ISSN 1391-0051

BULLETIN OF THE RUBBER RESEARCH INSTITUTE OF SRI LANKA

Rubber Research Institute of Sri Lanka

Vol. 60 2023

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Bulletin of the Rubber Research Institute of Sri Lanka, (2023) **60**, 1-11

CROWN BUDDING TECHNIQUE TO RESCUE *HEVEA BRASILIENSIS* CLONES THREATENED BY LEAF DISEASES

P Seneviratne, M N de Alwis and R K Samarasekera

INTRODUCTION

The rubber tree was propagated through rubber seeds during the period of domestication and until the bud grafting technique was developed in 1917 by the Dutch Horticulturists in Java. Since then the rubber clones were identified and produced and propagated using base budding methods. The base budding method had many developments over the years starting from ground seedling nurseries and the brown budding technique. The ground nursery is where the seedling rootstock nurseries are established and buds grafted using buds from clonal budwood nurseries. The resulting budded plants are later transferred to polybags or planted directly in fields.

There are two base budding techniques practiced for grafting of rubber, identified as "brown budding" and "green budding". The name is given for the colour of the budwood used for grafting and accordingly the bud grafting age varies. The older technique was the "brown budding" technique where the age of budwood and the rootstock seedling are both about 1-2 years. The green budding, on the other hand, is rather new and at present, almost all buddings are done using this method. In this technique, the age of the seedling rootstock can be as young as 2-4 months. The age of the budwood also can be similar to rootstocks. More than the age, the important criterion is the diameter of the bud wood and the rootstock seedling which are to be similar in size.

Crown budding is not a bud grafting method but it can be performed with either brown or green budding techniques. Also crown budded trees are called three-part trees as there are three different parts combined in a tree, *i.e.* seedling rootstock, stem belonging to one clone, and the crown or the canopy of another clone. Also, as the name implies this method is grafting for the crown and generally, the crown clone is selected to be resistant to diseases or wind damage. Therefore, the usage of crown budding is not common and is always done to add a disease-resistant or wind-resistant canopy. Producing a rubber tree with high yielding trunk and a disease-resistant crown was reported in 1929 at Java. The clone LCB 870 had been selected for resistance to *Oidium hevea* in Java (Young, 1954). Gunaratne *et al.,* 1984 have discussed the possibilities of reduced wind damage losses, and reduced yield depression during wintering while protecting against leaf diseases of crown budded trees. There are reports of serious disasters as a result of South American Leaf Blight (SALB) in South

America (Yoon, 1973). Crown budding can be used as a plant management method in humid areas to substitute susceptible crowns totally or at least partially. In these 'mixed-crown' plantations, the plants with resistant crowns will serve as a barrier to the dispersal of inoculum and concurrently represent a favorable environment for natural enemies of both pathogens and phytophagous insects.

However, unlike in the base budding, crown budding has to be carried out in the field and with the use of ladders or temporary scaffoldings as bud grafting is done above the tapping panel area *i.e.* about 8 feet height on the trunk. Therefore, whether to undertake brown budding or green budding is decided by the age of the trees. If the trees are about one year, then green budding can be adopted. But if the trees are older than that then it would be brown budding (Seneviratne, 1997). Also, the maximum age would be about 3 years as even at that age the girth of the trees is about 30 cm and bud grafting on large trees is not only impractical, laborious, but results in low success rates, too.

In 1985 the clone RRIC 103, which is a high-yielding clone recommended in Group I, got succumb to *Corynespora* leaf disease and every single tree of clone RRIC 103 available in the country died after repeated defoliation. Similarly, in 1995, the clone RRIC 110, which was recommended in group II was affected by *Corynespora.* Trial 1 reported in this article is on the performance of the crown budding done on a field of RRIC 110 in 1996. Trial 2 was also on the performances of crown budding on clone RRISL 224 which was severely affected by *Corynespora*.

Accordingly, the general objective of the two trials reported in this article was to rescue two fields and also two high-yielding clones which was succumbed to *Corynespora* leaf disease.

MATERIALS AND METHODS

Trial 1

This trial was initiated to rescue the clone RRIC 110 which showed symptoms of *Corynespora* leaf disease. Trees for crown budding were selected from clearings replanted in 1995 in the Menerigama division and the same clone replanted in 1993 in the Main division of Padukka Estate in Kaluthara district. Although the trees were affected by the disease the condition was not severe at the time of bud grafting.

There were 25 trees per a crown clone trial and the following clones used for the trial in the Menerigama division were:

T1 - RRIC 100
T2 - RRIC 102
T3 - RRIC 117
T4 - RRIC 121
T5 - RRIC 110
T6 - *Hevea spruciana*

In the Main division the crown clones used were as follows:

T1- RRIC 100

T2- RRIC 102

T3 - RRIC 110

T4 -RRIC 117

T5 - *Hevea spruciana*

Crown budding was done in the year 1997. The trees in the Menerigama division were about one year old and they were grafted with green buds. The trees at the Main division were about 3 years old and brown buds were used. Grafting operation in the Main division was extremely difficult and the upper part of the successful grafts was cut and removed using a cross saw.

In the Menerigama division, the girth of the trees was measured at 120 cm from the ground and was taken annually from 1999 to 2011. Growth measurements of the trees in the Main division were taken annually from 1998 to 2011. Tapping was started in both experiments in the year 2005 and the crop was taken from 2006 to 2008. The number of trees affected by Tapping Panel Dryness (TPD) in each experimental plot was also recorded annually from 2006 to 2011. During the trial period, some trees died and they were not considered for the data collection. TPD affected trees were also removed from the data. This is the reason for lower mean girth reported for some years.

The mean girth of the trees in the Menerigama division is shown in Figure 1.

