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IDENTIFICATION OF PLANT GROWTH – PROMOTING RHIZOBACTERIA FROM RUBBER GROWING SOILS OF SRI LANKA

T H P S Fernando, M K R Silva and Dilshari Siriwardena

The necessity to increase agricultural productivity in our country has become a must. To achieve the above expectation of the country, agricultural practices should also be moving towards a more sustainable and environmentaly friendly approach. Among the possibilities, one of the main aspects would be to explore the potential of beneficial microbes and their applicability under local conditions. However, there may not be a single, very simple practice that can be effectively used in promoting the growth and health of plants under all conditions; some of the strategies which have been identified already show great promise. Any soil sample, having bacteria may affect plants in three main ways. This interaction between the plants and microbes from the perspective of the plant can be beneficial, neutral, or harmful.

Soil which provides the main substrate for all the crops has depleted with all the beneficial microbe life including bacteria, fungi, actinomycetes, protozoa, and algae. It is well known that the soil contains a large number of bacteria (approx 10^8-10^9 cells per gram of soil) and generally the culturable is about 1% of the total number. However, with various environmental stresses and intensive agricultural practices, these beneficial micro-organism groups have been disturbed. The rhizobacteria capable in promotion of plant growth are called PGPR (Plant Growth Promoting Rhizobacteria). They directly promote plant growth by facilitating plant hormone levels. Otherwise, they achieve this indirectly by the inhibitory effects of various pathogenic micro-organisms acting as bio-control agents.

The rhizosphere is the narrow region of soil or any substrate which is directly influenced by roots. Another very important component inhabiting this zone is the associated soil micro-organisms which are called the root microbiome. These micro-organisms generally feed on plant tissues or root exudates. Sometimes these microbe:root interactions lead to a symbiosis condition. These interactions influence plant growth too. Some of these micro-organisms cause disease suppression by antibiotics. These microbes act as antagonistic microflora and can be utilized as bio-controlling agents in plant disease control.

Beneficial Rhizobacteria

Many species of beneficial bacteria in the rhizosphere are known as plant growth-promoting rhizobacteria (PGPR). These rhizobacteria show a capability of direct plant growth promotion while acting as antagonists against pathogenic micro-organisms. PGPR includes a wide variety of bacterial genera including *Bacillus* sp. and *Pseudomonas* sp. They affect plant growth directly as well as indirectly. PGPR shows the nitrogen fixation and phosphorus solubilization ability making soil nutrients available and effectively influencing the nutrient uptake from the soils. Moreover, some PGPR are responsible for creating siderophores promoting chelation of iron-binding capacity which contributes to indirect plant growth promotion.

One of the indirect benefits of PGPR is the bio-controlling ability of phytopathogenic micro-organisms. The mechanism will either by secretion of antagonistic substances or the suppression of pathogen growth. Antagonistic substances are mainly hydrolytic enzymes and antibiotics which are capable of the lysis of pathogenic cells of the micro-organisms. Lipases, proteases, amylases, peroxidases, lysozymes are active as above secretions. These micro-organisms are producing a wide range of antimicrobial compounds which are capable of acting against microbial actions. Another mechanism inducing host resistance is the activation of plant secondary metabolites.

Potential Biological Controlling Agents

Hevea brasiliensis (Rubber) one of the main plantation crops in Sri Lanka contributes with many socio-ecological and economical benefits. The diseases are affecting the productivity levels of the plantations. Hence, the management of economically important diseases of the rubber plantations is very important in maintaining the yields. Hence, a study carried out at the Plant Pathology and Microbiology Department of the Rubber Research Institute has revealed that thirteen number of PGPR strains as potential biological controlling agents.

They had shown the ability to solubilize phosphorus. Some strains produced significant levels of lipases, amylases, and pectinases. Moreover, secretion of IAA was also significant. These micro-organisms and their symbiotic associations were antagonistic to all the economically important diseases of rubber such as White root disease, Patch canker, and Fusarium disease. The use of PGPR in agriculture and other plant production systems is becoming increasingly important as they are proven to show synergistic effects on crop growth and protection as given below.

Facilitation of Nutrients

Microbes are capable of plant growth promotion by providing nutrients. Soils of the agricultural lands lack sufficient amounts of nutrients so that plant growth is suboptimal. To overcome the situation farmers have become dependent totally on chemical fertilizers especially N and P. they are costly while posing human and environmental hazards. Initially, if it would be possible for us to introduce microbes at least to provide a portion of the nutrient requirement it would be beneficial. *Rhizobia* spp., *Azospirillum* spp. are able to fix nitrogen. Generally, phosphorus is insoluble in the soil and hence they are mostly not in the available form to support plant growth. Moreover, much of the soluble inorganic phosphorus that is used as chemical fertilizer is immobilized once they are applied to the soil and therefore they are wasted. Mycorrhiza and many PGPR are capable of solubilizing phosphate. Moreover, the siderophores produced by bacteria show high affinity to various irons such as Fe facilitating their utilization. Plant hormones play a main role in plant growth and development, especially under stress conditions. Plant growth promotion by some cytokinin, gibberellin and IAA-producing bacteria has been reported.

The Way Forward

Promising results were recorded by combinations of PGPR strains. Collectively, interactions of different strains provide a strong establishment of bacteria and encapsulate the diversity of active mechanisms. Moreover, their associations evolve numerous strategies to augment the acquisition of nutrients. On the other hand, activities such as motility, antibiotic production, and coordinated behavior will boost the competitive balance. The native PGPR strains that have been isolated by the Plant Pathology & Microbiology Department of RRISL can be further explored for commercialization of bio-controlling & growth promotion in sustainable agriculture to produce vigorous plants.

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TRAINEES' PERCEPTION ON 'TRAINING SCHOOLS FOR LATEX HARVESTERS' IN THE SMALLHOLDER RUBBER SECTOR

P K K S Gunarathne

INTRODUCTION

Latex Harvester (LH) is the person who extracts latex from the rubber tree. Harvesting of latex is a highly skilled task and the LHs have to be trained to perform harvesting to get the best returns and also to protect the rubber tree to get an optimum economic outcome over the entire lifespan of the tree. The shortage of skilled LHs is a major issue in the smallholder rubber sector. Certain impacts have been caused due to the lack of skilled LHs, *viz.* damaged trees, early uprooting, less potential yield due to poor harvesting quality, abandoning of harvestable holdings which finally lead to low national rubber production. Therefore, the knowledge and skills in harvesting recommendations and practices developed by RRISL are important for addressing of above issues. Hence, it is essential to increase the availability of skilled LHs and improve the skills of those who are already in the service through systematic training programmes. In 2010, the Advisory Services Department (ASD) of RRISL introduced "Training Schools for Latex Harvesters (TSLHs)" (RRISL, 2010). As the establishment of TSLHs is one of the solutions to address the shortage of skilled LHs while improving their knowledge and practical skills which ultimately increase the adoption of correct harvesting practices recommended by RRISL. The TSLHs is a systematic training programme that is conducted to introduce skilled LHs to the rubber smallholder sector as a solution for the shortage of skilled LHs. The TSLHs have a syllabus including both practical and theoretical aspects with a duration of ten full days and refreshments are provided free of charge. The participants selected from the Rubber Extension Officers (REOs) are grouped into classes of a maximum of 25 participants per class. Trainees are provided with both theoretical knowledge and practical skills in rubber harvesting by the REOs at convenient locations. Rubber logs are used for practical sessions. At the end of each TSLHs, trainees are evaluated by both theoretical and practical tests by the REOs (Gunarathne *et al*., 2019). This study attempts to assess the Perception on the TSLHs (PTSLHs) by Trainee LHs (TLHs).

METHODOLOGY

The study was conducted in Ratnapura District in Sri Lanka in 2019. A stratified random sampling procedure was employed based on REO ranges in this study. The study sample comprised 256 TLHs. The perception of each indicator was presented as an item/statement (Segnon, 2015). Eighteen items (nine for theoretical aspects and nine for practical aspects) (Table 2 and 3) were selected to measure the PTSLHs with the discussion of the experts of the rubber sector and literature review. A pre-tested questionnaire was used to collect data from the respondents.

Perception is the cognitive process where people used to make sense out of the environment by selecting, organizing and interpreting information from the environment (Perrotta, 2021). TLHs were asked to mark their opinion on each item (Babbie, 2010). A five-point modified Likert-type scale was used to measure the extent of agreement; strongly agree, agree, neutral, disagree and strongly disagree (Likert, 1932). The weighted values on the Likert scales were used to derive the mean score of each item. The weights assigned to the responses were 4, 3, 2, 1 and 0, respectively. The values on the Likert-scales were used to derive the mean score of each item and then the aggregate mean scores of the nine items of each theoretical and practical session were calculated (Jayasinghe-Mudalige and Henson, 2006).

The respondents were separated into three perception categories by using the confidence interval method (Fisher, 1935) and categorized the respondents as follows; Least favourable group = Below X – 1.96*SE, Favourable group = Between X – 1.96*SE and Between X + 1.96*SE and Most favourable group = Between X + 1.96*SE. Cumulative frequency distribution and percentage analysis were used to quantify groups. The statement-wise perception was evaluated by using descriptive statistical methods. The scale reliability of the statements was tested using the Cronbach alpha value (α) by using the STATA 15.0. The perception analysis of the alpha values exceeding 0.7 was considered sufficient (Lord and Novick, 2008).

RESULTS AND DISCUSSION

Key socio-economic characteristics of trainee latex harvesters

The majority of the TLHs were females (73%). Most of the TLHs were in the middle age category (35-55 years) and participation of the younger generation (less than 35 years of age) was (15%) not satisfactory which will lead to a problem in the future. The education level of TLHs ranged from Grade 7 in school to GCE (Advanced Level). Seventy percent of them were self-harvesters (engaged in harvesting in their own holdings). The average harvesting extent was 0.6 ha/day (approx. 287 trees). This figure seems reasonable and manageable to maintain the sustainability of the cultivation. Most of the TLHs had experience of more than 24 months. The mean wage rate of hired TLHs was LKR 12,328 per month which varied from LKR 9,750-18,500. The majority (88%) were paid on daily basis.

Distribution of latex harvesters by perception categories

Table 1 explains the category of PTSLHs at the theoretical and practical sessions. Around 66% of the TLHs in this study area consider TSLHs as the most favourable theory sessions while 28% of the TLHs consider it as a favourable and 6% of the LHs consider it is as least favourable sessions. Nearly 74% of the TLHs of the sample in this study area were considering the TSLHs as the most favourable on practical sessions. However, favourable and least favourable percentages were 22 and 4, respectively perception on practical sessions.

Table 1. *Distribution of latex harvesters by perception categories on the evaluation of the theory and practical sessions of TSLHs.*

Category	Theoretical aspects		Practical aspects	
	Mean perception score	Percentage of respondents	Mean perception score	Percentage of respondents
Most favourable	>3.632	66	>3.743	74
Favourable	3.631-3.465	28	3.742-3.122	22
Least favourable	<3.464	06	<3.121	04

Perception of the theory sessions of the TSLHs

The theory sessions of the TSLHs were evaluated under nine criteria; time allocated for lectures, presentation of lectures, opportunity to share the experience with other TLHs, opportunity to share the experience with the lecturers, assessments made on venue, refreshments, seating arrangements, evaluation of knowledge level at the end of the school and enhancement of tapping knowledge were evaluated by the trainee LHs (Table 2). As all items exceed 0.7 (α), the indicators used in this study are valid and reliable to explore the perceptions of TLHs (Table 2 and 3). The assessment shows that the mean of overall PTSLHs for theory sessions is 3.62 (Table 2). The highest mean score was recorded from the enhancement of tapping knowledge (3.87) and the lowest (3.35) was recorded from the opportunity to share the experience with lectures, according to the responses.

Table 2. *Mean scores of the items to assess the perception on the evaluation of the theory sessions of TSLHs against the evaluation criteria.*

Items	Mean score of items	Cronbach Alpha
Content of lectures	3.63	0.7215
Time allocated for lectures	3.55	0.7815
Presentation of lectures	3.55	0.7999
Specimen supplied for lectures	3.69	0.8125
Opportunity to share the experience with lecturers	3.35	0.7325
Opportunity to share the experience with other trainees	3.87	0.7721
Assessment made on venue, refreshments, seating, etc.	3.61	0.7815
Evaluation of knowledge level at the end of the school	3.45	0.7561
Enhancement of tapping knowledge	3.87	0.7781
Mean score of the overall perception	3.62	

Perception of the practical sessions of the TSLHs

The practical sessions of the TSLHs were evaluated under nine criteria; the time allocated for practical sessions and the opportunity to share the experience with the resource person were in poor condition. The specimen supplied for practical sessions, an assessment made on venue, refreshments, skills of the resource persons, evaluation of the practical skills at the end of the school and enhancement of skill level.

The mean scores of PTSLH on practical sessions are given in Table 3. The assessments show that the mean of overall PTSLH on practical sessions is 3.76 while the highest mean score was recorded from the enhancement of tapping skills (3.93) and the lowest (3.21) was recorded from the opportunity to share the experience with other trainees.

Table 3. *Mean scores of the items to assess the perception on evaluation of the practical sessions of TSLHs against the evaluation criteria.*

Items	Mean score of items	Cronbach Alpha
Time allocated for practical sessions	3.87	0.7112
Specimen supplied for practical sessions	3.84	0.7425
Opportunity to share the experience with resource persons	3.21	0.7102
Opportunity to share the experience with other trainees	3.89	0.7001
Assessment made on venue refreshment, etc.,	3.88	0.7253
Evaluation of the practical at the end of the school	3.77	0.7451
Skills of the resource persons	3.81	0.7815
Evaluation of skill level at the end of the school	3.66	0.2845
Enhancement of tapping skills	3.93	0.7145
Mean score of the overall perception	3.76	

CONCLUSION

Items used to evaluate the perceptions of TLHs on the PTSLH at both theoretical and practical aspects were valid and reliable. According to the findings, the perception of TLHs towards the evaluation of TSLHs theoretical and practical aspects under most favourable level. Therefore, TSLHs can be expanded into the rubber sector in the country as an enhancement of human resource development programme for the improvement of the skill and knowledge on tapping practices of LHs.

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RAW RUBBER PROPERTIES OF SOME PROMINENT *HEVEA CLONES*

K V V S. Kudaligama, A P Attanayake and V H L Rodrigo

INTRODUCTION

The latex obtained by tapping the bark of rubber trees contains not only rubber hydrocarbon but also a considerable number of non-rubber substances which include carbohydrates, lipids, proteins, amines, carotenoids, phenolic substances, and some inorganic constituents (George, *et al*., 2004). Constitution of these substances is primarily a clonal factor) (George, *et al*., 2004; Yip, 1990) and ultimately has an impact on raw rubber properties of natural rubber directly and indirectly. Nowadays breeding and selection programs of *Hevea brasiliensis* are also concerned with the quality of raw rubber produced with desired characteristics for some downstream production. This is particularly important when new rubber-based products are coming to market. The quality of the product depends on the quality of raw materials and so the raw rubber. Adjustment of raw rubber properties is extremely difficult or costly hence attention has been given to select *Hevea* clones that need the producers' requirements.

The influence of non-rubber constituents on the properties of raw rubber although present in small quantities, is substantial. The composition of these components varies among the clones which in turn, affect the properties of the bulk product. Initial plasticity, plasticity retention index, Moony viscosity, colour, nitrogen and ash content are known to be the major raw rubber properties for which industrialists are concerned.

Raw rubber properties

Various technological advances made during the recent past have led to the escalation of consumer interest in the quality and properties of raw rubber. Hence, the Rubber Research Institute of Sri Lanka has stipulated different standards for latex crepe and Lankaprene grade based on end-user requirements (Table 1).

Table 1. *Specifications for raw rubber stipulated for Sri Lankan crepe rubber and Lankaprene (Seneviratne and Sarath Kumara, 2003*)

Property	**Specifications stipulated**	
	Crepe rubber	**Lankaprene**
Initial plasticity (Wallace units)	30 (min.)	35 – 50
Plasticity retention index	60 (min.)	70 – 85
Mooney viscosity (ML 1+4 @ 100ºC)	75 – 85	70 – 80
Nitrogen (%)	0.35 (max.)	0.35 (max.)
Ash (%)	0.25 (max.)	0.25 (max.)
Lovibond colour	1.5 (max.)	1.5 (max.)

Clonal difference of raw rubber properties

The study has clearly shown the clonal differences in almost all the properties examined with respect to the specifications set for latex crepe and Lankaprene (Table 2). The selection is basically done on latex yielding capacity and other desirable agronomic characteristics. Whilst no individual grower, either planter or smallholder, pays any attention to plant rubber with desirable raw rubber characteristics, raw rubber producers and manufacturers resolve the problem by adjusting the procedures in production lines resulting in additional costs. If clones having desirable raw rubber properties are used for cultivation, the cost of production could be minimized and raw rubber could be produced to niche markets. Focus on raw rubber properties in breeding programs is inadequate resulting in considerable variations among recommended *Hevea* clones (Table 2). Therefore, paying special attention in this regard would be of great use to the producers as well as to the consumer.

