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Effect of tapping rest during wintering months on latex yield and tapping panel dryness in three rubber (*Hevea brasiliensis*) clones

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Abstract

Hevea brasiliensis (Muell Arg.) undergoes annual leaf shedding commonly known as wintering. The wintering period in the traditional rubber growing areas in the Wet Zone of Sri Lanka is from December to February followed by flowering and flushing in March. Tapping rest during wintering is recommended in certain countries while in some other countries year round tapping is practiced. In Sri Lanka, until early1970s winter resting was practiced, but this is not being practiced at present. Incidence of tapping panel dryness appears to be high with currently recommended clones and hence the objective of the present study was to investigate on the effect of winter resting on the annual yield and tapping panel dryness in rubber clones. Experimental trials were conducted for two consecutive years (2018 and 2019) with three clones viz., RRIC 100, RRIC 121 and RRISL 203 at the Substation of RRISL at Kuruwita in Ratnapura district. Treatments tested were continued tapping with no winter rest (T1), resting during the wintering period (T2) and once in six days tapping during the wintering period (T3). Trees were tapped at S/2d3(once in three days) intensity. Data were collected on latex volume, bark consumption and TPD incidences. Results for two years showed higher g/t/t/ in all three clones when rested during the wintering period in both years as compared to those with no winter rest. Significantly higher annual total crop (kg) was recorded for T1 when compared to T2 in all three clones for both years. Though total number of partially and totally dry trees of winter rested trees of clones RRIC 100 and RRIC 121 were low, the differences were not significant. In terms of profits obtained as indicated by economic analysis, resting the trees during wintering resulted in the highest profits, followed by d6 tapping during the same period. Winter rest should be tested for a longer duration (4-5 years) for all the clones recommended at present that are vulnerable to tapping panel dryness.

***Key words*:** bark consumption, *Hevea*, rubber, tapping panel dryness, winter rest, yield

Introduction

Wintering is a term that is used to describe the annual shedding of senescent leaves which renders the tree partially or fully leafless for a period of time. Unlike in trees in temperate countries where defoliation occurs during the winter period of the year, in

rubber which grows in tropical countries, wintering takes place during the drier months of the year. Rubber trees, generally of more than four to five years of age, undergo this phenomenon for about two to three months, from December to February in traditionally rubber grown areas (Nayanakantha and Seneviratne, 2008), wintering is followed by the terminal bud bursting and expansion of new leaves. Yield reduction has been recorded during this period due to reduction of sucrose content in cells which is aggravated during re-foliation followed by flowering; all demands extra resources Priyadarshan, (2011).

The physiology behind senescence and abscission of leaves is identified as an imbalance between growth promoter Indole Acetic Acid (IAA) and growth inhibitor Abscisic Acid (AA). According to Priyadarshan, (2011), defoliation of rubber is a circumvent process to overcome moisture and low temperature stress through minimizing transpiration and to ensure reproduction. The tree, acquiring new leaves without undue damage by diseases such as *Oidium* and *Colletotrichum*, by this process, is considered to have an added advantage. Temperature and rainfall are two major factors that influence on yield and phenology of rubber. As reported by George *et al.*, (1980) and Meenattoor *et al. (*1989) wintering depends on the clone, age of the plants, location and agro climatic conditions and the weather prevailing. It has been evidenced that the duration of wintering tends to be short in areas experiencing a dry period. Re-foliation is completed fast minimizing yield reduction in such areas. All the leaves fall within a short period of time followed by a rapid re-foliation under that situation. On the other extreme, where there is no pronounced dry season with infrequent low rainfall leaf fall occurs gradually. Reduction of yield is greater under this condition.

In Sri Lanka research have been done to study the pattern of wintering with the clones available by Pathologists to understand about disease spread, severity and also to plan or to decide on chemical spraying to control diseases. As reported by Liyanage (1976), wintering has been induced by drier weather and much influenced by rainfall occurring during the period as observed in clone PB 86, in an experiment conducted in almost all rubber growing areas in Sri Lanka. Weather pattern has been reported as the closest factor to influence on the pattern and the time of wintering. Age of the trees seems to influence the pattern of wintering; the older trees seem to defoliate and re-foliate earlier than younger trees. The pattern of wintering has been observed of clones RRIC 7, RRIC 45, RRIC 52 and PB 86 by Wimalaratne and Pathiratne (1974) and indicated that resting was not necessary until the bud break starts where the yield drop is not up to uneconomical level. However, only two weeks rest has been recommended for the local clones and even a shorter period for PB 86.

Nayanakantha and Seneviratne (2008) conducted studies on wintering and flowering patterns of eighteen *Hevea* clones in Wet and Intermediate Zones of Sri Lanka. Significant early wintering was observed in clones of RRISL 223,

RRIC 100, and RRISL 216 in Dartonfield while in Kuruwita, RRISL 217, RRIC 100, RRISL 201 and RRISL 202 clones showed early wintering. It was also found that there was no significant difference in wintering and flowering patterns of RRIC 100 between Pitiyakande which located in Intermediate Zone and most of the sites in wet zone and the same pattern was observed with RRIC 121 (Nayanakantha and Seneviratne, 2008).

Tapping rest during wintering period is recommended in some countries (Martin, 1969 and Chantuma, *et al*., 2017) while in some other countries year round tapping is practiced Meenattoor (1989). Earlier it was a common practice to stop tapping during wintering (winter rest) in Sri Lanka. Majority of the small holders practiced this while estate sector did not adopt it mainly due to high rubber prices during this period. Currently winter resting is not recommended by RRISL and not practiced in any of the sectors. As per the records available, until 1970s winter resting was recommended in Sri Lanka, but after that RRISL had recommended to tap during the wintering period too, based on the results of an experiment carried out for a nine year period, from 1964 to 1972, with clones PB 86 and NAB 12 (Annual Review, 1972). The main treatment had been with and without winter rest, but stimulations and different tapping frequencies had also been tested over the period. After nine years it had been concluded that no significant difference in the yield whether the trees were winter rested or not. PB 86 then has been considered a high yielding clone and during the last of the trial the yield had been around 37g/t/t on S2d2 tapping when the trees were 20 years of age with average girth of about 70 cm.

Over the past decades, the potential rubber yield has been significantly increased, due to the cultivation of high yielding clones and adopting improved agro-management practices. However, latex production still faces serious economic losses caused by high percentage of tapping panel dryness (TPD). Annual rubber production loss due to TPD accounted for 15-20% (Chen *et al.*, 2002) and no effective treatments has been developed for it so far (Li *et al.*, 2010). In the current context, high tapping panel dryness incidences are being reported, especially of the clones recommended after 1990s. It is hypothesized that the tapping frequency of d2 or d3 with ethrel may be too harsh for the high yielding clones and also, continuous tapping without a rest during wintering and flowering period could be one of the major reasons for trees to become stressed and occurrence of high TPD in rubber clones.

The current study, was thus, aimed at investigating the effect of tapping rest during the wintering and flowering period on latex yield and tapping panel dryness incidence in three selected rubber clones.

Materials and Methods

Location and duration

Experimental trials were conducted at the Substation of RRISL at Kuruwita in Ratnapura district belonging to WL2 Agro-climatic Zone, for two consecutive years, 2018 and 2019.

Plant materials, treatments and design

Three fields representing three clones *viz.,* RRIC 100, RRIC 121 and RRISL 203 were selected for the present study. The year of planting of the three clones were 1993, 2005 and 2009 respectively. Ninety trees were selected from each experimental field avoiding runts and tapping panel dried trees. There were three blocks for each experimental field and each block had ten trees per treatment distributed randomly so that each treatment was imposed for 30 trees (replicates). Treatments tested were as follows.

T1- continues tapping with no winter rest
T2- resting or no tapping during the wintering period
T3- tapping at d6 frequency during the wintering period

Trees were tapped at S/2d3 intensity, as practiced on the estate. As the trees of above mentioned clones should be tapped at S/2d2 frequency as per the recommendation of RRISL, trees were stimulated using 2.5% ethrel in order to tap at S/2d3 frequency. Although four rounds of ethereal application was planned, only two rounds could be applied as panel application for all clones. In 2018, application dates were 21st August and 21st December and in 2019 they were 16th May and 1st August. Tapping was stopped for the winter resting treatment when the leaves started to fall and recommenced when majority of the leaves turned in to apple green color. Winter resting period for 2018 and 2019 were from 29.01.2018 to 02.05.2018 and 27.01.2019 to 03.04.2019 respectively.

Data collection and analysis

Total volume for ten trees per block *i.e*. each treatment, was measured and recorded on every tapped day. Metrolac reading was taken for the treatment bulk. Bark consumption was calculated using the difference between the starting and the finishing panel height for each year. The percentage of incidence of tapping panel dryness (%TPD) was calculated for each treatment using following formula. Three clones were tapped by three tappers.

%TPD = (TPD tress/Total trees) x 100

Bark consumption was measured using a tape and the girth was measured at 60 cm from the bud union using a tape. Partial and total tapping panel dryness condition was assessed when trees being tapped.

Significance of the observed treatment differences was tested by analysis of variance using proc ANOVA procedure of the SAS software package (version 9.1) and significant means were separated using the least significant difference (LSD).

Financial analysis was conducted to measure the economic viability of implementing the treatments in the three clones. Hence cost and income per one hectare of rubber land was calculated separately for the three treatments. Tapping cost was based on the current daily wage of workers LKR 1000 and Ethrel application cost. Selling price of one kilogram of rubber was considered as LKR 300. Stand per hectare is

considered as 500 trees and number of trees for a tapping block as 250 trees. Wintering periods were three months and two months for 2018 and 2019 respectively.

Results

Monthly total crop of the ten trees for the two years and for three treatments, for continuous tapping (T1), winter rested (T2) and d6 tapping during the wintering period (T3) for the three clones are given in Tables 1a (for RRIC 100), 1b (for RRIC 121) and 1c (for RRISL 203). The behavior of crop pattern is similar for all three clones. Total monthly crop is higher, especially during cropping months, when trees were rested during wintering period. But, the annual total crop is lower when the trees were winter rested, due to lower number of tapping days when rested during wintering period.

The impact of the duration of wintering period on the monthly crop is clear from the data for all three clones. The trees under continuous tapping have resumed the high crop, as per the general crop pattern only in July for all three treatments in 2018 where the wintering period was three months. But in 2019, wintering period was only for two months and the high crop is resumed in May-June, *i.e.*, 1-2 months earlier than 2018.

Table 1a. *The monthly total crop (kg) of ten trees for the three treatments, for continuous tapping (T1), winter rested (T2) and d6 tapping during the wintering period (T3) of the clone RRIC 100 for the two years*

Treatment	2018												Total crop (kg)
	Total crop (kg)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
T1	5.9	1.1	3.1	2.7	2.4	2.7	10.4	9.9	10.1	10.1	7.7	12.9	79
T2	6.0				2.3	2.5	11.0	10.4	11.7	9.4	7.7	12.6	73
T3	5.9	0.4	0.7	0.9	2.3	2.6	10.2	9.9	10.4	9.5	7.5	12.7	73
	2019												
T1	15.9	7.1	5.9	1.9	6.8	14.2	12.8	2.5	3.2	2.3	3.3	2.9	79
T2	17.2				6.9	13.5	12.9	2.6	3.2	2.2	3.5	2.9	66
T3	16.5	3.7	3.8	1.8	6.3	13.3	12.3	2.6	3.0	2.2	3.3	2.9	72

Table 1b. *The monthly total crop (kg) of ten trees for the three treatments, continuous tapping (T1), winter rested (T2) and d6 tapping during the wintering period (T3) of the clone RRIC 121 for the two years*

Treatment	2018												Total crop (kg)
	Total crop (kg)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
T1	14.9	6.2	5.9	2.2	3.6	5.4	13.0	22.8	24.6	14.6	10.0	17.3	141
T2	17.0				3.5	5.4	13.2	21.3	22.8	13.8	10.2	17.4	125
T3	15.0	1.7	3.3	1.2	3.6	5.4	13.1	22.3	25.8	12.9	10.1	16.8	131
	2019												
T1	13.7	9.1	7.7	3.3	11.8	8.8	16.5	1.1	3.6	1.3	2.7	4.6	84
T2	14.2				11.0	8.7	19.0	1.0	3.4	1.3	2.8	4.6	69
T3	13.7	4.8	3.9	3.0	11.4	8.8	16.6	1.0	3.5	1.2	2.8	4.7	75

Table 1c. *The monthly total crop (kg) of ten trees for the three treatments, continuous tapping (T1), winter rested (T2) and d6 tapping during the wintering period (T3) of the clone RRISL203 for the two years*

Treatment	2018												Total crop (kg)
	Total crop (kg)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
T1	9.7	1.5	3.8	2.9	2.3	2.9	10.9	10.4	9.9	9.2	10.4	16.2	90
T2	9.6				2.3	2.9	10.1	10.5	10.5	9.9	10.3	15.9	82
T3	10.3	0.8	2.2	1.0	2.1	3.0	10.8	10.4	9.7	9.3	10.8	15.6	86
	2019												
T1	19.0	8.0	6.5	2.2	7.6	11.2	13.1	2.8	3.1	1.8	3.4	3.1	82
T2	19.3				8.8	14.0	13.6	1.8	3.2	2.0	3.4	3.3	71
T3	19.4	4.1	3.3	2.1	8.5	13.0	12.9	2.3	2.9	1.8	3.3	3.0	77

Monthly mean crop for three clones for three treatments and for two years are shown in Figures from 1a to 1f. No significant differences in mean monthly crops were recorded for three treatments except for the months in which tappings were not done or tapping was done at d6 frequency for the clone RRIC 100 for

2018 (Fig. 1a). More or less similar patterns were recorded in RRIC 121 and RRISL 203 for 2018 (Figs. 1c and 1e). However, a significantly higher annual total crop (kg) was recorded for T1 when compared with T2 and T3 in RRIC 100 and in RRIC 121for 2018 (Figs. 1a and 1c). Nevertheless, the annual total crop for T1 was in par with T3 for RRISL 203 for 2018 (Fig. 1e). Interestingly, higher g/t/t values were recorded for T2 as compared to T1 and T3 in all three clones for 2018.

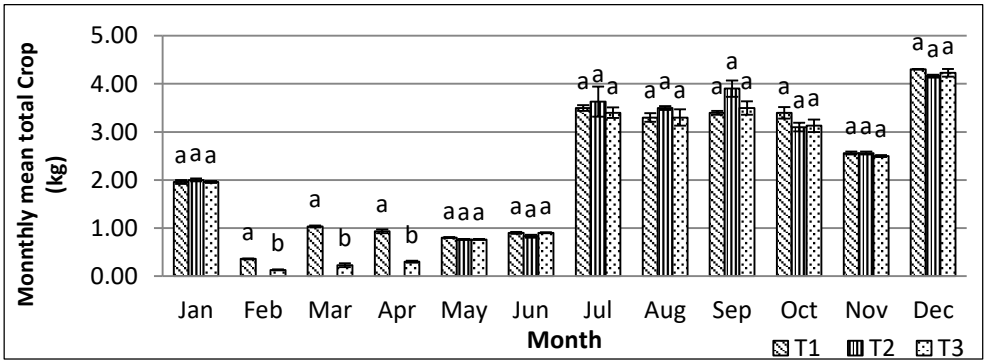

Fig. 1a. Mean monthly latex yield (kg), for the clone RRIC 100 for three treatments, T1- continuous Tapping, T2- winter rested and T3- d6 tapping during the wintering period for 2018.

Means followed by the same letter (s) are not significantly different at p≤0.05, according to Duncan's Multiple Range Test (DMRT). Standard error of the mean is shown on the column.

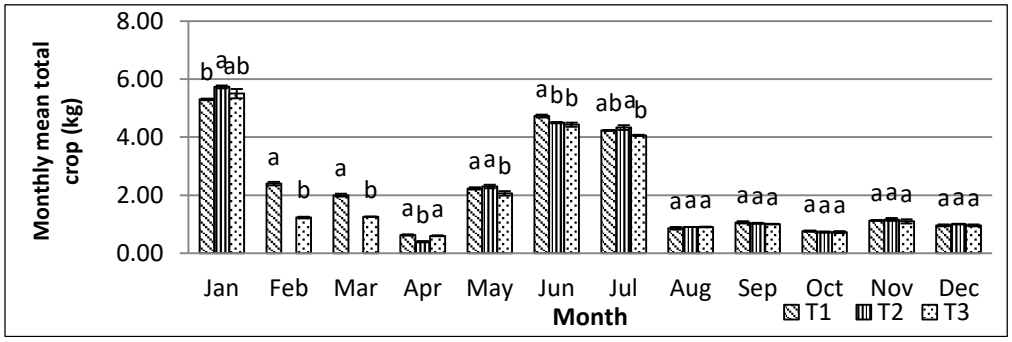

Fig. 1b. Mean monthly latex yield (kg), for the clone RRIC 100 for three treatments, T1- continuous Tapping, T2- winter rested and T3- d6 tapping during the wintering period for 2019.

Means followed by the same letter (s) are not significantly different at p≤0.05, according to Duncan's Multiple Range Test (DMRT). Standard error of the mean is shown on the column.

Monthly mean crop from August to December is very low with compared to the same period of 2018, owing to loss of tapping days due to heavy rain.

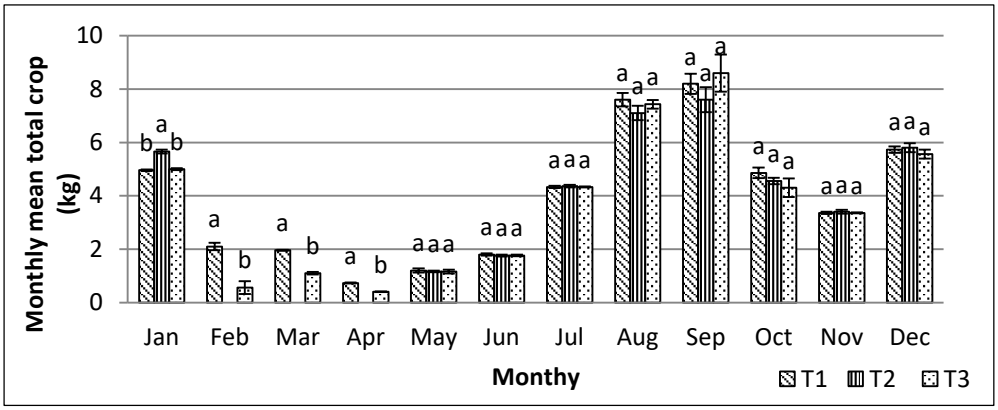

Fig. 1c. Mean monthly latex yield (kg), for the clone RRIC 121 for three treatments, T1- continuous Tapping, T2- winter rested and T3- d6 tapping during the wintering period for 2018

Means followed by the same letter (s) are not significantly different at p≤0.05, according to Duncan's Multiple Range Test (DMRT). Standard error of the mean is shown on the column.