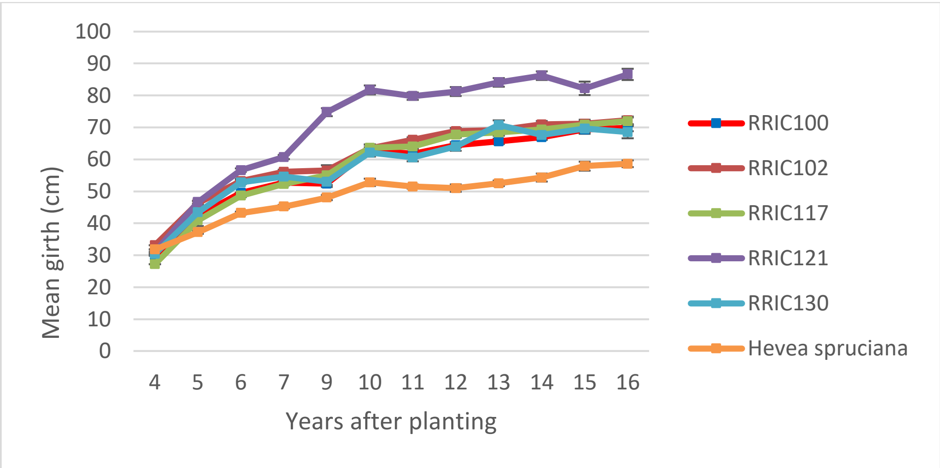

Fig. 1. Mean annual girth of RRIC 110 trees with different crown clones in the Menerigama Division

As seen in the Figure 1, the highest mean annual girth was seen in the trees of T4 throughout where RRIC 110 trees were grafted with RRIC 121. The mean annual girth of trees of T6, the RRIC 110 trees grafted with *Hevea spruciana*, was the lowest among all trunk x crown combinations. The girth of trees of the rest of the four clones showed comparable performances. Some crown budded trees were damaged and some showed tapping panel dryness and the mean girth value is affected due to those issues.

The mean girth of the trees in the Main division is shown in Figure 2.

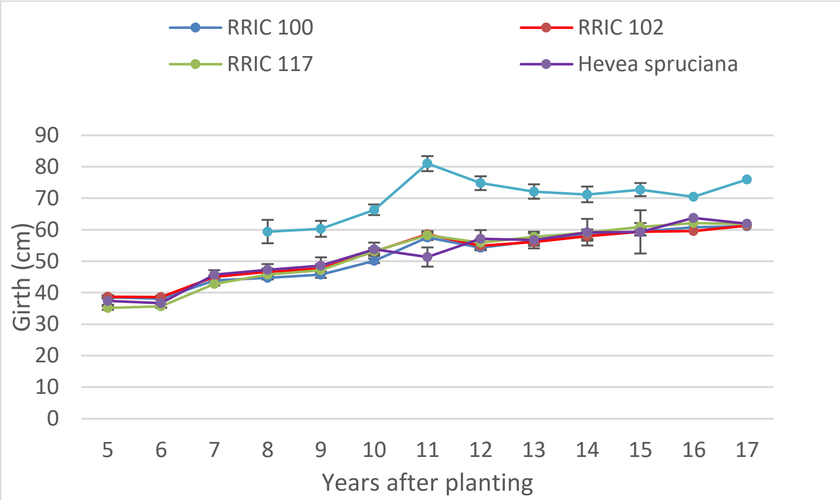

Fig. 2. Mean annual girth of RRIC 110 trunks with different crowns from 2006 to 2011 in the Main division

As seen in Figure 2, the highest mean annual girth at the Main division was recorded by RRIC 110 which was the control treatment. Even though growth performances of all treatment combinations are lower than the control, the girth increment and variation within treatments are comparable.

The mean yield (g/t/t) of the trees in the Menerigama division is shown in Figure 3.

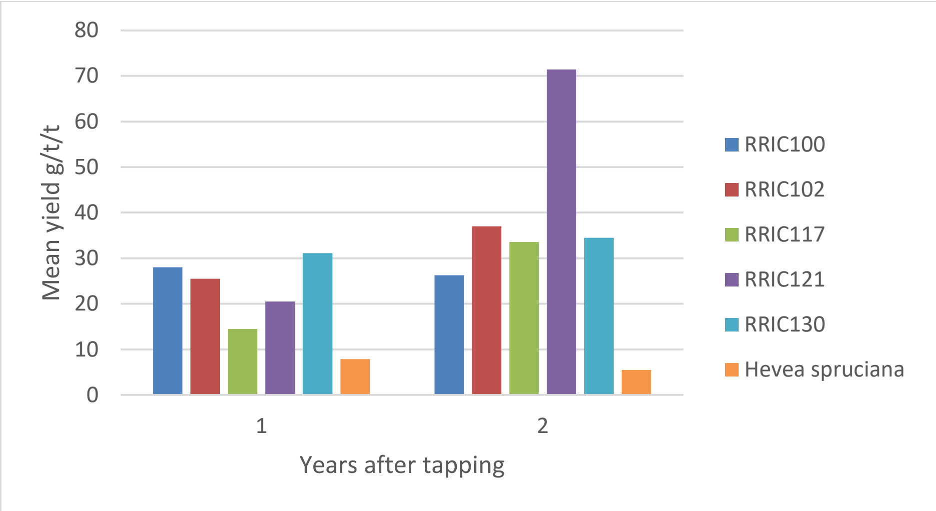

Fig. 3. Mean yield (g/t/t) of RRIC 110 trunks with different crown combinations in 2005 and 2006 in the Menerigama division

The mean yield (g/t/t) of the trees in the Main division is shown in Figure 4.

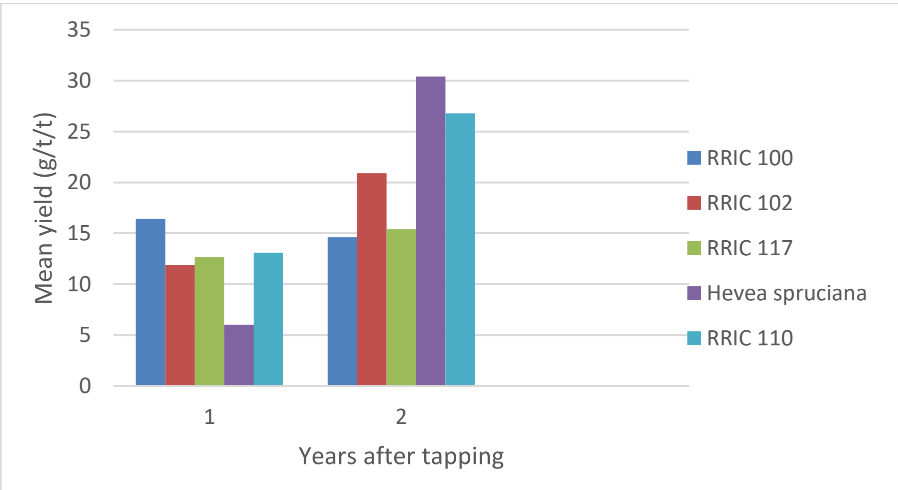

Fig. 4. Mean annual yield (g/t/t) of RRIC 110 trunks with different crowns combinations after 1 and 2 years in tapping in the Main division

The number of trees affected by tapping panel dryness was recorded from the year 2006 to 2011 and the percentages are given in Table 1.

