year. Above average monthly rainfall values were observed in May, August, September and November while below average values were recorded in the rest of the months, except for January, October and December which were very close to the long term average. The minimum monthly rainfall of 61 mm and the maximum monthly rainfall of 749 mm were recorded in February and May, respectively.

Distribution of rainfall in different seasons at Dartonfield is given in Fig. 3. Rains during the South West season (May - September) carried most of the rains (2,259 mm) during 2017. This rainfall amount contributed 54% to the total rainfall, which is, comparatively higher than the long term average contribution (48%).

Rainfall during IM2 (October & November) in 2017 brought 1,040 mm whilst IM1 (March & April) recorded a fairly low rainfall of 424 mm. During the North East season (November to January 2018), 469 mm of rain was recorded, which is again comparatively lower than the long-term average contribution of this season.

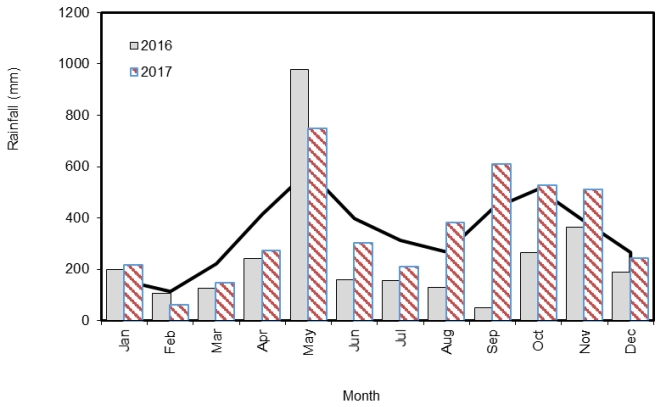


Fig. 2. Distribution of monthly rainfall in 2016 and 2017 at Dartonfield (The line chart indicates the long-term average)

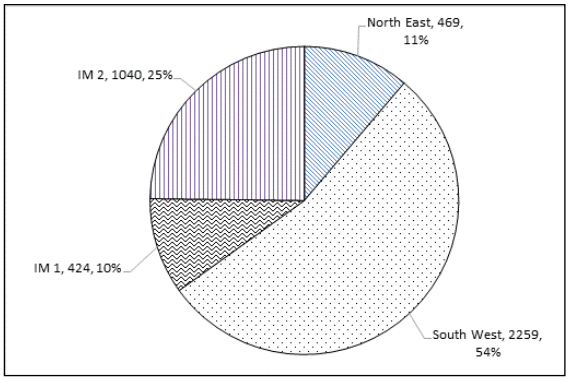


Fig. 3. Seasonal distribution of rainfall at Dartonfield in 2017

The distribution of weekly rainfall is illustrated 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 453 mm was observed in the 21st standard week, which coincided with the latter part of May.

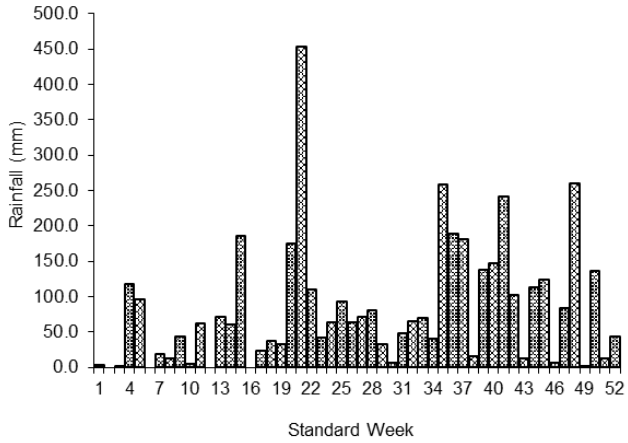


Fig. 4. Weekly variation in rainfall in 2017

There were 5 rainfall events that exceeded the hazardous limits for land slides (100 mm of rainfall during a day) reported during the year under review. The amount of rainfall and number of rainy days under low, moderate and high rainfall categories are listed in Table 1. The observed total number of rainy days of the year was 220, which was similar to the long term average. A dry spell lasted over a month or more can have adverse impacts on rubber plantations. There were only 6 dry spells greater than or equal to 7 days; the longest being 18 days, from 3rd to 20th January. The details of the dry spells are given below.

Details of dry spells at Dartonfield

Period	No. of days
3rd to 20th January	18
01st to 13th February	13
12th to 26th March	15
14th to 20th April	7
22nd to 29th April	8
5th to 12th December	8

Rainfall at RRISL Substations:

There are three Substations maintained by RRISL in Kuruwita (WL_{1a}), Narampola (IL_{1a} bordering WL_{2b}), Moneragala (IL_{1c}) and Nivithigala Kele (WL_{1a}). A total rainfall of 4,681 mm, 1,975 mm, 1,421 mm and 3,287 mm were recorded respectively, in Kuruwita, Narampola, Moneragala and Nivithigalakele stations during 2017. The details of rainfall in these stations are given in Tables 2 to 5.