Table 2. *Average raw rubber properties of unfractioned unbleached crepe rubber produced from latex of different Hevea clones (coefficients of variation are in parentheses)*

Clone	Initial plasticity number (Wallace units)	Plasticity retention index	Mooney viscosity (ML 1+4 @100°C)	Lovibond Colour	Ash % (w/w)	Nitrogen% (w/w)
RRIC 100	38 (7.89)	72 (9.72)	78 (5.13)	2.2(25.11)	0.19(21.05)	0.44(6.87)
RRIC 121	52(11.54)	63(28.57)	89(4.49)	1.6(27.67)	0.14(28.57)	0.45(15.56)
RRIC 130	52(9.62)	71(7.04)	96(3.13)	1.4(44.12)	0.11(36.36)	0.42(16.67)
RRIC 102	41(4.76)	69(17.39)	79(6.33)	2.1(25.84)	0.17(29.41)	0.48(22.92)
RRISL 201	42(9.67)	77(11.30)	78(7.91)	1.9(31.42)	0.12(44.97)	0.45(2.22)
RRISL 203	59(11.56)	68(5.28)	106(5.28)	2.1(13.75)	0.15(20.97)	0.41(36.66)
RRISL 205	43(10.78)	75(10.30)	81(8.08)	2.0(25.50)	0.14(17.59)	0.54(14.11)
RRISL 206	50(8.02)	72(12.67)	91(3.54)	4.7(24.52)	0.15(22.24)	0.41(4.88)
RRISL 208	46(9.51)	76(11.76)	83(6.15)	1.5(33.33)	0.15(13.37)	0.38(3.72)
RRISL 211	45(15.82)	76(13.49)	83(10.25)	1.4(13.11)	0.16(23.66)	0.41(12.67)
RRISL 215	34(11.43)	79(14.15)	63(7.89)	1.3(19.67)	0.13(16.58)	0.44(7.87)
RRISL 216	50(11.32)	69(12.46)	87(15.09)	1.4(23.26)	0.14(19.20)	0.41(6.30)
RRISL 217	40(14.12)	77(14.30)	74(12.58)	1.3(17.36)	0.14(23.05)	0.48(4.47)
RRISL 219	42(11.63)	74(13.88)	77(7.31)	1.6(28.58)	0.14(35.92)	0.43(6.15)
RRISL 220	35(6.44)	73(15.74)	66(12.29)	1.2(21.11)	0.12(13.97)	0.42(6.73)
RRISL 221	42(10.22)	68(11.36)	79(7.86)	2.8(40.66)	0.13(11.75)	0.42(6.73)
RRISL 222	41(11.86)	75(11.17)	76(8.46)	1.6(35.47)	0.13(29.22)	0.41(9.87)
RRISL 223	41(10.20)	72(11.45)	77(10.03)	1.3(19.36)	0.14(17.75)	0.44(1.63)
RRISL 226	32(7.96)	74(23.73)	59(7.37)	1.8(38.11)	0.14(17.89)	0.45(3.37)
RRISL 2000	44(6.82)	69(4.89)	85(6.88)	1.6(30.16)	0.12(34.08)	0.38(14.89)
RRISL 2001	43(9.68)	72(7.37)	81(11.76)	1.7(40.07)	0.14(16.62)	0.41(8.68)

Classification of clones according to variation of raw rubber properties

Initial Wallace plasticity (Po)

Initial Wallace plasticity (Po) is a measure of the plasticity of the rubber which indirectly gives the estimation of the polymer molecular chain length (or molecular weight). In general, rubbers with high Po values would process high molecular weight (Sekhar, 1971). The specification limit of Po should be 30 (min.) in order to ensure that the rubbers have a certain minimum molecular weight. Very low Po values are normally associated with rubbers whose molecular chains have been degraded or undergone extensive chain scissions, which are noted to have poorer technological properties. Po provides a “picture” of the micro structure of natural rubber that can be attributed to the macro-molecular structure including average chain length, molar mass distribution, degree of branching along the chain, micro gel and the macro gel contents. None of the clones tested show Po value of less than 30.

Plasticity Retention Index (PRI)

The plasticity retention index is a measure of oxidisability of the rubber and it reflects the resistance of rubber to molecular breakdown by heat. A high value of PRI denotes high resistance to oxidative break down (Eng *et al.*, 2005; Sekhar, 1971). The plasticity of the natural rubber and PRI varies with the molecular weight distribution and the gel content. However, it is virtually independent of the initial plasticity (Po) of the rubber (Eng *et al*., 2002). Natural rubber obtained from the tree displays excellent resistance to oxidation and this situation may deteriorate mainly due to the leaching of antioxidants during processing. The initial plasticity and plasticity retention index of all clones tested met the requirement of latex crepe and but a few did not satisfy the level of Lankaprene (Table 3).

Table 3. *Classification of Hevea clones based on plasticity retention index*

Group	Range	*Hevea* clones
Low	<60	-
Moderate	60-75	RRIC 100, RRIC 121, RRIC 130, RRIC 102, RRISL 203, RRISL 205, RRISL 206, RRISL 216, RRISL 219, RRISL 220, RRISL 221, RRISL 222, RRISL 223, RRISL 226, RRISL 2000, RRISL 2001
High	76-85	RRISL 201, RRISL 208, RRISL 211, RRISL 215, RRISL 217
Very high	>85	-

Mooney viscosity (V_R)

Mooney viscosity (V_R) depends on the average molecular weight of the polymer and the extent of plasticization imparted by the non-rubbers. It gives an indication about the hardness of rubber and is very essential to quantify the mechanical work required during the initial steps of the process line *i.e.* mixing (Yip, 1990). Rubber with high viscosity may require a long pre-mastication period or need expensive peptisers to obtain a workable product. Crosslinks among the rubber molecules involving the aldehyde groups harden the rubber, reflected by high Mooney viscosity values (Subramaniam, 1975) and the concentration of these groups varies with rubber clones. Most of the clones tested showed a moderate viscosity level and there is a tendency of increasing viscosity in high yielding clones (Table 4).

Table 4. *Classification of Hevea clones based on Mooney viscosity*

Group	Range	*Hevea* clones
Low	<70	RRISL 215, RRISL 220, RRISL 226
Moderate	70-85	RRIC 100, RRIC 102,
		RRISL 201, RRISL 217, RRISL 219, RRISL 221, RRISL 222,
		RRISL 223, RRISL 205, RRISL 208, RRISL 211
		RRISL 2000, RRISL 2001,
High	86-95	RRIC 121,
		RRISL 216, RRISL 206
Very high	>95	RRIC 130, RRISL 203

Ash content

The ash of natural rubber contains varying proportions of oxides, carbonates and phosphates of potassium, calcium, magnesium, sodium and trace elements (George *et al*., 2004). Additionally, silica or silicates either from rubber or from contaminations will raise the ash content of rubber. This reflects the mineral content of rubber. All clones were in the safe category showing their suitability for the production of good quality rubber.

Nitrogen content

Protein is the major source of nitrogen in rubber. Latex contains about 1% proteins, of which 20% is adsorbed on rubber particles and the rest 80% is associated with the sedimentable particles and cytosol. In the production process, a part of these proteins is removed with non-rubber fraction and mostly proteins adsorbed to rubber particles have remained with the final product. The maximum nitrogen % stipulated in raw rubber for food and pharmaceutical products grade, is 0.35% (Seneviratne & Sarath Kumara, 2003). None of the clones tested produced crepe with nitrogen content below 0.35% (Table 5). The nitrogen content of rubber produced from these clones would be reduced to a certain extent by fractionation during the production of crepe rubber. The use of proteolytic enzymes such as papain is another option to bring down the nitrogen content below 0.1% to make low nitrogen grades. Due to minimal water absorption and low heat build-up with friction, low nitrogen rubber is ideal for special rubber products such as water seals, aircraft tyres and bridge bearings. Especially, for the pharmaceutical grade, a rubber with a minimal amount of leachable proteins are required to minimize allergy problems when used in contact with the human.

Table 5. *Classification of Hevea clones based on nitrogen content*

Group	Range	*Hevea* clones
Low	<0.35	-
Moderate	0.35-0.45	RRIC 100, RRIC 121, RRIC 130, RRISL 201, RRISL 203, RRISL 206, RRISL 208, RRISL 211, RRISL 215, RRISL 216, RRISL 219, RRISL 220, RRISL 221, RRISL 222, RRISL 223, RRISL 226, RRISL 2000, RRISL 2001
High	>0.45	RRIC 102, RRISL 205, RRISL 217

Lovibond colour

Colour is an essential property in the production of light-coloured goods such as infant teats, catheter tubing, blood tubing etc. Conventionally raw rubber is graded visually according to its colour and it doesn't represent the technical quality. In particular, higher amounts of poly-phenolic substances and carotenoids increase the colour of raw rubber. Fractionation of latex and bleaching may improve the colour of crepe rubber. Unfractioned unbleached (UFUB) crepe of most of the clones tested was calssified in low and moderate groups in classification (Table 6, Plate 1). Carotenoids and phenolic substances are responsible for yellowish and greyish to blackish colour in crepe, respectively. Fractionation of latex and bleaching may improve the colour of crepe rubber.

Table 6. *Classification of Hevea clones based on Lovibond colour index*

Group	Range	*Hevea* clones
Low	<1.5	RRIC 130, RRISL 211, RRISL 215, RRISL 216, RRISL 217, RRISL 220, RRISL 223
Moderate	1.5-2.5	RRIC 100, RRIC 121, RRIC 102, RRISL 201, RRISL 203, RRISL 205, RRISL 208, RRISL 219, RRISL 222, RRISL 226, RRISL 2000, RRISL 2001
High	2.6-3.5	RRISL 221
Very high	>3.5	RRISL 206

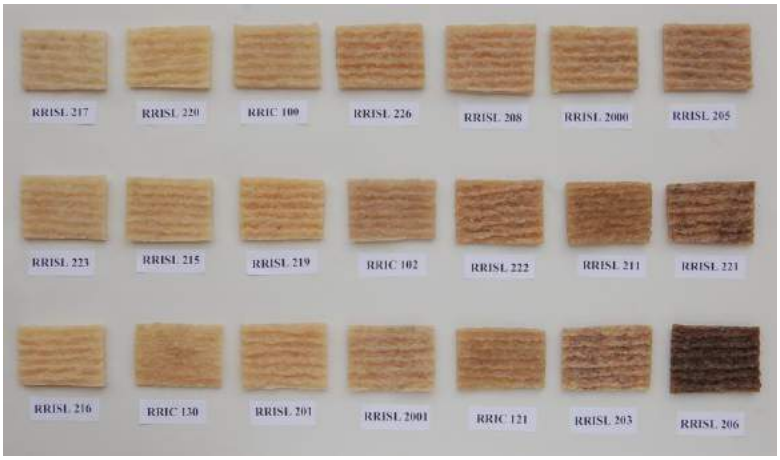

Plate 1. Colour of unfarctioned unbleached crepe of different *Hevea* clones

Non-rubber constituents of latex as well as the degree of polymerization of the rubber molecule varies among the clones which in turn, affect the properties of the bulk product. The quality of raw rubber plays a major role in the quality of the final product. Adjustment of raw rubber properties is extremely difficult or costly hence attention has been given to the selection of *Hevea* clones that need the producers' requirements.

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THE EFFECT OF THE SIZE OF THE POLYBAG TO RAISE YOUNG BUDDING RUBBER PLANTS AND FACTORS AFFECTING THE QUALITY OF BUDDED PLANTS

P Seneviratne, N M C Nayanakantha and G A S Wijesekara

INTRODUCTION

The rubber tree was propagated by seeds since its domestication in 1876. The next development in planting material was the selected seeds from seed gardens especially maintained for collecting seeds for propagation. High variation among trees for growth and the yield which could only be detected when the trees are opened for tapping was the main disadvantage even with selected seeds. The size or the girth of the tree has shown a low correlation to the yield of these seedling populations, as expected. It has been documented that about 75% of the crop of these seedling plantations was obtained from about 25% of the trees in a clearing (Wright,1906).

The bud grafting technique, to propagate rubber plants was developed in 1917, and since then seeds were used to establish rootstock nurseries for bud grafting, and annually these seedlings were bud grafted to cater to the annual requirement of budded plants. In ground-rootstock nurseries, the age of the rootstock plants was about two years. Budwood nurseries on the other hand are maintained for 8-10 years, and the age of the budwood for bud grafting, using the brown budding technique, is about two years. However, when the green budding technique was adopted for rubber, the age of the ground rootstock nursery could be reduced to 7-8 months and the age of the green budwood to 5-6 months. Though the growth phase or the juvenile phase of seedling trees was longer, generally 6-7 years, the budded plants have a shorter, about 4-5 years of juvenile phase as the age counts from the seed itself.

In Sri Lanka, from the early days, there were many private rubber nurseries to produce budded plants in all rubber growing regions, but there was little coordination to determine the annual planting material requirement and the budded plant production. Therefore, there was no proper control on the quantity of budded plants produced or available within a year. This affected the quality of the budded plants used for replanting programmes to a greater extent. The rootstock plants unused due to not reaching the buddable size, in ground-nurseries were not removed after two years, but sometimes maintained for more than three years until they reach the buddable size, without grafting. When there is a budded plant requirement, the stock plants in the ground rootstock nursery are bud grafted and issued as bare root budded stumps, which takes only about 4-5 weeks. Therefore, the quality assurance of bare root budded stumps produced in ground rootstock nurseries was extremely difficult as the life span of one nursery gets extended up to 3-4 years, as explained, though bud grafting can be started when seedlings are about 1-1 ½ years of age and each nursery is expected to complete within 2 years in order to maintain the quality, especially the age. But, every year a rootstock nursery is established with the seed fall in August, and January. Therefore, every nursery owner had 2-3 nurseries, at any given time but of different ages. Always the bud grafting is done in the oldest nursery and the farmers too preferred to buy big plants. But, as the growth phase of the rubber tree is only 5-6 years, the budded plants need to be field planted as early as possible. During the growth phase, when the plant is juvenile, the growth rate of plants is at least 10 cm per year and the trees grow without branching up to about 7-8 feet (Fig.1). When the age of the rootstock plant is close to three years, and bud grafted and field planted, it is three years old. Then it has only two to three more years before it enters the mature phase. This was a serious problem that was aggravating due to the lack of a controlling mechanism. On the other hand, rubber fields established with such 2-3-year-old bare-root budded stumps, start to show mature characteristics of rubber trees such as branching, wintering, and flowering when the trees grow for about 3-4 years in the field (Fig. 2 and 3).

Fig. 1. Straight trunk without branching below eight feet of the main stem

Fig. 2. Twisted stem, branching at lower heights and weak growth of the trees

Fig. 3. Four years old rubber clearing of clone RRIC 121 showing wintering characteristics during February.

As a solution to this, the young budding technique was introduced to Sri Lanka in 1992, initially to govern rubber nurseries. The bag size used to raise green budded bare-root budded stumps up to 2-3 leaf whorl stage was 6′x18′, black, guzetted bags of gauge 500. For young buddings however a bigger size bag, 7′x18′ had been recommended earlier. Some nursery owners used the large size bags of 9′x18′ as bigger plants can be produced in larger. When the young budding technique was adopted on a large scale in Sri Lanka, the effect of the bag size was tested along with many other requirements needed to raise high-quality young budding plants (Senevitatne *et al.*, 1994). The bag size of 6′x15′ was recommended since then. When the government rubber nurseries converted their plant production to young buddings, the need for topsoil to fill the polybags was very high as the annual plant production was 2-3 million plants per year.

Though recommending the small size bag was a breakthrough, the need for further reduction of soil quantity remained a priority. With the start of using subsoil to fill polybags, adding 50 g of compost to each bag was recommended along with rock phosphate (Advisory Circular 2016/4: Fertilizer to rubber).

Available data and experience with young buddings prove that, when high-quality seeds are collected from the early seed fall and the early germinated seeds are harvested from the germination bed, the taproot of the seedlings reaches the base of the bag in less than one month. During the rest of the period, the roots grow outside the bag. Also, after bud grafting when the stock is removed about 6 inches above the bud patch, the root system gets reduced (Dharmakeerthi *et al.*, 2008). Therefore, though the bag size is large, the amount of roots in the bag is negligible.

As the grafted bud starts to grow then the roots too, seem to regenerate. At two leaf whorl stage, the root system inside the bag is minimum. The objective of the present study was to see whether the size of the bag can be reduced further.

MATERIALS AND METHODS

The trial reported here was started in the year 2014. Early germinated seeds for the germination bed were selected to plant in the polybags filled with soil mixed with IRP and compost, 50 g/bag (Advisory Circular 2016/04 Fertilizer to Rubber). The bags were gazzetted and the bottom half perforated. The central hole was made by removing one square inch from the base of the bag. Bags were of gauge 300 black polythene. Bags of 6’x15’ size, were arranged in about 5′x6′deep trenches touching each other to keep them erect without additional mechanical support. As the bag size tested was 4′x15′ in this trial, keeping a gap between two bags in rows was also tested, to lessen the foliage getting crowded. Bags were buried in trenches as for normal young budding nurseries. Plants were arranged in a nursery, according to Randomized Complete Block Design (RCBD) with six treatments (Table 1). Each treatment were replicated five times with 25 seedling plants. Manuaring, watering, and aftercare were done as recommended (Advisory Circular 2016/09 Production of Budded Plants). Diameter measurements were taken after 6 weeks of planting germinated seeds in the bags and just before and grafting.

Table 1. *Treatments, bag sizes, presence of central hole and the plant arrangements.*

Treatment	Specification of the bag
A	(4′X15′) bag without a hole at the bottom and placed touched with each other
B	(4′X15′) bag with a hole (1′X1′ square) at the bottom and placed touched with each other
C	(4′X15′) bag with a hole (1′X1′ square) at the bottom and placed leaving a gap (4′) between two bags
D	(4′X15′) bag without a hole at the bottom and placed leaving a gap (4) between two bags
E	(6′X15′) young budding bag (control) with a hole at the bottom
F	Control (7′X18′) young budding bag (control) with a hole at the bottom

Y/B- define here

RESULTS

The mean diameter of the seedlings, six weeks and 5 months after transplanting into bags and the diameter increment of plants are given in Table 2.