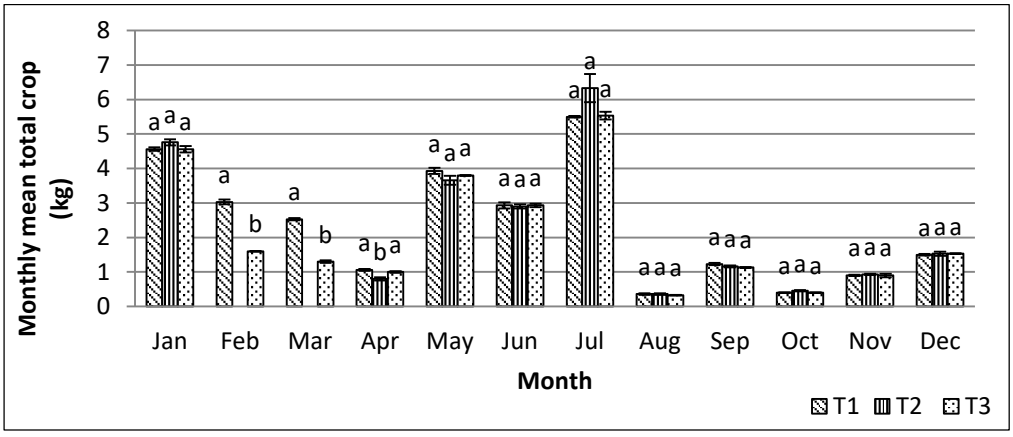

Fig. 1d. Mean monthly latex yield (kg), for the clone RRIC 121 for three treatments, T1- continuous Tapping, T2- winter rested and T3- d6 tapping during the wintering period for 2019

Means followed by the same letter (s) are not significantly different at p≤0.05, according to Duncan's Multiple Range Test (DMRT). Standard error of the mean is shown on the column.

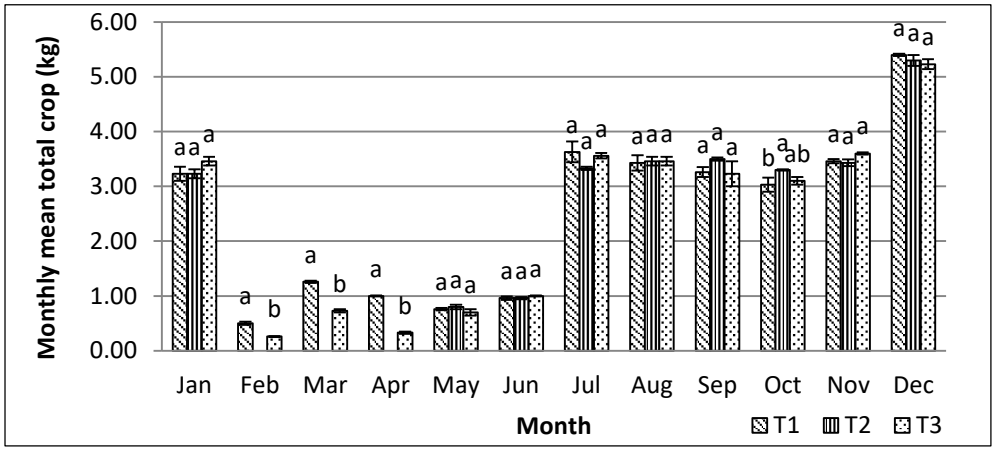

Fig. 1e. Mean monthly latex yield (kg), for the clone RRISL 203 for three treatments, T1- continuous Tapping, T2- winter rested and T3- d6 tapping during the wintering period for 2018

Means followed by the same letter (s) are not significantly different at $p \leq 0.05$, according to Duncan's Multiple Range Test (DMRT). Standard error of the mean is shown on the column.

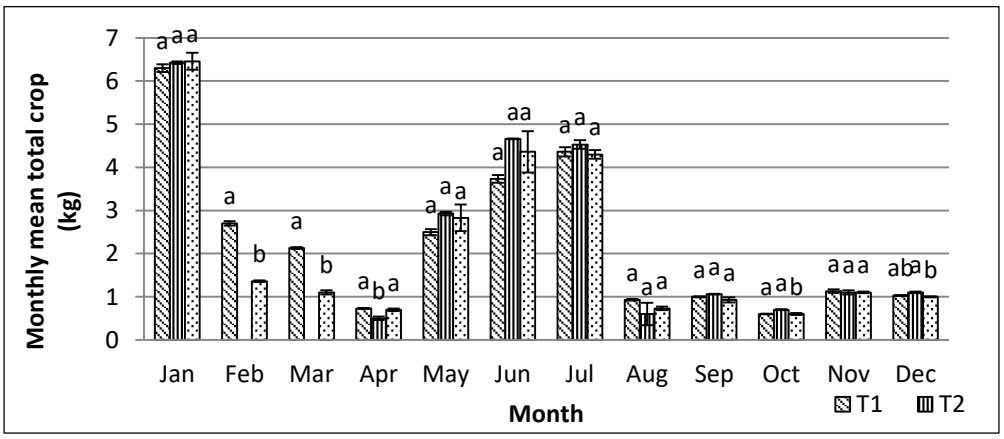

Fig. 1f. Mean monthly latex yield (kg), for the clone RRISL 203 for three treatments, T1- continuous Tapping, T2- winter rested and T3- d6 tapping during the wintering period for 2019

Means followed by the same letter (s) are not significantly different at $p \leq 0.05$, according to Duncan's Multiple Range Test (DMRT). Standard error of the mean is shown on the column.

The number of trees per treatment, number of tapping days, number of tapping days as a % of continuous tapping days, annual total crop for 30 trees (TC), annual total crop as a % of continuous tapping treatment, average crop per tree per tapping (g/t/t), g/t/t as a % of continuous tapping, crop per tapping day for 30 trees, % crop increase with reference to continuous tapping, for two consecutive years 2018 and 2019 for the clones RRIC 100, RRIC 121 and RRISL 203 are given in Tables 2a,2b and 2c. As it is clear from Table 2a, the number of tapping days as a % of that of continuous tapping is different correlating to the length of the winter resting period. In 2018, only 74.7% of the tapping days have been tapped but 92.9% of the crop has been achieved. Similarly, g/t/t or the crop per tapping day per 30 trees show 24.4% increase. But in year 2019, % number of tapping days is higher than that of 2018 (77%), due to shorter wintering period and therefore the % increase of g/t/t or the crop per tapping day per 30 trees is lower than that of year 2018 (8%). The data for d6 tapping during the wintering period also behave in the same pattern for two years. However, when the number of tapping days per annum is lower, the g/t/t is higher.

Table 2a. *The number of trees per treatment, number of tapping days, number of tapping days as a % of continuous tapping days, annual total crop for 30 trees (TC), annual total crop as a % of continuous tapping, average crop per tree per tapping (g/t/t), g/t/t as a % of continuous tapping, crop per tapping day for 30 trees, % crop increase with reference to continuous tapping, for two consecutive years 2018 and 2019 for the clone RRIC 100*

Treatment	No. of Trees	No. Tapping days	No of tapping days as a % of continuous tapping treatment	Annual TC for 2018 per 30 trees	Annual TC as a % of continues tapping	Crop per tree per tapping day (g/t/t)	g/t/t as a % of continues tapping	Crop per tapping day per 30 trees	% crop increase with reference to continues tapping
	2018								
T1	30	91	100	79.0	100	28.94	100	0.868	100
T2	30	68	74.7	73.4	92.9	36.00	124.4	1.080	124.4
T3	30	76	83.5	72.9	92.2	31.96	110.5	0.959	110.5
	2019								
T1	30	83	100	78.8	100	31.65	100	0.95	100
T2	30	64	77.1	66.0	83.6	34.39	108.7	1.03	108.4
T3	30	74	89.2	71.6	90.9	32.27	102	0.97	102

As shown in Table 2b, the number of tapping days as a % of that of continuous tapping is different correlating to the length of the winter resting period for the clone RRIC 121 too. In 2018, only 76.1% of the tapping days have been tapped but 88.6% of the crop has been achieved. Similarly, g/t/t or the crop per tapping day per 30 trees show 16.4% increase. In the year 2019, % number of tapping days is similar to that of 2018 (76%), despite the shorter wintering period and the % increase of g/t/t or the crop per tapping day per 30 trees is lower than that of year 2018 (7.6%). The data for d6 tapping during the wintering period also behave in the same pattern for two years. However, when the number of tapping days per annum is lower, the g/t/t is higher for the clone RRIC 121 also.

Table 2b. *The number of trees per treatment, number of tapping days, number of tapping days as a % of continuous tapping days, annual total crop for 30 trees (TC), annual total crop as a % of continuous tapping, average crop per tree per tapping (g/t/t), g/t/t as a % of continuous tapping, crop per tapping day for 30 trees, % crop increase with reference to continuous tapping, for two consecutive years 2018 and 2019 for the clone RRIC 121*

Treatment	2018								
	No. of Trees	No. Tapping days	No of tapping days as a % of continuous tapping treatment	Annual TC for 2018 per 30 trees	Annual TC as a % of continues tapping	Crop per tree per tapping day (g/t/t)	g/t/t as a % of continues tapping	Crop per tapping day per 30 trees	% crop increase with reference to continues tapping
T1	30	88	100	140.7	100	53.28	100	1.60	100
T2	30	67	76.1	124.6	88.6	62.00	116.4	1.86	116.3
T3	30	77	87.5	131.1	93.2	56.76	106.5	1.70	106.3
	2019								
T1	30	75	100	84	100	37.33	100	1.12	100
T2	30	57	76	68.7	81.8	40.16	107.6	1.20	107.1
T3	30	66	88	75.4	89.8	38.07	101.2	1.14	101.8

Table 2c shows the data for clone RRISL 203. The number of tapping days as a % of that of continuous tapping in 2018 is only 74% of the continuous tapping but 91% of the crop has been achieved. Similarly, g/t/t or the crop per tapping day per 30 trees show 23.8% increase. In the year 2019, % number of tapping days is similar to that of 2018 (78%), but due to shorter winter rest period the % increase of g/t/t or the crop per tapping day per 30 trees is lower than that of year 2018 (10.7%). The data for d6 tapping during the wintering period also behave in the same pattern for two years. For the clone RRISL 203 too, the lower number of tapping days per annum resulted higher g/t/t though the differences are there for two years with different lengths of wintering periods.

The total crop harvested from 30 trees for three clones and for three treatments, continuous tapping (T1), winter rested (T2) and d6 tapping during the wintering period (T3) during the year 2018, are shown in Figure 2a. Significantly higher annual total crop have been harvested for the clones RRIC 100 and RRIC 121 for both years. For RRISL 203, total annual crop values are not significantly different for the three treatments.

Table 2c. *The number of trees per treatment, number of tapping days, number of tapping days as a % of continues tapping days, annual total crop for 30 trees (TC), annual total crop as a % of continues tapping, average crop per tree per tapping (g/t/t), g/t/t as a % of continues tapping, crop per tapping day for 30 trees, % crop increase with reference to continues taping, for two consecutive years 2018 and 2019 for the clone RRISL 203*

Treatment	No. of Trees	No. Tapping days	No of tapping days as a % of continuous tapping treatment	Annual TC for 2018 per 30 trees	Annual TC as a % of continues tapping	Crop per tree per tapping day (g/t/t)	g/t/t as a % of continues tapping	Crop per tapping day per 30 trees	% crop increase with reference to continues tapping
	2018								
T1	30	87	100	90.1	100	34.51	100	1.04	100
T2	30	64	74	82.0	91	42.73	123.8	1.28	123.1
T3	30	75	86	86.0	95.4	38.21	110.7	1.15	110.6
	2019								
T1	30	82	100	81.8	100	33.25	100	1.00	100
T2	30	64	78	70.7	86.4	36.82	110.7	1.10	110
T3	30	73	89	76.7	93.8	35.00	105.3	1.05	105

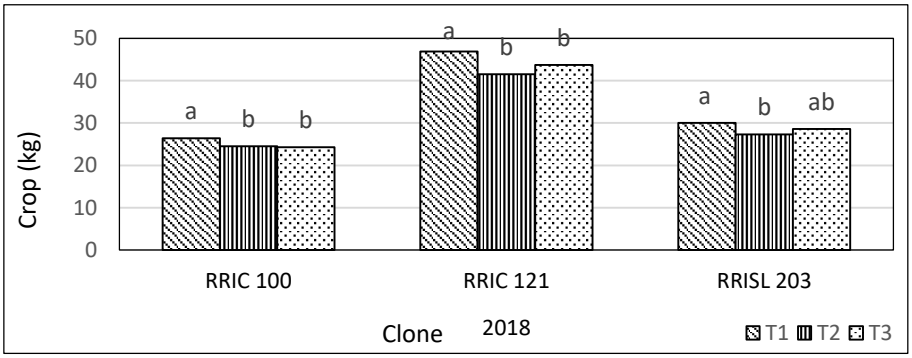

Fig. 2a. The total crop collected for three clones and for three treatments, for continuous tapping (T1), winter rested (T2) and d6 tapping during the wintering period (T3) during the year 2018. (The yields represented by the columns with the same letter are not significantly different).

The total crop collected for 30 trees for three clones and for three treatments, continuous tapping (T1), winter resting (T2) and d6 tapping during the wintering period (T3) during the year 2019, are shown in Figure 2b. The annual total crops for the three treatments are significantly different for the clones RRIC 100 and RRIC 121. Winter rested trees gave higher g/t/t values during the rest of the months but in the year 2019, the tapping days of cropping months were affected by heavy rain for all three clones the monthly mean values were very low for the year 2019. However, for the clone RRISL 203, differences were not significant between continuous tapping and d6 tapping during wintering (Fig. 2b).

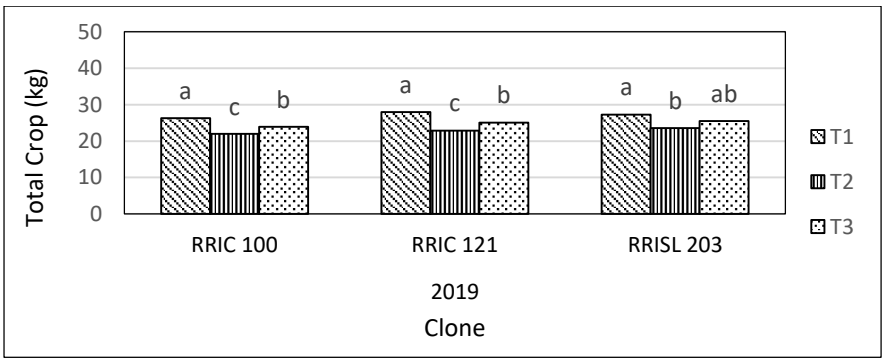

Fig. 2b. The total crop collected for three clones and for three treatments, continuous tapping (T1), winter resting (T2) and d6 tapping during the wintering period (T3) during the year 2019 (The yields represented by the columns with the same letter are not significantly different)

The girth increment for the three treatments and for the three clones for the trial period of two years are given in Table 3. No significant differences in girth increment (cm) values were recorded in all three treatments for all three clones.

The age of each selected clone for this trial is 25, 13 and 9 years for the clones RRC 100, RRIC 121 and RRISL 203 respectively. Therefore, comparison among clones is not possible for girth increment. However, the differences among treatments are not significant for all three clones. The clone RRIC 100 has long passed its growth phase. Though not significant a higher girth increment is observed in winter rested trees of RRISL 203.

The percentage tapping panel dryness in different treatments of the three clones tested are given in Table 4. No significant differences in the incidence of tapping panel dryness (partially dry, totally dry or both together) were recorded among treatments for the clones RRIC 100 and RRISL 203. Nevertheless, significantly lower percentage of partially dry trees was recorded for winter rested trees (T2) when compared to continuous tapping (T1) in RRIC 121.

Results of the economic analysis for the treatments and three clones are given in Table 5. The profit per hectare is highest in T2 in clones RRIC 100 and RRISL 203. For the clone RRIC 121, T1 shows the highest profit. However, the benefit to cost ratio is highest in T2 for all three clones.

Table 3. *Mean girth increment (cm) during the study period of trees in three treatments, continuous tapping (T1), winter rested (T2) and d6 tapping during the wintering period (T3) for the period. Values in each column followed by the same letter do not differ statistically (LSD test; $p<0.05$)*

Treatment	Mean girth increment (cm)		
	RRIC 100	**RRIC 121**	**RRISL 203**
T1- continues tapping with no winter rest	1.56[a]	0.46[a]	0.76[a]
T2- resting or no tapping during the wintering period	0.36[a]	0.73[a]	1.00[a]
T3- tapping at d6 frequency during the wintering period	0.86[a]	1.03[a]	0.76[a]

Table 4. *Effect of different tapping systems during wintering period on the occurrence of tapping panel dryness percentage. Values in each column followed by the same letter do not differ statistically (LSD test; $p<0.05$)*

Treatment	RRIC 100			RRIC 121			RRISL 203		
	Partial dry (PD) %	Total dry (TD)%	Both PD and TD%	Partial dry (PD)%	Total dry (TD)%	Both PD and TD%	Partial dry (PD)%	Total dry (TD)%	Both PD and TD%
T1	23.3[a]	36.7[a]	60.0[a]	20.0[a]	33.3[a]	53.3[a]	30[a]	20[a]	50[a]
T2	26.7[a]	20.0[a]	46.7[a]	13.3[ab]	33.3[a]	46.7[a]	20[a]	30[a]	50[a]
T3	26.7[a]	30.0[a]	56.7[a]	6.7[b]	46.7[a]	53.3[a]	30[a]	30[a]	60[a]

Table 5. *Economic analysis for three treatments, T1-continuous tapping, T2-winter resting and T3- d6 tapping during the wintering period for three clones (BCR: benefit to cost ratio)*

Clone		RRIC 100	RRIC 121	RRISL 203
Mean yield (kg/tree/year)	**T1**	2.63	4.69	3
	T2	2.45	4.15	2.73
	T3	2.43	4.37	2.87
Tapping days	**T1**	107	107	107
	T2	80	80	80
	T3	93	93	93
Tapping cost per ha year				
(labor wage*Tapping days per year)/250)*500	**T1**	214,000	214,000	214,000
	T2	160,000	160,000	160,000
	T3	186,000	186,000	186,000
Labor wage (Rs.) for ethrel application	**T3**	1,700	1,700	1,700
Total cost T3		187,700	187,700	187,700
Benefit per ha	**T1**	395,009	703,310	450,310
	T2	367,245	623,050	410,230
	T3	364,370	655,597	429,850
Assuming other costs are constant Profit per ha	**T1**	181,009	489,310	236,310
	T2	207,245	463,050	250,230
	T3	176,670	467,897	242,150
Assuming other costs are constant BCR	**T1**	1.85	3.29	2.10
	T2	2.30	3.89	2.56
	T3	1.94	3.49	2.29

Discussion

Pattern of wintering seems to depend mainly on geo-climatological conditions, the clone, age and the weather. The annual yield pattern of a rubber tree basically indicates the yield that can be harvested and in the present study the general pattern is shown in both years. Though it correlates with the weather to a greater extent, re-foliation and flowering seem to have a greater impact on the crop that is harvested during wintering months. Crop reduction starts with defoliation and gets to the maximum with re-foliation and flowering, indicating the tree's priorities. The present study further confirms the findings of previous studies on the direct relationship of the crop and the weather for re-foliation when the pattern of defoliation of 2018 and 2019 are examined. Once the defoliation completes re-foliation commences irrespective of the weather as shown by the data of the present study.