Table 2. *Monthly variation of rainfall and rainy days in 2017 - Kuruwita, Ratnapura*

	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	77.7	7	2	5	-
February	21.2	5	2	3	-
March	412.4	20	5	13	2
April	239.7	13	1	11	1
May	952.4	29	3	20	6
June	439.9	26	6	19	1
July	260.9	19	7	11	1
August	388.7	21	2	17	2
September	437.5	26	5	19	2
October	697.4	31	6	20	5
November	545.4	21	4	11	6
December	208.0	15	2	13	-
Total	**4,681.2**	**233**	**45**	**162**	**26**

*A rainy day is defined as a day with a rainfall ≥ 0.3 mm

Table 3. *Monthly variation of rainfall and rainy days in 2017 – Nivithigalakele, Matugama*

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	192.9	7	-	6	1
February	68.7	5	1	4	-
March	176.0	10	-	9	1
April	165.2	11	-	11	-
May	522.7	17	1	14	2
June	219.8	17	-	17	-
July	167.6	10	2	7	1
August	281.6	18	4	12	2
September	426.8	17	1	13	3
October	479.9	22	1	18	3
November	400.0	16	4	9	3
December	185.6	5	1	3	1
Total	**3286.8**	**155**	**15**	**123**	**17**

*A rainy day is defined as a day with a rainfall ≥ 0.3 mm

Table 4. *Monthly variation of rainfall and rainy days in 2017 - Narampola, Polgahawela*

Month	Total rainfall (mm)	No of rainy days *	No. of days under each category		
			0.3-2.5 (mm)	2.6-50 (mm)	>50 (mm)
January	36.8	9	4	5	-
February	46.7	5	1	4	-
March	290.2	12	2	8	2
April	57.1	3	1	2	-
May	322.5	13	2	8	3
June	136.2	21	8	13	-
July	37.8	6	2	4	-
August	85.0	17	9	8	-
September	205.7	25	6	19	-
October	347.8	22	6	14	2
November	286.6	21	6	14	1
December	122.4	10	1	9	-
Total	**1,974.8**	**164**	**48**	**108**	**8**

*A rainy day is defined as a day with a rainfall ≥ 0.3 mm

Table 5. *Monthly variation of rainfall and rainy days in 2017 - Kumbukkana, Monaragala*

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	139.8	12	2	10	-
February	80.2	5	1	4	-
March	227.4	13	3	9	1
April	91.0	4	-	4	-
May	109.4	11	5	6	-
June	3.8	3	3	-	-
July	69.4	7	-	7	-
August	19.4	3	1	2	-
September	3.6	1	-	1	-
October	249.4	15	3	12	-
November	222.4	16	4	12	-
December	205.1	11	1	8	2
Total	**1,420.9**	**101**	**23**	**75**	**3**

*A rainy day is defined as a day with a rainfall ≥ 0.3 mm

Other meteorological parameters:

Table 6 depicts the monthly values of some important meteorological observations together with averages from 1980 to 2005 at Dartonfield. Daily

fluctuations of the minimum and maximum temperatures at Dartonfield are illustrated in Fig.5. During the year under review, the minimum temperature dropped below 20^0C in 17 days; 10 days in January and 7 days in February.

The daily average temperature pattern was fairly steady with a mean annual temperature of 27.4^0C and a standard deviation of 0.9, which could be a favourable condition for rubber plantations. The lowest mean minimum temperature of 21.4^0C was observed in January and February while the highest mean maximum temperature of 33^0C was observed in March and April. However, any signs of adverse conditions with respect to the temperature regime at Dartonfield were not reported during the year.

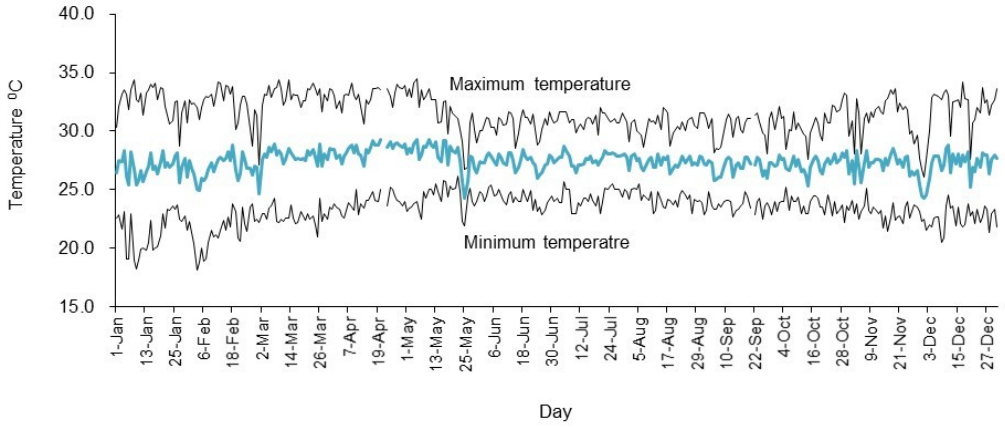


Fig. 5. *Daily minimum, maximum and average temperature distributions in 2017*

A total of 1825 bright sunshine hours was received at an average rate of 5.0 hr/day which was comparatively lower than the respective figures observed during the last year. The distribution of bright sunshine hours during the year is depicted in Fig. 6. Bright sunshine hours exceeded 6 in 47% of the days, while in 28% 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 2017 was observed in the range, 62% to 98%. The mean RH values recorded at 08:30 and 15:30 were 86% (SD=6.0) and 74% (SD=10.0), respectively.