Table 2. *Mean diameter (mm) of the seedlings 6 weeks and 5 months after planting in bags.*

Treatment	Mean diameter after 6 weeks (mm)	Mean diameter after 5 months (mm)	Diameter Increment (mm)
A	3.92	6.64	2.72
B	3.63	6.15	2.52
C	3.59	6.07	2.48
D	3.55	6.01	2.46
E	3.60	6.37	2.77
F	3.56	6.27	2.71

As it can be seen from Table 2, the diameter values do not show differences among treatments, 6 weeks after transplanting into bags or 5 month after transplanting. All plants in all treatments have reached the buddable diameter of 6 mm size.

Figure 4. One full page

As it can be seen from Figure 4 when there is a central hole, the taproot penetrates easily, without coiling at the base. But the gauge of the polythene is 300 and vigorous tap roots can penetrate the bag. The small size of the bag allows minimum coiling as there is no space at the base for coiling.

Stem Morphology					
Treatment Bag Size	**- Gap, - Hole**	**- Gap, + Hole**	**+ Gap, + Hole**	**+ Gap, - Hole**	**- Gap, + Hole**
	4”				**6”**
	A	**B**	**C**	**D**	**E**

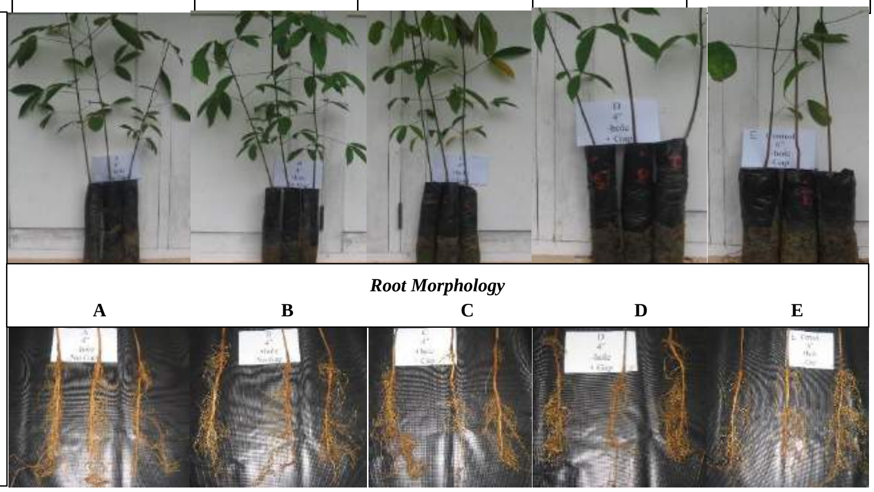

Fig. 4. Morphology of the shoot and root systems at 5 months for the different treatments

DISCUSSION

The effect of the size of the bag on the growth performances of the seedling as well as the grafted plants has been studied by many workers. As reported by Seneviratne *et al.,* (1994), plants grow bigger in larger size bags. But the intention in adopting the young budding technique was to produce high-quality vigorous plants.

Big plants can be obtained through growing in large size bags as well as delaying bud grafting until the seedling is about two years old, as practiced in ground nurseries. Selecting vigorous seedlings will result in buddable size plants of 6 mm diameter in 4-5 months.

Weak plants remain very thin in small bags. However, for plants grown in large size bags, the growth of seedlings is extra benefitted with the extra resources available. Generally, 9′x18′ bag holds about four times the volume of 6′x15′ size bag which was recommended to grow bare root budded stumps to produce 2-3 whorled polybag plants. Some nurseries use large size bags to raise young buddings too believing that the growth is better. Every year, Sri Lanka needs 3-4 million rubber plants for replanting programmes. Though the soil used in bags is returned to the planting hole, dislocating such a big volume is harmful to the environment. Handling large-size bags is not only ergonomically difficult but also costly. Further, a larger volume of polythene is added to the environment by using large size higher gauge bags. Therefore, it can be concluded that a 4′x15′ bag is as good as a 6′x15′ size as far as the growth of the seedlings is concerned. This was observed in a trial conducted to test the size along with the colour of polythene also (Seneviratne *et al.*, 2019). Different bag sizes including 3.75′x15′ have been tested and it has been reported that no significant differences among the three sizes, 3.75′x15′, 5′x15′, and 6′x15′ for growth characteristics (Annual Review, 2015).

Including coconut husks cut into pieces into the bag has also been tried with normal 6′x15′ size bags, but practical usage had issues and the cost was high. Root coiling at the base of the bag was overcome by having a hole at the center of the base of the polybag (Annual Review, 2011).

The main concern here is the volume of soil required and easy handling when the bag is lighter and small. Further, when the size of the bag is small, only the vigorous plants would become buddable in four months.

In India, some private companies produce root trainer plants in nurseries where the cone shape containers are filled with a nutrient-rich mixture of coir pith (Soman, 2009). As far as the volume of the potting mixture is concerned, small size polybags of 6′x15′ size is comparable with root trainers. Root morphology can be improved by having a central hole at the base, as in root trainers (Annual review, 2009). Further, the effect of the volume of the bag and the shape have an effect only until the taproot penetrates the base of the bag. Furthermore, a trial conducted to test the effect of the container has revealed that the effect of the container lasts only until the plants are field planted (Annual Review, 2015). Therefore, it can be concluded that the small size bag (4′x15′) is as good as the recommended size, as the taproot penetrates the base of the bag after about one month of transplanting the germinated seeds into the bags.

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THE CHANGE OF CLONAL COMPOSITION OF RUBBER PLANTATIONS IN SRI LANKA: SURVEY RESULTS

P Seneviratne, L Zoysa and W M D Wickramakumari

INTRODUCTION

Clones recommended by the Rubber Research Institute of Sri Lanka (RRISL) fall under several different categories; i.e. for large-scale planting, for limited planting, for estates under Regional Plantation Companies (RPCs), and smallholder farmers. In Sri Lanka, Smallholder farmers are those who possess less than 10 ha. and even 0.1 ha. is eligible for the government subsidy scheme meant to encourage farmers for new and replanting of rubber.

Evaluation of a clone is a very laborious and time-consuming activity and normally it takes about 20 years before a clone is recommended for large-scale planting. Since the usage of clonal rubber for planting and replanting programmes in Sri Lanka, maintaining a proper balance became vital for the sustainability of the industry. Making the rubber industry thrive amidst a diverse range of diseases has been a challenge faced by the growers and scientists ever since the plantations were established on a large scale. Though the first disease on rubber was reported as early as 1903, Sri Lanka had been at the top as far as the management of rubber diseases. The most significant milestone in rubber plantations in Sri Lanka which received huge recognition from all rubber growing countries was the release of RRIC 100 series clones; especially the clone RRIC 100, which exhibited resistance to *Oidium* leaf disease.

The effective strategy used to control rubber diseases in Sri Lanka from the beginning was having a substantial number of clones recommended at any given time, withdrawing susceptible and affected clones from the list of recommended clones while maintaining a healthy composition.

Decisions on recommending new clones and withdrawing them due to various reasons such as low yield, susceptibility to diseases, or exceeding recommended hectarage etc. have always been taken by the Rubber Research Institute of Sri Lanka. The clone PB 86 was withdrawn in 1983 due to poor yield. RRISL is the responsible institution that sustainably looks after the rubber industry through proper studies and issuing timely guidelines.

Disease management

Though rarely, the clones in group I are withdrawn due to sudden outbreaks of new diseases and recommended clones becoming susceptible partially or fully. The same parents in the hand pollination program produce susceptible and tolerant clones e.g., RRIC 100 and RRIC 103.

When the clone RRIC 103, which was recommended in Group I, was withdrawn due to getting succumb to *Corynespora* leaf fall disease in 1985. To compensate it PB 86 was given back to Group I which was withdrawn again in 1989. In 1993, another clone series was recommended for Sri Lankan plantations designated as RRISL 200 series clones. But, in 1995, the clone RRIC 110, which was recommended in Group II then, got succumb to *Corynespora* and it was withdrawn immediately.

From the mid-1980s onwards special attention was paid to the selection of disease-resistant parent clones for *Hevea* breeding programs as some of the previously recommended clones were susceptible to *Corynespora* Leaf Spot disease, found for the first time in Sri Lanka in 1985.

The common diseases listed for economically affecting rubber plantations are *Oidium* leaf fall, *Collatoricum* leaf disease, *Phytophthora* leaf fall, Corynespora leaf fall *Phytophthora* bark rot, and white root disease. Chemical control methods were recommended, which included techniques such as dusting Sulphur and Copper during the re-foliation period and the southwest monsoon rainy periods, respectively.

Economic factors, as well as environmental pollution, were the main concerns of many scientists at RRISL, and efforts to reduce the number of chemical applications to a possible minimum and search for less hazardous alternative chemicals were undertaken throughout.

The recent disastrous situation faced by the rubber plantations in the South East Asian region is the leaf fall disease caused by one or more pathogens including *Pestalotiopsis* reported for the first time in rubber in Indonesia in 1917.

It has now reached many neighboring countries and in 2019 it was found in some areas in Sri Lanka with characteristic symptoms and partial defoliation. *Pestalotiopsis* is not a quarantine pest and is found in many tree species, mainly fruit crops, and it is too early to comment on the economic importance of this pathogen in Sri Lanka. Due to mass-scale usage of disease-resistant clones, spraying of sulfur or copper has not been practiced in Sri Lanka since 1970s.

Clone balance

New clones are recommended mainly for the high yield and resistance to common diseases. Timber volume is also considered an important secondary characteristic. The reason for maintaining a proper balance is the clones getting succumb to diseases and therefore to minimize the loss due to a clone getting wiped out by a disease such as RRIC 103 and RRIC 110, experienced in 1985 and 1995, respectively.

In the year 1997 the clone RRIC 100, the world-recognized prestigious clone was withdrawn from Group I, as it covered more than 40% of the extent in the country. Yet, it continues to recommend for non-traditional rubber growing areas.

Though the poor yielding clone PB 86 was withdrawn twice, once in 1983 and then in 1989, according to the published data of Agricultural and Environment Statistics Division, Department of Census and Statistics in 2002, the clone composition of rubber in Sri Lanka in 2002 is in Fig. 1.

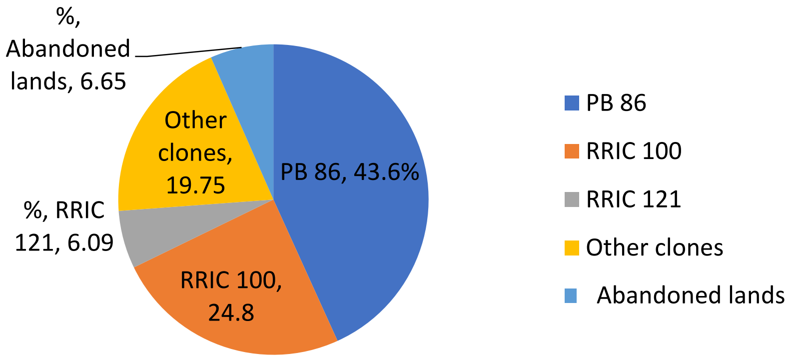

Fig. 1. The clone composition of rubber plantations in Sri Lanka in 2002.

The reason for the existence of a high percentage of 43.6% of PB 86 even after 13 years of its withdrawal in 1989 is the long replanting cycle of rubber that is 30 years.

The clone composition was surveyed in 2009 by the Rubber Research Institute of Sri Lanka and the composition was as in Fig. 2.

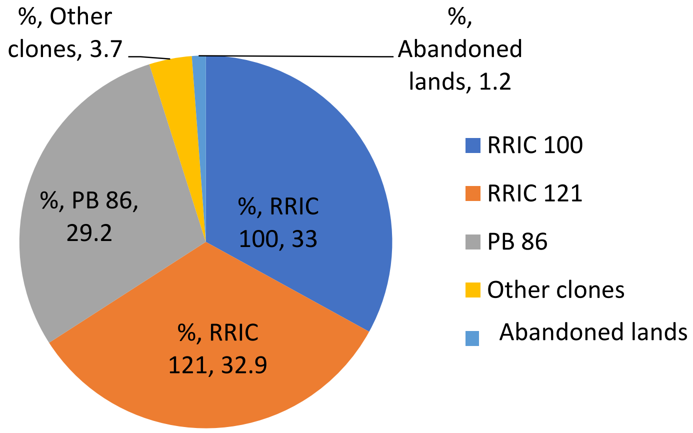

Fig. 2. The clone composition of rubber plantations in Sri Lanka in 2009.

The percentage coverage of the clone PB 86 has come down to 29.2% from its 43.6% during the 7 years from 2002. The data itself guarantees that PB 86 has not been planted since 2002. The percentage of clone RRIC 100 has increased from 24.8% to 33% partly due to allowing it for non-traditional areas. The extent of RRIC 121 has reached up to 32.9% and therefore it was necessary to restrict RRIC 121 from further expansion, especially for the estates managed by Regional Plantation Companies. The clone composition for the estates under Regional Rubber Plantation Companies in 2009 is shown in Fig. 3.

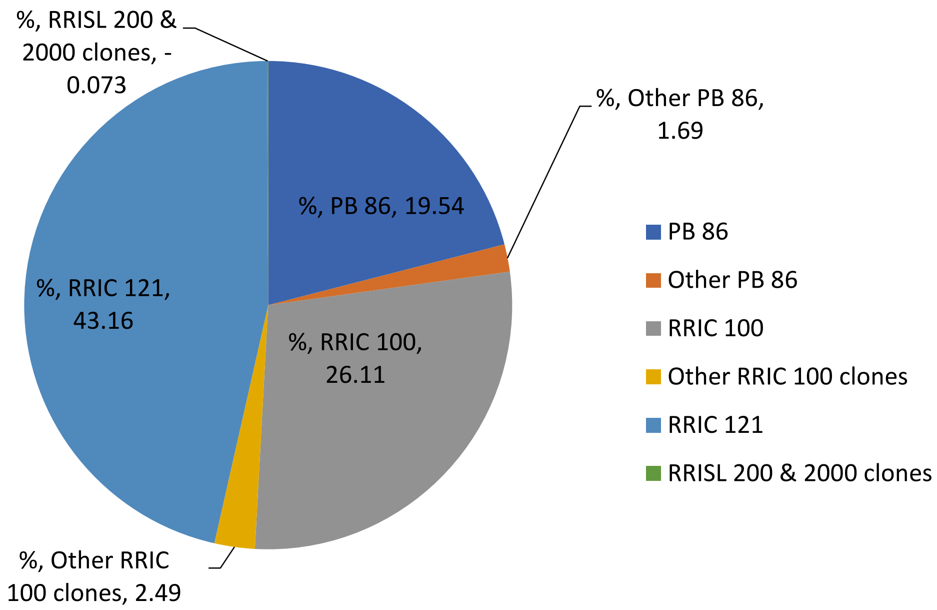

Fig. 3. The clone composition for the estates managed by Regional Plantation Companies in 2009.

As per the data, the extent under both the clones RRIC 100 and PB 86 have come down from 2002 over the seven years but unfortunately, the coverage of clone RRIC 121 has exceeded even the national coverage of 32.9% by RPC sector, covering 43.16%, and therefore, restrictions were imposed on RPCs to prevent from using RRIC 121 in their replanting programmes. The estate sector is recommended with a list of clones having more than 40 clones and they can always maintain a healthy and appropriate clone balance.

On the other hand, the smallholder sector has only RRIC 102 in Group I for large-scale planting, if RRIC 121 is withdrawn and therefore it was not withdrawn but guidelines were issued to scale down the use of the clone RRIC 121 gradually from 2011 as stated in Table 1 below.

Table 1. *The guidelines issued by RRISL in 2009 for Rubber Development Department nurseries to scale down the usage of clone RRIC 121.*

Year	Percentage of plant production	
	RRIC 121	**Other clones**
2011	60	40
2012	50	50
2013	40	60
2014	30	70
2015	20	80
2016	10	90
2017	00	100

METHODOLOGY

In 2020, a clone composition survey was conducted again from collecting data from estates with the support of the Planters' Association and from the Regional Offices of Rubber Development Department (RDD) for the smallholder sector. A questionnaire was emailed to them asking to provide us with the data recorded by them on clone composition. Data from all estates were received from their head offices and information for the smallholder sector from all regional Offices of RDD.

RESULTS

The result of the survey was alarming and especially concerning the clone RRIC 121, total coverage was 72.93%. The clone PB 86 covers only about 2% and RRIC 100 about 7.67%.

Table 2. *Clone composition hectarage and percentage of rubber cultivation in Sri Lanka in 2020.*

	Clones						
	PB 86	**RRIC 100**	**RRIC 121**	**mixed+121**	**Mixed**	**others**	**Total**
RPC (hectorage)	687.51	4350.67	7749.10	2900.71	2362.05	2789.66	20839.71
RPC %	3.30	20.88	37.18	13.92	11.33	13.39	
Smallholder sector (hectorage)	1113.00	2313.11	55635.21	0.00	0.00	7012.69	66074.01
Smallholders Sector %	1.68	3.50	84.20	0.00	0.00	10.61	
Total in the Country (hectorage)	1800.51	6663.79	63384.31	2900.71	2362.05	9802.35	86913.72
Total for the country %	**2.07**	**7.67**	**72.93**	**3.34**	**2.72**	**11.28**	

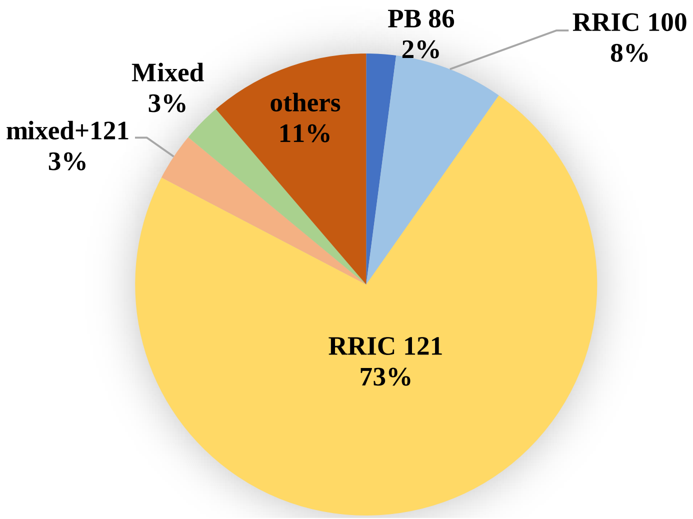

Fig. 4. The clone composition of rubber cultivation in Sri Lanka in 2020.