The monthly crop of the present study indicates a clear reduction during the wintering period. In 2018, significantly low yields are observed for five months, from February to June for all three clones and for all three treatments, due to longer wintering period. In 2019, when the wintering period was shorter, *i.e.*, February to March, significantly low yields were observed only from February to April. This confirms the impact of wintering on the yield.

In Sri Lanka, although winter resting had been practiced by both small holders and plantation companies until 1970's, the practice has gradually disappeared under the present scenario. The common belief in early time was that tapping rest could give some additional benefit to the rubber tree, especially to minimize the effect of stress imposed on tapping during the wintering period and thereby to minimize tapping panel dryness condition. In the present study, although tapping rest induced higher yield per tree per tapping (g/t/t) in all three clones over the two year period, annual total crop obtained from trees of all three clones rested during the wintering period was significantly low as compared to crop obtained from trees with no winter rest for both 2018 and 2019. Nevertheless, no significant difference was recorded for total annual crop obtained from trees rested during the wintering period as compared to those tapped at d6 frequency in RRISL 203.

For other two clones, RRIC 100 and RRIC 121, even d6 tapping frequency did not contribute to increase the annual total crop as compared to normal d3 frequency with no winter rest.

The effect of winter rest on the yield had been studied by the scientists at RRISL using clones PB 86 and Nab 12 as far back as in 1964, in a field which was replanted in 1952 and opened for tapping in 1958, after six years (Annual Review, 1972). Harvesting system had been S/2d2 with and without stimulation at six month intervals during the initial years but later only with or without winter rest had been looked at. Average girth and yield recorded at the end of nine years are reported in Annual Review for 1972 and it had been concluded that the yield differences measured as g/t/t for both clones for winter rested and continuously tapped trees were not significant. These

findings must have compelled the RRISL to declare that winter resting has no effect on the total annual crop.

Chantuma, *et al.* (2017) have conducted a trial with the clone RRBM 600 to see the effect of winter resting on the yield. As explained by them the winter period seems very long in Thailand, especially in Chachoengsao, from January to May and resting 4-5 months seems too long to get a good income. Also, they report of poor adoption of correct d2 tapping system. Accordingly, they have tested on the effectiveness of different winter resting periods during this long wintering period, to recommend the most effective period. They also have reported that the winter resting has resulted in higher g/t/t/ during the rest of the year though the difference is not significant. They also have reported that resting during the latter two months *i.e*. during the re-foliation period when the tree needs more storage food for its own internal functions, the beneficial effects are more.

In the present study, the duration of the wintering period for the two years are different and the closest reason for the shorter wintering period observed in 2019 was the severe drought that prevailed during the first few months of the year. As far as yield reduction is concerned, a marked yield reduction was observed during defoliation period which is more than during re-foliation. According to Sethuraj (1977), the extent to which clones suffer from yield depression during wintering period also depends on the clone. Some clones tend to shed and replace part of their foliage in a simultaneous manner over a long period of time, thus they do not show obvious signs of wintering where some clones become leafless for a period of time. Some of the clones fall in between these two extremes. Behavior on the yield depression is also dependent on characters of the clone. Latex metabolism is mainly regulated by the availability of sugars in the laticifers, which depends on the carbohydrate loading to the laticiferous tissues which is used at cell level (Tupy, 1998). Sucrose produced by photosynthesis in leaves are subjected to catabolism process and release acetate molecules initiate isoprene chains and provide energy that required for the biosynthesis of latex within latex vessels. It has been evident that there is a positive and highly significant correlation between sugar concentration and production of latex which accounts for the variability in yield of latex (Jacob *et al*., 1985). Flowering and fruit formation utilize large amounts of carbohydrate reserves which leads to low yielding phase. Therefore, the yield obtained during the wintering period is said to be comparatively low when compared to that of other months due to the low sucrose content. Nutrient drain has become a significant factor with tapping and taking out of latex during wintering. However, some of the studies have found that there is no significant damage to the physiological processes of the plants, even though they are tapped without winter resting (Ng *et al.,* 1969). As reported by them, the reduction of the number of tappings due to the resting period was compensated by the higher yield in g/t/t during the producing

months. The longer the tapping rests during wintering season, the higher the g/t/t was. This observation was true for the yield data for 2018 and 2019 where the length of the wintering period was different. Experiments of Menattoor *et al*., (1991) demonstrated that the girth increment is minimum during winter months. There is a threat for occurrence of incidences like tapping panel dryness of trees if they are tapped intensively without giving any winter rest.

Five major climatic zones have been identified in India as i). tropical rain, ii). tropical wet and dry, iii). sub tropical wet iv). arid and v). desert (Priyardarshan, 2011). First three regions are identified as suitable regions for the cultivation of rubber. Rubber plantations in north-east region (*eg*. Tripura) experience wintering during December to January and re-flushing commences by February. Rubber cultivated in non-traditional areas of India experience a complete defoliation during the period of February to March and it is evident that *Oidium* like leaf diseases occurring during re-foliation period (Priyadarshan, 2011). As suggested by Priyadarshan *et al*. (1998); latex yield becomes poor in this period due to several reasons namely, low temperature and utilization of carbohydrate reserves for re-foliation, flowering and fruit set during the months of February to April. Non-traditional areas record lowest yield during the period of January to May. Normally trees are given about four weeks rest if the soil is very dry and yield is uneconomic during re-foliation and flowering of rubber trees in India (Rubber Research Institute of India, 2002). Rubber growing areas in Brazil such as Sao Paulo, experiencing defoliation, re-flushing and seed fall once a year (Ortolani *et al*., 1998) and the trees are exploited throughout the year.

A study was undertaken in India, to group rubber *(Hevea brasiliensis)* clones based on their wintering behavior in Tripura (one of the rubber growing areas of North East India) with the objective of analyzing performance of wintering pattern in different clones. Fifteen clones from a clone evaluation trial were scored for the wintering pattern at weekly intervals for six weeks from December to February during 1988-89, 1989-90 and 1991-92 period. Wintering pattern of clones was uniform for all the years under the study. However, three distinct clusters of i) early, ii) intermediate and iii) late wintering clones were obtained *viz*., (i) RRII 105 and RRIC 105, (ii) RRIM 600, PB 86, GT 1, RRIC 52 and PB 235 and (iii) RRII118, RRIM 605, Gil, Harbell, RRII 5, PB 5/51 and RRIM 703. RRII 203 was found to fall in between the second and the third clusters (Vinod *et al*., 1996).

One of the main objectives of the present study was to see the impact of winter resting on the incidence of brown bast. As we expected a reduction in brown bast condition in trees rested during the wintering season as compared to those tapped at normal frequency (d3) or d6 frequency during the wintering, was observed for all three clones RRIC 100 and RRIC 121, but not significant. One of the possible reasons for this could be the effect of tapping employed before imposing the treatments. Trees of RRIC 100 had been tapped for 20 years, RRIC

121 for 8 years and RRISL 203 for 4 years before being subjected to present treatments during the wintering period. If incorrect tapping policies such as excessive tapping and over stimulation had been practiced, the negative effect of them could not be fully ruled out even under best tapping conditions also all three clearings had brown bast affected trees when the trial was initiated and they were excluded from selecting. Further, brown bast is a result of a long term exposure to over exploitation and two seasons of rest is not sufficient to show any effect. Furthermore, another factor contributing to mask the differences among treatments for brown bast may be that the entire Kuruwita estate has been rain guarded and tapped at d3 frequency with stimulation for many years. The average dry tree percentage in entire substation is very high, about 30%. As it is seen in Table 4, partial dry tree percentage is also high in all three clones. Dry trees were determined when tapping is being done and there can be some trees which are nearing to dry but not showing symptoms. Therefore, effect of winter resting on incidence of dry trees should have been tested with new trees to see the difference among treatments.

The tapping panel dryness is an accumulation of stress within which exhibits after exposed to the factors contributing for many consecutive years. Therefore, future research, more physiological parameters should be included and the maintenance of the clearings to recommended standards right from the beginning is also important to get a clear understanding on physiological behavior of wintering. Effect of winter tapping seems to be prevailed throughout the year and thus throughout life cycle of rubber tree. It is important to analyze leaf samples for nutrients and growth parameters such as girth, bark thickness, growth of root systems *etc*. Apart from the expected effect on tapping panel dryness, incidences of other diseases also should be taken in to consideration.

The data obtained in the present study too show the differences in the g/t/t between winter rested and continuously tapped trees. But the economic analysis show a gain by resting during the wintering period. As evident by the crop figures, the rate of reduction of the crop vary among the clones and the year in the present study. The effect of winter resting on the trees becoming dry is a long term process and if continued may expect some reduction in TPD. Saving on the bark or in other words extending the tappable period is a beneficial result of winter resting. The cost of tapping is generally two thirds of the cost of production and therefore, tapping during the wintering months should be very uneconomical. Though the wintering period in Sri Lanka is not as long as in Thailand, the resting period may be reduced, more towards the re-foliation period through further trials. Martin (1969) recommends winter resting of young rubber fields where trees girth better during winter months if rested. He further states resting during the latter part of the wintering period as more effective. In conclusion, resting during the wintering, flowering and flushing period generally from February to March or

April, length depending on the weather prevailing, will lead to reduction in total crop for a given year irrespective of clones. Resting during the wintering period increases the g/t/t for the rest of the months. Also, as confirmed by the economic analysis, winter resting is beneficial for the grower and for the tree in many ways. Although winter rest has not minimized brown bast or tapping panel dryness significantly, during the present study period of two years, lower values are reported for RRIC 100 and RRIC 121. Therefore, all recommended clones should be tested for the effect of winter resting and also for different periods, *i.e*. at the beginning, towards re-foliation *etc*. for many consecutive years. New fields should be selected and also different harvesting systems need to be included in these trials.

However, based on the results of the present study, winter resting can be recommended as advantageous.

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Capital assets impact on rubber farming in Moneragala in Sri Lanka: Rubber smallholders' perception

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Abstract

Rubber farming in Moneragala district has been considered as an initiative to poverty alleviation and livelihood sustainability. Thus rubber farming was introduced to eight Divisional Secretariat (DS) divisions in the District. Yet, no study was found which addresses the impact of capital assets on rubber farming. Hence, a questionnaire survey was conducted in 2019 to evaluate rubber smallholders' perception on the impact of capital assets on rubber farming at the household and community level and also to identify the factors affecting the perception. Several were defined to capture changes in the capital asset categories of livelihoods, viz. financial, physical, natural, human, and social assets at both household and community levels. A five-point modified Likert-type scale was used to measure the extent of agreement of variables and weighted values were used to derive the mean score of each item. The mean perception score of respondents was calculated and their key socio-economic characteristics were measured. Perception of the respondents was categorized as, least, moderate and most favourable groups using the confidence interval method. Descriptive methods and Spearman rank correlation analysis were used in data analysis. The indicators used to evaluate the Perceptions on the Impact of Rubber Farming on Capital Assets (PIRFCA) were reliable with Cronbach's alpha exceeding 0.7. The overall perception level of RSs on the impact of rubber farming on livelihood assets at the household and community level was under the most favourable level. The level of education, age, the experience of farming and rubber farming, rubber farming extent, training programmes attended, contacts with fellow farmers and income from rubber farming were significantly correlated with PIRFCA, while gender and type of job did not have a significant relationship. Accordingly, RSs' perceived perception explained that rubber farming is the main source of their livelihood developments. Hence, policymakers should critically consider these factors when expanding rubber farming to non-traditional areas in the country as a livelihood strategy.

Key words: capital assets, impact of rubber farming, perception

Introduction

The rubber cultivation is expanded to the agro-ecological regions, IL1c, IL 2 and IM 2b belonging to the eight Divisional Secretariat (DS) divisions of Moneragala District, with the aim of transforming the existing system of shifting cultivation and cash crop farming to more ecologically stable cultivation systems with proper land management by smallholders. Rubber Farming (RF) was originally expanded to Moneragala with two major objectives in the Millennium Development Goals; namely, poverty alleviation and livelihood sustainability (Wijesuriya *et al*., 2011). However, during the period from the year 2000 to 2005, a considerable increase was observed in the rubber extent due to the adoption of RF by the smallholders in Moneragala (Dissanayake *et al*., 2005). At present, the total extent of rubber smallholdings in Moneragala is about 4,402 ha which involves 7,802 holdings in number, out of which, the economically productive harvesting extent is only 689 ha which accounts for 20% (7,802 holdings). However, only about 5% of cultivable lands are being utilized for rubber cultivation in Moneragala (MPI, 2017). On the other hand, Moneragala is the first intermediate zone RF practice that has been implemented in Sri Lanka.

There is a positive relationship between the growth of agriculture and poverty alleviation with the engagement of the majority of rural people in the agriculture sector. Agricultural development programmes would affect poverty reduction and focus on up-lifting of the Capital Assets (CA) in rural areas. The Government of Sri Lanka implemented policies and strategies for expanding RF among the smallholders to reduce poverty in rural areas, to enhance the CA of the peasant smallholders and finally, to uplift the socioeconomic status of them. Thus, the public eye by the RF as a livelihood strategy in the non-traditional area has focused on the development of the CA in both levels of household and community (Wijesuriya *et al*., 2011). Therefore, the adaptability of the RF as a livelihood strategy may affect the CA of the rural smallholders at the household level and community level both positively and negatively.

Many studies were found in the literature in expansion of RF into rural areas and its effects on the farmers' socioeconomic status (Kromkratoke and Suwanmaneepong, 2017; Kongmanee *et al*., 2020). Also, the most of studies of RF in Moneragala have only focused on the aspects of extension and technical matters. Therefore, there is a research gap in the studies of CA impact of RF in Moneragala. This study contributes new insights by comparing independently observed changes in usage of land and associated CA changes, with perceptions of those changes, and the impacts of change in the lives of rural people. In the light of the above, the success of RF during and after the establishment of RF would be a major learning curve, so to mention, and if recorded properly, its successes and failures would be of enormous value for planting development programmes which are to be planned in the future in Sri Lanka.

As noted in the background of the research problem, it is clear that RF is expected to change the CA and linkage between RF on the household and community level. This study, therefore, attempts to make a point of filling the prevailing gap in the literature and to uncover the impact of RF on CA of smallholders through achieving the objectives; *viz.* to study the perception on the impact of RF on CA of smallholders based on household and community level in Moneragala and identify the factors affecting to the perception.

Methodology

Sampling procedure and data collection

The study was conducted in the Moneragala District (6.872575°N 81.33728°E) in Sri Lanka during 2019. The farmer survey was conducted with 511 Rubber Smallholders (RSs) in eight rubber growing DS divisions (Table 1). The stratified sampling technique was applied according to the distribution of RSs in each division. Pre-tested questionnaire and field observations were used to collect data and information from the RSs. The questionnaire consists of questions from the key general information of RSs and perception on the impact of RF on the development of CA on RSs based on the household and community level.

The qualitative methodology was selected for this study because of its ability to elicit experiences through a descriptive, reflective, interpretive and engaging research framework (Creswell, 2009). Some research has been conducted about perception, including

Table 1. *The selected sample sizes of rubber smallholders from different DS divisions in Moneragala District*

DS division	No. of smallholders
Bibila	43
Madulla	65
Madagama	92
Siyabalanduwa	4
Moneragala	99
Badalkumbura	182
Wellawaya	19
Buttala	7
Total	511

factors related to agriculture such as extension (Moore, 1988), adoption of farming systems (Williams and Wise, 1997), environment (Bruening *et al*., 1992) and information technologies (Ahmed *et al*., 2004). Perception is the cognitive process where people used to make sense out of the environment by selecting, organizing and interpreting information from the environment (Lindsay and Norman, 1977). Attitudes affect perceptions and *vice versa*. Hikson and Keith, (2000) mentioned, that assessing farmers' perceptions is an important means to evaluate their knowledge level on a particular issue, as perception refers to an individual's current appraisal of an object or program. People base their perceptions on past experience and knowledge; therefore, if a person has limited knowledge and experience about a topic, then they cannot accurately perceive it or form an opinion on it (May, 1969; Bohlander and Snell, 2004). Therefore, the impact of RF on RSs' CA was investigated by RSs' perception to gain deeper understanding

through experiences. So that it might be helpful to the concerned policymakers to have the field level idea during policy making and implementation process.

Measuring the impact on capital asset

The CA impact of this study was considered whether and to what extent the RF has affected peoples' livelihoods in Moneragala area. The hypothesis was that increasing trade of rubber products (Latex and Ribbed Smoke Sheets - RSS) would provide income, employment, changing environment and other opportunities for RSs to improve their welfare in the household and community level. According to the definitions of CA that include non-financial aspects of sustainable rural livelihoods framework was used (Carney, 1998, DFID, 2005) to guide the selection of indicators (Table 2) (DFID, 2005; IFAD, 2007) and these may be tangible and intangible assets (Eldis, 2010; Lindenberg, 2002; Tennakoon, 2002). Accordingly, items (indicators) were defined to capture changes in the five CA categories that form the main components of RSs' livelihoods, namely financial, physical, natural, human, and social assets and these categories have been widely adopted as an organizing principle of RSs' CA impact (Bebbington, 1999: Bossel, 2001; Campbell *et al*., 2001; Cramb *et al*., 2004; Gottret and White, 2001).

Developing the items to measure the perception on capital assets at the household level

The perception of each indicator was presented as an item/statement (Segnon, 2015). Twelve household level items were selected to measure the CA with the discussion of the experts of the rubber sector and literature review (Table 3).

Table 2. *Definitions of the five capital assets*

Type of capital asset	Definition
Natural capital	The natural resource stocks from which resource flows useful for livelihoods are derived (land, water, wildlife, biodiversity and environmental resources)
Physical capital	The basic infrastructure (transport, shelter, water, energy and communications) and the production equipment and means that enable people to pursue their livelihoods
Social capital	The social resources (networks, membership of groups, relationships of trust, access to wider institutions of society) upon which people draw in pursuit of livelihoods
Human capital	The skill, knowledge, ability and good health of the labour which are important to pursue different livelihood strategies
Financial capital	The financial resources which are available to people (savings, supplies of credit or regular remittances or pensions) and which provide them with different livelihood options

Table 3. *The selected items to measure the capital assets at the household level*

Type of capital	Items
Natural capital	HN 1: Improve soil condition in the rubber land
	HN 2: Protects water resources in the rubber land
Physical capital	HP 1: Development of living house
	HP 2: Buying vehicles
	HP 3: Buying household durables
Social capital	HS 1: Improves social relationships
	HS 2: Access to wider institutions of society
Human capital	HH 1: Improve the health status of family members
	HH 2: Improve the nutritional status of family members
Financial capital	HF 1: Continuous income throughout the year
	HF 2: Household savings were developed
	HF 3: Access to credit was improved

Developing the items to measure the perception on capital assets at the community level

To measure the impact of RF on the community level, a set of items relevant to each CA was selected, based on the discussion of the experts of the rubber sector and also through literature review. At the community level, indicators address the effects on overall community assets in the rubber growing areas (Dove 1994; Ashley and Hussein, 2000). Theoretically, a strong production-consumption system might also contribute to economic performance at the national level through job creation and foreign exchange earnings. However, in this study, national-level impacts were not analysed. Table 4 shows the items selected to measure the CA at the community level.