Monthly values of soil temperatures recorded at 08:30 and 15:30 hrs in 4 different depths are depicted in Fig. 7 and Fig. 8.

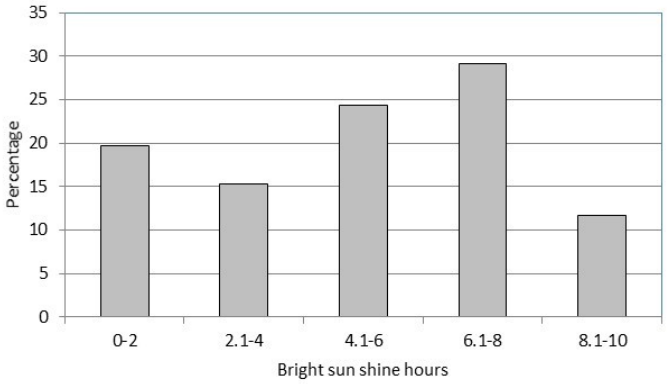


Fig. 6. Distribution of bright sunshine hours in 2017

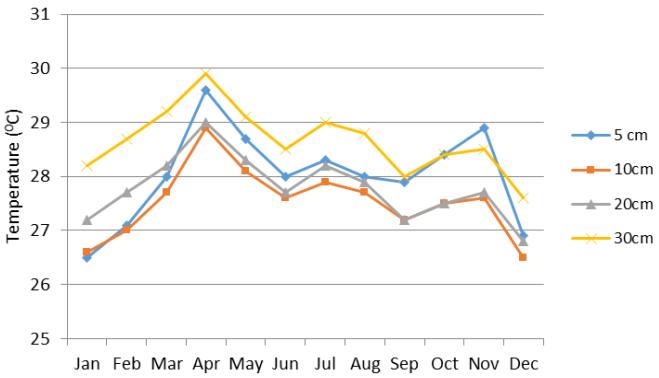


Fig. 7. Distribution of soil temperature at 4 different depths at 08:30 hrs during 2017

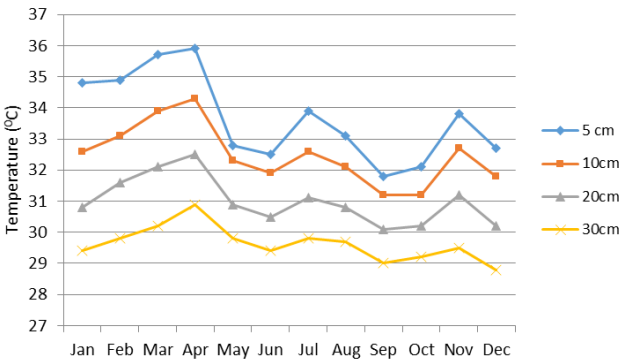


Fig. 8. Distribution of soil temperature at 4 different depths at 15:30 during 2017

Table 1. *Monthly variation of rainfall and rainy days in 2017*

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	218.2	(156)	11	(11)	5	4	2	97.9
February	61.2	(114)	7	(09)	2	5	-	88.3
March	149.4	(222)	14	(13)	4	10	-	102.1
April	274.7	(415)	13	(18)	4	7	2	85.1
May	749.3	(584)	27	(24)	4	18	5	83.3
June	304.4	(398)	25	(23)	3	22	-	84.7
July	211.2	(313)	19	(22)	7	10	2	81.6
August	382.7	(268)	22	(20)	1	20	1	75.9
September	611.4	(436)	27	(22)	4	18	5	68.6
October	528.7	(513)	25	(23)	3	19	3	73.5
November	511.6	(387)	19	(20)	5	10	4	70.5
December	244.9	(266)	11	(15)	2	8	1	76.2
Total	4,247.7	(4,072.0)	220	(220)	44	151	25	987.7

* A rainy day is defined as a day with a rainfall ≥ 0.3 mm

** Average values for 1980-2005 are shown in parentheses

Table 6. *Variation of observed meteorological factors at Dartonfield - 2017*

Month	*(Latitude $6^0$32'; Longitude 80.09 E; Altitude 65.50m)*								
	Temperature (^{0}C)					Relative humidity (%)			Mean Wind speed (km/hour)
	Mean Max	Mean Min	Mean	No of days Min Temp<20	Sun shine hours	8.30 am	No of days 8.30am>90%	3.30 pm	
January	32.5	21.4	27.0 (26.7)	10	5.3	85 (88)	11	73 (68)	1.70
February	32.3	21.4	27.0 (27.1)	7	6.0	86 (86)	8	75 (65)	1.60
March	33.0	22.8	28.0 (27.6)	-	6.4	82 (85)	3	69 (68)	1.80
April	33.0	23.9	28.5 (27.8)	-	6.3	83 (85)	1	70 (75)	1.90
May	31.5	24.3	27.9 (27.6)	-	4.2	87 (88)	11	80 (77)	2.00
June	30.6	24.2	27.4 (26.9)	-	4.5	88 (89)	13	77 (77)	1.80
July	31.2	24.4	27.8 (26.7)	-	5.4	86 (89)	5	72 (75)	2.20
August	30.5	24.2	27.4 (26.6)	-	5.0	88 (88)	11	76 (74)	2.30
September	30.4	23.6	27.0 (26.7)	-	4.3	87 (88)	11	79 (75)	1.90
October	30.8	23.7	27.3 (26.6)	-	4.3	85 (86)	8	76 (77)	1.50
November	31.1	23.1	27.1 (26.6)	-	3.7	85 (85)	7	74 (77)	1.40
December	32.0	22.8	27.4 (26.7)	-	4.1	85 (85)	7	72 (73)	1.20