The actual value could be a little lower than this due to RDD providing data for the last 20 years only for a few regions. But, a high percentage of RRIC 121 needs to get down to a reasonable level immediately.

Corrective measures

It was decided that RRIC 121 to be withdrawn until its share gets down to about 25% of the total extent.

Reintroducing the clone RRIC 100 which was withdrawn in 1997 was recommended until it covers about 20% of the total extent.

Also, the underutilized clones RRIC 102 is to be promoted, through establishing budded nurseries and also making use of available budwood in nurseries, up to a level of 20-25% of the smallholder sector.

Estates under Regional Plantation Companies are expected to use the clones recommended in Group II and III in their replanting programmes.

It is also suggested to reintroduce the clone PB 86 for the smallholder farmers on their request but only up to 5% of the total extent and also after revealing the data on growth and yield.

Maintenance of the clone balance

Though corrective measures have been suggested in 2012 to maintain a balanced clone composition, the data gathered in 2020 show that the guidelines have not been adopted by either the Smallholder sector or the estates managed by Regional Plantation Companies. This is similar to most other recommendations and guidelines issued by Rubber Research Institute for the rubber sector in the country. As any non-adoption of proper clone usage can have serious effects on the sustainability of the rubber plantations in the country, and also the correction of it takes a few decades due to long life span, Rubber Research Institute may conduct this kind of survey more frequently, at least biannually, and take precautionary actions through adding and removing clones to the list of clone recommendations.

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TAPPING PANEL DRYNESS (TPD) IS A CHALLENGE FOR THE RUBBER INDUSTRY IN SRI LANKA; RESULTS OF A CASE STUDY

P Seneviratne, R K Samarasekara, P K W Karunathilake and G M N Sandamali

INTRODUCTION

Tapping panel dryness (TPD) commonly known as Brown bast is a syndrome encountered in rubber plantations, characterized by the stoppage of latex production. It is a physiological disorder that harms the performance of the rubber industry. As per the literature, this had been observed in 1887 in wild *Hevea* trees in the Amazon forest with the domestication of rubber plantations in Asia (Rutgers and Dammerman, 1914): this is earlier to the first report of disease on rubber. The first sign of the appearance of TPD is small patches of dry bark on the tapping cut, which are visible when the tree is tapped. A detailed review of the histological, histochemical and cytological study of the affected bark has been presented by Fay and Jacon (1989). Tapping intensity, clone, the physiological condition of the tree, ground condition and use of yield stimulants are common factors contributing to tapping panel dryness in commercial plantations (Senevirathna *et al.*, 2007). The incidence of TPD has now become the main factor that widens the gap between the potential and commercial yields of high-yielding clones (Obouayeba, *et al.*, 2011).

When a tree is affected with TPD it cannot be cured or completely recovered. An exact remedy for this is not yet identified but resting the tree for some period seems to help reverse or slow down the process to some level. But the tree's response to discontinued tapping and resting seems to depend on the severity of the state when detected. (Perera *et al.*, 2011) This is adopted in estate practices with a yellow colour band painted on the tree trunk.

The involvement of a causative organism for TPD was suspected by early researches but they all failed due to not being able to identify the causing the TPD condition.

However, by practicing recommended management methods TPD can be minimized. Over-exploitation should be avoided and prolonged immature periods of plants due to quality of planting material, problems with lands & poor management should be avoided. The long immature phase is often attributed to poor-quality planting materials. So using good quality planting materials at the beginning and implementation of correct agro-management practices especially during the immature phase is of prime importance. Loss of crop due to TPD is reported elsewhere also and found to be around 12-15% as reported by Chen *et al.*, 2003. But some cases reported locally indicate a very high level of TPD in both estate and smallholder sectors showing a high variation from about 10% to 70% in extreme cases. Over exploitation of trees through high tapping intensity, excessive stimulation using ethylene releasing compounds, or through a combination of both could further aggravate the TPD (Fan and Yang, 1995; Seneviratne, *et al.*, 2007).

This survey was carried out during the latter part of 2015 to early 2016 at the Kuruwita substation of Rubber Research Institute of Sri Lanka where the TPD rates of all fields were reported to be very high.

METHODOLOGY

Kuruwita substation of RRISL is located at 6° 30’- 7° 00N and 80° 00’- 80° 30’E and belonged to the Ratnapura district of the Low country Wet zone of Sri Lanka. Soil is sandy, clay loam texture and yellowish-brown color. Average annual rain fall of above 2500 mm is recorded which is distributed throughout the year. The entire estate has been rain-guarded for many years and high crops have been recorded compared to other estates of RRI and also in the area.

Data collection was carried out from November 2015 to April 2016. Every tree in each tapping block was physically monitored and data collected included the year of planting, year of tapping, clones planted, extent, number of tapping panel position, tapping system and TPD occurrence in each field. A total of 26,950 trees were observed in the survey during a period of 132 days and in 22 different fields of the estate.

RESULTS

Data collected on field number, year of planting, year of tapping, clones planted, extent, number of tapping blocks in the field, extent (ha.), panel position, tapping system, number of healthy trees, number of TPD affected trees in tapping (partially dry trees), number of TPD trees not tapped (totally dry trees), number of damaged trees, number of dead trees, total number trees and percentage of total dry trees for the fields from 1 to 22 are summarized in Table 1.

The average percentage of TPD-affected trees in the Kuruwita substation is 17% and there is another 16% of trees that are TPD affected partially and therefore, the tapping is carried out.

The highest incidence of TPD (>30%) can be observed in fields 13 and 17, whereas >20% was observed in 10, 12, 15, and 16 fields. A comparatively lower percentage of TPD (10%) is observed in 1, 2, 4, 5, 7, 8, 9 and 19 fields. Compared with higher and lower incidences moderate TPD percentage is observed in 3, 6, 11, 14 and 18 fields (Table 1).

When comparing the planting year and the percentage of TPD-affected trees, it is clear that older trees have a higher susceptibility to TPD. Most of the highly affected fields are planted during 1992 and 1999. Although some information is not recorded these fields must have been opened for tapping from 1998 to 2005.

The lowest TPD percentages are shown in 1, 2 and 9 fields which are planted in 2006, 2007 and 2001 respectively. 1 and 2 fields have been opened for tapping in 2015

(Table 1). Figure 1 shows the TPD percentage of trees categorized into partially and fully affected and the total of the two for four categories based on the planting year.

Table 1. *A summary of the data gathered from 22 fields*

Field Number	Year of Planting	Year of Tapping	Clone/s planted	Number of tapping blocks	Extent (ha)	Panel position	Tapping system	Number of Healthy trees	No. TPD trees in tapping	No. TPD trees not tapped	Runts	Damaged trees	Dead trees	Total trees	Total TPD trees (%)
1	2006	2015	RRISL 203	1	0.8	A1	S/2 d2	289	.	4	68	3	4	368	1
2	2007	2015	92/132, 92/124, 92/129	1	0.6	A1	S/2 d2	250	.	9	17	.	3	279	3
3	2006	2012	78/759, 78/278, 78/873, 87/203, 78/534, 78/510, 78/770, HP clones	3	2.2	A1, A2, A3, B1	S/2 d3	769	169	234	174	1	3	1350	17
4	2006	2012	RL 212, 93/12, RL 214	1	0.8	A1, A2, A3,	S/2 d3	101	1	14	26	2	.	144	10
5	2005	2012	RRISL 201, 203 (mixed), 100 seedling s, RRISL 2000, GPS 2	4	4.0	A3, A4, B1	S/2 d2	1559	160	131	100	3	12	1965	7
6	2002	2009	95/33, 95/55	1	2.9	A1, A2, B1	S/2 d3	21	65	15	6	.	5	112	13
7	2002	2009	99 hp ,90 hp clones	3		A4, B1, C1	S/2 d3	695	340	85	114	15	35	1284	7
8	2002	.	RRIC 121	6	3.8	A6, B1	S/4 d3, S/2 d4	1119	316	91	67	8	37	1638	6
9	2001	2008	98 hp clones	3	2.3	B3, C1	S/2 d2	468	489	45	30	17	83	1132	4
10	1999	2006	RRIC 100,102, 121,131	3	2.0	B6, C1	-	1542	70	563	37	28	153	2393	24
11	2001	2008	RRIC 121	12	6.0	B2, B3, C1	S/2 d3	2737	248	445	81	31	180	3722	12
12	1992	1999	RRIC 101, 102	2	1.8	C1, C2, C8, D1	S/2 d2	287	176	156	7	9	23	658	24

13	1992	1999	RRIC 101, 102	4	4.3	C,D	S/2 d2	484	668	855	25	24	115	2171	39
14	1992	1999	Mixed clone	1	1.0	C6, D1, D2	S/2 d2	694	554	462	48	22	213	3226	14
15	1998	.	Mixed clone	1	0.4	B6, C1	S/2 d2	523	84	193	24	6	61	891	22
16	1993	.	RRIC 100	6	5.0	C	S/2 d2	1529	451	834	121	37	393	3365	25
17	1994	.	RRISL 201,202	6	3.0	B6, C1	S/2 d2	456	242	397	.	13	.	1108	36
18	1995	.	RRIC 222, 133,217	3	2.0	B6, C1, C2	S/2 d2	495	182	134	46	29	.	886	15
19	2006	2012	RRIC 121	1	0.8	B, C	S/2 d2	117	65	14	9	5	48	258	5
20	1991	.	RRIC 121, 203,100	8	6.1	D2	S/2 d2	276	132 5	117 7	40	30	160	3008	39
21	1990	.	Mixed clones	6	3.0	D	S/2 d3	146	406	418	7	9	14	1000	42
22	1990		Tea and rubber mixed clones	3	2.3	D	S/2 d2	78	155	189	12	37	421	892	21

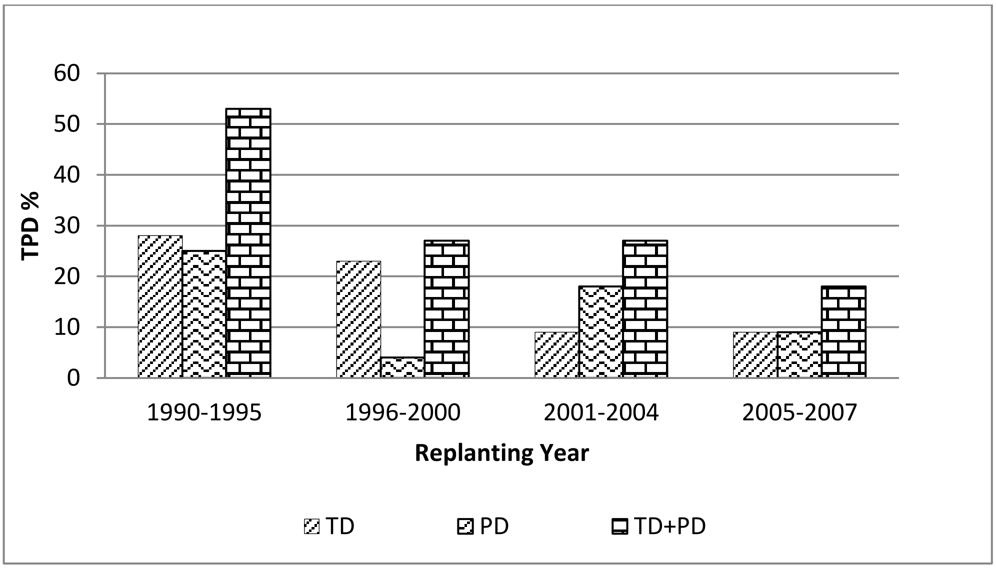

Fig.1. TPD percentage of trees categorized into partially and fully affected and the total of the two, for four age categories based on the year of planting.

Partially dry tree percentage show a decline in 1996-2000 age category than that 0f 2001-2004 age category which is mainly owing to difficulties encountered in taking physical observations However, when both partially and totally TPD affected tree percentages show a reducing trend with the age when the two are considered together (Fig.1). The correlation of percentage of totally TPD affected trees and planted year for individual fields are shown in Fig. 2.

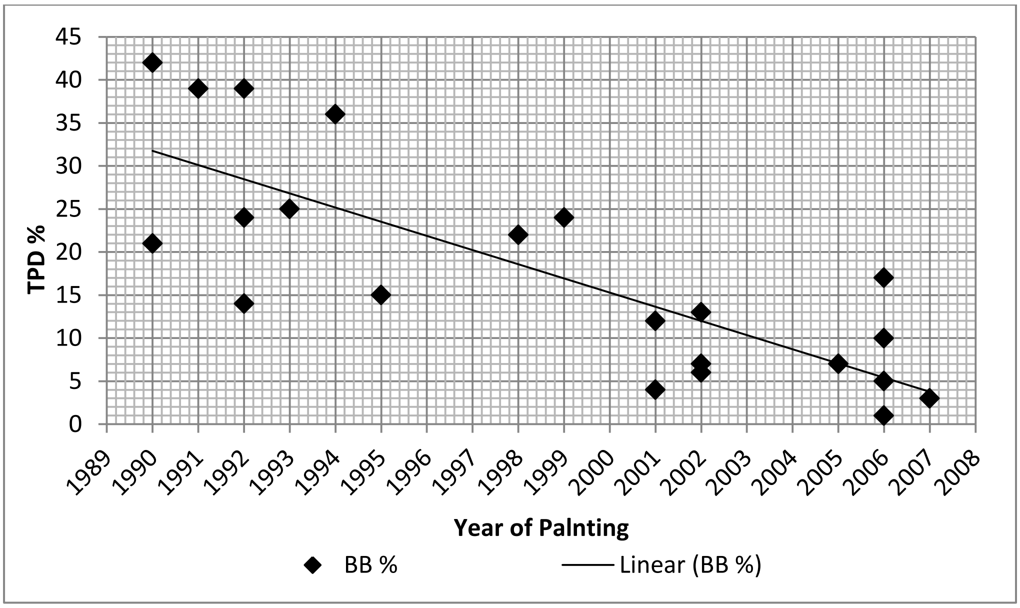

Fig. 2. Correlation of percentage of totally TPD affected trees and planted year for individual fields.

As shown in Fig. 2, when the totally TPD affected trees are correlated to the age of the clearing, TPD percentages show differences though a linear relationship is seen. This can be mainly attributed to the clones planted and further, the presence of hand-pollinated progenies. Furthermore, the years of the opening of tapping are also different. Details of the fields with relatively high TPD affected trees are shown in Table 2.

Table 2. *Details of the fields with relatively high TPD affected trees*

Field	YOP	Clones planted	Tapping system	TPD%
10	1999	RRIC100,102,121,131	-	24
12	1992	RRIC 101, 102	S/2 d2	24
13	1992	RRIC 101, 102	S/2 d2	39
15	1998	-	S/2 d2	22
16	1993	RRIC 100	-	25
17	1994	RRIC 201,202	S/2 d2	36

These fields have been planted between 1992 and 1999 and with RRIC 100 series clones, RRIC 100, RRIC101 and RRIC 102.

Discussion

The reason for the survey on TPD at the Kuruwita substation was the high percentage of TPD recorded in many experimental fields conducted mainly by the Genetics and Plant Breeding Department which contains hand-pollinated progenies most of the time. The results confirm above-average percentages of TPD but, the TPD incidences are high with RRIC 100 series clones than that of HP progenies. High TPD in RRIC 101 has been observed by Zoyza *et al.,* (1984) and in RRIC 100 series clones by Seneviratne *et al*., (2007). In the present survey too, a high percentage of TPD is reported for RRIC clones in general, but direct comparisons are not allowed due to differences of different fields more than the clone.

Though the advancement of panel positions shows a gradual increase with the age of the trees, a detailed bark auditing was not conducted to report the bark consumption rate due to TPD is a result of many factors as reported by almost all who have studied or surveyed on factors contributing to TPD. However, high yielding clones show the effect of TPD on the crop more than the low yielding trees as discussed by Obouayeba *et al*., (2011), due to the high gap between potential and commercial yields. Generally, the latex yield is the capacity of the tree to supply latex vessels with sucrose which depends on photosynthetic rates and sucrose translocation. The simple explanation for this is that when the rate of latex harvesting exceeds the rate of physiological regeneration trees, the tree should react for its survival and TPD is known as a protective mechanism. A series of biochemical changes take place within the plant showing the most common symptom of excessive late dripping with a significant fall in the rubber content in latex followed by a gradual decline in the volume leading to drying up of the tapping cut Premathilake *et al.,* (1986).

In that case the bark auditing alone cannot be used to explain the TPD incidences but the frequency and also the time of the year too along with tapping frequency. Frequent tapping and usage of the stimulants increase the rate of harvesting and thereby increase TPD as reported by Seneviratne *et al.*, (2018) based on data gathered from a survey on bark auditing of about 5000 ha on estates managed by regional plantation companies. As explained earlier, the Kuruwita substation was on rainguards continuously for many years and the number of tapping days per year is maintained at optimum possible.

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NON - WICKHAM GENETIC BASE TO ENRICH THE *HEVEA* BREEDING POOL IN SRI LANKA

B W A N Baddewithana and S P Withanage

INTRODUCTION

After the discovering of the rubber plant from the Amazon rainforest of South America by Sir Henry Wickham, 70,000 seeds were germinated at the Kew Garden in England. Then, this collection was distributed to main rubber producing countries and from that, 1919 seedlings were transferred to Sri Lanka and planted at the Henerathgoda Botanical Garden in 1876.