Table 4. *The selected items to measure the capital assets at the community level*

Type of capital	Items
Natural capital	CN 1: Reduce soil erosion
	CN 2: Protects water resources in the area
Physical capital	CP 1: Development of access roads to access farming lands
	CP 2: Development of bridges to access the farming lands
Social capital	CS 1: Improves the socio-cultural cohesion
	CS 2: Effective community organization
Human capital	CH 1: Enhance the full-time employment opportunities
	CH 2: Enhance the part time employment opportunities
Financial capital	CF 1: Improves the community financial resources
	CF 2: Access to credit facilities

Measurement of items

The assessment of CA outcomes was based on the last ten-year reference period (2009 to 2019), due to no baseline data regarding livelihood status, the assessment relies on the expert judgment of changes on indicators. The ten year period was deemed sufficiently long to be able to observe changes, but short enough for the assessor to make reliable judgments of changes based on the information available. Changes that occurred before 2009 were not captured in the assessment. Each item was assessed according to the questionnaire. RSs were asked to mark their opinion on these items based on a five-point ordinal scale (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 indicator. 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 five capital aspects were calculated (Jayasinghe-Mudalige and Henson, 2006). The mean perception score of a respondent was determined by adding up the weighted values for all the responses against all the items and RSs' key socio-economic characteristics.

Data analysis

Respondent's perception was measured by summing up the score of each item in the questionnaire. The mean perception score in each capital was measured. The respondents were separated into three perception categories *viz.* most favourable, favourable and least favourable attitude based on their total score 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 (SE is the standard error). Cumulative frequency distribution and percentage analysis were used to quantify groups. Statement-wise perception was evaluated by using descriptive statistical methods. Descriptive methods and Spearman rank correlation analysis were used in data analysis employing STATA 15.0. The scale reliability of the statements was tested using the Cronbach alpha value. The perception analysis of the alpha values exceeding 0.7 was considered sufficient (Lord and Novick, 2008). The aggregate mean scores of the five CA and mean perception score of a respondent were measured at the household and community level. RSs' socio-economic characteristic and their influence on the perception of CA impacts were also analysed.

Results and Discussion

Key socio-economic profile of the farmers

The key socio-economic characteristics of RSs (Table 5) were used to identify the relationships with perception (Shankaraiah and Swamy, 2012). The age of the rubber farmers varied from 21-

78 years and the majority was young and were 40 years or below. The half of the sample of the smallholders had studied up to O/L while about 9% of smallholders had studied up to grade 5 and 21%, up to advanced level. Around 30% of smallholders had less than 15 years of experience in farming, while 36% were reported to have more than 36 years of experience. The mean land size was 0.62 ha. About 50% of the lands were less than 2.9 ha in size.

Table 5. *Distribution of key socio-economic characteristics of rubber smallholders*

Key socio-economic characteristics and their categories	**%**
Age (years)	
< 40	42
41-60	38
>61	20
Range	21-78
Education level	
Up to grade 5	09
Up to grade 8	19
Up to Ordinary Level	51
Up to Advanced Level	21
Experience in farming (years)	
<15	31
16 – 25	15
26 – 35	18
>36	36
Range	5-55
Land size (ac.)	
< 1	7.5
1-1.9	38
2- 2.9	7
3-3.9	22.5
4-4.9	21
>= 5	4
Mean	1.5

Consistency test of perceptions of rubber smallholders on the impact of capital assets

Table 6 shows the mean and reliability coefficients (Cronbach alpha values) of the indicators used to evaluate the Perceptions on the Impact of Rubber Farming on the Capital Assets (PIRFCA) at the household and community level by RSs. As all items exceed 0.7 (Cronbach Alpha value), the indicators used in this study are valid and reliable to explore the perceptions of RSs.

Distribution of rubber smallholders by perception categories

More than 50% of the RSs in this study area consider RF as the most favourable livelihood strategy on their impact on CA (Table 7). Whilst, 30% of the RSs consider it as a favourable livelihood strategy, 16% of the RSs consider it as the least favourable. However, overall PIRFCA is considered as the most favourable level.

Table 8 explains the category of PIRFCA at the household and community level. More than 50% of the RSs in this study area consider RF as the most favourable livelihood strategy on their CA at household level while 28% of the farmers considering it as a favourable livelihood strategy and 8% of the RSs considering it as a least favourable livelihood strategy. Nearly half of the RSs of the sample in this study area are considering the RF as the most favourable livelihood strategy (44%) on their CA at the community level. However, favourable and least favourable percentages are 32 and 24 respectively, at community level perception.

Table 6. *The reliability of perception variables*

Type of capital	Household level		Community level	
	Cronbach Alpha	SD	Cronbach Alpha	SD
Natural capital	0.8777	0.3322	0.7777	0.3555
Physical capital	0.7807	0.6964	0.7507	0.6567
Social capital	0.7277	0.4183	0.7531	0.5183
Human capital	0.9833	0.3864	0.7621	0.4868
Financial capital	0.9817	0.6924	0.7111	0.7930

SD=Standard deviation

Table 7. *Distribution of rubber smallholders by overall perception categories*

Category	Mean perception score	% of respondents
Most favourable	>3.382	54
Favourable	3.381-3.300	30
Least favourable	<3.301	16

Table 8. *Distribution of rubber smallholders by perception categories*

Category	Household level		Community level	
	Mean perception score	Percentage of respondents	Mean perception score	Percentage of respondents
Most favourable	>3.521	64	>3.243	44
Favourable	3.520-3.485	28	3.242-3.119	32
Least favourable	<3.484	08	<3.118	24

Analysis of item-wise perception

The mean scores of PIRFCA at household level are given in Table 9. The assessment shows that the mean of overall PIRFCA at the household level is 3.74. The highest mean score was recorded from physical capital (3.69) and the lowest (3.73) was recorded from social and financial CA. The mean scores of natural and human capitals were 3.81 and 3.78, respectively.

The mean scores of PIRFCA at the community level are given in Table 10. The assessments show that the mean of overall PIRFCA at the community level is 3.27 while the highest mean score was recorded from human capital (3.99) and the lowest (2.16) was recorded from physical capital. The mean scores of financial, natural and social assets were 3.53, 3.89 and 2.76 respectively.

Table 9. *Mean scores of the items and capital assets to assess the perception at household level*

Type of capital	Items	Mean score of items	Mean score of capital assets
Natural capital	HN 1: Improve soil condition in the rubber land	3.835	3.812
	HN 2: Protects water resources in the rubber land	3.790	
Physical capital	HP 1: Development of living house	3.730	3.696
	HP 2: Buying vehicles	3.645	
	HP 3: Buying household durables	3.715	
Social capital	HS 1: Improves social relationships	3.690	3.730
	HS 2: Access to wider institutions of society	3.770	
Human capital	HH 1: Improve the health status of family members	3.825	3.780
	HH 2: Improve the nutritional status of family members	3.735	
Financial capital	HF 1: Continuous income throughout the year	3.700	3.730
	HF 2: Household savings were developed	3.730	
	HF 3: Access to credit was improved	3.760	
Mean score of overall perception at the household level			3.74

Table 10. *Mean scores of the items and capital assets to assess the perception at the community level*

Type of capital	Items	Mean score of items	Mean score of capitals
Natural capital	CN 1: Reduce soil erosion	3.860	3.896
	CN 2: Protects water resources in the area	3.932	
Physical capital	CP 1: Development of access roads to access farming lands	2.215	2.163
	CP 2: Development of bridges to access the farming lands	2.112	
Social capital	CS 1: Improves the socio-cultural cohesion	3.324	2.765
	CS 2: Effective community organization	2.205	
Human capital	CH 1: Enhance the full-time employment opportunities	3.941	3.996
	CH 2: Enhance the part time employment opportunities	3.992	
Financial capital	CF 1: Improves the community financial resources	3.514	3.536
	CF 2: Access to credit facilities	3.559	
Mean score of overall perception at the community level			**3.27**

Perception of the natural capital assets development

From the items which assessed the impact on natural capital assets, the HC1 (improve soil condition in the rubber land) had the highest mean with (3.83) and HC2 (protects water resources in the rubber land) in the rubber land second. The overall perception on improving natural capital development is under the most favourable level (mean =3.81) at household level while, the CN2 (protects water resources in the area) had the highest mean with (3.93) and CN1 (reduce the soil erosion in the area) was the second. However, the overall perception on improving natural capital assets development is under the most favourable level in (mean =3.89) at community level. Rubber is a perennial tree crop and it has a deep rooting system and a closed canopy. Therefore, rubber plantations have the ability to reduce the high-intensity of rains and prevent soil erosion (Samarappuli *et al*., 2005). From an ecological point of view, rubber plantations can be considered as a self-sustaining environmentally acceptable eco-system, which are capable of mitigating extreme weather conditions and protecting biodiversity (Samarappuli *et al*., 2005). One of the main ecological services of the rubber plantation is carbon sequestration which was estimated as 1296 MT/ha, at the end of 24 years of the life cycle (Munasinghe *et al*., 2011). Therefore, the environmental impact of rubber cultivation is a crucial factor to the Moneragala as this district covers different agro-ecological regions.

Perception of the physical capital development

From the indicators used for evaluating the impact on physical capital, HP1 (Development of living house) has the highest mean (3.73) while, the means of HP2 (Buying vehicles) and HP1 (Buying household durables) are 3.64 and 3.71, respectively. The overall perception on improving physical capital development is under the satisfactory level (mean =3.69). The CP1 (development of access roads for farming lands) had the highest mean with (2.21) and CP2 (development of bridge to access the farming lands) in the cultivated area second. However, the overall perception on improving natural capital development is under the least favourable level (mean =2.16) at the community level. RSs developed some access roads to their farms in Badalkumbura and Medagama areas, but reported cases were limited. RSs in this sample believe that rubber cultivation has the most favourable impact on physical capital development at household level.

Perception of the social capital development

The mean scores of items HS1 (improves the social relationships) and HS2 (access to wider institutions of society) are 3.69 and 3.77, respectively. The overall perception on improving social capital development is under the most favourable level (mean =3.73) at household level. Considering the community level, the mean scores of indicators CS1 (improves the socio-cultural cohesion) and CS2

(effectiveness of community organization) are 3.32 and 2.20, respectively. The overall perception on improving social capital development is under the least favourable level (mean =2.76). Most of the RSs in the Monaragala are members of the *Thurusaviya* rubber society. This society have welfare and credit schemes to the members and society members share the labour among themselves for free of charge to engage in agronomic practices of rubber cultivation, such as planting, weeding and manuaring. RF is considered as a subculture in the agricultural sector in Moneragala and it is important to maintain the social integrity of non-traditional RF areas (Dissanayake and Wijesuriya, 2012; Wijesuriya *et al*., 2008).

Perception of the human capital development

From the two indicators used for evaluating the impact on human capital, the HH1 (improve the health status of family members) has the highest mean score (3.82). The overall perception on improving human capital development is under a most favourable level (mean =3.78). Wijesuriya *et al.*, (2012) reported that most RSs spend more than 95% of their income on food and beverages and health care. From the indicators used for evaluating the impact on human capital based on community level, indicator CH2 (enhance the part-time employment opportunities) has the highest mean (3.99) whilst, the means of CH1 (enhance the full-time employment opportunities) is 3.94. These findings support the human development programes operated by RRISL with the aim of providing new job opportunities as harvesters and sheet makers have been conducted Thus, many types of job opportunities were created as latex collectors and transporters, RSS collectors/dealers, input sellers of rubber farming and private advisors due to the rubber farming in Moneragala (RRISL, 2012).

Perception of the financial capital development

The mean scores of the perception on HF1 (continuous income throughout the year), HF2 (enhance the household savings) and HF3 (access to credit facilities) are 3.70, 3.73 and 3.76, respectively. The overall perception on improving financial capital development is under the satisfactory level (mean=3.73) at the household level. From the indicators used for evaluating the impact on financial capital, indicator CF2 (access to credit facilities) has the highest mean (3.59) whilst, the means of CF1 (improves the community financial resources) was 3.51. The overall perception on improving the financial capital assets development is under the most favourable level (mean =3.53). Although most of the RSs in the study area are engaged in seasonal farming, their main source of income is rubber farming throughout the year. Further, the main economic objective of RSs is to maximize their family income (Dissanayake and Wijesuriya, 2012). RSs in this sample believe that RF has an

impact on this financial capital development on their livelihoods.

Influence of socio-economic characteristics of rubber smallholders' on their perceptions

This section examines the impact of the key socio-economic characteristics of the RSs on their PIRFCA. Except for gender and type of the job, the other eight variables had a significant positive correlation with the farmer's perception at 0.001 significant level (Table 11). Age is negatively correlated with PIRFCA. Age is an important factor that determines the response of a person during various activities in his life. Rational decision making process also depends on age and a younger person has more ability to adapt and respond to an activity (particularly, in communication and understanding) than an older person (Tsur *et al*., 1990). RSs' PIRFLA is positively correlated with the level of education. This is an indication that more the education level of RSs, the greater their ability to perceive the economic and non-economic benefits from the RF. Education helps people to gain knowledge and understanding about a particular idea and makes them more communicative (Khan, 2005).

Farming and RF experience showed a significant positive influence on PIRFCA. With the accumulated farming experience RSs can compare the different farming systems with RF with regard to CA. Experience is very important in any field of life to gain benefits and quality (Khan, 2005). It develops the communication network among the RSs and also helps to share the knowledge, experience and attitudes among them. The extent of cultivation of RF positively influenced PIRCL. It means that the perceived livelihood benefits from large scale RF is comparatively high.

Table 11. *Rubber smallholders' socio-economic characteristic and their influence on their perceptions*

Farmers' characteristics	Coefficient	P value
Gender	0.0599	0.3994
Level of education (years)	0.9704*	0.0000
Age (years)	-0.9764*	0.0000
Type of the job (full time, part-time)	0.0944	0.1835
Experience of farming (years)	0.3562*	0.0000
Experience of rubber farming (years)	0.9600*	0.0000
Total cultivated rubber land extent (ha)	0.9796*	0.0000
Participated training/extension programmes	0.9591*	0.0000

Participation in training/extension programs is positively correlated with PIRFCA. Agricultural extension is responsible for technology transfer and plays a significant role in increasing productivity, income and profit (Luqman *et al*., 2004). Agricultural education, information and skill development are the main concerns of agricultural extension agencies (Farooq *et al*., 2007). Thus agricultural extension organizations are entrusted with the primary task of educating and disseminating the latest agricultural technologies to the farmers, using various extension teaching methods like individual, group and mass contact methods. Therefore, by participating the programmes conducted by RRISL and RDD, RSs can gain knowledge and skill on rubber farming and its impact. Contacts with other RSs for advisory purposes is positively correlated with PIRFCA. Advisory contacts are necessary for RSs to gain practical knowledge and solve practical ongoing problems. These provide an opportunity to learn by doing. The income of RF is positively correlated with PIRFCA.

Conclusion

Indicators used to evaluate the perceptions of RSs on the PIRFCA at both of household and community level were valid and reliable. RSs perceived perception explained that RF is the main source of their CA developments. According to the findings, the perception of RSs towards the impact of RF on CA at household level and community level under most favourable level. Therefore, RF can be expanded into non-traditional areas in the country as a livelihood strategy to enhance the development of CA. The level of education, the experience of farming and RF, rubber farming extent, participated training programmes, contacts with other RSs and income of RF are positively correlated with PIRFCA, while age is negatively correlated. Hence, policymakers should critically consider these factors in the programmes on expanding RF as a livelihood strategy.

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Silica/white rice husk ash hybrid filler for rubber composites for the manufacture of low speed castor wheel rubber treads

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Abstract

The possibility of replacing a part of the 60 pph of commonly used silica filler imported from Wellink Chemical Co., India used in rubber composite for the manufacture of low speed castor wheel rubber tread formulations was studied. The curing characteristics and mechanical properties such as specific gravity, hardness, tensile strength, rebound resilience and abrasion volume loss of the composites prepared with varying amounts of White Rice Husk Ash (WRHA) ranging from 15 to 60 pph were determined. Results obtained were compared with those properties of the control composite containing 60 pph of commercial silica alone. The composites were then modified into a hybrid filler system by incorporating 6% (w/w) silane coupling agent based on the load of silica it contains. Commercial silica loading in the composite were varied from 10, 15, 20 and25pph, keeping WRHA loading at 45 pph at which loading, composites showed the closest properties to the properties of the controlled composite among candidate WRHA composites. Physical and mechanical properties of the vulcanizates were determined. The results showed that WRHA/Silica: 45/20 hybrid containing rubber vulcanizates exhibited the properties comparable to those of the vulcnizates of the control.

An approximate cost estimation analysis revealed that around 50% of the imported filler material cost saving could be achieved using this recipe instead of using only imported silica filler in the formulation to produce economically competitive tire treads.

Key words: rubber composites, silane coupling agent, silica, tyre tread formulae, white rice husk ash

Introduction

During the manufacture of rubber products, incorporation of fillers to rubber matrices, in order to meet the end user service requirements and to gain economic advantages has been a common practice. Carbon black and silica are the most popular, widely accepted and technologically proven conventional reinforcing fillers used in the rubber product manufacturing applications irrespective of whether rubber is Natural Rubber (NR) or Synthetic Rubber (SR). In view of growing public concerns of the environment, increasing stringent

regulations on disposal of waste and associated cost coupled with the increasing global competitiveness of rubber products in the market, interest has been growing among researchers to study the potential use of materials derived from agricultural and industrial waste to be used in the rubber product manufacturing sector. Materials derived from agricultural waste such as rice husk ash (RHA), palm kernel shell powder and industrial waste such as ground rubber tyre (GRT), buffing dust, fly ash, *etc.* are some of such waste materials that have been studied for their potential use in industrial applications (Maan *et al*., 2015; Tatangelo *et al*., 2019; Daud, *et al*., 2016; Withayalcool *et al*., 2017). Among the derived materials from agricultural waste, rice husk ash, obtained from rice husk using low cost processing technologies based on combustion process contains a considerable quantity of silica (Jembere and Fanta, 2017). WRHA has a firm guarantee of a reliable supply in significantly high quantities and therefore, could be considered a potential raw material for industrial applications. When referred the numerous studies that have been carried out, it is evident that the use of this material is very common in a wide spectrum of industrial sectors including rubber sector. Use of rice husk ash in other sectors such as ceramics, and cement industries has been reported in literature (Hossin, 2018; Zareei, 2017).

Basically two types of rice husk ash namely Black Rice Husk Ash (BRHA) and White Rice Husk Ash (WRHA) are derived from rice husk depending on the conditions in which the burning process of RHA is carried out. Among these two types, former is produced by partial combustion of rice husk under limited oxygen supply and contains substantial amounts of both silica and carbon. Carbon in BRHA is responsible for the black colour. On the other hand, WRHA is produced by complete combustion of the rice husk in the atmosphere at a higher temperature than that in BRHA. Both types have been widely studied for their vulcanization characteristics and mechanical properties in the rubber composites. These studies have shown that the effect of BRHA and WRHA on the processing and the vulcanizate properties of rubber composites are generally similar to the effects of semi reinforcing or non-reinforcing fillers when filled in natural rubber composites (Arayapranee, 2005; Da Costa, 2014a). It has been reported that rice husk as filler does not adversely affect the vulcanization characteristics or the aging properties of rubber compounds. A study carried out by De Costa *et al.*, 2001 observed that the rice husk ash responds to Si-69 silane coupling agent marginally improving the performance of filled natural rubber composites (Da Costa 2001b).