Table 1. *The percentages of trees affected with tapping panel dryness (TPD) in different trunk x crown combinations from the year 2006 to 2011*

Division	Crown clone	% of TPD trees					
		2006	**2007**	**2008**	**2009**	**2010**	**2011**
Menerigama Division	RRIC 100	26	30	48.1	26.2	47	43
	RRIC 102	27	23	50.4	28.5	57	39
	RRIC 117	18	31	42	23.3	56	43
	RRIC 121	8	30	31	19	61	50
	RRIC 130	42	40	53.2	38.7	45	55
	Hevea spruciana	35	63	52.7	73.1	78	68
Main Division	RRIC 100	18	16	10	20.8	34	31
	RRIC 102	9.8	19	7.9	15.1	21	35
	RRIC 117	12	16	10.8	23.1	20	30
	RRIC 110	12.2	25.4	16	22.9	30	26
	Hevea spruciana	40	50	33.3	33.3	46	55

A high percentage of TPD trees is recorded for all crown budded trees. A very high percentage is observed in the trees with *Hevea spruciana* as the crown. Both the girth and the yield are also lowest in the trees having *Hevea spruciana* as the crown. The lowest TPD percentage was reported for RRIC 110 clone maintained as the control without crown budding which had the highest girth and yield.

The bud grafting process at Menerigama and Main division are shown in Figure 5. As it can be seen. Bud grafting of even 1year old trees is very difficult as the grafting is done at 8 feet on the trunk. When the trees are 3 years old not only grafting but also the pruning of the main trunk after grafting is practically very difficult and costly

Trial 2

This study was conducted at a RRISL 224 clearing planted in 1997 at Galewatta division in Dartonfield group, Agalawatta (WL1a). The field was severely affected by *Corynespora* where repeated defoliation was observed. These plants were sprayed regularly as per the instructions of the Plant Pathology Department for 3-4 months to improve the foliage and peeling quality to undertake crown budding.

There were seven trunk x crown combinations and the following clones were used for crown budding. The main difference between this and trial 1 is that this trial has more than one crown clone in some combinations as follows.

1. RRIC 100
2. RRIC 102
3. RRIC 121,
4. RRIC 100 +RRIC 121
5. *Hevea pauciflora*,
6. *Hevea pauciflora* +RRIC 121,
7. *Hevea pauciflora* +RRIC 100+RRIC 121

Annual girth measurements were taken from 2000 to 2014 and tapping started in November 2003. The yield from each trunk x crown combination was recorded from 2006 to 2010.

RESULTS

The mean girth of the trunk x crown combinations is given in Table 2 and Figure 5.

Table 2. *The mean girth of the trunk x crown combinations from 2000 to 2014. The trunk clone is RRISL 224.*

Year	Mean annual girth (cm)						
	RRIC 100	RRIC 102	RRIC 121	RRIC121+ RRIC100	*H.pauciflora*	*H.pauciflora+* RRIC121	*H.pauciflora+* RRIC100+121
2000	28.4	23.4	29.3	27.4	28.4	-	-
2001	40.6	35.7	41.7	41.1	35.4	40.0	32.2
2002	40.5	27.0	41.5	38.9	37.1	-	40.0
2003	61.3	-	59.0	64.9	53.5	68.5	64.5
2005	74.2	-	57.0	67.0	51.3	68.7	62.1
2006	67.0	-	66.5	72.7	60.8	70.3	82.0
2007	69.7	-	75.2	79.7	51.3	-	-
2008	73.4	-	79.3	82.0	52.3	-	-
2009	75.6	-	82.6	86.7	54.0	-	-
2010	77.2	-	83.9	87.8	55.4	-	-
2011	78.2	-	84.8	93.5	58.5	-	-
2012	81.6	-	87.1	94.7	59.2	-	-
2013	82.4	-	88.8	95.3	59.5	-	-
2014	83.9	-	89.3	95.0	69.4	-	-

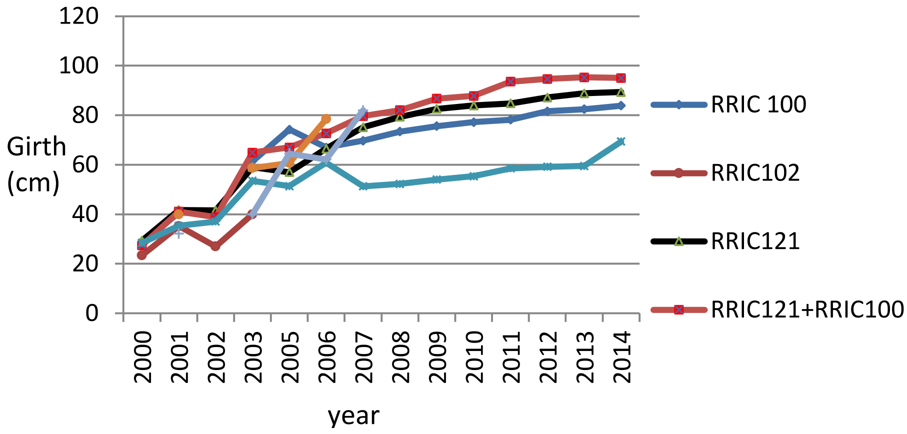

Fig. 5. The mean girth of the trunk x crown combinations from 2000 to 2014. The trunk clone is RRISL 224.

Among the crown combinations, the highest mean annual girth was recorded for the RRIC121+RRIC100 crown combination.

The performance of the *Hevea pauciflora* as the crown clone was comparatively poor. Furthermore, the clone combinations of *H. pauciflora* with RRIC clones also recorded low girth. Most of the *H. pauciflora* crowned plants and the combinations later died and the rest of the budded plants showed tapping panel dryness at a high rate.