The rubber cultivation in Sri Lanka was initiated as a commercial cultivation in 1883. At the beginning, planting materials derived from seeds and seedlings introduced by Sir Henry Wickham were used for rubber cultivation and multiplication purposes. So, it is commonly called the "Wickham genetic base". However, introduction of new materials from natural habitats of Amazon basin has been restricted due to the fear of accidental introduction of South American Leaf Blight (SALB). Therefore, genetic base in the original population is narrow.

Starting from this introduction which yielded around 300-400 kg/ha/yr. (Jayasekara and Fernando, 1994). At the beginning, high-yielding trees were identified from rubber estates and seedlings were raised from seeds collected from these high-yielding trees. Later, they were used as the planting materials. Nevertheless, with the perfection of the bud grafting technique in 1917 by Van Helten clones became the main type of planting material. As a result, now it is yielded around 2000-25000 kg/ha/yr. However, This Wickham genetic base has been utilized for *Hevea* breeding in past extensively. Even today, it contributes largely in *Hevea* genetic improvement.

Non-Wickham genetic base or 1981 collection of *Hevea* germplasm

In the 1970s, the need for new *Hevea* germplasm arose from the realization that there was a gradual erosion of the genetic variability of the rubber clones in many natural rubber plantations due to extensive use of Wickham originated planting materials. Hence, to broaden the genetic base of the major producers of natural rubber, it became necessary to undertake an expedition to the Amazon basin. Therefore, in 1981, member countries of the International Rubber Research and Development Board (IRRDB) funded a project to collect new *Hevea* germplasm considered as non-Wickham genetic base to obtain materials for the current 'gene pool'. As a result, collection teams travelled into the remotest parts of the Amazon rain forests and it was covered three Brazilian states: Acre, Mato Grosso and Rondônia looking for high-yielding and disease-resistant trees from which to collect seeds, budwoods and seedlings growing around the trees. Three teams collected a total of 64,256 seeds, 1413 meters of budwood, and 1160 seedlings. (Onokpise, 2004; Simmonds, 1989).

Establishment of 1981 *Hevea* germplasm in Sri Lanka

As the first consignment, Sri Lanka received of 100 germplasm accessions in 1984 and periodically 8564 genotypes during the period 1985-1989. This *ex*-situ collection was established at Dickhena division of Neuchatle estate, Galpatha, Horana in Kalutara district. The total extent of this ex-situ collection is 13 ha and there are four plants each genotype planted in space (1 m x 1 m).

Fig. 1. 1981 *Hevea* germplasm established at Neuchatle Estate, Horana

Evaluation and utilization of 1981 *Hevea g*ermplasm around the world

1. Several genotypes of 1981 *Hevea g*ermplasm have been evaluated in Malaysia in 1987. In here, they were used the disease resistant ability of them as a criterion to study the genetic variability within and between genes.

2. Preliminary evaluation of some of the 1981 *Hevea* germplasm in India, also reveal that the wide variability with respect to growth parameters like plant height, girth, number of leaves, number of flushes, bark thickness, number of latex vessel rings and juvenile yield in 1988.

3. Further, 162 genotypes have been studied from 2004 to 2005 in Malaysia by the International Rubber research development Board (IRRDB). In here, they were recorded their girth, yield, number of latex vessels. Yet, suitable genetic traits for use in commercial cultivation have not been identified.

4. In 2011, growth habit, yield, bark thickness and timber quality have been evaluated for selected accessions of a mature plantation in 1981 germplasm by Indian scientist.

Thus, there have been morphologically evaluated of most of the genotypes established in Asian countries, African countries, South America and Vietnam in 2012. Even, some of these genotypes are successfully utilized for breeding purposes also.

Evaluation of 1981 *Hevea* germplasm in Sri Lanka

Although, germplasm evaluation is an alternative for the conventional breeding process of *Hevea*, it is somewhat difficult to perform successfully due to its unpredictable genetic gain. However, some of the accessions have been studied from

1981 germplasm collection from 1988 to present. Moreover, some selected accessions were used for breeding programmes also.

1. First consignment of 100 accessions were established at Kuruwita substation under small scale level and Morris - Man test tapping has been done at the end of year 1989 (Jayasekara, 1989). In here, five girth measurements were recorded from 1988 to 1992, inclusive of both years growth rates were assessed by regressing individual tree using girth on taking years 1,2,3,4 and 5 as independent variable (Jayasekara 1991). In there, accession MT-C-1-1 was recorded highest mean girth value than RRIC 121, RRIC 102 and RRIM 600 clones which originated from Wickham's collection.

2. In 1993, 600 genotypes have been evaluated in at the nursery stage and two promising genotypes were identified by test tapping in 1994. Yield of one genotype (GPS II) dropped and other genotype (GPS 1) continued to give high yields. (Jayasekara, 1994). Number of test tapings done and mean yield of these two genotypes in 1994 are shown in Table 1.

Table 1. *Number of test tapings done and mean yield of two promising genotypes at Kuruwita sub station*

Accession and Accession code	No. of Test Tapping	Yield (g/t/t)
GPS 1 (AC/S/12-559)	40	91.7
GPS II (AC/F/6A -471)	36	40.2

By further test tapping of plants, it has been able to identify another four genotypes which yielded more than 30 g/t/t. Average test tapping yield of first three years and the average yield on fourth year are given in Table 2.

Table 2. *Average test tapping yield of first three years and the average yield on fourth year of four promising genotypes yielded more than 30 g/t/t selected from evaluation of first consignment of 100 genotypes at Kuruwita sub station*.

Accession code	Average Yield (g/t/t) for first 3 years (1992 to 1994)	Average yield (g/t/t) on fourth year 1995
22-137 (RO/JP/3-137)	41.65 (77)	33.41 (156)
GPS II (AC/F/6A -471)	46.36 (73)	42.72 (151)
GPS 1 (AC/S/12-559)	77.65 (73)	99.85 (156)
44-24 (RO//CM/10-24)	48.01 (77)	46.83 (153)

* Numbers/ data in parenthesis indicates the number of test tappings done for each average yield. (Source: Review of the Genetics and Plant Breeding department, 1994)

Further in 2014, a project was implemented for multiplication/establishment and scientific evaluation of the *Hevea* germplasm collection.

Main objective was,

- Enhancement of productivity through genetic improvement and management of genetic resources of *Hevea*.

Specific objectives were,

- Establishment and maintenance of the 1981 IRRDB germplasm collection obtained from 1981 IRRDB expedition to the Amazon.
- Scientific evaluation of the *Hevea* germplasm collection to classify the genotypes according to genetic parameters and by using molecular markers to identify promising genotypes for future breeding programme.
- Incorporation of promising genotypes to *Hevea* breeding programme.

Evaluation in 2014

There are four thousand fifty-seven (4057) trees were selected from 1478 number of accessions and pollarded at the height of 4 ½ ft above the ground level to prepare bud woods. A Poly bag nursery was raised with 16,000 plants and ground nursery was established with 1000 plants. After bud grafting of these sections, they were planted at three planting sites Nivitigalakele substation (9.2 ha), Polgahawela substation (2 ha) and Monaragala substation (1ha) (Withanage, 2015). Girth and yield data are being collected from these sites continuously.

Evaluation in 2015

Twenty-five accessions were selected out of around 2000 accessions of Neuchatel estate germplasm nursery by evaluating their girth, bark thickness, canopy architecture and latex flow (g/t/t) as preliminary selection criteria. The 25 top performing accessions were selected and the mean values of each criterion are given in Table 3.

Table 3. *Average mean values of girth, bark thickness, floral canopy rating and latex flow (g/t/t) of each selected 25 accessions*

Accession	Girth (cm)	Bark thickness (mm)	Floral canopy rating	Latex flow (g/t/t)
1	57.5	12	3	58.5
2	68.5	10	3	65.2
3	80	12.5	2	58
4	75.5	9	3	60.4
5	78.5	9	3	60.2
6	68.5	9	3	59.7
7	67.5	12	4	63.3
8	77	11	3	58.5
9	59	10.5	4	60.3
10	65	11	4	62
11	58.5	11	4	60.5
12	65.5	10.5	3	61

13	58	12.5	4	57.3
14	66	10	4	55
15	69	11	3	60.7
16	59	10	4	61
17	65	12	3	56.4
18	68.5	13	4	62
19	90	13	3	71.4
20	83.5	10.5	4	60.7
21	63	11	4	64.2
22	72.5	11.5	4	67.1
23	88	12	4	78.3
24	85	12	4	76.7
25	73.5	11	4	66.8

Based on the average values of girth, bark thickness, floral canopy rating and latex flow (g/t/t) of each selected 25 accessions from preliminary selection criteria, their variations are shown in Figure 2.

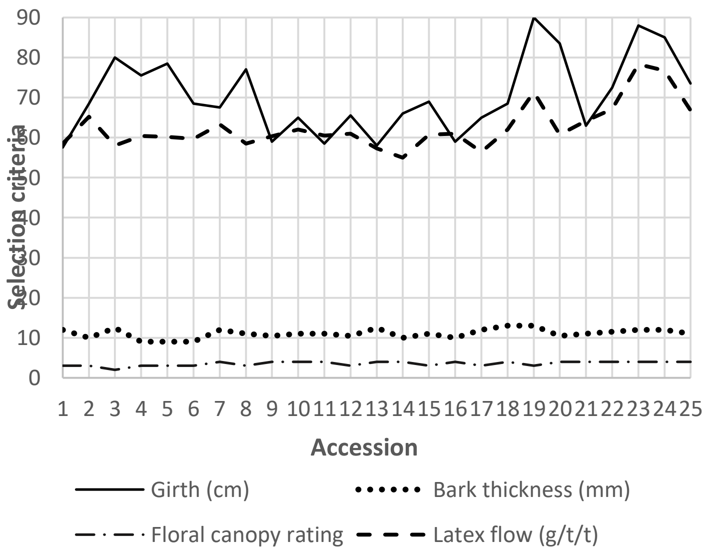

Fig. 2. Average values of girth, bark thickness, floral canopy ratings and latex flow (g/t/t) of each selected 25 accessions

Key	
No.	**Accession**
1	1-4
2	1-44
3	1-53
4	RO 2-4
5	RO 2-32
6	RO 2-96
7	RO 3-298
8	RO 3-300
9	RO 3-467
10	AC 4-58
11	AC 5-153
12	AC 5-163
13	AC 6-13
14	MT 7-23
15	MT 7-36
16	MT 7-61
17	MT 7-187
18	MT 10-100
19	MT 10-146
20	MT 10-158
21	MT 10-161
22	MT 11-13
23	MT 11-76 I
24	MT11-76 II
25	MT 7-88

Above 25 accessions were multiplied and planted in completely randomized block design with three replicates in Neuchatel estate and each replicate contained five plants from each 25 accessions and as controls, clones RRIC 121 and RRISL 203 were used. After one year of planting, the measurements were taken. As morphological and physiological measurements i.e., their girth, leaf area, chlorophyll content, leaf colour, tree height and inter whorl length were recorded. After taking the mean value of each accession for each criterion, data was analyzed using one-way ANOVA.When significant differences were detected, multiple comparison procedures (Duncan's Multiple Range Test) were performed to study the differences among the means. Also, average linkage multivariate cluster analysis was done to combine the relationships of each 25 accession and control clones for all morphological and physiological parameters. According to the dendrogram, seven different clusters were shown at average distance of 0.85 (Fig. 3 & Table 4).

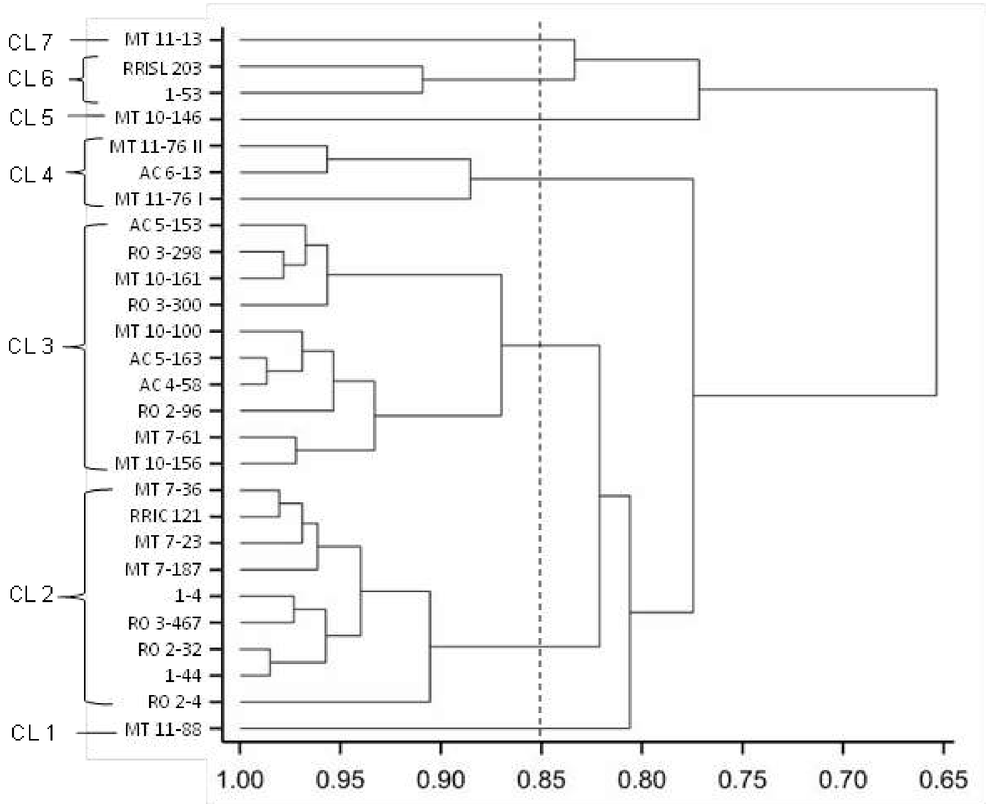

Fig. 3. Dendrogram for 25 accessions and two control clones based on average linkage multivariate cluster analysis using all the morphological and physiological data (Baddewithana *et al.*, 2017).

Table 4. *Explainable relationships of among all accessions and control clones under different clusters.*

Cluster No.	Explainable relationship for cluster divergence
1	There is no explainable relationship within and between clusters
2	There is no explainable relationship within and between clusters
3	There is no explainable relationship within and between clusters
4	MT 11-76 I and MT 11-76 II have shown significantly higher values than all the accessions and both of control clones under the leaf color measurements MT 11-76 II has recorded significantly higher values than control clone RRISL 203 and another sixteen accessions from girth measurements MT 11-76 II has shown significantly higher values than another six accessions from tree height measurements MT 11-76 I has recorded significantly higher values than another five accessions from chlorophyll content measurements MT 11-76 I has shown significantly higher values than another three accessions from girth measurements There is no explainable relationship with accession AC 6-13
5	MT 10-146 has recorded significantly higher values than another five accessions from girth measurements MT 11-76 I has shown significantly higher values than another six accessions from tree height measurements MT 11-76 I has shown significantly higher values than another 23 accessions from inter - whorl length measurements
6	There is no explainable relationship within and between clusters
7	There is no explainable relationship within and between clusters

Therefore, according to the conclusion of this study, accessions MT 11-76 I, MT 11-76 II and MT 10-146 showed good performances compared to control clones. In addition, accession MT 11-13 also showed good performances than other accessions and two control clones except MT 11-76 I, MT 11-76 II and MT 10-146. From these selected accessions, MT 11-76 I, MT 11-76 II are already added for the clone recommendation as the interim clones.

In addition to above evaluations, these germplasm accessions have been used successfully for annual hybridization programmes from 1995 to 2020 as the male parent, female parent or both.

Current situation of 1981 *Hevea* germplasm in Sri Lanka

In Sri Lanka, 1981 *Hevea* germplasm is now about nearly 30 years old. Vigorous accessions have over grown by hindering the less vigorous ones. It is badly affected to loss of less vigorous genotypes from the collection. Also, some accessions may be destroyed by various abiotic reasons. Therefore, it is necessary to protect them by restoring. On the other hand, almost all the genotypes in this location should be duplicated to avoid it from being lost to the world. Moreover, germplasm collection is a valuable asset to a country to develop high quality varieties and planting material through the incorporating them for the breeding programme.

Therefore, it is clear that how it is important to future uses of the rubber sector and it is a better alternative for the conventional breeding programme of *Hevea* through the ensuring their genetic gain. To conclude, evaluation, utilization, maintenance and conservation of this germplasm collection is very valuable not only to prevent the loss of them to the world but also, to expand the genetic diversity of *Hevea*.