Most of the studies have been based on general recipe and to date, not much studies appear to have been reported on the use of these filler as partial filler in a hybrid filler system with commercial

silica targeting a specific product. It has been reported that carbon black could be replaced partially from rice husk ash with satisfactory physical properties and improved in tyre tread compounds with reduced rolling resistance (Fernandez *et al*. 2017). A study carried out on partial replacement of silica by WRHA in natural rubber composite has shown the replacement of silica by WRHA improves cure rate and increase the resilience (Ismail and Chung 1999). In the work reported on WRHA/Silica filled systems, there is no much work carried out on the use of WRHA or its hybrid filler system in the rubber composites based on virgin rubber-reclaim rubber blends aiming to manufacture specified rubber products. Considering the above facts and the more or less similar colour of WRHA to that of commercial silica, attention was paid to study the possibility of the use of WRHA as filler in a specific rubber product formulation used in low speed castor wheel (up to 4 km/h) manufacturing sector where silica is used as component filler with other non-reinforcing fillers.

Present paper focuses on WRHA/silica filled composites based on NR and reclaim rubber blend, which meets a set of general specifications suitable for manufacture of a particular type of export market oriented low speed wheels at industrial scale.

Materials and Methods

Materials

Natural rubber (RSS Grade no. 3) and reclaim rubber (hydrocarbon content > 78%, Mooney viscosity ML (1+4) @100 and specific gravity 1.14) were supplied by C.W. Mackie PCL, Horana Sri Lanka and Raplast reclaim company Pvt. Ltd. India respectively. Commercial silica (purity 98%, Moisture content 6%, pH value 6.8, average particle size < 18 µm, and surface area 165 m^2/g) was supplied by Wellink chemical industrial company in India. The silane coupling agent, bis (3-triethoxysilylpropyl-tetrasulfane (Si-69) used was manufactured and supplied by Grand Central Intillc. (Pvt.) Ltd. China. China clay (Aluminum silicate 90%, Moisture content 5%) and Calcium Carbonate ($CaCO_3$ 90.8%, $MgCO_3$ 6.12%, moisture content 5.5%) were supplied by a local supplier, Lanka mineral clay (Pvt.) Ltd. Process oil was supplied by Raj petro specialties (Pvt.) Ltd. in India.

Preparation and characterization of WRHA

White rice husk ash was prepared by controlled burning of dried raw rice husk for four hours at controlled specific temperature of 600 ^oC in a Muffle furnace at University of Moratuwa for 4 hrs. Ash content of the rich husk ash generated was around 20% (w/w). The product was washed in clean water and dried to a constant weight. The dried product was then sieved through 80 mesh size to minimize the particle size variations. Particle size distribution in WRHA were analysed by using Beckman Coulter LS 13 320 particle size analyser.

Typical formulation

The formulation shown in Table 1, which is a recipe suitable for particular

type of castor wheel tread, was used as the typical formulation in this study. Filler loading of this formulation was modified by replacing silica with different WRHA loading as shown in Table 2 and properties of the composites evaluated in the first phase of the study.

Rubber compound preparation

The rubber compound preparation was carried out using a 1.2 liter laboratory Banbury mixer (mixer type Farrell, Model BR Mixer, Item no 1529) and a 12-inch Farrell (1.5:1 friction ratio) laboratory type mill. Mixing sequence used is given in Table 3.

Table 1. *Typical formulation used for commercial products*

Material name	Amount (g)
Natural rubber (Ribbed Smoked Sheet 3)	77.00
Reclaim rubber [77% Rubber hydrocarbon (RHC)]	15.00
High styrene resin [HS 68 type; 32% (RHC)]	20.00
Precipitated silica	60.00
Mineral fillers	95.00
Coupling agent	3.50
Zinc oxide	5.00
Stearic acid	1.50
Antioxidant	2.00
Antiozonant	1.00
Sulphenamide accelerators	3.0
Guanidine accelerator	0.75
Sulphur master batch [S % 50 (w/w)]	10.00

Note: The recipe contains total rubber 100g contributed from RSS, reclaim rubber, high styrene resin and sulphur master batch.

Table 2. *Different filler types and loading used in the first phase*

Materials	Filler loading (phr)				
	Control	A	B	C	D
Silica filler	60	0	0	0	0
WRHA	0	15	30	45	60

Table 3. *Mixing sequence ingredients*

Time (min.)	Ingredients
0	Rubbers
1	Silica filler + Diethylene glycol + Coupling agent
2	China clay + Whiting + Crumb rubber + Oil + Styrene Resins
3	Zinc oxide + Stearic acid and other materials
3.5	Sulphur + Accelerators
4	Dump

Silica filler and Rice husk ash were dried before use at 100 ^{0}C and sieved through 80 mesh sieve to minimizes the particle size variations. During the first phase of the study, a series of WRHA filled composites with varying loadings from 15-60 phr at 15 intervals were prepared (Table 2). Silane coupling agent was added based on the WRHA loading maintaining the 6% (w/w) ratio. A commercial silica filled rubber composite of 60 phr based on the same formulation (a comparable commercial recipe) was also prepared as the control composite. Physical and mechanical properties of these composites were compared with the commercial silica based composite prepared following the commercial formulation of interest (Table 1). WRHA filled composite with closest properties to the properties of the typical composite was selected for the next phase of the study, *i.e*. study of silica/WRHA hybrid rubber composites.

Preparation of hybrid silica/WRHA filled rubber composites

WRHA based formulation which offered the closest properties to the typical composite was selected as the reference for further studies. This composite was modified to form a hybrid filler system of WRHA and silica by varying the Silica content of the composite (Table 4). Silane coupling agent equal to 6% (w/w) of the hybrid filler loading was also added in these formulations.

Determination of curing characteristics

Curing characteristics of the composites at 150 ^{o}C were studied using an Oscillating Disc Rheometer (ODR) according to ASTM D2084. The cure time (t_{90}), scorch time (t_{s2}) maximum torque (M_H), minimum torque (M_L), *etc.* were determined from the respective rheographs.

Physico-mechanical testing of the samples

Mixes were vulcanized for their respective t_{90}s in an electrically heated laboratory press (Press Model Schubert and press size 18 x 18 inches) at a pressure of 10.5 MPa. Vulcanizates were conditioned for 24 hours before testing. Physico-mechanical properties (Shore A hardness, tensile properties, rebound resilience and abrasion volume loss) were measured following the ISO 7619, ISO 37, ISO 4662 and ISO 4649, respectively. Tensile tests were carried out on an Instron Universal Testing machine, model 3365. All the mechanical tests were conducted at the ambient temperature at 28 ^{o}C ±2.

Table 4. *Formulations with progressive increment of silica in the selected WRHA filled rubber composite*

Materials	**Filler loading (Phr)**			
	E	**F**	**G**	**H**
Silica filler	10	15	20	25
WRHA*	X	X	X	X

* X: WRHA content in the selected formulation in the study carried out in the first phase

Results and Discussions

Particle sizes of the composites

Average particle size and the surface area of the WRHA used are presented in the Table 5 along with the corresponding information of commercial silica obtained from the technical data sheet provided by the supplier. It could be seen that average particle size of WRHA is larger than that of commercial silica used in the study. Commercial silica is a synthesized product made under control conditions while WRHA obtained here is a product obtained from agricultural waste using a simple and economical burning process without a strict control of the process.

Table 5. *Particle sizes of the filler*

Fillers type	Average particle size (um)	Surface area (m^2/g)
RHA (Rice Husk Ash)	45	75
Silica	18	165

Cure characteristics of filled composites

Table 6 shows the values of the scorch time (ts_2) and optimum cure time (t_{90}) of the composites. WRHA loading has only a slight retarding effect on both (ts_2) and t_{90}. WRHA is known to affect the curing rate differently depending on the levels and nature of the impurities, burning conditions, and the basicity of the fillers (Da Costa 20014a; Da Costa 2001b; Fernandez *et al.*, 2017; Ismail and Chung 1999; Siriwardena *et al*., 2001).

It could also be seen that control sample (60 phr silica loaded) has exhibited almost similar ts_2 and t_{90} values when compared with those exhibited by the corresponding WRHA filled sample (W60). Minimum torque (M_L) values presented in Table 6 shows that it is increased with increased WRHA loading. As WRHA forms aggregates and convoluted structures in NR phase, this trend is elucidated. The maximum value (M_H) which is an indicative of the stiffness of the vulcanizate also increased with the increasing loading probably due to the restrictions exerted by the possible agglomerates formed against the macromolecule movements with increasing filler loading. However, both control sample and WRHA filled NR composite at 60 phr loading exhibit almost similar properties irrespective of their source. Therefore, it could be concluded that filler type has no influence on the processability as far as the curing characteristics of both types of composites are concerned. Therefore, WRHA could be incorporated into wheel formulations under study without any processing problems.

Table 6. *Curing characteristics of the rubber composites studied*

Cure parameter	Control	A	B	C	D
t_{90}	1.43	1.29	1.47	1.55	1.62
t_{s2}	0.38	0.22	0.30	0.49	0.50
M_L	4.00	1.95	2.90	3.10	3.60
M_H	28.00	9.00	16.00	20.00	26.00

Physical properties

Specific gravity

Specific gravity of a composite is of great importance in rubber product manufacture as it directly determines the weight of the product. Generally, specific gravity and hardness of rubber composite increase with the increasing rigid filler loading in rubber composites (Osabohicn 2007). Figure 1 and 2 show that variation of those properties are in agreement with the trend mentioned above. Being inorganic fillers, both silica and WRHA have higher specific gravity than natural rubber and consequently, addition of filler increase the specific gravity of the composites. It could be noted that at the same filler loading (60 phr), WRHA filled composite exhibit a higher specific gravity than the commercial silica filled composites which probably may be due to the higher specific gravity of WRHA. However, specific gravity of all the samples closely falls within the acceptable levels as per the technical specifications recommended for the castor wheel in question given in Table 7 below.

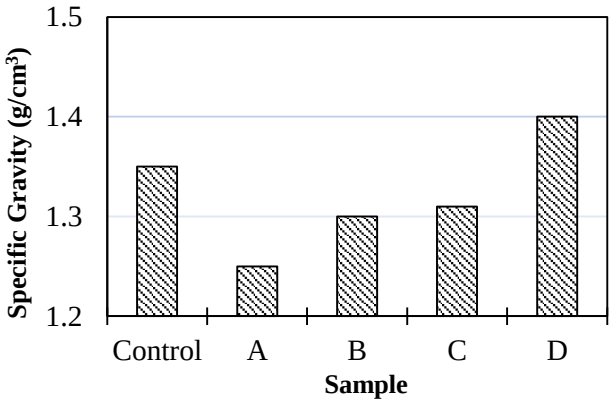

Fig. 1. Variation of specific gravity with filer loading

Hardness

Increasing WRHA loading from 15 to 60 phr has shown a gradual increase in the hardness value of the composites from 45 to 75 shore A (Fig. 2). Being a silica rich source, when percentage of rigid WRHA content is higher with simultaneous reduction of the percentage of softer elastomer content in the material, increase in the hardness is an expected trend. Similar trend could be seen for the numerous rubber composites studied with varying contents of similar filler types including WRHA filled rubber composites (Osabohicn *et al*., 2007, Daud *et al*., 2016b, Pongdhorn *et al*., 2002).

The hardness value of the control sample which has 60 phr silica has yielded the highest value among all the studied samples. At the same filler loading, WRHA filled composite shows a lower hardness value than that in silica filled counterpart suggesting the non-reinforcing character of the former. WRHA is renewable, but non-conventional filler derived from rice husk ash and consist of large size particles. Consequently, WRHA agglomerates yields a smaller surface area as reported earlier. Therefore, filler to matrix interaction become poorer in WRHA filled composites and lower hardness value is obtained for the composites in comparison to corresponding silica filled NR composites. However, it should be noted that the hardness of the composite D which has 60% WRHA loading is closer to the hardness value range set out (formulated) in the specifications given for the commercial composite (Table 7).

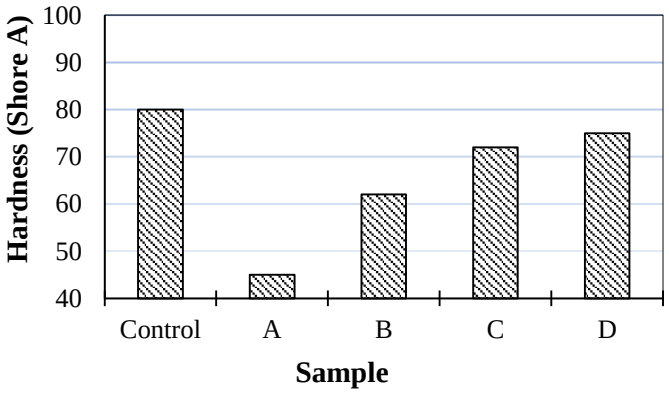

Fig. 2. Variation of harness with filer loading

Mechanical properties

Rebound resilience

Figure 3 shows the effect of filler type and WRHA loading on the rebound resilience of composites. As expected, rebound resilience has shown a gradual reduction in composites with increasing WRHA loading from 15 to 60 phr. Rebound resilience is related to the flexibility of molecular chains in the vulcanizate; the more flexible the molecular chains, the better the resilience is. However, when the filler loading is increased, it restricts the molecular movement which affects the flexibility with a simultaneous reduction of the flexible elastomer content in a unit volume of the composite. Therefore, with the addition of WRHA, composites exhibit poor flexibility and enhanced stiffness of matrix resulting in a gradual decrease in rebound resilience (Daud *et al.,* 2016b). At 60 phr filler loading, silica filled NR composites (control sample) has also showed lower resilience values than the first three WRHA filled composites. However, at the same filler loading, silica filled composites exhibits slightly higher resilience than 60% WRHA filled composite (W 60). This may be due to the better dispersion and reinforcement effect of silica in the rubber matrix. However, it is interesting to note that resilience values of Sample W45 and W60 (WRHA loading 45 and 60 phr) fall in the recommended range given in the specifications (Table 7).

Tensile strength

As it could be seen in Figure 4, WRHA filled composites have shown a slight reinforcing effect as evident from the increased tensile strength from sample W15 to W45. As the WRHA content exceeds 45 phr, it has shown a dramatic reduction in tensile strength. It has been reported in literature that WRHA has a tendency to agglomerate the particles (Siriwardena *et al.,* 2001). As the WRHA loading increases, they may form lager agglomerates reducing the surface area of filler particles that could be wetted by the rubber molecules. Consequently, the efficiency of stress transfer from the rubber matrix to the WRHA particles is reduced resulting in a drop of tensile strength with increasing filler loading. It is also shown that at the same higher filler loading (60 phr), WRHA filled composites have shown a drastic reduction in tensile strength compared to the corresponding silica filled counterpart. This observation clearly suggests poor reinforcing effect of WRHA than that in commercial silica used composites in this study. When the tensile properties required for the product which has given in the recommended specifications is considered, none of the WRHA filled composites has exceeded the minimum limits. Therefore, if WRHA is to be incorporated to NR to qualify the composite for particular application, it is necessary to modify the filler system to achieve the required level of tensile strength.

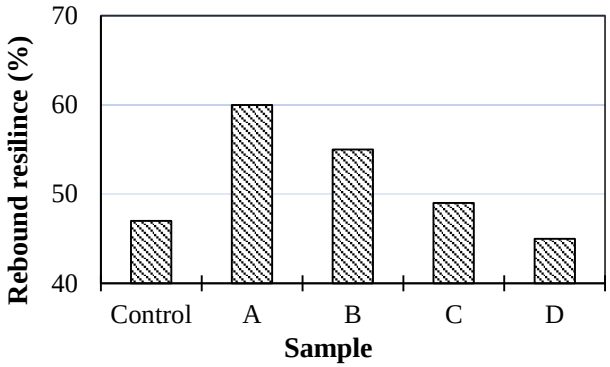

Fig. 3. Variation of rebound resilience with filer loading

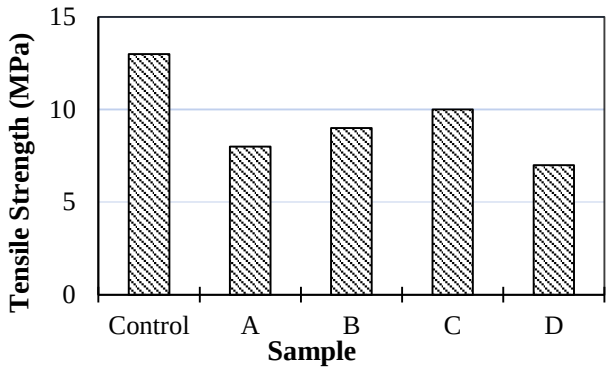

Fig. 4. Variation of tensile strength and modulus 100% elongation with t filler loading

Modulus @ 100% elongation

Modulus @ 100% elongation at different filler loading is presented shown in Figure 5. Increase in WRHA loading has only a slight increase in the modulus. This result is in agreement with the observations made with regard to WRHA filled natural rubber composites found in literature (Siriwardena *et al.*, 2001, Pongdhorn 2002). The highest modulus has been recorded by the WRHA filled composites with 60 phr filler loading. Comparison of modulus values of composites having 60 phr filler loading reveals that WRHA has a higher impact on the modulus of the composites which perhaps may be due to the presence of the larger WRHA agglomerates in the matrix. However, it has no any significance as the difference of the modulus values is only around 1 MPa. As far as the modulus values are concerned, all the composites qualify for the purpose as they all have met the required level of modulus given in the specifications for intended product (Slow speed castor wheel tread) given in Table 6.

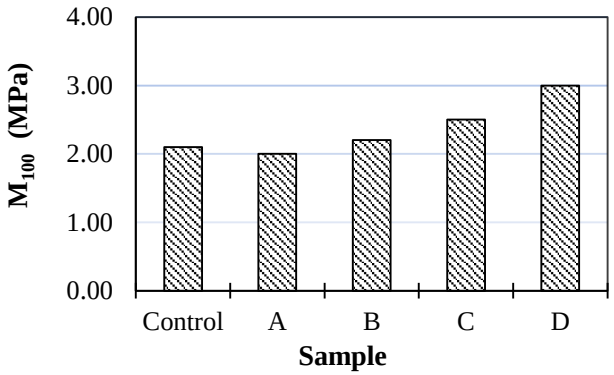

Fig. 5. Variation of Modulus @ 100% elongation with filer loading

Elongation @ break

Elongation at break of the WRHA filled composite series has shown a gradual reduction with increasing filler loading (Fig. 6). WRHA particles are not surface treated and therefore, rubber-WRHA interface is not strong enough to reinforce the matrix. Simultaneously, increase in WRHA loading, may tend to form larger WRHA agglomerates reducing the surface area of the filler particles as already reported in literature (Siriwardena *et al*., 2001). Strain induced crystallization of NR molecules is also restricted as fillers are added to the composites. As the filler loading increases, this effect becomes more prominent. These factors justify the decrease in elongation as the WRHA loading increases. However, when the elongation values of controlled sample (60 phr silica loaded sample) and the corresponding WRHA filled composite (60 phr WRHA loaded sample), former has recorded a higher elongation at break. At the same filler loading, silica may form agglomerates smaller than the WRHA fillers and wetted by the macromolecules more efficiently and therefore, higher elongation at break value could be expected due to the higher interactions (Van der Waals forces) between rubber matrix and filler particles. However, it is interesting to note that elongation at break of all the WRHA composites studied shows values more than 300%, thus the elongation at break of the composites could be obliterated as a determinant factor in the selection process of optimum WRHA loading.