The increase in girth during the first three years is relatively low but, as soon as the terminal growth stops and the branches begin to develop, the girth development of the stem is greatly accelerated. After the 8th to 10th year, the growth rate has retarded.

The yield of the crown budded trees from 2006 to 2010 are given in Table 3 and Figure 6

Table 3 Mean annual yield of RRISL 224 trunk with different crowns combinations

Table 3. *Mean annual yield of RRISL 224 trunk with different crowns combinations*

	Mean annual yield(g/t/t)						
Year	**RRIC 100**	**RRIC 121**	***H.pauciflora***	**RRIC121+ RRIC100**	**RRIC100+*H. pauciflora***	**H.pauciflora+ RRIC121**	**H.pauciflora+ RRIC 100+121**
2006	22.7	16.1	17.4	13.4	28.7	15.8	19.7
2007	39.3	38.8	32.7	-	52.2	-	-
2009	58.8	76.3	28.4	-	78.0	-	-
2010	39.5	59.9	22.5	-	50.8	-	-

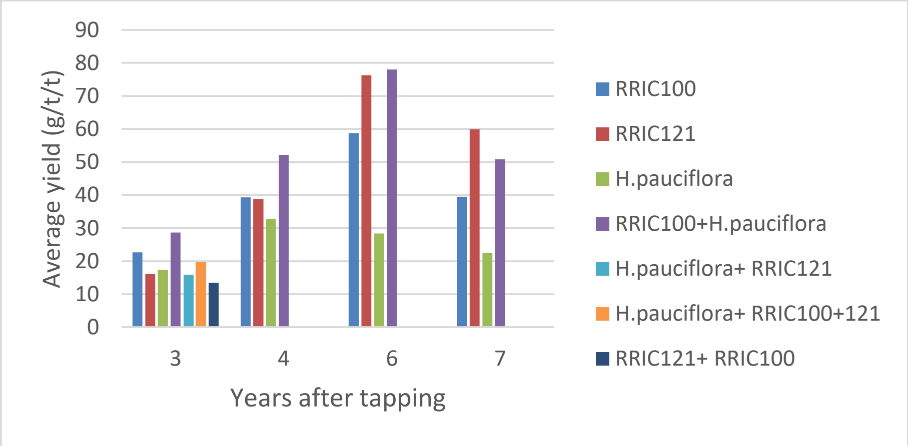

Fig. 6. Mean annual yield of RRISL 224 trunk with different crowns from 2006 to 2010.

As per the data given in the Table 3 and Figure 5, the yield of the trees seem to affect most with crowns of other *Hevea* species, in this trial, *pauciflora*.

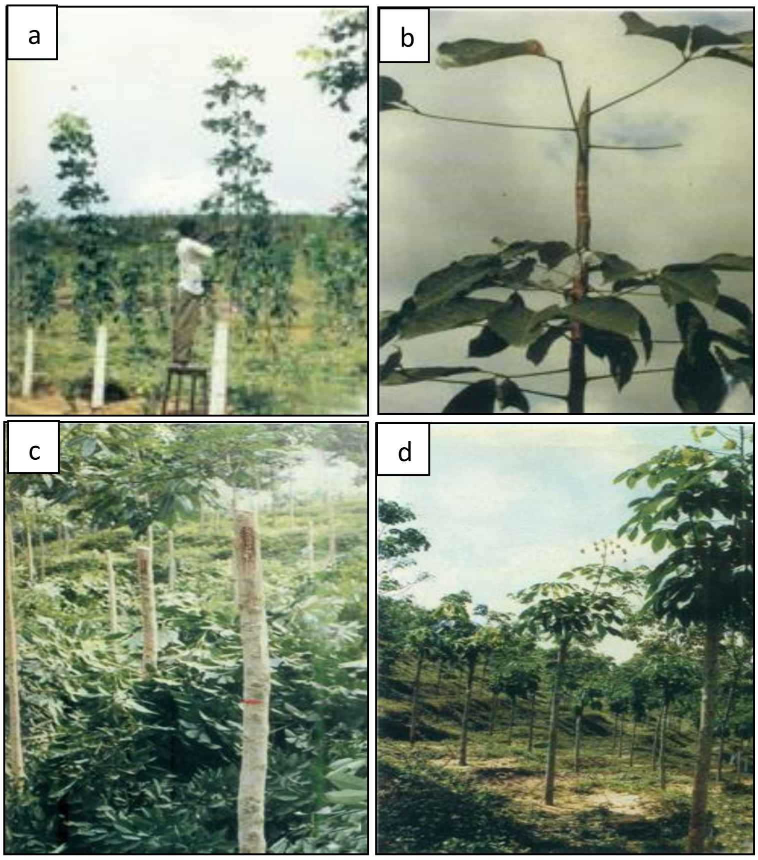

Fig. 7. Crown budding trial at bud grafting (a), successful graft (b) at Menerigama division and after pollarding (c) and growth of crown budded spruciana (d) at Main division

DISCUSSION

The results of the two trials indicate that other *Hevea* species, both *spruciana* and *pauciflor*a are not successful as crowns. However, the knowledge on different trunk x crown combinations are important for the management of sudden disease outbreaks in the future. Trial 1 generated a lot of knowledge as it had trunk clones of different ages: one year and four years of the same clone.

Although difficult, even 3 years old trees can be crown budded and the trunk clone could be saved. Yield data collection of these trials were discontinued due to constraint at the institute but high yielding clones seem to perform well. The correlation between the growth and the yield seem to be present even in crown budded trees as per the results. This also suggest that even susceptible clones can survive if the population is low as the control block of 25 RRIC 110 trees survived and gave good growth and yield. But the RRIC 110 fields in other locations got wiped out due to repeated defoliation.

Crown budding with 2-3 clones seem very advantageous not only to alleviate foliar diseases but also to obtain higher yields. Further, if one graft fails, then the rest of the grafts can function as the crown. With one year old trees this is possible and practically and economically feasible. Another usage of the knowledge on trunk x crown combinations is the use of 2-3 crown clones for the same trunk trees to lower the density of crown clone which is conducive to foliar disease attacks.