** Average values for 1980-2005 are shown in parentheses

List of Publications

Scientific Journals
(Bold type - Employees of Rubber Research Institute of Sri Lanka)

Attanayake, A.P., Karunanayake, L. and **Nilmini, A.H.R.L.** (2015). Insight into prevention of enzymatic browning and increase of antioxidant potential of crepe rubber with ethephon stimulation. *Journal of the Rubber Research Institute of Sri Lanka* **95**, 58-65.

Edirisinghe, D.G., Sampath, W.D.M. and **Wettasinghe, P.C.** (2015). Effect of latex coated coconut fibre on cure characteristics and physico-mechanical properties of natural rubber-coir composites. *Journal of the Rubber Research Institute of Sri Lanka* **95**, 1-13.

Hunupolagama, D.M.N.V., Chandrasekharan, N.V., Wijesundera, W.S.S., Kathriarachchi, H. S., **Fernando, T.H.P.S.** and Wijesundera, R.L.C. (2017). Unveiling members of *Colletotrichum acutatum* species complex causing *Colletotrichum* Leaf disease of *Hevea brasiliensis* in Sri Lanka. *International Journal of the Current Microbiology* **74,** 747-756.

Liyanage, K.K. and **Baddewithana, B.W.A.N.** (2015). Phenotypic diversity of Sri Lankan rubber clones at their immature stage. *Journal of the Rubber Research Institute of Sri Lanka* **95**, 14-23.

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GENETICS AND PLANT BREEDING

To enrich the Hevea breeding pool, eighty eight new genotypes were produced in hand pollination programme carried out at Neuchattle Estate. Eighteen genotypes including four out standings selections from 2011 hand pollinated progeny were selected for planting in 2018. Around 1800 non-Wickham accessions were multiplied and 460 accessions were planted at Polgahawella Substation. Comprehensive data collection in Eladuwa 2009 ECT trial was continued with an objective of developing yield indexes for commercial scale clonal evaluation. The cyclone "Ockhi" affected a number of trials in Eladuwa, Pallegoda and Paiyagala Estates.

New field establishment was done with eight RRIC 100 series clones, eighteen RRISL 200 series clones, eight RRISL 2000 series clones, five RRISL Centennial clones, eight foreign clones, 20 non-Wickham selections and four hand pollinated selections from 1995 HP evaluation of breeding garden at Neuchattle Estate. Two plants from each clone/genotypes were established.

Under multilateral clone exchange programme, RRISL offered five clones namely RRISL 203, RRISL 208, RRISL 211 RRISL 219 and RRISL2001 to India, Myanmar, Ghana and Thailand and received 12 clones from India, Thailand and Myanmar.

Analysis of antioxidant gene expression in tapping panel dryness (TPD) in affected rubber trees, showed that TPD affected laticifer tissues may run short of antioxidants mainly HbSOD antioxidant enzyme making the clone more likely to prone to TPD. To study the effect of exogenous application of antioxidants such as ascorbic acid to compensate this shortage of antioxidants and the potential of ascorbic acid to recover TPD affected clones was done and a considerable recovery percentage from 5% to 20% percent, compared to control in all clones in both sites was observed.

A fragment of Rubber Elongation Factor promoter and gene was sequenced in eight genotypes and showed difference in nucleotide level. Simple and rapid method for RNA extraction from different plant tissues was developed and optimized.

PLANT SCIENCE

Seed production was low in 2017 as observed during the last five years irrespective of clones and areas. A number of cost effective sowing media as an alternative to river sand was evaluated and promising results were obtained from coir pith and elephant dung. Priming of rubber seeds with sodium nitroprusside improved germination, storage life and seedling performance. Reduced bag size was found to be sufficient to raise nursery plants. Seedlings derived from illegitimate seeds of seven clones showed no significant differences in growth. Growth and physiological data obtained from bud wood nurseries established in Wet Zone (Egaloya), Dry Zone (Inginiyagala) and Intermediate Zone (Moneragala) showed differences in clonal performance under varying climates. Pretreatment with sodium nitroprusside and Moringa ("Murunga"/drumstick) leaf extract enhanced physiological and growth attributes of rubber plants under sub optimal climatic conditions in the Intermediate Zone. An Exogenous application of salicylic acid at monthly intervals in dry period showed growth improvement in rubber nursery plants at Monaragala.