Abrasion volume loss

Abrasion volume loss indicates the reinforcing effect of the filler and the heat development during the fiction of the material (Fig. 7). WRHA loading has resulted in increase of abrasion volume loss. This observation again suggests that WRHA is not a filler with reinforcing characteristics. Analysis of previous results observed for mechanical properties shows that, silica filled composites exhibit better reinforcing characteristics than that of corresponding WRHA filled composite (Controlled sample and W60). As discussed earlier, tendency towards filler agglomeration at

high filler loading is also evident from these results, when one compares the abrasion volume loss trend of WRHA filled composites with that of increasing WRHA loading. However, as in the case of modulus and elongation, all the composites have abrasion volume loss below the limits of the recommended specifications for castor wheel given in Table 7.

A comparison of the recommended specifications and the mechanical properties achieved for the WRHA filled composites shows that sample W45 (WRHA loading 45 phr) exhibits the closest properties to the standard technical specifications presented in Table 7. Therefore, this composite was selected for preparation of hybrid fillers with silica in our further studies.

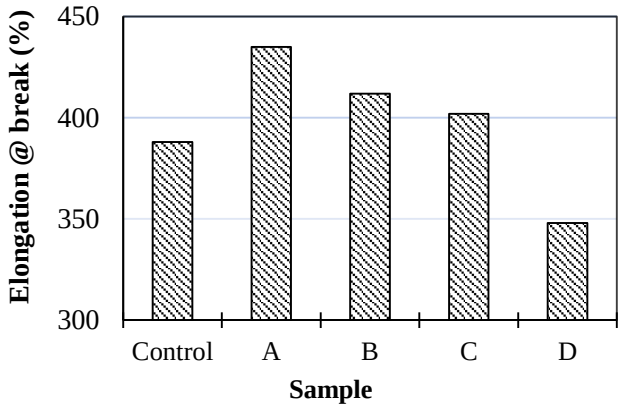

Fig. 6. Variation of elongation @ break with filler loading

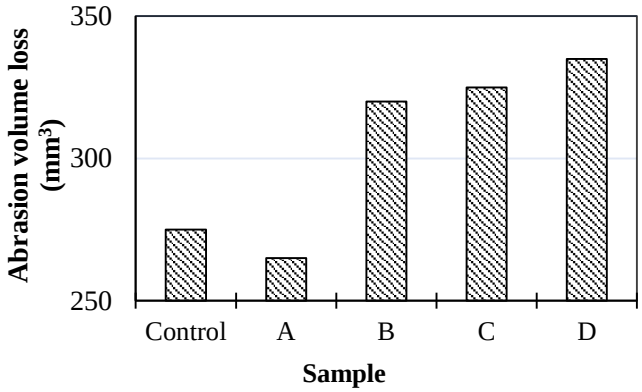

Fig. 7. Variation of abrasion volume loss with filler loading

Table 7. *Comparison of mechanical properties of different composites*

Physico-mechanical properties	C (WRHA loading 45 phr)	Control sample (Silca loading 60 phr)	Recommended specification
Specific gravity	1.31	1.35	1.34 ± 0.03
Hardness (Shore A)	72	80	79 - 82
Resilience (%)	49	48	45 ± 5
Tensile strength (MPa)	10	13	> 10
Modules 100 (MPa)	3.0	2.2	> 2
Elongation (%)	400	388	> 300
Abrasion volume loss (cm^3)	325	275	<350

Rubber composites with silica/WRHA filled systems

As the next step, composition of W45 which showed the closest performance to the required specifications was modified by using hybrid filler of WRHA and silica. As explained in the experimental section, silica content in the selected composite (W45) was progressively increased from 10 to 25 at 5 phr intervals. The resultant WRHA/silica hybrid filler system was treated with silane coupling agent as mentioned earlier. The physical and mechanical properties of these composites are tabulated in the Table 8.

Specific gravity of hybrid composites has shown a slight increasing trend with increasing silica loading. Specific gravity of the composites exceeds its value of control sample and reaches the level required in the specification as the silica content exceeds 15 phr loading. It could be seen that as the silica content increases the hardness values, rebound resilience, tensile strength and modulus @ 100% elongation of the composites also increase. This is attributed to the reinforcing effect of silica when used with a suitable coupling agent.

Both tensile strength and modulus @ 100% elongation of the hybrid composites increase with the silica loading. As the silica content exceeds 15 phr, composites have shown an increase in tensile strength. As the same WRHA content was used in each modified composite, it could be inferred that the contributing factor to these property changes is the silica incorporation. As the silica content reaches 20 phr, it could be seen an increase in tensile strength exceeding its value from the minimum required value given in specifications (10 MPa) presented in Table 7.

Table 8. *Mechanical and physical properties of hybrid composites*

Property	E	F	G	H	Control sample
Specific gravity	1.34	1.34	1.36	1.36	1.35
Hardness (Shore A)	75	77	78	80	80
Resilience (%)	51	51	51	53	48
Tensile strength (MPa)	10	10	12	14	13
Modulus @ 100% elongation (MPa)	4.0	4.0	5.5	5.5	2.2
Elongation %	370	380	388	400	388
Abrasion value (cm^3)	280	280	288	288	275

Increment seen in the modulus @ 100% elongation of the hybrid samples with silica shows improved filler to matrix attractions in the presence of a coupling agent. All the composites have registered higher modulus values than that required in the specifications for the intended product. It could be also observed that as the silica content of the hybrid composites increases, elongation at break has also increased. Similar property enhancements up to an optimum ratio of component fillers in hybrid carbon black and calcium carbonate fillers has been reported and the mechanical properties variations of the hybrid silica and WRHA filled composites reported in this study is in well agreement with the above observations (Reginald *et al*., 2019). This may be attributed to the contribution of the reinforcing filler on the property enhancement and the mutual restriction offered on each other by the component filler particles against the filler agglomeration.

Abrasion volume loss of the hybrid samples shows only a slight increase with the increase of the silica content of the hybrid composites as shown in Table 8. When the composite filled only with WRHA at 45 phr loading is compared with hybrid filler of Silica and WRHA treated with silane coupling agent, the latter has remarkably reduced the abrasion volume loss, *i.e.* improved abrasion resistance.

When physical and mechanical properties of the four WRHA/Silica hybrid composites studied are considered, there is no significant deviation in the properties from the minimum level of properties given in the recommended specifications. The work carried out by Chandrana *et al*. on a different combinations of silica containing hybrid filler incorporated NR composites has also shown that silica containing hybrid fillers could improve the mechanical properties of natural rubber composites (Candrana *et al*. 2018). Considering the economic aspects and the importance of having the allowance for the minimum specified limits in industrial applications, composite with Hybrid filler with 45% (w/w) WRHA and 20% (w/w) silica could be considered as the optimum hybrid filler combination for the application referred to.

Economic analysis

A summary of approximate estimation carried out on the cost of silica based filler materials (silica and WRHA) is given below (Table 9) using the rates in 2019 and certain assumptions. It could be seen that there is a potential for a considerable financial gain, if the hybrid filler is used to manufacture low speed wheel considered in this study achieving over 50% saving in the filler cost.

Table 9. *Approximate cost analysis*

Item	Approximate cost (Rs/kg)
Cost for Raw material (Cost for Husk in the local market)	5.00
Transport cost (assumption)	2.00
Cost for incineration based on an electrical box furnace (power requirement 3.33 kwh) used for incineration of rice husk (assumption)	11.37
Miscellaneous cost (10% of the total cost) (assumption)	1.18
Total cost of WRHA	20.21
Market price of silica	98.00
Total cost of selected hybrid filler (WRHA45:Silica 20)	44.13
Percentage of saving when silica filler is replaced with hybrid filler	54.96

Conclusions

Incorporation of WRHA in the composites studied has no remarkable influence on the curing characteristics of the composites. However, the physico-mechanical properties decreased with increase of WRHA loading. It has been shown that among the candidate WRHA filled composites, 45 phr WRHA filled composite exhibits physical and mechanical properties comparable to the properties of the control sample (commercial silica 60 phr filled composites) and also they are within the specifications given by the customers for the particular type of castor wheel under study except for abrasion resistance.

It was found that improvement of physico-mechanical properties could be achieved through hybrid filler systems of WRHA and silica composites treated with a silane coupling agent. This shows the potential for the use of hybrid filler systems in industrial applications replacing a considerable portion of commercial silica with WRHA filler. Therefore, this finding will certainly help to cut down quantities of commercial silica filler used in selected commercial white rubber compound recipes and to add value to the rice husk while mitigating the environmental problems associated with disposal of rice husk.

Considering overall properties of the hybrid composites studied, it was found that WRHA/silica: 45/20 filler system is qualified to be used to manufacture the low speed wheel of interest replacing 45 phr commercial silica in the formulation. It was also found that filler material cost saving would be approximately 50% per kg of silica filler used.

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The present status and role of the *Thurusaviya* Rubber Societies in the smallholder rubber sector in Moneragala District: Extension Officers' perception

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Abstract

The farmer-based organization known Thurusaviya Rubber Societies (TRSs) has been established by the Thurusaviya Fund (TF) for the development of the smallholder rubber sector. This study attempted to assess the present status and role of the TRSs in the smallholder rubber sector in the Moneragala District. The views of 18 Extension Officers (Rubber Development Officers and the two district Coordinating Officers of TF) with over five years of work experience were used to create two focus group discussions by Interpretative Phenomenological Analysis Approach. The perception of the key entities (Organizational structure, Organizational culture, Function of the organization, External environment and Intervention of organizational development) responsible for the development and welfare support for the rubber smallholders was assessed. Data were analysed qualitatively as a case study in Moneragala.

Results revealed, that the majority of TRSs considered in the study were not performing well due to factors such as poor leadership, lack of transparency, lack of enthusiasm of members, lack of trustworthiness, attitudes of members, the role of the Field Officers and changes in the external environment and politics. The contribution from the management unit and the membership was greater in TRSs that were highly active than that of the poorly active TRSs. The self-reliance capacity was low in the majority (99%) of the TRSs and was highly dependent on Extension Officers involved and the Government's assistance. The majority of TRSs were not goal-oriented and under performing and not dynamic in organizational performances. Hence, extension and development agents feel that critical intervention is required to overcome the above weaknesses. Therefore, organizational development should be done by concerning; goal orientation, need identification, the interaction between Field Officers and TRSs and guiding the TRSs, restructuring of organizations, offering compensation for the management unit, development of physical resources and developing as business entities to achieve their goals and objectives.

***Key words*:** Rubber smallholders, Rubber Societies, *Thurusaviya* Societies

Introduction

Rubber smallholders (<20.2 ha) is considered the most dynamic segment of the rubber sector as it represents 59% of the national rubber extent and contributes 48% to the rubber production in 2019 (MPI, 2019). During the last decade, a considerable increase was observed in the rubber extent due to the adoption of rubber farming by the smallholder farmers in Moneragala District (Wijesuriya *et al*., 2011). At present, the total extent of rubber smallholdings in Moneragala District is about 5,087 ha and it is the fifth rubber growing District based on land extent under rubber cultivation in Sri Lanka and has 7,802 holdings in number. Three government institutions are functioned to cater to the needs of the rubber smallholder sector in Moneragala; *viz.* Rubber Development Department (RDD) *Thurusaviya* Fund (TF) and Rubber Research Institute of Sri Lanka (RRISL). RRISL is responsible for research and development activities, while RDD is responsible for the development of all aspects of the smallholder rubber sector and TF is a supportive agency.

The TF has been established under Act No. 23 in 2000 to uplift the living standards of rubber smallholders by facilitating the production and marketing of quality rubber sheets and ensuring a fair price for their products through the establishment of Farmer Based Organizations (FBOs) called *Thurusaviya* Rubber Societies (TRSs) (smallholder rubber societies). There are two different layers in the system of TRSs; village-level rubber growers' societies called TRSs and district-level committees. The district-level committee comprises representatives of TRSs and its main role is coordinating between the TF and TRSs. About 85 TRSs are operating in the main rubber growing DS divisions in Moneragala (Table 1). Two District Coordinating Officers of TF (DCOTF) are the grassroots level personnel attached to TF who are responsible for managing the TRSs in Moneragala (http://www.rubberdev.gov.lk).

Table 1. *Thurusaviya rubber societies operating in Moneragala district in each Divisional Secretariat Divisions*

DS division	Number of TRSs
Bibila	04
Moneragala	12
Medagama	19
Siyabalanduwa	03
Madulla	10
Buttala	04
Badalkumbura	29
Wellawaya	04
Total	**85**

Studies revealed that FBOs could be used effectively in providing multifunctional services to the farmers such as delivering agricultural technologies and inputs, capacity building, assisting in value addition and marketing of products, and also providing welfare facilities (Chamala and Shingi, 1997). However, due to various reasons, these FBOs were unable to produce expected results. Political influences, poor managerial practices, poor monitoring and mistrust between

management and the member farmers, failing in value addition and establishment of effective market linkages, lack of product diversification are some of the possible reasons for failures (Esham, 2012). However, when it comes to Sri Lanka, it appears that traditional FBOs were unable to deal with the challenges that had faced due to poor leadership, poor attitudes, ideological conflicts of cultural and religious, political influences, structural matters and inefficiencies of relevant government officers (Girragama *et al*., 1999; Mahindapala *et al*., 2020 and 2021).

Dissanayake *et al.,* (2003) revealed that these TRSs failed to fulfill their expected organizational goals. In that context, it is important to understand how TRSs behave in the sector as which may give some valuable insights to add the value to smallholder rubber sector. Therefore, studying the organizational behaviour, the management system of TRSs and current issues are important to develop strategies for the organizational development of TRSs. The objective of this study was to examine the organizational role in the smallholder rubber sector in Moneragala District. Finally, it will help to improve the development of the smallholder rubber sector in Moneragala.

Methodology

Research approach

The Interpretative Phenomenological Analysis (IPA) approach was used in this study to collect the data towards the phenomenon being studied. IPA is an approach to qualitative research with an idiographic focus, which means that it aims to offer insights into how a given person, in a given context, makes sense of a given phenomenon (Arnold and Fischer 1994; Morgan and Arcelus, 2009; Petrovici, 2013; Sandberg, 2005). IPA approaches are used in Social Science research to explore how the subject-object dichotomy may be bridged by an interpreter focusing on the context (Farooqa and O'Brien, 2015; Goulding, 2005; Pernecky and Jamal, 2010; Szarycz, 2009). Thus the primary goal of IPA is to investigate how individuals make sense of their experiences. It was assumed that people are 'self-interpreting beings', which means that they are actively engaged in interpreting the events, objects, and people in their lives (Smith and Osborn, 2003; Thompson *et al*., 1989). According to the codes of Table 3, the interview guide was prepared with the assistance of experts in the smallholder rubber sector. Using the IPA, the overall organizational function of the TRSs which affect the status of rubber smallholders was investigated under the conceptual framework illustrated in Figure 1, based on the literature discussed above. In addition to the FGD, the secondary data published in various reports were also used (document survey) to interpret the results.

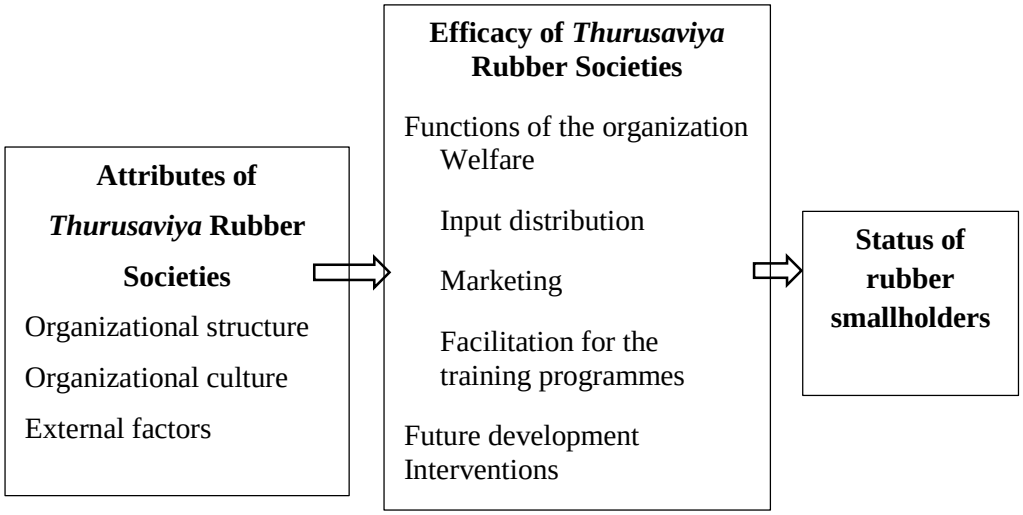

Fig. 1. Conceptual framework

Source: Adopted from the concept of Bohlander and Snell, 2004

Data collection

Both categories of Field Officers (FOs); Rubber Development Officers (RDOs) who are responsible for the extension activities in the field level attached to RDD and DCOTF are the closest officials to TRSs. Therefore, this study has investigated the role of TRSs through the perception of FOs, based on their experiences. The TRS members and committee members were excluded in the data collection anticipating the possible biasedness. FOs, the research participants belonged to different rubber growing DS divisions of Moneragala, and each of them was assigned for a specific geographical area known as an RDO range. The average number of TRSs in one RDO range was five, ranging from 3 to 7, based on the density of the smallholders in the respective range.

Data were collected through two Focus Group Discussions (FGDs) using an unstructured interview guide. Among qualitative primary data collection techniques, FGDs have been widely used in agricultural research dealing with a range of extension-related development topics and facilitating an in-depth understanding of certain issues (Morgan and Krueger, 1997). The main advantage of the FGDs is that they allow much more freedom of speech among participants, encouraging them to interact, debate and exchange views during the discussion (Krueger and Casey, 2015). FGDs are conducted with the participation of seven to twelve people to capture their experience and views regarding specific issues closely related to the research objectives. FGDs were moderated by the main author in a manner that adheres to the accepted

guidance related to the particular research strategy given by Bryman, (2012).

FOs were selected for the FGDs purely on a random basis and based on the working experience with a minimum of five years of experience in Moneragala. The total number of respondents was 18, which is nearly 16 RDOs and two DCOTFs were selected (Table 2). They provide the services for nearly 85 TRSs. Each FGD consists of eight RDOs and one DCOTF. FGDs were held in the local language and were audio-recorded in addition to taking notes.