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UNDERSTANDING THE BASICS OF YOUR DATA: A KEY TO APPROPRIATE STATISTICAL ANALYSIS AND INTERPRETATION

Wasana Wijesuriya and Dilhan Rathnayaka

INTRODUCTION

In mathematical and statistical analysis, data is defined as a collected group of information. Information can be anything that may be used to prove or disprove a scientific guess during an experiment. Day-to-day, we come across data of different types in our research and questionnaire surveys that are collected, analyzed, interpreted and presented. The data are the individual pieces of factual information recorded, and it is used for the purpose of the analysis process. Some of them can be measured, some can be ranked and some are just information that can or cannot be categorized. Nowadays there are numerous statistical methods available for data analysis, but one needs to select the most suitable method to analyze the data collected in experiments and surveys. Hence, the objective of this article is to introduce the types of data we gather in experiments and surveys and to provide guidance to identify the most suitable statistical methods for the analysis of collected data.

Types of data

The most common classification of data is whether they are qualitative or quantitative in nature. Further, qualitative data can be classified into Nominal and Ordinal data and Quantitative data are classified into Interval and Ratio data as illustrated in Fig. 1 and the characteristics of different data types are illustrated in Table 1.

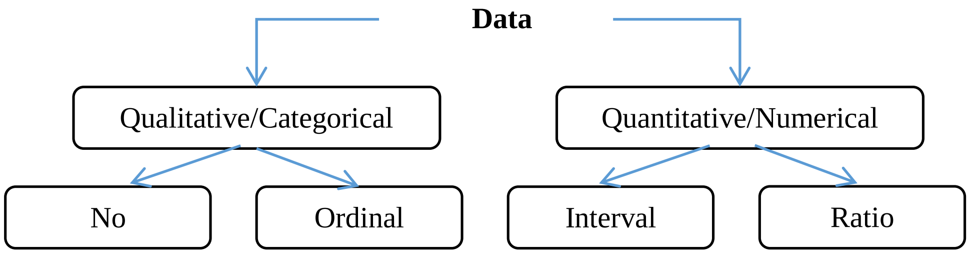

Fig. 1. Classification of types of data

Table 1. *Characteristics of different types of data*

What data can provide:	Type of data			
	Nominal	**Ordinal**	**Interval**	**Ratio**
A known value for the 'order'		☑	☑	☑
'Counts' and 'Frequency distributions'	☑	☑	☑	☑
Mode	☑	☑	☑	☑
Median		☑	☑	☑
Mean			☑	☑
Can quantify the difference between each value			☑	☑
Can add or subtract values			☑	☑
Can multiply and divide values				☑
Has 'true zero'				☑

Source: My market Research methods (available at https://www.mymarket_research_methods.com/

Qualitative or Categorical Data

In the simplest way, qualitative data are not numerical and cannot be measured, and they describe the data that fit into the categories. Qualitative data are further divided into nominal and ordinal data.

Nominal Data

Nominal data are regarded as the lowest level data providing qualitative information which helps to label the variables without providing the numerical value. These cannot be ordered and measured. The most popular example of nominal data is gender. The type of clone and the stage of growth (immature/mature) and the sectors; whether 'estate' or 'smallholder' are some examples in relation to rubber cultivation. Table 1 describes what nominal data can provide when they are analyzed. Accordingly, the frequencies (counts) and the mode of different categories can be interpreted in data analysis. The nominal data are analyzed using grouping methods. In these methods, the data are grouped into categories, and then the frequency or the percentage of the categories can be calculated. These data can be effectively represented by pie charts using categories as labels and the slices to represent the percentage or bar charts with categories on the x-axis and percentages of each category on the y-axis. Nominal data also can be represented using frequency tables. Almost all statistical packages come with the option 'cross tabs' under descriptive methods to receive the above output.

Analysis of nominal data

The nominal data types can be matched or unmatched according to the design of the experiment, and the tests carried out on each category are described below.

A) Unmatched category

Initially, a random sample is obtained, and subsequently, the counts are recorded for each cell to fit into a table as depicted in Table 2. In this example, from a sample of latex harvesters those who ‘do’ or ‘do not’ receive harvester training will be tested for whether they have adopted the correct harvesting methods.

Table 2. *A two-way table of counts with harvesters received or not received harvester training against adoption/non-adoption of correct harvesting methods*

Harvester training	**Adoption of correct harvesting methods**	
	Yes	**No**
Received	a1	a2
Not received	a3	a4

Note: a1, a2, a3 and a4 are counts recorded for each cell

The commonest way of analyzing nominal data presented in a 2-way table is by the chi-square test first introduced by Pearson (1900). However, this test is not recommended if the cell frequencies are less than 5. Fisher’s exact test (Fisher, 1922) is an alternative available in common statistical software and it can handle cell frequencies less than 5. Here, the test is based on the hypotheses; H_0: there is no association between the categories against H_1: there is an association and the results can be interpreted using percentages.

B) Matched Category

A common use for matched pairs is to assign one individual to a ’treatment group’ and another to a ’control group’. This process, called ‘matching’ is used in matched pairs design. The ‘pairs’ can be different people/objects with similarity or they can be the same study participants/objects, measured before and after an intervention. Paired samples can be analyzed with the following specific tests:

McNemar Test: This is a distribution-free test for paired nominal data in 2 groups. An example would be the intended adoption of a recommendation after attending a training programme. Table 3 describes an example 2×2 table for analysis, showing the impact of harvester training programmes on awareness build-up by rubber smallholders.

There is a basic difference between this table and the more common two-way table. In the matched-paired case, the count represents the number of pairs, not the number of individuals. The researcher wishes to compare the proportion of cases that adopt after training with the proportion of controls that adopt before training.

Table 3. *A two-way table of counts for pairs of rubber farmers who adopt or do not adopt a recommendation*

		Before Training (Control)	
		Adopted	Not adopted
After training	Adopted	a1	a2
(case)	Not adopted	a3	a4

Note: a1, a2, a3 and a4 are counts recorded for each cell

Cochran's Q Test: This is a test carried out on three or more groups. The Cochran test is a non-parametric test for analyzing randomized complete block designs where the response variable is a binary variable *(i.e.*, there are only two possible outcomes, which are coded as 0 and 1).