Rubber x Agarwood intercropping experiment revealed that the growth of local agarwood/"wallapatta" plant is low as compared to other two species. Growth data were recorded for density trials at Kandakadu, Galewatta and N' Kale. New tapping experiments were commenced at Sirikandura and Padukka estates. Development of latex vessels among different treatments and clones was significantly affected by different harvesting systems with varied bark consumption rates. New experiments were commenced at Pitiakande, Padukka and Dartonfield estates to assess the effect of different chemicals and botanicals on minimizing the incidence of tapping panel dryness. A new experiment on winter rest was commenced at Kuruwita Substation. Four new fields were established in Kilinochchi with 450 plants each of four clones employing different spacing systems. About 1200 number of plants was established at Kandakadu Army camp, Polonnaruwa for density experiments. Issuing authentic budwood to establish budwood nurseries, issuing marking plates and testing polythene were attended. All nurseries were inspected for quality assurance and reports were submitted.

PLANT PATHOLOGY AND MICROBIOLOGY

Incidence of the secondary leaf fall diseases, Powdery mildew and Colletotrichum leaf disease was mild during the refoliation period except for a few disease vulnerable sites. Sulphur application was completed successfully to control the diseases. Based on the Corynespora screening programme, there was no new disease reports from the field plants. Incidence of Phytopthora diseases was also at a mild condition. The severity of Corynespora Leaf Fall Disease in the non traditional areas was comparatively higher. The studies on the biology of the population of Rigidoporus spp. the causative agent of white root disease of rubber were completed. Testing the effectiveness of tree injection against white root disease management was examined. The antagonistic plants effective against Rigidoporus under laboratory conditions were tested in the field. Studies on the biology of the pathogen population Phellinus noxius were undertaken due to its high incidence in non traditional rubber growing areas. New antagonistic fungi identified in rubber growing areas to biologically control the white root disease. A compost based medium was found to be effective to grow the biological control agent. Field trials were conducted to prove the effectiveness of the bio-pesticide. Talc was identified as a less bulky medium for the formulation of the biopesticide. Beneficial microbiological studies were initiated. Fungi and bacteria from different environments were isolated to be included into the national level culture collection. Identification of pest and disease problems related to the non-traditional areas of the country was successfully carried out with the funds received by the Ministry of Plantation Industries.

SOILS AND PLANT NUTRITION

Seven research activities on improvement of soil fertility, increasing fertilizer use efficiency, soil, water and nutrient conservation, weed control and one capital project on "Modification of fertilizer recommendation systems of Hevea with reference to plant, soil and field parameters" were planned, promoted, implemented and monitored during the year. Continuous application of biofilm biofertilizer (BFBF) with recommended quantity of chemical fertilizers showed higher growth parameters of immature Hevea compared to recommended chemical fertilizer only treatment. Moreover, no significant differences of growth parameters and acceptable levels of major nutrients N, P, K and Mg could be observed with the reduction of the quantity of recommended chemical fertilizers with BFBF compared to recommended chemical fertilizer only treatment. Combine use of agro management practices such as cover cropping, green manuring and biofertilization showed significant enhancement of soil fertility parameters, such as organic carbon, total N, ammonium, available P, exchangeable K and Mg, microbial biomass, and growth parameters of immature Hevea plants. Controlled weed growth and extended regeneration time of weed growth in immature Hevea fields could be observed by the alternative weed management practices with straw and oil palm refuse mulch. Application of environmentally friendly alternatives for inorganic fertilizers were tested and commercially available compost, vermi compost, vermi wash and partially burn paddy husk showed beneficial effects on nursery plant performances. Single application of commercially available slow release fertilizer at bag filling stage showed better growth parameters than conventional biweekly fertilizer applications and could be benefitted for the growers by totally cut down on labour cost associated with regular fertilizer applications. Three soil maps relevant to rubber growing areas in Galle, Matara and Kegalle districts were prepared and fifteen different soil series were identified. Soil, plant and field parameters were collected from different soils series representing four estates in Galle district and two estates in Matara district.

Site specific fertilizer recommendation programme provided 43 fertilizer recommendation reports for 6500 ha of mature rubber. Six land suitability reports were issued for 81 ha under land selection programme. Analytical reports were sent for approximately 1050 samples (4000 parameters) including 400 fertilizer samples for outside organizations to assure application of good quality fertilizers to rubber lands.

BIOCHEMISTRY AND PHYSIOLOGY

Recently recommended S/2 d4 low frequency harvesting system has been introduced to five smallholdings and S/4 d3 low intensity harvesting system to one smallholder. Investigations on S/2 d4, S/2 d12d/7 and S/4 d3 systems in the Wet Zone was continued in plantations of Kuruwita Substation of RRISL. Monitoring of fields under S/2 d4 system at Galewatta and Nivithigalakele divisions of Dartonfield estate continued. Performance evaluation of S/2 d4 and S/4 d3 harvesting systems in the Intermediate Zone was continued at RRISL Substation, Polgahawela. Investigations on new d4 based double cut harvesting system began in a view of overcoming low yields during the harvesting on renewed bark.

In order to identify best performing genotypes for different agro-ecologies, fields established with four clones were evaluated in four locations. Collection of physiological, biochemical and growth data of ten clones began at newly established experimental fields in four locations. Studies on the variations of biochemical components and physical properties of rubber wood of RRIC 121 associated with tree maturity continued.

Analysis of latex samples for biochemical components to identify their effectiveness on quality of raw rubber continued with five rubber clones in view of developing a system to screen best clones producing quality raw rubber at the early stages of the breeding and selection programme.