Table 2. *Selected sample of RDOs for the study representing the DS divisions*

DS division	No. of RDOs participated	
	FGD 1	FGD 2
Bibila	1	1
Madulla	1	0
Madagama	1	1
Siyabalanduwa	0	1
Moneragala	1	1
Badalkumbura	2	3
Wellawaya	1	0
Buttala	1	1
Total	**8**	**8**

Data analysis

The audio recorded data were transcribed following the method suggested by Colaizzi (1978). Then a set of codes and categories were developed according to the grounded theory approach as shown in Table 3 and following the method described by Strauss and Corbin (1997). A similar method was adopted by (Mahindapala *et al.*, 2020) to investigate the role of tea smallholding development societies in the tea smallholding sector. The quotes were indicated as P_nD_n (P_n= Identification number of participant, D_n=Identification number of FGDs).

Results and Discussion

According to the view of FOs, around 65% of the rubber smallholders in Moneragala were members of TRSs. According to the views of FOs, the reasons for not obtaining the membership of TRSs were;

1. TRSs have not been established in areas where rubber lands were dispersed arbitrarily, especially in Bibila, Buttala, Wellawaya and Siyabalanduwa DS divisions,
2. Medium-scale rubber growers were not interested to join the TRSs because of social dignity, and
3. Terminating the membership by themselves of the TRSs due to various matters. Based on the opinion of RDOs, there was variability in the status of activeness of the TRSs in Moneragala. It was revealed that 38 TRSs were entirely 'dormant', where no action has been taken place in the last three years. The relevant quote concerning the above is given below.

"The effort of FOs to reestablish the dormant TRSs was turned out be a failure several times, due to the internal politics within societies and ruthless management practices of the management unit of TRSs" **(P5D1)**.

Table 3. *Perception matrix of Field Officers of the TRSs*

Categories	Codes
Structure of the organization	Structure of the management unit, Decision making, Type of the membership, Goal orientation
Organizational culture	Leadership, Gender issues, commitment, Attitudes
Function of TRSs	Welfare, Input dealing, Marketing, Facilitation for the training programmes
External Environment	Interaction between FOs and TRSs, Political influence, Political pressure, Link with external organizations
Organizational development of TRSs	Restructuring of organizations, Development of physical resources, Developing as business entities

Three TRSs under the purview of FOs acted beyond their expectations. Overall, as per their opinion, 43 of TRSs in Monaragala district provide reasonable service to their members. Further, the activeness scale based on a scientific approach should be developed to categorize TRSs as it would help to develop the TRS by solving their specific issues and achieve the expected goals.

Organizational structure of *Thurusaviya* rubber societies

Structure of the management unit

Organizational structure refers to the framework in which the organization defines how tasks are divided, resources are deployed, and departments are coordinated (Bohlander and Snell, 2004). As per the constitution of TRSs, the Management Unit (MU) comprises 11 volunteer members, including the President, Vice President, Secretary, Assistant Secretary and Treasurer, and six committee members. In the case of highly active TRSs, usually MUs and the majority of the committee members and sometimes even ordinary members were deliberately involved in the management functions. It appeared that the activeness of TRSs greatly depended upon the members in the MU. Although the MU of these TRSs was supposed to meet at regular intervals (usually 2 months), and discuss various issues that affect the members and take decisions, it was revealed in FGDs that the majority of the TRSs were not doing so. The composition of the MU also matters to a great extent to the decision-making of TRSs. Most of the office-bearers of MU were older and retired people (the School Principals, Teachers, Bank Officers) or village leaders who have been holding the post for the previous five to ten years. Usually, most village leaders do not wish to have the younger generation in the MU. This can be identified as the main reason for the non-active nature of the TRSs. The decision-making process in active TRSs was more systematic than the other societies. The used to have regular MU meetings, special meetings address burning issues and annual general meetings conducted at regular time intervals. Thus, active TRSs used proper and active communication channels among members. It was revealed in the following quotes.

"*Most of the active societies invited FOs to participate in their regular meetings. If FOs were unable to participate, MU even postponed the particular meeting"* **(P6D2)**.

"*One of the active societies had a WhatsApp group to share ideas among members. This society had young members in the MU. FOs also linked with this group and shared pieces of advice and views with the society members"* **(P2D2).**

It was also revealed that some TRSs did not have a proper mechanism to conduct annual general meetings. The majority of the FOs in FGDs were of the view that the accounting procedure of these TRSs suffers from lapses such as transparency, incompleteness and mistakes. FOs were not in a position to individually monitor all TRSs as they had other extension tasks. The most serious issue was that those TRSs failed to adopt a transparent auditing procedure in their final accounts and that paved the way to misuse of collective funds. This had affected the membership morale and engagement of societal activities. One of the Field Officers explained his view in the following quote.

"*One of the Presidents and a Treasurer of society had used society funds for personal affairs. Members couldn't recover the misused funds from both these persons. It had generated a bad attitude on the society and finally it was collapsed"* **(P3D1)**

Both full-time and part-time rubber smallholders were members of the TRSs. As per the general understanding of the FOs, the youth involvement had been at a moderate level in both categories. The majority of the FOs argued in the following way:

"Full-time farmers fully engaged in rubber cultivation-related practices and their preparedness in TRSs activities was high as it was a part of their livelihood strategies. With the part-time rubber smallholders, they may be employers or self-employed and have to engage in many activities and therefore, they did not have time to spend for TRSs activities" **(P2D1)**

Because of that, FOs and MU faced difficulties when distributing limited subsidized resources among the members. Many members argued that priority should be given to the active members, except for 12 TRSs, where the majority of the members were women. One of the reasons for the higher participation of females was that most males are unable to participate in meetings of TRSs during the daytime. Sometimes, the registered rubber smallholders do not participate in meetings of TRSs, but their children tend to participate in these unless their registration is canceled. The following quote is about the memberships, as stated by the respondents.

"However, under normal circumstances, the level of participation did not exceed 50% of the total membership. But in the

subsidy distribution period, the participation was more than 80%. However, attitude on the MU by the members was also effecting the participation in societal activities" **(P6D1)**.

"Although most of members were not in an active state in societies, they maintained their membership as it is a requirement to receive subsidies from TF." **(P5D2)**.

Except for a very few TRSs, the majority of the societies had not set a goal/target to be achieved and no activity plan had developed. However, TF had some targets and had prepared a common activity plan common for the whole country. Therefore it should be changed and developed according to individual societies. Yet, this situation should be changed by the training of MU. Participatory and need-based activity plans should be developed for each society with the assistance of the FOs and the district committee. Implementation of extension programs should be based on their own needs. Therefore, TRSs maintain good interaction with the FOs. On the other hand, the majority of the FOs were of the view that some societies were established solely to capture Government aids. The relevant quote by the respondents is stated below.

"*Some societies were created only to obtain a subsidy for the smokehouses, coagulate cups and trays and rollers for rubber processing, while they were not keen enough to arrange any extension and welfare programme in order to achieve the development of rubber farming*" **(P1D1)**

Nevertheless, in a few TRSs close to the urban areas, there were no such factors (subsidies) taken into consideration in the development of their societies. Therefore, TF should make policies attract young and energetic generation into the MU by facilitating with attractive allowances, due recognition and conducting human resource development programmes for the members of MU.

Organizational culture of *Thurusaviya* rubber societies

Organizational culture is defined that a system of shared meaning held by members that distinguish the organization from other organizations (Bohlander and Snell, 2004). The role of leadership plays a key role to influence people towards the attainment of organizational goals. Therefore, leadership qualities and role of MU is the most crucial factor highlighted in discussions as TRS is FBO. The active and successful TRSs represent the multi-talented and skilled leaders in MU. They always tried to achieve their organizational goals effectively and efficiently. It was described by many respondents as in the following quote.

"Not only the input distribution programmes under the subsidy, but also in other programmes (extension, welfare and marketing), effective leaders promptly involve and accomplish the basic requirements of

programmes in an efficient and in a transparent manner" **(P8D2)**

With the poor leadership traits of MU, there were many conflicts arisen among the members of the MU and also the members and MU. It would be affected the effectiveness and efficiency of TRSs. The relevant quote by a participant is given below.

"Two of my eight TRSs had been performing well under a good leadership, whilst the rest were not. Because of that the members were not participating even in the annual general meeting and not paying membership fees" **(P4D1)**

Some members of MU who have personal issues with member groups would treat the particular group differently, and that affects the organizational commitment as stated in the quote below.

"*One of the Presidents always tried to facilitate his neighbours and close relatives and this society is now under dormant condition*" **(P9D1)**

Thus, a FO pointed out that;

"*TRSs especially located in remote areas or when most of the rubber smallholders were not well-educated or due to both of reasons, members with respectful characters were in the top positions of the MU. Because of that situation, "The president and the Secretary of that TRSs were suspects for misuse of funds and distribution of subsidized inputs among members was not done in the proper way. However, no one is going to question. On the other hand, they did not have an idea about their misuse also"* **(P8D1)**.

Although the majority of the members in MU comprised of female members, there were no issues related to gender in the management of TRSs. There were no specific relations with gender and management with respect to the activeness of the committee and the society. According to the respondents, trustworthiness and transparency were the essential characters of the members of MU. They were required to maintain trust in their actions and it helped to develop a favourable relationship between all stakeholders (the MU, FOs and the members) as it was necessary to have good interactions with each category.

The function of *Thurusaviya* rubber societies

The major functions of TRSs were, subsidized input distribution, developing the marketing facilities, organizing the training programmes for members for the rubber farming and welfare activities. As revealed in the FGDs, the training programmes organized by MU were poor in most societies. FOs had targets to conduct training programmes for rubber farming, yet, it was difficult to organize training programmes with most of TRSs. TRSs do not identify the importance of the technology transfer programmes whilst they always tried to implement subsidy disbursement programmes. It seemed that a hidden objective of the establishment of some of the TRSs was

just to acquire the benefits given by the Government as explained by respondents in the following quote

> *"All the TRSs were highly concerned about the benefits and subsidies that are given by the Government. Those who have left the society will be re-joined when the Government introduces a beneficiary program (GPCs and rubber rollers) again. Most of the society members perceived that the technical knowledge had less value than those physical and financial inputs. Rubber smallholders were highly addicted to the subsidy and seek subsidies for every aspect. It was a dependency mentality, developed over the decades through the policies that have been adopted"* **(P7D1)**.

Carrying out a decent welfare system promotes the group dynamics within the TRSs, people were encouraged to attract to the TRSs, which leads to strengthen the activities of TRSs. Most of the TRSs were given less priority to promote welfare activities due to various reasons; lack of initial funds, management not being in the position to initiate welfare projects, and presence of many specific welfare societies at village-level. However, a few societies started successful programmes as stated in the quote below.

> *"One society had a well-functioned money lending system. The interest rate of these societies which was comparatively low compared to other micro-finance institutions in the village. They had a separate act for the loan scheme and not only that, gifts (books and toys) were given to the children of members at the end of every year by using profits of the society"* **(P4D2)**

The major function of the TRSs was to strengthen the rubber marketing system in the village level rubber smallholders. To achieve this objective, 28 TRSs had established Group Processing Centers (GPCs). Rubber smallholders who don't have rubber processing facilities can use these centers to produce quality sheet rubber. This product was sold in bulk at a high price. The most of GPCs have functioned well and achieved their targets. There were many successful cases of TRSs as mentioned by FOs and as a summary;

> *"Many advantages were achieved by the establishment of GPCs, low sheet production cost, high-quality sheet production, time-saving for rubber smallholders, enhancement of the activeness and group cohesiveness in the society"* **(P3D2)**.

A few of the FOs highlighted the issues of GPCs; *viz.*

1. There was a trend that rubber smallholders opt to purchase their processing equipment such as rollers and smokehouses. Therefore, they did not want the facilities of GPCs. This led to discontinuation of the functions of GPCs, as the capacity of the smokehouse could not be fulfilled,
2. Difficulty inmanaging the maintenance cost and

3. Non-stability of marketing channels. According to the above discussion, most of TRSs were not focused on their major role at the village level.

External environment

This section explains how FOs recognized TRSs' response against the external factors/effects. It was revealed that all the TRSs were highly sensitive to external support in relation to extension activities and forms of subsidies. FOs guide the TRSs on different occasions, such as the time of the election of office bearers, organizing the extension programmes and financial matters. If there was a burning issue, meeting with the MU of each TRSs was taken under FOs purview. RRISL gets direct support from the TRSs for their technology transfer programmes and research purposes. There were a few active TRSs that effectively utilized RDD and RRISL to bridge their knowledge gap. On the other hand, TRSs gave their reasonable support for RRISL and RDD in every aspect as evident from respondents according to the following quote.

> *"I had only one active society under my purview, and they come up with some topics and requested me to conduct training programmes such as agronomy, tapping and processing of rubber. Not only that, one training programme on tapping skill development was arranged by themselves by directly contacting RRISL"* **(P2D2)**.

Rubber sheet and latex collectors had requested TRSs to strengthen the rubber marketing channel. It helped to get a marketing commission into the TRSs. Concerning the political influence, there were differences in opinion based on the locality. Some FOs had expressed that political influences were affecting TRSs' affairs especially in the distribution of rollers. One of the major roles of FOs was the development of TRSs. The opinion of all FOs was that TRSs were not independent organizations but they mainly depend on FOs in the particular region. As per the discussions, they were not sure about their strength and always seek help from FOs. It appeared that reasonably independent TRSs were quite rare and even not common among TRSs. However, two TRSs were identified with acceptable qualities as stated below.

> *"TRSs were mostly independent of the FOs. They conducted monthly meetings on their wish. FOs participate when a serious issue has occurred and in annual general meeting only"* **(P8D2)**.

The majority of the FOs had expressed that they would like to see TRSs running as independent societies. All FOs had accepted that they need the support of TRSs in their extension and development activities in the rubber sector as they cannot reach many rubber smallholders.

Organizational development of *Thurusaviya* rubber societies

The various drawbacks with regard to the TRSs had been explored previously under different categories. This section

attempted to gather the FOs suggestions and views to overcome those weaknesses and organizational development. Most FOs (96%) were of the view that the present framework as a voluntary organisation had to be changed. They argued that these TRSs could not be survive in the current competitive world as an entirely voluntary organisation. However, most of them express that it was necessary to study the structure of a similar organisation operating in different sectors in Sri Lanka and the world. Then the best model should be developed and adopted. Most of them have expressed that;

1. It was also necessary to change the mindset of rubber smallholders as they have lost their faith on TRSs,
2. Right people should be appointed to the leadership of the society,
3. To offer an allowance for the members of MUs to recognize their service and compensate for their time involvement,
4. Improving the physical resource pool (instruments of land preparation and equipment for tapping panel marking, ICTs facilities),
5. TRSs should be developed as a business entity by manufacturing various rubber-based products such as rubber bands and automotive accessories.

Conclusion

The study revealed that the majority of TRSs were not performing well due to certain internal and external factors. Internal factors were identified as poor leadership, lack of enthusiasm of members, issues in trustworthiness, transparency and attitudes of the members, while external factors were Government assistance, the role of the extension agent, changes in the external environment, the effect of other organisations and politics. TRSs were poor as they mainly depend on FOs and are highly sensitive to government aids. The majority of TRSs were not goal-oriented. From the extension and business perspectives, the majority of TRSs were not dynamic in organisational performances. The study suggests the necessity of interventions to address the above weaknesses under the organizational development perspective.

Limitation and direction for future research work

Only the FOs were used to collect the data on the assumption that they were impartial and none of the TRSs members were considered. Therefore, the findings of the study may be subjected to confirmation by another study.

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SHORT COMMUNICATION

An attempt to validate molecular and field level screening results for the Corynospora leaf fall disease in rubber (*Hevea brasiliensis*)

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Abstract

Corynespora Leaf Fall (CLF) disease is one of the serious diseases, caused by Corynespora cassiicola, affecting rubber (Hevea brasiliensis L) plantations. Clones rated as resistant to the disease under the polybag nurseries became susceptible at the field level causing major problems in clone recommendations. Therefore, it is of utmost importance to add new CLF resistant genotypes to the breeding pool. Therefore, the present study was carried out to attempt to validate the molecular screening by field screening results. The molecular screening was carried out using 35 genotypes from 2005 hand-pollinated progeny, their grandparents (RRIC 100 and RRIC 103), grate grandparents (RRIC 52 and PB 86), and two check clones (RRISL 201 and RRISL 208). The 2005 hand-pollinated progeny which has comprised with self progenies, raised at 1978 hand pollination by selfing at CLF susceptible clone RRIC 103 and CLF resistant clone RRIC 100. Four SSR Primers (HB 1, HB 11, HB 29, hmct 5) were selected based on polymorphism between the CLF free clone RRIC 100 and susceptible clone RRIC 103 for molecular screening. Field screening was done at polybag nursery, budwood nursery, and at field level in three locations viz., Nivithigalakale, Monaragala, and Gallewatta. Completely randomized design (CRD) was used with five to ten replicates. Disease assessment was carried out allowing plants for the natural infection based on the index developed for scoring of disease severity. Observations were taken three times during peak and off seasons of CLF disease occurrence and were assessed along with control clones. All primers generated two fragments for Hevea and built the genetic distance matrix using a power maker (V 3.0) computer program and a tree diagram was drawn using the Tree view computer program. Cluster analyses revealed four distinct clusters. Two primary clones, PB 86 and RRIC 52, and the clones RRIC 103 and RRIC 201 were grouped and another cluster was again grouped into three main sub-clusters. Around 40% of field screening results obtained agreed with molecular grouping whereas, 57% were not agreed and around 3% of genotypes did not show a clear correlation. However, further screening at the field level and molecular screening is needed.

Key words: Corynespora leaf fall disease, Hevea breeding, molecular markers, resistance, SSR

Introduction

Natural rubber from *Hevea brasiliensis* is one of the most versatile industrial raw materials. Corynespora leaf fall (CLF) disease caused by *Corynespora cassiicola*, is a serious disease affecting rubber yield with relatively a recent origin. The disease now has become a serious threat to the natural rubber industry affecting several outstanding clones in Sri Lanka as well as in South and South East Asia, and Central Africa (Jayasinghe, 2000).

The clones identified as highly susceptible in Sri Lanka during the first epidemic in 1985-1986 are RRIC 103, RRIC 104, RRIM 600, Tjir 1, RRIM 725, IAN 873, and FX 25 (Jayasinghe and Silva, 1996). The use of chemicals to control CLF disease in mature fields is not an economically feasible method and also creates environmental and health hazards where it is not recommended by the Rubber Research Institute (RRI) of Sri Lanka, at present.