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POTENTIAL OF GROWING SOME ECONOMICAL CROPS ALONG THE BOUNDARIES OF RUBBER PLANTATIONS

T U K Silva, N M C Nayanakantha and D Priyadarshana

INTRODUCTION

Fluctuations or stagnations of natural rubber prices and increasing trends in the cost of production cause uncertainty in the rubber industry. The long immature period and adverse weather conditions (Jeewanthi *et al*., 2016) during themature phase of rubber aggravate the problem further. With this context, rubber-based intercropping has become one of the proven technologies to mitigate these problems providing opportunities for rubber growers to earn an extra income from their lands while increasing the land-use efficiency (Rodrigo *et al*., 2005). However, the applications of intercropping practices at the field level are limited due to different socio-economic limitations (Pathirathna, 2006). Further, due to some procedural barriers, possible reluctance on higher investments and difficulties faced while attending to the agronomic practices are compelled some growers to move away from systematic rubber intercropping models (Wijesuriya *et al*., 2007). Therefore, a simple technique that is more practical can be implemented in order to achieve some sort of benefits rather than a mono-cropping condition. Early attempts made by Rodrigo *et al*., (2002), utilizing the fencing area with timber plants were prominent in rubber plantations. However, it is difficult to adopt these practices due to some socio-economic conditions of farmers such as long gestation period, legal and procedural barriers and difficulties in felling of trees. Therefore, the introduction of diverse crops has to be considered in order to utilize the boundary of rubber plantations in a useful manner. According to Hitinayake *et al*., (2018), diverse crops along the living fences provide extra protection to the field and also provide timber, fruits, medicines and foods. Further, the living fences act as a hidden resource of soil fertility by providing green manure (Theobald *et al*., 2014). On the other hand, some perennial crops such as tea and cinnamon cannot be accompanied by rubber smallholdings due to the limited land size (Pathirathna and Perera, 2003). With this context, the aim of this study was to determine the possibility of growing some economical crops along the rubber fences in order to utilize the-boundaries of the rubber land more economically.

MATERIALS AND METHODS

The experiment was established in 2010 incorporating rubber with five crops in a 5.0 ha field at Hapugastenna estate, Ratnapura (Table 1). The clone RRIC 121 was used as the planting material of rubber.

Table 1. *Different crop species planted along the boundaries of rubber field and spacing kept within the species*

Crop	Spacing (m) along the fence
Cinnamon (*Cinnamomum verum*)	0.6 x 0.6 paired rows
Rattan (*Calamus rotang*)	2.5
Messengiana (*Dracaena messengiana*)	0.9
Cane Palm (*Dypsis lutescens*)	0.9
Arecanut palm (*Areca catechu*)	2.0

Rubber and five species of border crops were planted from May 2010 to October 2010. Lining was done for rubber planting following spacing; 2.4 m within the row and 7.75 m inter-rows. The boundary area was divided in to three parts in order to establish three replicates considering the light availability and space for the neighboring field. Each replicate was divided in-to five sub-sections to facilitate each crop following the spacing given in Table 1.

Immature upkeep of rubber was done following the recommendations given by RRISL. Weeding was done around the crops planted along the boundary. Fertilizer was applied for the boundary crops only during the first two years after planting because of the ambition of maintaining those under low inputs. However, the establishment of cane palm was difficult from the very early stages due to the pest attacks like wild boar, porcupine and rabbits. Also, the establishment of rattan showed similar results. Therefore, infilling had to be done in May 2011 for the above two crops.

Growth of rubber has been assessed as the girth measurement taken at 150 cm above the ground level from the first year onward. Growth of each crop in terms of basal girth at 5 cm height and overall plant height were measured annually. Count of the number of harvestable sticks of cinnamon was taken annually. Two complete samplings have been conducted during the period of study in order to estimate the bark yield of cinnamon. At first, the fresh weight of the cinnamon bush was taken and then separated into the main stem, branches, twigs and leaves. These parts were also weighed separately as fresh weights and then the main stem has been taken to assess the bark yield. The bark yield was estimated using the samples collected from three places of the stem, i.e. top, mid and bottom. These samples were peeled using a peeling set of cinnamon and bark collected from each stem was dried at room temperature to get the constant dry weight of the bark. Ultimately, woody parts, leaves, twigs and bark were dried in an oven at the temperature of 105 ^{0}C for constant weight. The above information was used to estimate the bark yield of cinnamon in each stem.

RESULTS AND DISCUSSION

In this experiment, the gap (m) between rubber trees and adjacent boundary crop in terms of maximum, minimum and mean are shown in Table 2. Generally, such gaps varied according to their own spacing as widely spaced fence crops, i.e., arecanut and messengiana kept wider gaps (mean) with rubber as well.

Table 2. *The gap (distance) in terms of maximum, minimum and average between the boundary crop and the outermost rubber row*

Crop	Gap (m) between the first rubber row and the adjacent crop		
	Maximum	**Minimum**	**Mean**
Arecanut	6.40	0.50	2.15
Cinnamon	5.40	0.65	1.81
Messengiana	4.90	0.85	2.85

The establishment rates of cinnamon and messengiana were higher than that of the other three species. The height and girth of different crops are shown in Table 3 and 4, respectively. Plants of arecanut and cane palm were damaged by the rabbits frequently as the trial field is very closer to a forest reservation. Rattan plants showed very slow growth compared to other crops at the beginning but new shoots could be seen at the basal area of the plant (Table 3). Infilling has been done in order to minimize the casualties of the above three species up to the year 2011.

The growth of rubber trees was assessed by measuring the girth at 150 cm above the ground level annually (Table 4). The mean girth of trees in three consecutive rubber rows adjacent to the arecanut, cinnamon and messengiana is shown in Figure 1.

Table 3. *Mean overall height (m) of different crops grown along the boundary from 2012 to 2017*

Crop	Overall height (m)					
	2012	**2013**	**2014**	**2015**	**2016**	**2017**
Cinnamon	0.784	0.21*	2.1	1.73*	2.14	2.61
Rattan	0.184	0.61	0.7	0.97	0.97	0.82
Messengiana	0.513	1.44	1.64	1.73	1.80	nm
Cane Palm	0.819	1.28	1.3	1.32	1.43	**
Arecanut	0.575	1.18	1.3	2.86	3.60	4.58

* reduction due to harvesting, ** damaged by rabbits and wild boars, nm- not measured

Table 4. *Mean basal girth (cm) of different crops grown along the boundary from 2013 to 2017*

Crop	Basal girth (cm)				
	2013	**2014**	**2015**	**2016**	**2017**
Cinnamon	8.25	8.85	6.26*	10.53	11.05
Rattan	nm	nm	nm	nm	nm
Messengiana	14.05	15.02	21.02	21.93	26.53
Cane Palm	11.75	12.35	12.35	13.75	**
Arecanut	14.06	15.26	33.67	35.06	39.11

* reduction due to harvesting, ** damaged by rabbits and wild boars nm- not measured

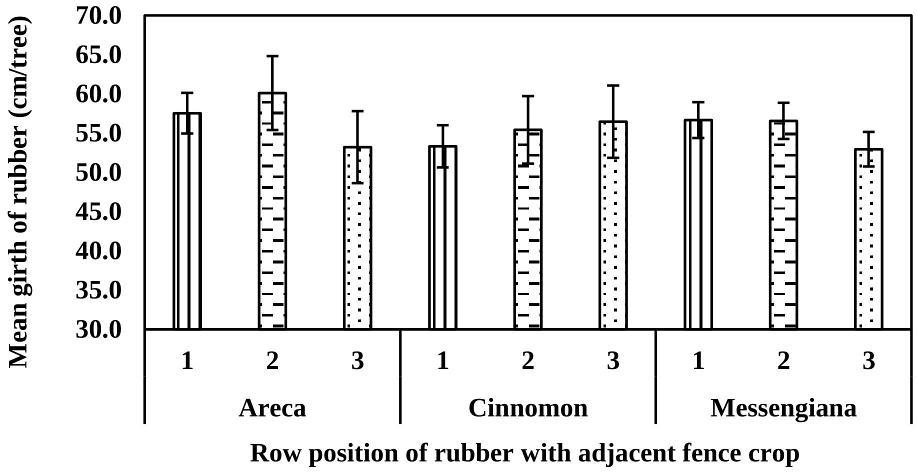

Fig. 1. Mean girth of rubber trees representing three rows of rubber adjacent to the three boundary crops. Error bars represent the Standard Error of Means.

The girth values across the row position were more or less similar indicating the effectiveness of each other was negligible. As far as the rubber yield per tree per tapping is concerned, a similar pattern of results was recorded for the same row positions with similar adjacent crops Figure 2.

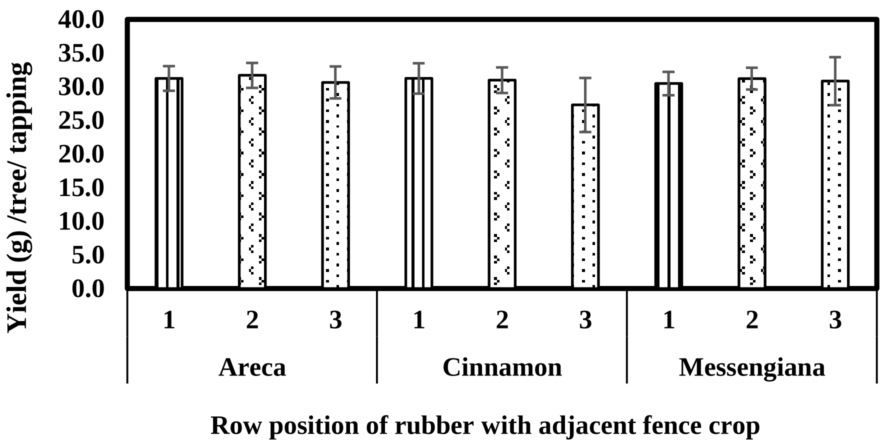

Fig.2. Mean yield (g) per tree per tapping of three rows of rubber adjacent to the three boundary crops. Error bars represent the Standard Error of Means.

No marked differences of yield among rubber rows in any fence crop adjacent to the rubber rows were observed. The cinnamon performed better from the initial establishment as described in Figure 3. Although, cinnamon became the harvestable stage at the end of 2013, harvesting has been started in 2014 until sampling has been done. Cinnamon yield in terms of dry weight per bush in three replicates is given in Table 5.

Fig. 3. Growth of rubber and cinnamon at 1st & 2nd year after planting

Table 5. *Yield assessments of cinnamon, dry weight per bush, harvested sticks and total crop in between 100m distance of three replicates along the fence during 2014*

Replicate	Dry weight (g)/bush	Harvested sticks/100 m	Total crop (kg)
1	141.9	365	52
2	92.83	280	26
3	131.56	378	50
Mean	122.00	340	43

Dry weight per bush was lowest in replicate 2 which has been directed to East-West row position due to the mutual shade along the cinnamon hedge. The other two replicates are planted in the North-South direction allowing an equal chance to get sunlight. However, the mean dry weight was 122 g per bush. Harvested sticks and bark yield per 100 m distance along the hedge also behaved similarly among the three replicates. Finally, this system produced 43 kg of bark yield along 100 m distance along the boundary.

Assuming that the 400 m theoretical peripheral for one hectare of rubber land, the total cinnamon crop will be four times (43 kg x 4) and nearly 172 kg. The net sale average of cinnamon was Rs. 1,600 at that time and therefore, the estimated income was Rs. 275,200.00. In 2018, the mean bark yield was 27 kg and therefore, the total crop was 108 kg. At present the net sale average (NSA) of cinnamon is Rs. 2500.00 per kg and therefore, the estimated income will be Rs. 270,000.00.

Conclusions

According to the growth, yield and financial performance cinnamon can be recommended as a boundary crop for the rubber plantations. There are no marked variations of growth and yield of rubber adjacent to the fence crops.

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POSSIBLE PEST AND DISEASE PROBLEMS IN RUBBER CULTIVATIONS OF NON-TRADITIONAL RUBBER GROWING AREAS

T H P S Fernando, M K R Silva, B I Tennakoon and S C P Wijayaratne

Rubber plantation industry plays an important role in the economy of Sri Lanka. This industry-provides employment to over 500,000 people (CARP, 1992) and the plantations supplements thousands of hectares to the forest cover providing many other socio-ecological and economical benefits. The natural rubber exports generate foreign exchange annually on large scale compared with the other income sources of the country. The industries based on natural rubber latex are flourishing in the country in view of enhancing the value addition.

Rubber cultivation in Sri Lanka has been limited mainly to the Wet Zone of the country for almost around one hundred years since its domestication. There is virtually no way for further expansion for rubber growing in traditional rubber growing areas due to urbanization, land fragmentation and industries. Hence the government had taken steps to expand the cultivation initially to Uva province and further to Eastern and Northern provinces. As a result of the efforts, rubber cultivation in the Uva province has shown great improvements. Stakeholders are now getting a stable permanent income and socio-economical status is showing positive trends. These areas are currently being developed by the government and it has been reported that more land is available in these areas for the expansion of rubber cultivation.

Even though the main factors affecting the growth are sufficient, compared to the traditional rubber growing areas more attention should be given to maintain the required management practices. The new climatic conditions not only influence the crop growth and development but are also expected to alter stages and rates of pathogen developments, host resistance and host-pathogen interactions. Increasing pressure on the conventional agricultural systems in these areas may disturb the harmony among the crops & pathogens leading to sudden disease outbreaks.

In the recent past, positive factors have been identified to show that disease incidence and severity levels may change while moving from traditional to non-traditional areas. The potential disease threats specific to those areas should also be identified. And all the possible attempts should be made to keep the new and potential diseases to a minimum level. During the past, more than sixty diseases and pest attacks have been reported from rubber plantations in Sri Lanka (Jayasinghe, 2010). With long experiences in the traditional rubber growing areas, the Department of Plant Pathology and Microbiology is surveying for potential threats in new rubber growing areas. The Department wants the Researchers, Extension Officers and growers to be vigilant on the changing disease conditions. The relative disease severity levels, time durations and also the symptoms may change with the new conditions. Weather pattern plays an important role in the development, spread and management of diseases since the severity and timing of attack is often linked to certain sequences of weather factors and their patterns. It has been reported that rainfall is the most important climatic factor while the temperature, humidity and the length of the rainy season too, play a role.

Foliar diseases

Under low moisture and high temperature, the establishment rate of pathogens may decrease but once established, the spread will be much more enhanced. Organisms such as *Corynespora cassiicola*, the causative agent of Corynespora leaf fall disease and *Drechslera heveae*, which causes birds eye spot disease have been declared as sun-loving diseases. These pathogens produce toxic metabolites which are harmful against the host plants and their action will be much more enhanced under adverse climatic conditions. Pathogens like *Corynespora cassiicola* show a wide host range and many home garden-plant species are reported as alternative hosts. Many vegetable & fruit crops such as cowpea, peanut, brinjal, tomato, manioc, papaw etc. were found infected with the pathogen and have been regarded as alternative hosts. Under laboratory conditions, the cross infection abilities have been shown and hence there is a high possibility for cross-infections to occur leading to sudden disease outbreaks. On the other hand, foliar pathogens like Colletotrichum have also been isolated from Ampara, Padiyathalawa, Mahaoya, Polonnaruwa, Vavuniya etc. in the multi-cropping systems from alternative host plants.

Stem & Branch Diseases

Stem & branch diseases have not commonly been reported from these non-traditional areas. There were several disease reports of pink disease condition caused by *Corticium salmonicolor* and ustulina stem rot condition caused by *Ustulina deusta*. With regard to the pink disease, our growers should be vigilant as it is very serious in India. However, a disease of the collar region like Patch Canker has been reported several times. The spread of the disease is slow as the wet days are limited. However, in the case of any incidence, immediate control is needed. It has been noted that the occurrence of predisposing factors for these diseases is high. Hence proper recommendations are needed to avoid such disease incidences.

Root Diseases

In Sri Lanka, three main root diseases; i.e. white root disease, brown root disease & black root disease have been reported. Compared with the destructive leaf diseases, management of root diseases is possible. But usually, root diseases receive less attention probably as they are ‘unseen’ until very late stages. In traditional rubber growing areas, white root disease is identified as the most destructive and causes a considerable economic loss.

There is a high possibility to occur root diseases in nontraditional areas as well as it has been reported that the recommended land clearing methods are not properly adopted. The repercussions of such negligence will be evident after about 5-10 years of planting. The Extension Officers should educate the growers of the negative outcomes of these mal-practices as these growers have less experience of the disease problems.

Though there is a possibility to occur any root disease, so far the Department has received complaints on White root disease & Brown root disease incidences. The spread of white root disease is comparatively slow compared to the disease spread in wet areas because of the low soil moisture levels. Furthermore, the disease identification too will become problematic as the movement of the fungal growth to the collar region will be very slow due to the high temperature and low moisture levels in the soil.

The white root disease fungus *Rigidoporus microporus* shows a wide host range and many timber plants that are seen in these areas have been found to be infected with this disease 'Katakela', Kanda, Teak and some intercrops have been identified as alternative hosts. The land clearing methods that are not properly carried out at the time of land preparation show direct correlations with the level of disease distribution. Brown root disease is also regarded as a disease of many forestry plants and woody perennials. Furthermore, the multi-cropping systems that are normally being adopted in these areas too will enhance the disease distribution.

However, the relatively high levels of infection in forestry areas, broad host range and also improper land clearing techniques suggest future root disease problems for rubber cultivations in non-traditional areas.

Pest problems

Studies are being conducted to identify new and potential pest problems specific to these areas. However, host-pest natural interactions are considerably influenced by weather changes and also by the change of cropping systems.

Complaints are received frequently on termite problems. Growers should know that many of the damages were not by termite attacks but dead plants due to some other diseases or physical injuries that had been attacked by termites. These insects usually attack plants in stress conditions and they have nests under-ground, woods or inbuilt mounds. Usually, termites feed on crop residues and mulches but once they are not freely available, they attack live plant parts too. The base of the plants will be ring barked or termites will eat the taproots and fill the cavities with soil. Damaged plants wilt and may die within a few days particularly under drought conditions. For the symptoms & possible management strategies, please refer: Termite Attacks on Rubber Plantations: Methods for Prevention (Fernando *et al.,* 2012).

More studies, surveys and observations are needed to conclude the future needs, appropriate adaptations and also to develop mitigation strategies. They should be developed to meet the existing problems and also to avoid the worst possible scenarios. Suitable recommendations should be adopted immediately to reduce future negative impacts with the extension of the cultivations. As received by the Plant Pathology & the Microbiology Department, many symptoms are uncommon and new. Hence in any unusual or complicated disease problems, you can receive the assistance of the Plant Pathology & Microbiology Department, RRISL.