Ordinal data

Ordinal data is a type of data that follows a natural order. This variable is mostly found in questionnaire surveys and research that deals with diseases (disease severity measures) and in socioeconomics (perceptions/awareness of recommendations of farmers). These data are investigated and interpreted through many visualization tools. The information may be expressed using tables in which each row in the table shows a distinct category. This is a data type with a set order or scale to it. However, this order does not have a standard scale on which the difference in variables is measured. Both the mode and the median exist in ordered data (Table 1).

Many examples can be stated from the rubber sector for this data type. In disease studies susceptibility of different rubber clones for a disease can be measured on a scale of ‘severe’, ‘moderate’, and ‘mild’ and can be analysed using non-parametric statistical methods coding the categories as 1, 0, and -1 or 2, 1 and 0, respectively, for the categories. The appropriate non-parametric analysis for Completely Randomized Designs (CRDs) is the Kruskall-Wallis test (sometimes called "one-way ANOVA on ranks") followed by the Wilcoxon Rank Sum test (also called Mann Whitney U test) for comparing possible combinations of treatments. This is the non-parametric alternative test for the independent sample t-test in parametric data analysis.

There are two main categories of ordinal data variables, namely; unmatched and matched categories. Below are the tests recommended for each category:

A) Unmatched Category in Ordinal Data Variables

Wilcoxon rank-sum test: This test is used to investigate 2 groups of independent samples.

Kruskal-Wallis 1-way test: This is used to investigate 3 or more groups.

B) Matched Category in Ordinal Data Variables

Wilcoxon signed-rank test: This is a test used to assess the differences between 2 groups of matched samples.

Friedman 2-way ANOVA: This is used to find differences in matched sets of 3 or more groups.

Likert scale data

The Likert scale data is said to exhibit both categorical and numerical data characteristics making it in between these data types. The controversy on the appropriate analysis of various types of rating scales has existed for over 65 years dating back to the time when the original framework for levels of measurement was proposed by Stevens (Stevens, 1946). Now many experts on this debate state parametric tests can be used to analyze Likert scale responses (Sullivan and Artino, 2013; Harpe, 2015). However, to describe the data, means are often of limited value unless the data follow a classic normal distribution.

A Likert scale is a type of scale used in survey research that measures respondents' attitudes towards a certain subject. Likert scale questions are single-choice, closed-ended questions, and the primary benefit of using a Likert scale is that it provides more information on people's attitudes towards a subject than a simple yes/no question type. The term Likert comes from the creator of the Likert Scale, Rensis Likert, a social psychologist who invented the scale in the 1930s (Likert, 1932). A full Likert scale consists of a series of related statements as given below in the example, which can be used to study the perception of smallholders on clonal preference (Tab37le 4). Likert scales also can be used for single non-related questions.

Table 4. *An example for full Likert scale to study the perception on clonal preference*

Statement	**Strongly disagree**	**Disagree**	**Neither agree nor disagree**	**Agree**	**Strongly agree**
The growth of Clone A is very consistent				☑	
The yield of Clone A reaches 1500 kg/ha/year		☑			
The Brown Bast % in Clone A does not exceed 5%					☑

Likert scales are most commonly 5-point or 7-point scales with a neutral middle-point, such as 'neither agree nor disagree' 'neutral' or 'undecided'. While a 7-point Likert scale can provide an even greater level of granularity than a 5-point Likert scale, respondents may find it harder to distinguish between the options on a longer scale. Hence, the 5-point scale is mostly used in conventional surveys and mobile-based survey modes.

Likert scales are useful as they provide a number of pre-written answer options that are applicable to a wide range of scenarios. For instance, the 'disagree to agree' Likert scale can be applied to almost any topic by asking respondents to rate their level of agreement with a statement regarding their beliefs. Some common Likert scale question examples are given below.

1. **Agree to Disagree Likert Scale -** Strongly Disagree, Disagree, Neither agree nor disagree, Agree, Strongly Agree
2. **Satisfaction Likert Scale -** Very dissatisfied, Somewhat dissatisfied, Neither dissatisfied nor satisfied, Somewhat satisfied, Very satisfied
3. **Likelihood Likert Scale -** Very unlikely, Somewhat unlikely, Neither likely nor unlikely, Somewhat likely, Very likely
4. **Bad to Good Likert Scale -** Very poor, Poor, Average, Good, Excellent
5. **Frequency Likert Scale -** Never, Rarely, Sometimes, Often, Always

Quantitative or Numerical data

Quantitative data is also known as numerical data which represents the numerical value, *viz.* how much, how often and how many. Numerical data gives information about the quantities of a specific thing. Some examples of numerical data are plant height, fresh weight of seeds and tree girth. Continuous data can be measured and has an infinite number of possible values between two realistic measurements. Continuous data can be either interval or ratio data (Fig. 1).

Discrete data, include whole or concrete numbers or counts, for instance, the number of leaves or number of seeds are also considered as quantitative data.

Interval data

The characteristics of interval data are given in Table 1. They can be subtracted or added but cannot be multiplied or divided to form ratios. It is a numeric scale that represents not only the order but also the equal distances between the values of the objects. The most popular example is the temperature in degrees Fahrenheit or Celsius and the pH value where a meaningful or true zero does not exist. The time, age, date and voltage are also some examples for interval data.

These characteristics allow interval data to have many applications in the field of statistics as for ratio data. Yet, there is one major disadvantage, the lack of an absolute zero. The lack of the 'true zero' make it impossible to make conclusions about how many times higher one value than another. Thus, interval scale only allows you to see the direction and the difference between the values.

Ratio data

Ratio data are considered the highest level of data as indicated in Table 1. They have continuous intervals like in interval data. However, ratio data has a true zero, which interval data does not. Some examples for ratio data from the rubber sector are tree height and girth, tapping cut height and length.

Descriptive statistics that can be generated from quantitative data are frequency distribution, central tendency measures (mode, median, and mean) and variability measures (range, standard deviation, and variance). Parametric tests can be used to analyze quantitative datasets. Some of the most common tests are the t-test, Analysis of variance (ANOVA), Pearson correlation coefficient and simple linear regression which are available in common statistical software.

Summary

The basic idea of this article is to introduce the types of data and basic statistical methods for data analysis. However, with the advancement of the field of Statistics and computational software, new methods have been proposed especially to handle both qualitative and quantitative data together to produce meaningful outputs.