The sudden susceptibility of the resistant high-yielding clones, which came through laborious evaluation procedures, has raised a big problem for rubber breeders and makes it difficult to recommend a clone for growers with confidence. Clones which showed resistance to Corynespora leaf fall during the evaluation were susceptible at field level after some time and disturb the clone recommendations. Therefore, it is very important to add precise Corynespora leaf fall-resistant genotypes to the breeding pool. The development of Corynespora leaf fall-resistant clones along with other performances such as high yield and vigor is a great challenge in *Hevea* breeding. The laboratory-based *in vitro* screening methods are not dependable and *in vitro* screening methods should be used only to obtain preliminary data. This also consumes considerable time under field experiments. And also field evaluation through visual observation and laboratory assays through excised leaf inoculation have led to the screening of putatively resistant Wickham clones and wild germplasm. However, laboratory bioassays are preliminary and may not ensure actual field-level resistance as observed for the disease of other forest trees. Many man-hours of labor and enormous quantities of fungicidal chemicals have been reported to be required every year for the management of the above disease in a vast area of rubber plantations in India and other rubber growing countries. The cost of fungicides and their long-term effect on the environment justify the need for breeding disease-resistant trees.

Molecular markers have now been proved very useful in selecting disease resistant clones (Collard *et. al.,* 2004). SSR (Simple Sequence Repeats) is a newly selected molecular marker to detect the resistant gene of different plant species due to its numerous advantages like hypervariability, displaying high levels of polymorphism, and ease of detection by PCR (Mantello *et al.*, 2012). Four SSR Primers (HB 1, HB 11, HB 29, *hmct 5*) were selected based on polymorphism between the CLF disease free clone RRIC 100 and the complete susceptible clone RRIC 103 (Tharanga *et*

al., 2018). Hand pollinated progeny developed in the year 2005 showed a wide range of CLF disease responses, as complete susceptible to free from the disease, is having second self progenies of the clone RRIC 100 as well as the clone RRIC 103. 2005 hand pollinated progeny which has comprised with self progenies, was raised at 1978 hand pollination by selfing at CLF susceptible clone RRIC 103 and CLF resistant clone RRIC 100. The resistance screening using SSR marker to select high performing CLF resistant rubber clones and correlation between molecular and field screenings have not yet been undertaken. Therefore, the current study was carried out with the objective of the attempt to validating the results of Microsatellite based molecular markers during molecular screening for CLF resistance with field level screening for the disease resistance.

Methodology

The experiment was carried out at the Department of Genetics and Plant breeding of Rubber Research Institute, Nivithigalakale substation, Matugama, Monaragala Substations, and Gallewatta estate.

Thirty five genotypes from the 2005 hand pollinated progeny program, with their grandparents (RRIC 100 and RRIC 103), great grandparents (RRIC 52 and PB 86) and with two check clones as RRISL 201 and RRISL, 208 were selected for the study.

Thirty five genotypes from the 2005 hand pollinated progeny which has comprised with self progenies of three *Hevea* genotypes that 1978 HP 375, 1978 HP 377 and 1978 HP 878 raised at 1978 hand pollination. That three 1978 HP genotypes already CLF resistant. The 1978 HP 375 and 1978 HP 377 were raised by selfing at CLF susceptible clone RRIC 103. 1978 HP 878 was raised by selfing with CLF resistant clone RRIC 100.

Molecular screening

DNA extraction

The genomic DNA extraction from leaves at the immature apple green stage was done according to the mini preparation method developed at RRISL (Withanage, 2013). The Purity and the concentration of extracted DNA samples were checked using agarose gel electrophoresis and visualized under gel documentation. Initially, thirty SSR primers were supplied by AVON PHARMO CHEM Private Ltd., USA, (*i.e.* HB1 to HB4, HB6 to HB12, HB14 to HB22, HB24 to HB30, *hmct* 5, *hmac*4, and *hmtc*1) were used.

PCR amplification

PCR optimization was performed with minor changes with a standard protocol developed at RRISL to obtain clear and precise repeatable fragments. PCR amplification was done in 20 µl reaction volume containing 50-100 ng template DNA with 1× PCR buffer, 2mM dNTPs, and one unit of Taq polymerase (Gene Tech, Sri Lanka) and 5mM of primer. Amplification was performed in Multigene DNA thermal cycler (Multi gene, Lab Net international Inc.) and the program consists of an initial denaturing

step at 94 ºC for, 4 minutes, 35 cycles of 1 minute at 94 ºC, 1 minute at the specific annealing temperature of each primer pair, and 2 min at 72 ^{0}C, followed by a final extension reaction. The amplified PCR products were resolved in 1.5% Agarose containing gel. The banding pattern was visualized in gel documentation.

Data analysis

Power marker software program, version 3.0 (Liu, 2004) was used to develop a phylogenetic tree and genetic distance matrix for the analysis. The construction of the phylogenetic tree was based on the Unweighted Pair Group Method (Koichiro Tamura *et al.*, 2013) with Arithmetic Averages (UPGMA) embedded in the MEGA6 software.

Field screening

All experimental materials, thirty five genotypes from 2005 hand pollination progeny, with their grandparents (RRIC 100 and RRIC 103), great grandparents (RRIC 52 and PB 86), and with check clone as RRISL 201 used were established at the RRISL substations in Nivithigalakelle, Gallewaththa estate (a traditional rubber growing area) and Monaragala (a non-traditional rubber growing area).

Screening of genotypes and their control clones in polybag and budwood nurseries at Nivithigalakele and in field establishments at Galewatta estate and Monaragala Substation

A completely randomized design (CRD) was used with five to ten replicates per genotype. Plants were screened for CLF disease resistance under natural infection and three observations were taken in the one-year-old plants. Five to ten plants were demarcated for the observations and the disease severity assessment was carried out based on the index for scoring of disease severity (score index) as shown in Table1. The results of the field experiment mean score index were subjected to cluster analysis to distinguish resistance of CLFD.

Table 1. *Score index for the assessment of CLF disease severity*

Index for scoring of disease severity (score index)	Description
0	No disease
1	Mild (0-25% of the leaf area is covered by the disease)
2	Moderate (25-50% of the leaf area is covered by the disease)
3	Severe (50-75% of the leaf area is covered by the disease)
4	Very severe (> 75% of the leaf area is covered by the disease)

(Fernando *et al.*, 2010)

Results and Discussion

In molecular screening, a pairwise genetic distance matrix was developed, based on two amplified DNA fragments of four primers, using Power marker program V 3.25. According to the dendrogram constructed using the "MEGA 6.06" computer program (V 3.25), two primary clones PB 86 and RRIC 52, and also the clones RRIC 103 and RRIC 201 were grouped together and the other cluster was again grouped into three sub-clusters. When considered the clustering pattern along with their pedigree, it is showed their close genetic relationship, by grouping genotypes that shared the same parentage (Fig.1a and 1b).

All thirty five genotypes of 2005 hand pollination progeny were grouped into the second main cluster named B, which was again divided into three clusters as B1, B2, and B3 (Fig. 1b). Cluster B1 comprised of the clone RRISL 208 and few genotypes. Cluster B2 was comprised of 20 genotypes and cluster B3 was grouped with the clone RRIC 100. The CLF moderately susceptible clone RRISL208 was grouped with HP 09, HP 05, HP 03, and HP 04 (group B1) and those genotypes were the products of CLF resistant genotype 1978 HP which showed moderately susceptible CLF response at field screening. The cluster B2 comprised with genotypes HP 1, HP 11, HP 13, HP 19, HP 23, HP 32, HP 58, HP 26, HP 10, HP 46, HP 50, HP 52, HP 21, HP 22, HP 06, HP 07, HP 15, HP 17, HP 2 and HP 49.

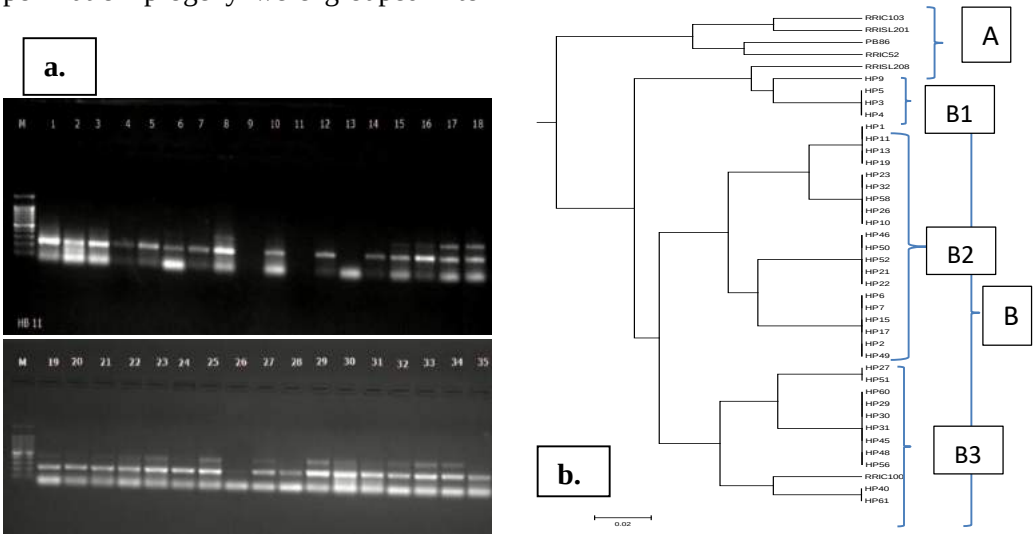

Fig. 1. Cluster analysis of the molecular screening and field screening to identify CLFD resistance **a.** Microsatellite profile of HB 11 primer for 35 genotypes in 2005 Hand pollination progeny **b.** Dendrogram of recommended clones including grand grandparents, grandparents of 2005 Hand pollination progeny, moderate susceptible recommend clones and 35 genotypes of 2005 hand pollination progeny in molecular screening

Variation between genotypes and clones was observed, however, it is unable to explain this situation clearly by looking at the relationship between field screening and molecular variation.
Therefore, further studies are needed to carry out to confirm the molecular relationship for the field level, CLF disease response in *Hevea*.

Field screening

In Nivithigalakale polybag screening, cluster number one consisted of ten genotypes along with disease free clones RRIC 100 and PB 86. Out of these 10 genotypes, two genotypes (2005 HP 5 and 2005 HP 1) were free from the disease while the rest of the eight genotypes showed very low disease intensity. The second cluster was grouped with 15 genotypes which were moderately susceptible to the CLF disease along with susceptible clone RRIC 103 and moderately susceptible clone RRISL 201. The third cluster was comprised of nine susceptible genotypes along with susceptible clone RRIC 52.
In Nivithigalakale, budwood nursery screening, cluster number one consisted of seven genotypes, along with moderately susceptible clone RRISL 201 and severely susceptible clone RRIC 103. The second cluster had 14 genotypes with disease free resistance clone RRIC 100 and resistance clone PB 86. The third cluster comprised the susceptible clone RRIC 52 and 10 other genotypes.
Cluster number one was grouped with nineteen genotypes along with disease free clones RRIC 100 and PB 86 at Monaragala during the field screening where two genotypes (2005 HP1 and 2005 HP2) were free from the disease while the rest of 19 genotypes showed very low disease severity. The second cluster had 10 genotypes with the moderately susceptible clone RRISL 201. The third cluster comprised of the susceptible clones RRIC 52 and RRIC 103, and six genotypes.
In the field screening at Galewatta, cluster number one consisted of 24 genotypes along with two CLF disease resistant clones RRIC 100 and PB 86. Out of those, 2005 HP1 and 2005 HP3 were free from the disease and the rest of the genotypes were also showed very low disease severity (Mean score 213). The second cluster had five genotypes and the moderate susceptible clone, RRISL 201. The third cluster compared with the susceptible clones RRIC 52 and RRIC 103 and four other genotypes.
Fernando *et al.* (2010) found the different methods to evaluate the susceptibility and resistance of genotype screening methods and are not dependable and should be used only to obtain preliminary data.
The studies of Manju and coworkers (2010) showed a differential behavior for CLF disease infection in the field and nursery experiments. It would be worthwhile to look for genes conferring resistance in the first cluster as its genetic base is much wider than the remaining two clusters. The continuous distributions of resistance patterns within a population of 62 clones suggest involvement of quantitative inheritance

to the resistance of *Corynespora cassicola*.

A comprehensive review of the clonal susceptibility to CLF disease in various rubber growing countries (Mathew, 2006) suggested that the tolerance level of widely cultivated clones is declining and also the creditability of the resistance level of a cultivated clone is lost due to breaking down of previously known resistance. According to the findings of Othman *et al.* (1996), the clone RRIM 600 and GT1 earlier reported susceptible as a result of the development of newer races of pathogen favored by the exposure to a long period of monoculture.

Verification of molecular screening results by field screening

When, developing a relationship between field screening and molecular screening, around 40% [(14/35)*100] of the genotypes screened were agreed in both field level response and molecular grouping and around 57% [(20/35)*100 did not show similar results. Around 3% [(1/35)*100 showed varied results and could not be concluded (Table 2).

In general, *Hevea* clones and genotypes studied in this experiment showed a differential behavior for CLF disease infection in the field, nursery, and molecular screening. It would be worthwhile to look for genes conferring resistance in the first cluster as its genetic constituents distributions resistance pattern within a population.

According to dendrogram, molecular screening was grouped resistant, susceptible and moderate susceptible for control clones. As when grouped with RRIC 100 it has assumed having resistance), groped with RRISL 208 (assumed moderate susceptible) and grouped without RRIC 100 and RRISL 208 (assume susceptible) in their nursery and field screening (Table 2).

Table 2. *Verification of field screening results through molecular screening*

Confirmed the field screening by the molecular result	Unconfirmed the field screening by the molecular result	Vary in result with molecular results
05 HP 27	2005 HP 29	2005 HP 48
2005 HP 30	2005 HP 31	
2005 HP 40	2005 HP 56	
2005 HP 45	2005 HP 61	
2005 HP 51	2005 HP 1	
2005 HP 60	2005 HP 2	
2005 HP 4	2005 HP 10	
2005 HP 5	2005 HP 11	
2005 HP 9	2005 HP 13	
2005 HP 6	2005 HP 17	
2005 HP 7	2005 HP 19	

Confirmed the field screening by the molecular result	Unconfirmed the field screening by the molecular result	Vary in result with molecular results
2005 HP 15	2005 HP 21	
2005 HP 46	2005 HP 22	
2005 HP 3	2005 HP 23	
	2005 HP 26	
	2005 HP 32	
	2005 HP 49	
	2005 HP 50	
	2005 HP 52	
	2005 HP 58	

[The results were obtained based on cluster groups (resistance, moderate resistance, and susceptibility) produced in molecular screening at the poly bag and budwood nurseries and field establishments at Galewatta estate and Monaragala substation]

Conclusion

The 2005 hand pollination progeny showed a range of CLF disease responses *i.e*. free from the disease to severe susceptibility.

Hevea clones and genotypes studied showed a differential behavior for CLF disease infection in the field, nursery, and molecular screening. Forty percent of the studied genotypes confirmed the molecular grouping by field screening and around 57% of genotypes did not develop the correlation. Around 3% of genotypes did not produce a clear relationship. It would be worthwhile to look for genes conferring resistance to CLF in the first cluster as its genetics continuous resistance distribution pattern within a population.

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Titles for all figures and graphs should be typed separately and attached to the figures. If you have more than one graph to be included in one page, submit each graph separately with a sample giving details of placement of graphs and any text to be included.
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Scientific names: When first cited, genus, species and authority must be given; later the genetic name may be abbreviated to its initial letter, *e.g. F. lignosus*, *H. brasiliensis* and so on. It is preferable if cultivars are cited preceded by the abbreviation cv. As botanical names are usually printed in italics, these should be underlined. **Units:** SI (metric) should be used. Authors are advised to consult the relevant British standard (also the Sri Lanka Standard). **Abbreviations:** Ad hoc abbreviations should be avoided and authors are advised to consult the B.S. on "Letter symbols, signs and abbreviations". It should please be remembered that abbreviations are alike in singular and plural. The placing of a dot (stop) after a standard abbreviation should be avoided unless the abbreviated form is likely to be taken for another word, *e.g.* in. for inch, where a full stop would be necessary. **Headings:** The pattern of headings should be as simple and brief as possible. Usually not more than three classes are needed, including the main class of headings such as **Introduction, Materials** and **Methods** and so on. The latter class is usually in bold typed block letters, placed in the centre of the page. The second order headings are bold, left justified and 3rd order headings should be italic bold and always run on headings. **Numerals:** Numerals should be used for specific units of measurements, *e.g.* 4 cm. 10 gal. 5h, 2 ft and so on. Other quantities, up to and including ten, must be spelt, (except in tables and figures), *e.g.* two leaves, six plots, eight trees, five larvae, ten days and so on. Although measurements such as days, weeks, months, years, miles are specific, it is preferable to fit them into the latter group by spelling the quantities (up to ten) preceding such measurements. Sentences should never start or end with a numeral. **Capitalization:** Generally initial capitalizing should be limited to names or designations; common names of organic compounds, chemicals and minerals are usually not capitalized except in the case of proprietary products. For examples, aluminum, oxalic acid, boron, potassium, urea *etc*, are not capitalized whereas Antimycin, Epikote, Dutrex, Vaseline *etc* are capitalized.

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The Journal of the Rubber Research Institute of Sri Lanka reaches a golden milestone!

"Publish or Perish" is an aphorism describing today's reality of the need for publishing new research evidence. However, this need for publishing had been present for centuries and had been well understood by the scientists who researched on rubber more 100 years ago as well.

The RRISL, as an institute dedicated to research on rubber, started off from very humble beginnings in 1909 with one Scientist, an Analytical Chemist. It was followed by the establishment of the Smallholding Advisory Department in later years to provide advisory services. Thus research findings related to rubber had been disseminated through publications right from the beginning.

With the gradual and methodical expansion of the research work over the 112 years, the publications of the Institute also expanded over its long history. Annual Review, Journal, Bulletin and Rubber Puwath, are the main annual research publications of the Institute. The Handbooks and Advisory Circulars are not regular publications but published when the necessity arises.

Among the many publications of the Institute, "The Journal of the RRISL" is a unique publication which provided a platform for the researchers to publish their findings and also to share the knowledge with the rest of the world. The publication is exchanged with many national and international institutes on an exchange basis and its popularity is witnessed from the number of citations made by the researchers of the rubber growing world. This publication dates back to 1924 and has been published every year and this volume is the memorial 100th volume.

The development of this publication over the years is a fascinating story. The first 16 volumes, from 1924 until 1939, had been published as four numbers quarterly under the title "Rubber Research Scheme (Ceylon) Quarterly Circulars". The next five volumes (from Volume 17 to 21), from 1940 to 1944 had been published as "Rubber Quarterly Circulars". Then from 1945 to 1958 (Volumes 22-34) it carried the title "Rubber Research Institute Quarterly Circulars". The 14 volumes from the year 1959 (Vol.35-49) had been published as" Rubber Research Institute of Ceylon Quarterly Journal" until 1972. After Sri Lanka became a republic in 1972, Ceylon was changed to Sri Lanka and the title of the Journal too changed to "Rubber Research Institute of Sri Lanka Quarterly Journal" for the three volumes from 50 to 53. The title "Journal of Rubber Research Institute of Sri Lanka" has been started from 1977 with Volume 54 and remains unchanged up to the Volume 100, published in 2020.

While appreciating all the contributors who devoted to publish it continuously from volume 1 up to 100, the Library staff and the management of the Institute are especially remembered with heartfelt gratitude. It is the hope and the wish of all Scientists at RRISL for the Journal of the Rubber Research Institute to prosper for another 100 years or more on the Institute's path to a radiant future.