The following areas are needed to be studied.

- To improve the land preparation methods in order to prevent destructive root diseases.
- Identification of the multi-cropping systems currently adopted to assess their impacts on rubber diseases.
- Identification of disease resistant clones specific to those areas

Meanwhile, the Researchers, Extension Officers and Growers should be very careful on the above aspects. Growers should get the advice appropriately and for any unusual disease condition should seek immediate assistance from Rubber Research Institute to avoid further spread of a disease and also to minimize possible destructions. We need your cooperation to prevent the spread of unwanted pest & disease problems in rubber plantations.

This presentation has been made with five years of research work conducted in non-traditional rubber growing areas. The preparation of the journal paper are in progress.

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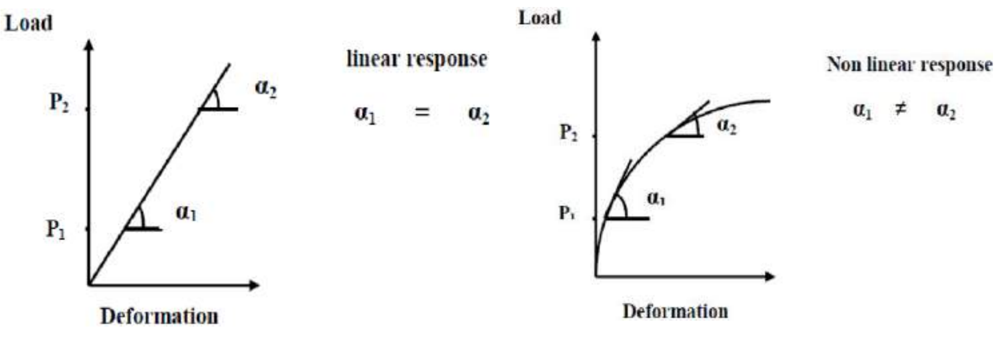
FINITE ELEMENT ANALYSIS AND ITS APPLICATIONS IN RUBBER PRODUCT MANUFACTURING INDUSTRY

S Siriwardena

The unique elastic and visco-elastic properties of rubber combined with the ability of formation of inter cross-links through vulcanization and reinforcement of the polymer matrix through filler incorporation have made rubber materials a highly versatile class of industrial raw materials. As in other industries, continuous product development, product optimization and innovations of new products in rubber product manufacture too are some of the important key aspects to be looked into, in order to be sustainable in a competitive global market. These activities are key to the assurance of high-level performance, guaranteed quality and cost reduction. Therefore, the design and analysis of the performance of rubber products particularly industrial and technical products more accurately in a shorter period of time are imperative in the above processes. Knowledge of the material response to the load under various service conditions is one of the basic and crucial factors in the product designing and development process. It is cumbersome to follow the repeated design-physical production-performance analysis cycle until user requirements are satisfied. The pragmatic route is the prediction of the performance of a product using the relevant load-response mathematical models. Materials show two types of response-load relations and yield two types of analysis namely linear analysis and nonlinear analysis. Figure 1 simply shows these two types of responses of a material to load. When the structural response (deformation, strain) is linearly proportional to the magnitude of the load (force, pressure, moment, torque, etc.), analysis of such a structure is known as linear analysis Figure 1a. When the load to response relationship is not linearly proportional, then the analysis of such a structure is known as nonlinear analysis Figure 1b.



1a. Linear analysis

1b. Non linear analysis

Fig.1a & 1b. Linear and nonlinear behavior of materials

Rubber being a visco-elastic material, often shows non-linear stress-strain relationship and therefore, it requires non-linear analysis to predict the performance of rubber products as well as rubber components. Non- linear relationships are explained in terms of Partial Differential Equations (PDEs) which cannot be solved with analytical methods. Finite Element Methods (FEM) are the computer aided mathematical computational methods that are used to solve these PDEs. This technology is now being widely used in many industries for virtual design, development and analysis of the performance of virtually developed or "manufactured" products with high accuracy.

Finite Element Methods (FEMs)

Finite Element Methods (FEMs) have been introduced in the early 1940s to solve the complex mathematical equations mainly found in the fields of aerospace and civil engineering (Hrennikoff, 1941; Jump, 1943). The applications of this technique have been gradually reaching their potential in a wide spectrum of fields. The application of these methods in solving the equations involved in the rubber industry has been reported in the 1990s (Nicholson and Nelson, 1990). However, these methods are not yet broadly used in the rubber product development process locally simply due to the lack of awareness, high investment and dearth of expertise in the field.

Finite Element Methods are numerical methods for approximating the solutions of mathematical problems to be solved with PDEs. FEM subdivides a problem into smaller, simpler and well defined discrete parts or elements referred to as finite elements. Then simple equations could be used to model these finite elements. This finite element represents the material and structural properties of the product in question. The simple equations applied on each finite element are then systematically assembled into a larger system of equations that models the entire problem. This subdivision (mesh generation) of a whole part or item in question (domain) into simpler parts has several advantages. It will provide an accurate representation of complex geometry and include dissimilar material properties while capturing their local effects. Figure 2 gives a simple representation of how a real-life problem is modeled with discrete elements.

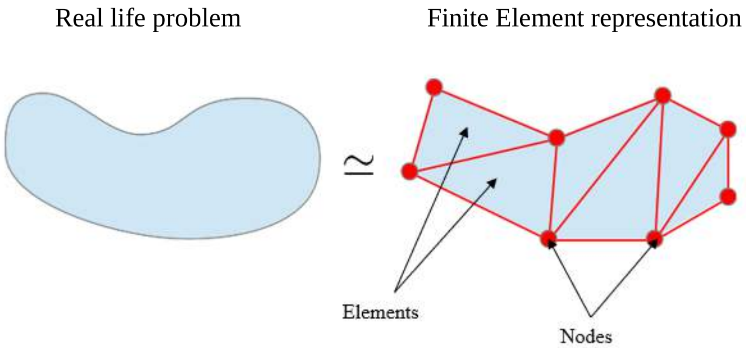


Fig. 2. Modeling of a continuous object with discrete elements

FEM allows detailed visualization of the structures and indicates the distribution of stresses and displacements. FEM software introduced with the development of computer hardware and software provides a wide range of simulation options for controlling the complexity of both modeling and analysis of a system. Similarly, the desired level of accuracy and associated computational time requirements can be managed simultaneously to address most engineering applications. FEM offers the opportunity to complete the entire designs to be constructed, refined, and optimized before the design is manufactured (resource and cost saving).

This powerful design tool has significantly improved both the standard of engineering designs and the methodology of the design process in many industrial applications. The introduction of FEM has substantially decreased the time taken to realize the products from the concept to the production line. It is primarily through improved initial prototype designs using FEMs in which process testing and development have been accelerated.

Finite Element Analysis (FEA)

Finite element analysis (FEA) is the study or analysis of a product behaviour using FEM and is a useful technique that could be used to simulate and analyze the physical behaviour of complicated objects (domains) such as tyres etc. when subjected to various loading criteria. FEA includes the use of mesh generation techniques for dividing a complex problem into small elements and first study the small component separately and applies the computer aided FEM computational tools for predicting and simulation of the performance. Therefore, FEA and simulation is a tool capable of analyzing and simulating product performance that can be carried out at any number of design variations for a particular product to determine the best design, materials etc.

Applications of FEA and Simulation

FEA is being used in a variety of specializations in the rubber industry in designing and simulation of the performance of rubber products and product components at real service conditions. Simulation offers a detailed visualization of various deformations and indicates the distribution of stresses and displacements. Therefore, in the field of rubber product manufacture, FEA offers its capabilities over a wide variety of applications.

Material and product behavior

FEM allows to predict the complex phenomena of rubbers such as mechanical responses at high deformations. FEAs could be employed to study the properties of rubbers based on their microstructures to model the characteristics of rubber like materials. Therefore, a comparison of the performance of the same rubber product made out of different elastomers under the user specified service conditions is possible (Bol and Reese, 2005).

Product design and virtual testing

As mentioned above, FEA is a well established powerful tool to design and simulate material behavior and rubber products, provided that software is provided with necessary data in a rightful and proper manner. FEA could establish the optimum material property requirements and the performance of a product before a material is selected for the manufacture of a rubber product. It allows analysis and simulation of the performance of the countless number of design variations for their overall performance. FEA and simulation could therefore be used to design any product, virtually develop, refine, and optimize the product before the design is manufactured. This will reduce the expensive molding manufacturing costs as mould could be manufactured after optimum product design is completed. The main field of application of the FEA and simulation in the rubber product manufacturing industry is the simulation of tyres and their components such as carcasses and belts at various stress levels. FEA could also be used to study the development of stress and strain points in the individual tyre component at various service loads. In addition FEA is being used to design and predict the performance of any rubber component or product other than tyres such as bushes, bearings, bumpers, rubber springs at user defined conditions in a virtual environment. Therefore, FEA facilitates virtual testing of rubber products at the design stage instead of carrying out performance testing after realization of the products for their performance evaluation (Poisson *et al*., 2018; Golbakhshi, *et al.,* 2014).

Product failure identification

It is of great importance to the early detection of causes for in-service failures of existing products and uses the information gathered to design and rectify the problems. FEA is a diagnostic tool that could be used to identify and analyze potentially intolerable load conditions and failure modes eliminating complex and less efficient trial and error problem fixing techniques. Early identification of product failures provides the opportunity to optimize the relevant factors such as shape and material properties of a rubber product minimizing product failures during its service.

Product design optimization

Product design optimization for the overall optimization of materials and performance is another field where FEA can be used as a tool. The aim of design optimization using FEA is to determine values for the input variables that will meet the design objective, while staying within the constraints. This is possible as FE methods can analyze multiple configurations of a product more quickly and accurately.

Estimation of life-time of the products

Treatment of stress and strain deformation into FEM could get information on the stress concentration points and their failures. Feeding of information such as un-aged and aged data of rubber components together with the deformation and stress-strain distribution information into the FEM software could predict the possible life time of a product or the component.

Estimation of cure rates

Inclusion of data such as thermal conductivity, the thermal capacitance of the rubber, ambient temperature as a function of temperature in relevant FEM modules could predict the cure rates and optimum cure of the rubber compounds too (Basterra-Beroiz *et al.*, 2017).

Reverse engineering support

As in the other fields such as mechanical engineering and electronic engineering, reverse engineering is applicable in the rubber product manufacturing field too. Traditionally, during the reverse engineering process, the object in question is disintegrated to analyze its composition to understand the materials used and their ratios in the product. Alternatively, product performance could be studied and virtual designs and testing can be carried out repeatedly for "virtual manufacture" of the same product with similar performance using FEA and simulation technology. This process would be a fast and cost effective approach in the field of reverse engineering.

Advantages of FEA and simulation technology

As briefly mentioned above, FEA and simulation technology offer a series of advantages to the rubber product manufacturing sector. Some of them are summarized below.

- High accuracy in the predicted properties.
- Possibility of carrying out virtual designs and virtual performance evaluations.
- Ability to have a deep insight into critical design parameters
- Possibility of obtaining a set of comprehensive results, generating various physical responses imitating different real user conditions of a similar product.
- Offers a faster and less expensive design cycle, consequently with increased productivity.
- Reduced number of hardware prototypes.
- Cost saving through analysis of the performance prior to manufacture.
- Cost savings in mould design and manufacture.
- Resource savings in new product developments.
- Possibility of identifying product failures in advance and proposing necessary modifications.
- Time saving through in-situ testing and analysis of new products and product failures.
- Continuous development of product performance with reduced physical manufacture and testing procedures.
- Marketability of products as products are with guaranteed quality

Achievement of the above advantages is governed by the quality of the analysis and simulation results which depends on the density of the nodes, boundary conditions, assumptions, accuracy of the service conditions, validation and the expertise of the FE analyst.

Note:
Finite Element Analysis and Simulation Center (FEAS) was established at the Rubber Research Institute of Sri Lanka (RRISL) in August, 2018 under a public-private partnership program with Plastics and Rubber Institute of Sri Lanka (PRISL)-FEAS services of the experts serving in the Center are available not only from the rubber sector but also for the plastic sector and other industries. Facilities available include Abaqus software, Plastic mould for software, work stations and in addition, a 3-D printer and they can be used under the supervision of the Senior Design Engineer who is available during normal working hours in the center.

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SUSTAINABLE NATURAL RUBBER FROM SRI LANKA: AN EMERGING MARKET OPPORTUNITY WITH MULTIPLE ADVANTAGES

V H L Rodrigo

Though not native to Sri Lanka, its originality from Amazon indicates how the rubber tree comes closer to the nature. This wonderful tree gives us the largest manmade forest cover in the country with 137,828 ha (Unpublished data for 2020 of the Rubber Development Department). The area in 2021 is around 90,000 ha only according to RDD! Rubber plantations are neither forests only for biodiversity nor agricultural lands met only for latex harvesting but provide a comprehensive package of both in a healthy environment with opportunities to enjoy the life. No Sri Lankan film nor tele drama is seen without a scenery of rubber plantation due to its pleasing tranquility.

Obviously during colonial time, as for any other traditional plantation crops, natural forests would have been destroyed to establish rubber plantations. However, it is not the case today. Though not a natural forest, rubber has been time tested for its suitability for sustainable land use. If not rubber, the economic use of hilly terrains in the Low Country Wet Zone of the country would be questionable due to the limitation of suitable crops. In assuring sustainability, the rights of future generations cannot be compromised and resources should be continuously available. Do the rubber plantations in Sri Lanka fulfill this? This article aims to discuss this matter with the intention of highlighting the possibilities of obtaining additional monitory gain for Sri Lankan rubber.

Member states of the United Nations have agreed to meet the 2030 agenda for sustainable development and therefore, the sustainability of rubber production is to be ascertained in rubber producing countries. With the growing demand for the same from the rubber product manufacturers, the Association of Natural Rubber Producing Countries (ANRPC) has formed a Working Group on Sustainable Natural rubber (WGSNR) with the participation of representatives from member countries in view of developing a set of comprehensive guidelines for Sustainable Natural Rubber (SNR). The first meeting was held in Siem Reap, Cambodia in 2019 with the participation of ten countries and the second meeting was held recently on a virtual platform due to the COVID pandemic with the participation of all member countries.

In developing guidelines for SNR, economic, social and environmental aspects are to be considered. Nevertheless, there should be an assurance in doing so; hence, the transparency in procedures and traceability of the supply chain are to be maintained. Therefore, the framework for sustainability is enclosed by five elements, namely;

- Traceability - Mapping of the supply chain and overlay with social and environmental risk zones.
- Transparency - Third party verification and stakeholder involvement.

- Environment - No deforestation, protection and conservation of sites with High Carbon Stock (HCS), High Conservation Values (HCV) & peatlands and biodiversity.
- Social - Assure Free, Prior and Informed Consent (FPIC) approach in land acquisition, land used and customary rights, land tenure, social conflict resolution mechanisms, dialogue.
- Productivity - Improve yields and promote good agricultural practices.

The set of guidelines on the negotiation table of the executive committee of ANRPC is as follows.

1. Human Rights Protection (People and Workplace)

Key criteria in consideration are, no exploitation, no discrimination and no child labour. Countries need to comply with all applicable local, national and international laws and regulations in the countries in which they operate.
In doing so, countries shall,

- Comply with applicable local child labor laws and employ only workers who meet the applicable minimum legal age requirement for the specific operation at the location. In the absence of local law, children under the age of 15 shall not be employed except as set forth in the next sentence. If local minimum age law is set below 15 years of age, but is in accordance with developing country exceptions under the International Labor Organization (ILO) Convention 138, the lower age will apply.
- Comply with applicable wage and hour labour laws including those related to minimum wage, overtime and legally mandated benefits.
- Not tolerate unlawful discrimination in the workplace and shall comply with applicable local laws concerning discrimination, hiring and employment practices.
- Assure zero forced or involuntary labour including, but not limited to, prison labour, indentured labour, slave labour, human trafficking, or other forms of compulsory labour.
- Recognize and respect the rights of workers to join organizations of their choice and shall promote the rights of all workers.
- Provide a safe and healthy work environment in accordance with all local and national laws. Personal protective equipment shall be provided to workers as necessary to ensure a safe working environment.
- Encourage industrial plantations to follow the standards set forth in the Plantations Convention 110 of the International Labour Organization (ILO).

2. Responsible Land Use

Key criteria considered are, no deforestation and no land-grabbing. Each country,

- Shall be free from deforestation and land grabbing that minimizes impact on biodiversity and local communities, and cultivation is to be economically viable.
- Shall comply with all applicable local and national laws for land use.
- Shall not plant rubber on known peatland. Industrial plantations should review available maps to identify possible peatlands and take appropriate abatement actions before planting commence.
- Shall not use fire in the clearing of land for natural rubber planting.
- Industrial plantations shall follow the High Conservation Value (HCV) toolkit, High Carbon Stock (HCS) toolkit, or other equivalent land assessment and management toolkits to ensure land is appropriate for natural rubber planting and to determine where natural ecosystems should be protected.
- Shall obtain full, fair consent and ensure adequate compensation where land use is granted.
- For land acquired and/or transformed for Industrial Plantations, the usage shall apply the Free, Prior and Informed Consent (FPIC) methodology and guidelines developed by the United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation (UNREDD). In addition, adequate and fair compensation for any land usage/transfer shall be present in all transactions.