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USE OF ROOT-BALLED PLANTS TO FILL THE VACANCIES IN IMMATURE RUBBER FIELDS IN THE INTERMEDIATE ZONE OF SRI LANKA

S A Nakandala, M N de Alwis, D L N Zoysa and N M C Nayanakantha

INTRODUCTION

Both large estates and rubber smallholdings in the majority of rubber plantations have poor tree stands. Presently recommended planting density in the fields accommodates 516 plants per hectare (Seneviratne, 2021). Stand per unit area affects latex production and productivity and as a result, poor tree stand in a tapping field reduces land productivity to a greater extent. Improper agro-management practices at planting *i.e.*, use of low-quality planting material, not adopting recommended planting practices, not replacing weak plants, and not supplying vacancies with high-quality plants are identified as the main reasons for this condition. Maintenance of optimum tree stand with good quality plants by replacing weak plants or casualties should be one of the priority areas in an early stage of immature upkeep. For that, it is recommended to keep an extra 10% of the total number of young budding plants to be used to replace weak and dead plants (Seneviratne, 2021). Transplanting by using these young budding plants can be done in the major planting seasons during the 2nd or 3rd year round of filling and after 2nd year until 3rd year of planting 10% extra plants in the field is self-up to use in 2nd to 3rd year to allow the extra plants to prepare stumped budding plants in the clearing (Seneviratne, 2021). Table 1 depicts the round of refilling casualties, the season of supply, age of the clearing at each supply, and planting type.

Table 1. *Round of supplying vacant plants during the immature period*

Round of refilling	Season of the supply	Age of the clearing	Form of the plants
1st	SW following year	6 months	3-4 whorls plants
2nd	NE same year	1 year	5-6 whorls plants
3rd	SW 2nd year	1½ years	Stumped buddings should
4th	NE 2nd year	2 years	be prepared with the plants
5th	SW 3rd year	2½ years	prior to moving.

Note: SW- South-West Monsoon rains ; NE- North-East Monsoon rains
Source: Handbook of Rubber (Agronomy), 2021.

According to Table 1, there are five rounds of plant supply after the field establishment. During the first year, casualties or weak plants can be replaced with the onset of the following monsoon rains without employing the stumped budding procedure as the plants are small. After second year onward, stumped buddings should be used to replace weak or dead plants until third year of field establishment for reaching the same tree girth with other rubber plants planted in the clearing.

This paper discusses the importance of maintaining full stand during immature period by replacing weak plants with a new method of preparing planting materials instead of using conventional stumped buddings. This method has an advantage in supplying vacancies in a field since it reduces the immaturity period when compare to stumped budding plants. The method was initially introduced to Intermediate Zone where the extended dry season is prominent every year that affects plant growth with a high number of casualties.

METHODOLOGY

A field trial was conducted in a newly established rubber field at the Sub Station of Rubber Research Institute of Sri Lanka, in Moneragala District which belongs to the Intermediate Zone (IL1c). The field establishment was done in November, 2016 with the onset of North-East monsoonal rains with young budded plants of clone RRIC 121. During first two years of planting, weak plants were replaced by using young budding plants that kept in the field as trench plants. After two years of planting , weak plants below 10 cm girth in the clearing were replaced with treatment plants *i.e.,* whole plants with root-balled as new planting material and stumped budding plants as control in 2018 with the onset of North-East monsoonal rains. Treatment plants were randomly distributed among the clearing in a Complete Randomized design (CRD).

Preparation of root-balled plants as new planting material

Root-balled plants were prepared by using normal young budded plants raised at the field as trench plants after two years of field establishment. Initially the tap root of the trench plant was pruned leaving about 1 m, *i.e.* tailing was done one month before the plants are needed. This was done by exposing the tap root by cutting a trench on one side of the plant. All lateral roots surrounding the tap root were shaped and tightly wrapped with a gunny bag (Fig. 1a and b). This process is known as balling of trees. This method prevents the root-balled from breaking while protecting root from water loss and stress. The root-balled plants were kept moist all the time to reduce water stress. Such plants were kept in site for one month before moving to replace the weak plants in the field. In this method, unlike stump budding upper canopy or crown was not pollarded and has remained the same. After one month of root-balling, plants were planted in the field according to a randomized design together with stumped buddings plants taken as the control treatment.

Fig. 1. Preparing root-balled plants: **a.** cutting roots **b.** cover with a gunny bag as a ball

Preparation of stumped buddings as control plants

Trench plants planted at 90 cm spacing are used for preparing stumped budded plants. Tap root of the plant was pruned leaving about 60 cm in the soil. The tailing was done 5-6 weeks before the plants are required and 3-4 weeks after tailing or 2 weeks before field planting, the tree was pollarded at the height of 2.4 m (8 feet) and water proofing dressing was applied after cutting the top and lime was applied on the stem to prevent desiccation (Fig. 2).

Fig. 2. Preparation of stumped buddings **Fig. 3.** Bud bursting stage

After about 2 weeks of pollarding, top dormant bud start sprouting and at that stage, plants were ready for field planting as stumped buddings (Fig. 3). At this stage after two years of field establishment, stumped budded plants together with root-balled plants were planted in the field. Data were recorded annually on growth of treatment plants in terms of girth at 120 cm height from the bud union at the base. Girth increment was calculated after establishing stumped budded and root-balled plants in the field. The girth of normal plants was also recorded at the same time in order to compare the growth performance of treatment plants. Statistical analysis was done by analysis of variance (ANOVA) followed by a T-test at a probability level of 0.05. SAS statistical software package-version 9.0 (SAS Inc., USA) was used to analyze data.

RESULTS AND DISCUSSION

Growth of treatment plants used for replacing weak plants and normal plants remaining in the field after 2 years of planting is shown in Figure 4. Growth of normal plants established in the field during 6 years of planting showed a satisfactory girth when compared to stumped budded or root-balled plants established in the field. As shown in the Figure 4, normal trees in the field reached the trappable girth (50 cm) after 6 years of planting. When considering the root-balled plants, the girth at a height of

120 cm showed a higher girth than stumped budded plants used as the control treatment (Fig. 4).