ADVISORY SERVICES

As a solution to the tapper shortage, 236 new harvesting assistants were introduced through Tapping Training Schools (TTS) and 673 semi-skilled harvesting assistants were trained to improve the technical quality in tapping. The extension strategy focused on farmer participatory development of selected rubber units in each REO divisions in traditional rubber growing areas was continued and developed 152 rubber lands as model rubber holdings. Status of 75 immature substandard rubber holdings and 77 mature substandard rubber holdings were improved successfully. Thirty seven rubber processing centers were developed as models and construction of 47 new RSS processing centers and rehabilitation of 20 substandard centers were attended. Farmer training programmes were conducted to educate 1,768 rubber growers on general cultivation and processing aspects of rubber. Also, five selected youth were trained on value addition of rubber.

Basic data and information were collected to develop selected villages as model rubber villages and action plans were prepared. Three technology transfer centers were established at Kegalle, Kalutara and Ratnapura areas for effective technology transfer to rubber growers. Group extension programme called "Vihidum Sathkara" was effectively conducted providing advisory and extension services for 580 small land units in traditional rubber growing areas for necessary improvements. Six hundred forty seven advisory visits were carried out to solve problems in technology adoption on requests made by rubber smallholders.

RUBBER TECHNOLOGY AND DEVELOPMENT

Pandanas (watakeiya) fibres were processed and surface treated with three different chemicals. Natural rubber (NR) based composites were prepared with these modified fibres and cure and physico-mechanical properties were evaluated and compared with those containing unmodified fibres. A NR based composite with good ageing properties was developed using a modified natural antioxidant extracted from a plant material.

Properties of blends of virgin NBR and reclaimed NBR glove waste, produced according to different mechano-chemical reclaiming processes were evaluated. An initiative was taken to develop a low cost oil resistant mat using the reclaimed rubber prepared according to a selected reclaiming process.

Properties of dry rubber/bitumen masterbatches prepared with RSS, TSR and ground rubber tyre (GRT) were tested at the Road Development Authority (RDA). Further, reclaimed rubber was prepared with GRT according to three different processes and blended with bitumen to prepare masterbatches. Property evaluation is in progress at RDA.

A non-toxic NR latex based adhesive and a paint were developed. A synthetic rubber based compound with heat, abrasion and oil resistance was developed at the request of the RDA for the sliding shoe of crawlers. A dry rubber and a latex based compound for the inner lining of tanks used for storage of sodium hydroxide was developed. Crepe rubber based toy item was developed at the request of an industrialist. NR latex foam suitable to manufacture ear plugs was produced at the request of an industrialist.

Forty SMEs and ten groups of students were trained on manufacture of NR latex based products. Also four training programs on "Manufacture of rubber based products" were conducted for rubber smallholders/SMEs in collaboration with Vidatha Centres, Thurusaviya Trust Fund and National Institute of Plantation Management. Further, the staff was actively involved in arranging the stalls at CRT Trade Fair 2017 and two National Exhibitions.

On the request of the industry, 150 sole crepe samples, 161 rubber compounds and 92 rubber products were tested.

POLYMER CHEMISTRY

A process was developed to form filler particles and their incorporation into the latex matrix in-situ with the objective of cutting down the compounding cost. No deterioration of properties of latex films was observed.

A novel nanocompound in combination with TMTD gave promising results as a preservative system for NR latex whilst reducing the dose of TMTD which is considered to be objectionable for latex based products as far as health is concerned.

Ribbed Smoked Sheets were prepared using a series of blends of natural rubber latex and skim latex with different ratios. It was found that skim latex could be blended with fresh NR latex up to 80% without any significant processing problems.

Several combinations of existing accelerators were used in preparation of dry rubber compounds in an attempt to develop nitrosamine safe sulphur vulcanizing system for dry rubber based product manufacture.

More than thousand samples of polymeric materials received from industry and academia were characterized using Fourier transform infrared spectrophotometer (FTIR), Differential Scanning Calorimetry (DSC) and Dynamic Mechanical Analyzer (DMA) available at the department. Industrial solutions were also given based on the characterization results on customer requests.

RAW RUBBER AND CHEMICAL ANALYSIS

Testing services on raw rubber and rubber chemicals were provided according to ISO international standards to stakeholders, particularly raw rubber manufacturers, rubber importers and exporters, researchers and University students. Number of testings carried out by the department includes two thousand & nine on raw rubber, thousand & fifteen on latex, twelve on chemicals, twenty three on glove and thirty nine on polythene samples. Four training programmes were conducted for laboratory personnel from rubber manufacturing industries and university students on raw rubber & latex testing.

Two new test methods were introduced for the determination of purity of a sulphur sample and volume change in vulcanized rubber product on request made by rubber industries. Development of a novel technique was commenced to estimate the dry rubber content at the field level as an alternative method for DRC estimation using metrolac. Two short term projects were carried out on "Effect of ethephon stimulation on vulcanized rubber product filled with carbon black" and "Study on latex, raw rubber and physico-mechanical properties of RRISL 203 genotype of Hevea brasiliensis.

Staff was also involved in trouble shooting activities on requests made by rubber industries.