3. Responsible Agricultural Practices

Key criteria on the above are, Good Agricultural Practices (GAP), Integrated Pest Management (IPM), conservation of soil, conservation of water and conservation of biodiversity. In each country,

- When and where available, all new and replanting efforts shall use only clones recommended by the relevant authority or leading research institutes of the country.
- All new and replanting efforts of Industrial Plantations shall follow planting density guidelines established by relevant authorities. Any trees that do not survive one year shall be replaced as soon as possible.
- All new and replanting efforts of Industrial Plantations shall ensure that the use of natural fertilizer is optimized, biological pest and disease control methods are employed, and chemical use is minimized.
- Shall adopt the best-known cultivation practices such as clone usage, fertilizer application, tree density, best agricultural practices, and tapping techniques based on the recommendation from a local authority or research institutes.
- Industrial plantations should have a transparent grievance process for local communities.
- The relevant local authority or research institute that takes charge of natural rubber shall ensure technology transfer and extension services be delivered to smallholders especially in the context of improving the productivity in farming and harvesting.
- Taking action to improve agricultural yields.

4. Environment Responsibility

Key criteria for the above are, Good Manufacturing Practices (GMP), treatment of water waste and treatment of solid waste. Each country should ensure,

- Zero deforestation and,
    - Shall observe national forest protection laws
    - Primary forests are completely protected and preserved
    - Areas of High Conservation Value (HCV) as defined and audited by the HCV Resource Network are protected and preserved.
    - Areas of High Carbon Stock (HCS) as defined and audited by the HCS Approach Steering Group are protected and preserved. Identification of these areas using participatory mapping and the outlining of suitable management methods are subjected to a consultation of all of the stakeholders involved to ensure economic, social and environmental needs are taken into account and the proposed farming techniques are socially accepted.
- Preserving surface water and groundwater by ensuring its operations related to NR cultivation, harvesting and processing does not have any adverse effect on the surface water or groundwater resources.
- Safeguarding peatlands
- Protecting forests
- Responsible management of waste (solid/water) – implement on-site systems for the collection, processing and recycling of waste or byproducts generated by farming or industrial operations or by other stakeholders.
- Ensuring the conservative use of chemical inputs
- Reducing odors by adopting best practices and the most advanced technology in order to reduce any odors especially at processing factories.

5. Enhance transparency and traceability

Each country,

- Shall have traceability back to the natural rubber production at farm level based on country level and local area sourcing methods.
    - Country level source – the country in which the rubber for the cup lumps, sheets or latex received by the factory was produced.
    - Local area source – natural rubber source will be assessed to the general region of a local dealer's/consolidator's business influence and/or assessed to the general region of consolidated farmers/direct sales.
- Committed to the corruption-free and transparent implementation of these principles.
- Increasing the material efficiency of Natural Rubber (NR)
- Interaction with stakeholders

Sri Lankan scenario

In general, the rubber plantation industry in Sri Lanka complies with most of the above mentioned guidelines due to existing national policies. With respect to human rights protection, neither forceful nor child labour is used in Sri Lanka. A Cabinet decision has been taken to increase the minimum working age up to 16 years. However, in practice, only those above 18 years are employed in plantations. All plantation companies contribute to the Employees' Provident Fund and Employees' Trust Fund. In addition, all workers are free to join unions, and the salary structure is generally decided through collective agreements with them or by the government if the former is not substantial enough as per the government policies. No gender based payment structures. Also, overtime payments and workmen compensation insurance are in place. The only improvement required would be on some personal protective equipment for workers in raw rubber factories where those are not properly monitored.

If considered on land use and environmental responsibility, rubber cultivation results in zero impact to natural forests in Sri Lanka; no any deforestation for rubber cultivation. Even in lands released to smallholder farmers for rubber cultivation in nontraditional areas, existing trees are to be protected hence no issues with UNREDD. Fire is used for root burning only in sites infected with White Root Disease. Effluent treatment plants have already been established in large scale rubber factories and measures are in pipeline to install small scale plants even at smallholdings. With regard to the responsible agricultural practices, both large scale plantations and smallholdings are guided by the recommendations of the Rubber Research Institute of Sri Lanka. No considerable issues with soil and water conservation and reservations are protected for water resources. As per the government policy, the application of organic fertilizer is encouraged and infilling for casualties is expected to be done on time. Some industrial plantations have already obtained the certification from the Forest Stewardship Council (FSC) assuring their sustainability. Therefore, dealing with the guidelines in SNR will not be a big issue. Obviously, this approach assures the achieving of the productivity levels to be comparable with that of other countries, thereby reducing the cost of production and also providing the in-country requirement of raw rubber for the product manufacturing sector. The only requirement to be abided by rubber growers would be the adoption of monitoring charts for proper implementation of good agricultural practices. That's what the country needs anyway.

In meeting the guidelines under the enhanced transparency and traceability, the value chain activities of raw rubber are to be properly recorded. The value chain comprises producers, dealers, processors, traders and manufacturers. Having not done this before, this requires extra involvement; however, such a system will help not only for proving sustainability but also for proper collection of cess and/or disbursement of any benefits. Obviously, a corruption free system could be established assuring a fair price at farmers' end.

Way forward

Although member countries of ANRPC have understood the importance of establishing sustainability, this has to proceed on a voluntary basis at the country as all are not in an agreement to establish a common system internationally. If effectively done, this could lead to provide a sustainable price for natural rubber. However, in the implementation process, limitations of resource poor farmers in adopting various farm practices are to be considered. Having met most of the criteria, guidelines are properly documented with monitoring systems established, Sri Lankan rubber can easily be classified as sustainable natural rubber (SNR). Also, this can be used as a tool to increase the productivity in rubber lands. Particularly with the subsidy programme of the government, the adoption of good agricultural practices along with SNR guidelines could be ensured.

On the above ground, should Sri Lanka has its own system to ascertain the concept, it could be possible to get an advantage to the Sri Lankan rubber industry to expand its market share or to approach niche markets. In doing so, third party certification and monitoring systems are to be established and that would add an additional cost. Such costs should not be passed into rubber growers. Instead of sector involvement in certification and monitoring which leads to high cost, a government own system could be established with proper accreditation and at a minimum cost. Also, this could be linked with a productivity based rubber land registration system. Having statutory powers for regulating the value chain of rubber, the Rubber Development Department may act as the certification body whilst Rubber Research Institute could assist in monitoring the system. This may also attract investors who expect to grab niche markets with high end rubber product manufacturing. So, this seems to be a new market place to harness the untouched advantages in the Sri Lankan rubber industry!

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FEASIBILITY OF MAKING RUBBER GROWERS RESILIENT TO FACE MARKET VAGARIES: NEED FOR PRAGMATIC, SUSTAINABLE AND INNOVATIVE SOLUTIONS

V H L Rodrigo, S Siriwardena and J K S Sankalpa

Natural Rubber (NR) cannot be missed out due to its multiple benefits offered to the society and environment. Rubber production provides livelihoods for millions of people in rubber producing countries and feeds an industry that produces a vast array of essential items in day-today use. In today's context, everyone needs rubber products and on average, each person consumes about 1.5 kg of NR annually (per capita usage as per the world rubber production and population statistics). Each rubber tree fixes about 1 MT of carbon dioxide in its lifespan of thirty years and saves natural forests by providing high quality timber as a substitute.

In the value chain of NR, the upstream sector of the industry comprises a higher headcount (i.e. growers and farm workers) than downstream (i.e. product manufacturers and factory workers). In addition, the middle stream operates with raw rubber dealers, processors and traders. To sustain the industry, all sectors should exist. Having a multi-business approach and dealing raw rubber with short-term batches, the middle stream has a high level of buoyancy in market pitfalls. In the general context, the downstream sector is affluent in terms of financial, social, and human capital and with that, it has a higher capability to adjust to market dynamics than the upstream. In contrast, the upstream suffers when raw rubber prices are low and also, finds it difficult to control theft of produce when the prices are high.

Just by looking at the high level of turnovers, the responsibility of taking care of the upstream cannot be given to the downstream through regulation as it comprises a large number of companies that should compete with each other for market survival. The general consensus is that each player in the value chain should fit into market flows through competition which ultimately leads to a high level of efficiency and profitability. Nevertheless, rubber farmers face difficulty in facing such market competition due to their limited influence or bargaining power at the individual level. Increase in land productivity or yields per unit of land is the most effective solution to manage the impact of price declines. However in particular, typical smallholders who give priority to family and other social commitments with limited access to finance, are not competitive as far as high productivity is concerned.

Although the low market price for rubber seems beneficial for rubber product manufacturers, they also cannot make greater profits than that in high price situation due to the market competition among each other, which ultimately increase the cost for promoting their products to secure the individual market share. If rubber growers are not protected reasonably at low price situations, their move to other undertakings will have a long-term negative impact not only on product manufacturers but also on the entire globe due to the present leading role of rubber plantations in environmental protection. Therefore, an alternative arrangement is imperative to sustain the rubber growers under unfavourable market conditions.

Please discuss the impact of the high cost of production in Sri Lanka whereas some South Asian countries with lower standards of living may sell rubber at a lower price to processors and still make a profit enough to sustain themselves. This means Sri Lankan manufacturers can import rubber at a relatively lower price to remain globally competitive.

This issue is on the discussion table even at the international level. Considering this long lasted low rubber price situation for many years, the Association for Natural Rubber Producing Countries (ANRPC) which represents the governments of member countries, has recently established a special task force for deriving a practical and equitable solution to this issue. Several proposals have been developed by different countries. The proposal to fix a sustainable floor price (SP) at individual country level with the aim of preventing rubber trading below this level was ruled out as only two countries showed their willingness to do so. Similarly, the proposal on export restriction was not supported by the majority of member countries.

Alternatively, Thailand and Sri Lanka submitted their proposals and both have advantages but difficulties may arise in implementation. The intention of this article is to describe these proposals along with the comments received from the representatives from member countries of the ANRPC and to solicit plausible amendments or alternative suggestions with an innovative approach from the industry stakeholders and reading public to these proposals.

ANRPC members have reached a general consensus on how the sustainable price mechanism (SPM) should be; the key features of a sustainable pricing mechanism.

It was agreed upon at the initial discussions of the ANRPC to meet the following conditions in developing a workable mechanism for SP.

- The mechanism should not be harmful to the downstream manufacturing sector
- It should not prompt end-user to substitute natural rubber (NR) with synthetic rubber (SR) or other material
- It should not encourage farmers to do extensive cultivation of rubber by new planting

In addition, any funds (if required) to maintain an SPM should be generated from the rubber industry itself to assure the true sustainability of the mechanism. Else, it will be a burden to other industries or the governments and such a step would also question the rationale for indirectly subsidizing a historical but modern industry value chain that generates billions of dollars in making and marketing rubber products. Further, that will be against WTO rules of fair trade and would be subjected to anti-dumping countervailing duties.

Proposal of Thailand for SPM

This will be a legal enforcement among member countries of ANRPC; hence, every Government should identify a regulatory body to the SPM in their respective countries. The SPM could be benchmarked either with the Free on Board price (FOB) or with the farm-gate price. Having a guaranteed price to growers, benchmarking with the farm-gate price seems beneficial despite the difficulties in monitoring. The mechanism comes into operation when the benchmarked price falls below a pre-defined minimum level or rises above a predefined maximum level.

In determining the minimum price, it is expected to covers-up around 90% of the cost of production (COP). When considering the COP, the inclusion of management cost is considered and it is proposed to have the minimum and maximum prices for SPM at FOB as 2.20 US$ and 3.50 US$, respectively for a kilogram of raw rubber (for common types, e.g. TSR 20, RSS 3).

In determining the associated benchmarked minimum and maximum farm-gate prices, it is proposed to use in-country data over the past few months; then the estimation is done based on the average deference (AD) between FOB & farm-gate prices and the Standard Deviation (SD) as given below.

Benchmarked farm-gate price = Benchmarked FOB price – AD – (2 x SD)

For instance, if the average difference between FOB price and the farm-gate price is found 50 US cents with a standard deviation of 10 cents, then the minimum farm-gate price corresponding to the proposed minimum FOB price of 220 US cents comes to 150 US cents [220 – 50 – (2X10) = 150].

It is expected to fix benchmarked FOB prices for the minimum and maximum by ANRPC to make them common to all member countries and Member Governments could individually fix the minimum and maximum farm-gate prices by considering the prevailing gaps between FOB and farm-gate prices and other domestic factors. A lead time of 3 to 5 months is expected to enable the stakeholders to adopt the proposed SPM, after issuing the notification.

The proposed SPM is expected not to disturb the contract trading systems based on the spot market and hedging with futures prices. Although no any direct funding (except for management and monitoring costs) is required to implement the proposed SPM, it would largely affect the free market dynamics. Although it assures a guaranteed price range, the rubber growers could not enjoy the high price when the supply is less than the demand. Also with non-inclusion of contract trading in SPM, its comparative effects on rubber product manufacturers in non-rubber growing and rubber growing countries are uncertain as the former could work on contract trading. Perhaps, it would be required to control the contract trading systems allowing them to operate only within minimum and maximum benchmarked FOB prices.

All countries are trying to recover from the economic damage caused by COVID-19; and so, most member countries of ANRPC are reluctant to interfere market flows of rubber at this stage. Also, the rubber price seems improving though ANRPC says it is short-term; therefore, the majority of member governments are not inclined to accept this system without further testing.

Proposal of Sri Lanka for SPM

Protection of the most affected party in the value chain of any product is a noble social responsibility of its beneficiaries. With that, it is expected to provide a greater responsibility in sustaining rubber farmers to the ultimate users of rubber products (i.e. consumers). When collectively done, the individual burden in monitory terms at the consumer level in protecting rubber growers seems affordable. If average consumption is considered at the global scale, the share of an individual person is to contribute for 1.5 kg of NR consumed annually. Therefore, it was proposed to impose a levy at retail sales of rubber products taking into account of NR composition and market price of NR to build up a separate fund to take care of rubber growers. Member countries of the ANRPC represent over half of the world population. Having the European Union (EU) as a member, the International Rubber Study Group (IRSG) has also a big voice in the world of rubber economics. If member countries of ANRPC and IRSG agree, the above-mentioned levy could effectively be implemented. The fund raised is ultimately distributed among NR producing countries considering their NR production share. Thereafter, it could be pumped back to rubber growers as a productivity incentive or by other means. The proposed methodology for deciding the levy is given below.

For establishing such a system, it is required to derive standard values with the consent of member countries of ANRPC and IRSG. The proposed levy is named as Rubber Growers' Sustainability Levy (RGSL). Firstly, a standard or bench market price for rubber (RPs) together with a corresponding standard value for RGSL (RGSLs) is to be set. For instance, RPs could be considered as 2 US$ per kg with 0.5 US$ for RGSLs for 1 kg of NR used in the product. With that, a conservative value for 'a' can be derived by multiplying RPs by RGSLs: [RPs *RGSLs = a]. If RPs is 2 US$ and RGSL is 0.5 US$, a = 1 (i.e. 2* 0.5). Once the value of 'a' is established, RGSL can simply be derived at any market rubber price (MRP) as,

$$RGSL = a/MRP$$

Considering the necessity and practicability, the maximum level of RGSL is to be decided collectively by the member countries of ANRPC and IRSG based on the maximum level of price to which the levy should be applied and levy per US$. For convenience, the maximum level of price can be set as the standard price.

In order to implement this system, the amount of NR used in rubber products is to be declared by the product manufacturers and verified by ANRPC with the assistance of Rubber Research Institutes of respective countries.

This method provides a price adjusted variable levy which consumers can afford as a social responsibility. In particular, this can go along with sustainable guidelines to be established for NR. For instance, the average passenger tyre weighs about 10 kg with 28% NR. It means 2.8 kg of NR in the particular tyre and if RGSL is 0.5 US$, the proposed levy for such tyre is about 1.4 US$ at the standard market price of rubber. On this basis, an additional amount to be paid by a consumer for other fast-moving items such as gloves and condoms would be a few cents. With proper advertising on the possibility of contributing to a green economy, the majority of consumers may willingly contribute to this fund and with that, all rubber growers in Sri Lanka and elsewhere can be protected. However, having large numbers of consumers in each country, the practicality of collecting the levy at consumers is a concern in the member governments of ANRPC. Also, existing tax structures in some countries seem not allowing to impose an additional levy on rubber (e.g. GST). Therefore, this proposal is to be developed further to address these issues.

As an alternative to collect the RGSL at the point of retail sale, this could be collected at the manufacturer level at the time of purchasing NR. Since the system is common to all manufacturers in the member countries of ANRPC and IRSG and ultimately, additional cost involved due to RGSL is passed over to the consumer of the product, there won't be any unfair competition among manufacturers. Also, an accurate estimation of the NR content in all products becomes unnecessary. However, to avoid the competition from SR due to this add-on value to NR, consumers of NR based products are made to be aware of their contribution towards the protection of nature through RGSL with proper publicity given. This could be in a way of a leaflet given with the product and publicity given through mass media.

Alternative proposals:

In addition to the above proposals, the possibility of establishing an insurance scheme to support rubber growers in the low price situations is also an option. The required funds are to be generated from the growers themselves. In such a case, fund collection is to be done when prices are above a certain limit in order to pay the compensation when prices come down to a certain limit. Index insurance approach in agriculture has already been established in many countries to compensate for yield losses due to various factors. Though superficially feasible, no price appended insurance schemes are in place in the country and so, in-depth studies are required to establish such a system. Past information on price variation indicates that there would not be possible to set the price point as high as growers expect, for paying compensation.

Way forward:

The above mechanisms to sustain rubber growers by supporting them at low price situations, are still in negotiation at various levels. This article is published with the aim of brainstorming the stakeholders to develop these mechanisms further. Enacting them is not easy but has to be attended as a joint effort of all for the smooth functioning of the NR industry. Therefore, views of others are welcome, particularly new ideas if any, and that will enable us to bring up practical measures to the notice of relevant authorities. Also, we expect all to raise their voice in support of the effective mechanisms to sustain the NR growers at low price situations and to save the rubber tree for the environment. Being the first country to domesticate the rubber plant, if Sri Lanka can get the leadership in introducing a suitable mechanism, its bequest care for the sustainable world can be proved whilst resolving a burning issue in the country.