RAW RUBBER PROCESS DEVELOPMENT AND CHEMICAL ENGINEERING

Design and construction of a user friendly simple and small scale latex coagulation tank with 10 kg capacity were completed. Construction work of a solar flat plate air collectors assisted greenhouse type dryer funded by Sri Lanka Climate Pvt Ltd. was completed at Bangalagoda Grameeya Rubber Sanwardhana Sansadaya, Badalkubura, Moneragala who is also a collaborator of the project. This unit was used for pre-drying of sheets. Preliminary trials have shown that smoke drying period of twenty four hours in a Single day Smoke drying unit (SS drying unit) could be further reduced by 50% when the sheets are pre-dried in the green house for two days.

Curing characteristics and physico-mechanical properties of used tea waste (UTW) incorporated NR composites have shown that UTW is suitable to be used as a diluent in certain rubber product applications.

A study carried out on the feasibility of recycling of processing water in crepe rubber manufacturing industry revealed that a minimum of 30% savings in process water used for the coagulum and laces washing could be achieved. Mill cooling water could be completely reused.

In a research project was conducted to improve shelf-life of natural rubber for special purpose applications, one retardant which could increase shelf-life of compounded latex and pre-vulcanized latex by three months and one month respectively was identified.

Dynamic Mechanical analyses of a series of rubber composites prepared using different types of raw rubber were conducted to study the variability of storage modules (E'), loss modules (E") and damping factor (tan δ). It was discovered that E' and E" of SLR-20 composites were significantly higher than those of other rubber composites studied in the glassy region. In the rubbery region, SLR-20, RSS and crepe rubber composites had similar dynamic properties while skim crepe rubber composite recorded higher E" values and lower tan δ peak value showing the necessity of careful selection of skim crepe rubber for dynamic applications.

Two different techniques were developed to dispose the sludge deposited in the field latex storage tanks and in the bowls of the latex centrifuging machines used in the latex centrifuging industry. Former was converted to a form of special rubber while latter was converted to form of value added filler. These two technologies have been made available to the industry providing technical solutions to the associated environmental problems.

The staff of the department continued to provide routine technical assistance/advisory, analytical services and training programs to stakeholders and academia.

ADAPTIVE RESEARCH

The study conducted in the rural community of Eastern province revealed that rubber cultivation has significantly either augmented or in the process of augmenting the livelihood capital assets in farmer households, justifying the efforts and investments made to expand the rubber cultivation in the area in terms of enhancing the rural livelihood. The survey conducted in Northern Province revealed that being Sinhalese and proficiency in Sinhala language, affiliation to social organizations, availability of water source and usage of mulch as a soil conservation practice at early stage of growth were the significant sociocultural, physical and agronomic factors affecting the success of rubber cultivation in the region. As a new approach in attracting Tamil community to rubber cultivation, farmer participatory adaptive research plots were established in Malayalapuram, Kilinochchi.

BIOMETRY

Statistical methods, research support and studies on climatology are the three major research and development focuses of the Biometry section. During the year under review, the Biometry section has been involved in research, focusing on Biometrical aspects especially on development, modification and application of statistical methodologies falling in line with the needs of the rubber sector. Spatial modeling for GIS has been focused further during the year under review. The research studies carried on climatology were mainly focused on drought analysis and rainfall anomalies through different indices and studies were also focused on forecasting these indices to use them as a decision making tool.

During the year under review, research support provided to other departments included assisting in design of experiments, data analysis, design and analysis of surveys, interpretation of results and database management. Databases on meteorological data collected in the stations at Dartonfield, Moneragala and Kuruwita and rainfall data collected in stations at Nivitigalakele, Galewatta and Polgahawela were updated and provided the data for scientific purposes on request.

A detailed document titled "Preparedness of the Natural Rubber sector against adverse impacts of climate change and variability" was compiled during the year under review, which focused on adaptation plan for climate change in the plantation sector.

AGRICULTURAL ECONOMICS

A study on Socio-economic implications of rubber-based farming systems of the smallholder sector in Moneragala district was completed. This study has shown the application of socio-economic based livelihood approach to characterize the farming systems which provides guidelines in policy making. One of the advantages of this approach is that it allows a bridging of divides, enabling different people to work together, particularly across the natural and social sciences.

A research was conducted to find out suitable interpolation method in mapping of Natural Rubber (NR) yield in rubber lands in Kalutara district in collaboration with the Biometry Section. This analysis was extended to find out driving forces of the productivity of smallholder rubber lands in Kalutara district. Special emphasis was made to compare different statistical interpolation techniques available in ArcGIS geostatistical analyst in developing spatial maps.

A few economic analyzes were conducted during the year and one such study was the shift share analysis of raw rubber international trade. This study highlighted significant changes in the rubber product market destinations during the past.

LIBRARY AND PUBLICATION

Thirty seven new textbooks were added to the reference section of the Library bringing the total collection to 6087. While three journals were purchased, twenty five titles were received on exchange basis.

In the CRT 2017 Exhibition, 84 copies of Advisory Circular Folder and 214 copies of DVDs were issued for the general public.

DARTONFIELD GROUP

A total crop of 161,455 kg, has been harvested during this season. The actual crop harvested was 86.9% of the estimated crop. When comparing with the previous year crop, records a decrease of 8.3%. The crop harvested from the rainguard area was 27,069 kg which amount to 17% of total harvested crop.

The YPH for the year was 917 kg compared with the same period last season YPH has decreased by 55 kg.

The average intake per tapper recorded during the year was 7.6 kg. from a tapping task of 230 trees. Highest intake per tapper of 12.5 kg was recorded from the 2010 clearing with a tapping task of 316 trees of clone RRISL 203/2001 tapped on S/2d4 tapping system with ethral of Nivitigalakale Division.

The total number of Normal, Late, Rain guard & No tapping days recorded during the year were 224, 02, 69 & 69 days respectively.

Total rain fall recorded for the year was 4,068.1 mm. with 188 wet days. When compared with the same period last year it is more by 58m.m. & wet days less by 22 days respectively.

The COP & NSA achieved for the year was Rs.280.55 and Rs.319.00 respectively, giving a Profit of Rs.38.45 per kg. and a total profit of Rs.6.2 million. Profit per hectare recorded for the year was Rs.35,262.40.

Latex Crepe No.01 manufactured during the year was 67% and RSS No.01 was 91% respectively.

KURUWITA SUB - STATION

The mature and immature extents of the Kuruwita Sub Station were 77.66 and 4.50 hectares respectively during the year.

A total crop of 84,391 kg was harvested during the year recording an decrease of 20,260 kg on previous year's crop.

The actual yield per hectare (YPH) was 1,086.67 kg. The average intake tapper (IPT) of the estate was 9.0 kg and this is a decrease of 0.1 kg when compared with the previous year.

The total number of Normal, Rainguarded, Rain Interference and No tapping days recorded during the year were 203, 78, 40 and 44 respectively.

The annual rain fall recorded during the year was 4,768.4 mm with 246 wet days as against 3,342.8 mm with 222 wet days during the previous year.

The cost of production (C.O.P) and the net sale Average (N.S.A) for the year were Rs.250.01 and Rs.294.18 per kg respectively. The profit made for the year was Rs.3.7 million and the profit per hectare recorded for the year was Rs.47,998.33.

POLGAHAWELA SUB - STATION

A total crop of 7,661 kg, has been harvested providing 65% of the estimated crop for the year. This was 44% less from the value recorded in previous year.

Average yield per hectare (YPH) for the year was 652 kg. In the months of February, March and April, tapping were not done due to severe drought condition prevailed. This resulted in a decrease of 518 kg (44%) over the last year's value.

The average intake per tapper during the year was 9.4 kg. The highest intake per tapper of 10.2 kg was recorded from the 2005 clearing with a tapping task of 216 trees of clone RRIC 121 tapped on S/2d2, S/2d3 & S/2d4 systems.

The total number of normal, late, and no tapping days during the year were 226, 8 and 131, respectively.

Total rainfall recorded for the year was 1,974mm with 164 wet days. Out of the total manufactured RSS, the share of No.01 grade was 77%.

METEOROLOGICAL REPORT

The total annual rainfall at Dartonfield was 4,079 mm which accounted for an increase of 43% compared to the previous year. The monthly rainfall distribution at Dartonfield during this year closely followed the usual bimodal pattern. Above average monthly rainfall values were observed in May, August, September and November while below average values were recorded in the rest of the months, except for January, October and December which were very close to the long term average. The minimum monthly rainfall of 61 mm and the maximum monthly rainfall of 749 mm were recorded in February and May, respectively.

Rains during the South West season (May September) carried most of the rains (2,259 mm) during 2017. This rainfall amount contributed 54% to the total rainfall, which is comparatively higher than the long-term average contribution (48%). Rainfall during the second inter-monsoon (IM2) (October & November) brought1040 mm whilst the first inter-monsoon (IM1) (March & April) recorded a fairly low rainfall of 424 mm. During the North East season (November to January 2018), 469 mm of rain was recorded, which is again comparatively lower than the long-term average contribution of this season.

There were 5 rainfall events that exceeded the hazardous limits for landslides (100 mm of rainfall during a day) reported during the year under review. The observed total number of rainy days of the year was 220, which was close to the long term average. A dry spell lasted over a month or more can have adverse impacts on rubber plantations. There were only 6 dry spells greater than or equal to 7 days; the longest being 18 days, from 3rd to 20th January.

The daily average temperature pattern was fairly steady with a mean annual temperature of 27.4^{0}C and a standard deviation of 0.9, which could be a favourable condition for rubber plantations. The lowest mean minimum temperature of 21.4^{0}C was observed in January and February while the highest mean maximum temperature of 33^{0}C was observed in March and April.

A total of 1,825 bright sunshine hours was received at an average rate of 5.0 hr/day which was comparatively lower than the respective figures observed during the last year. Bright sunshine hours exceeded 6 in 47% of the days, while in 28% of the days it was below 4 hours. The mean RH values recorded at 08:30 and 15:30 were 86% and 74%, respectively.

There are three substations maintained by RRISL in Kuruwita (WL_{1a}), Narampola (IL_{1a} bordering WL_{26}), Moneragala (IL_{1c}) and Nivithigalakele (WL_{1a}). A total rainfall of 4,681 mm, 1,975 mm, 1,421mm and 3,287 mm were recorded, respectively, in Kuruwita, Narampola, Moneragala and Nivithigala Kele stations.