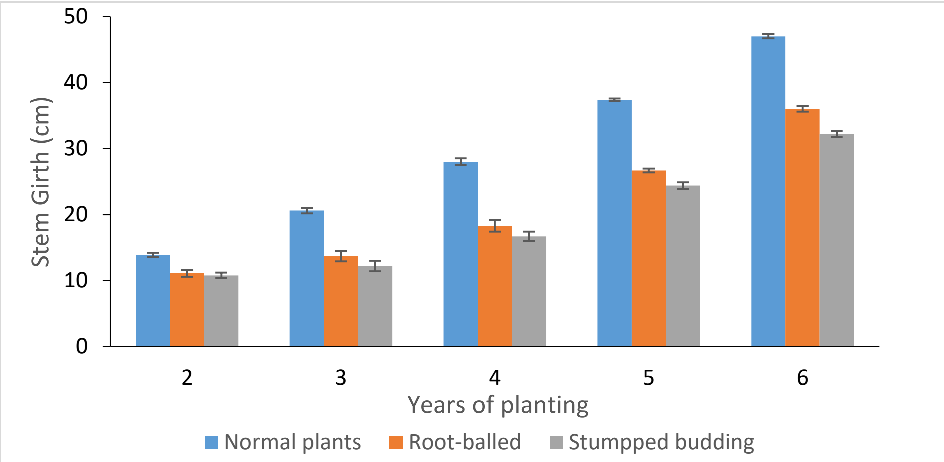


Fig. 4. Annual girth of treatment plants

Figure 5 indicates the annual girth increment of treatment plants and normal trees. In normal trees, the annual girth increment is in a range of 8-9 cm which showed a normal growth pattern expected in the Intermediate Zone.

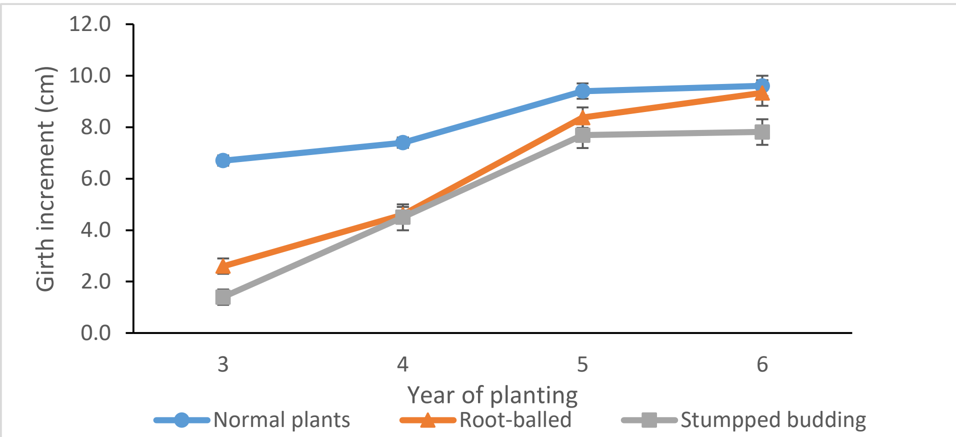
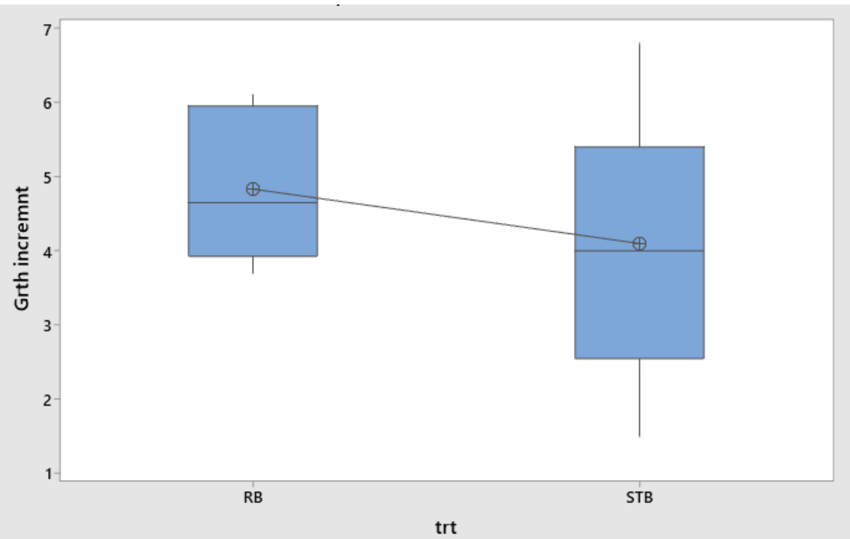


Fig. 5. Girth increment of treatment plants and normal plants

When considering the root-balled plants and stumped budding plants, there were set back in growth rate initially for a period of more than two years. But it was observed that the root-balled plants with their crowns were properly established in the field resulting in a growth rate equivalent to normal trees reached at 6^{th} year (Fig. 5). This may be due to its ability for giving a sufficient photosynthetic area by existing canopy for photosynthetic assimilations. In stumped buddings, it was revealed that when plants were pollarded, there were no crowns grown at one or two years after planting happened to set back the growth for more years (Fig. 5). Moreover, Figure 6 depicted that the statistical variance of girth increment of two treatments in a boxplot diagram.



RB-Root-balled plants; STB-Stumped budding plants; trt-Treatments; Grth increment-girth increment (cm)

Fig. 6. Boxplot diagram of girth increment of root balled and stumped budding plants

T-Test was done to compare the effect of two treatments *i.e.*, root balled and stumped buddings and that is observed as less variation in girth increment was significant in root balled plants when compared to stumped budded plants means that uniform growth can be reachable by using root-balled plants when compared to stumped budded plants (Fig.6).

A previous research study on crown budding conducted by Chandrasekera (1980) also concluded that crown budding has resulted in a similar setback to growth by approximately two years and an average yield depression appeared during the first four years in tapping. Similarly, when stumped buddings were used for replacing weak plants, it took more than eight years for reaching tappable girth. Figure 7 (a) and (b) show the growth variation of root-balled plants and stumped budded plants at present.

Fig. 7. Actual size of the treatment plants (a) Root-balled plant (b) Stumped budding

By comparing present field condition of the treatment plants in Figure 7, it was revealed that the new method of preparing root-balled plants for replacing weak plants performed well in supplying vacancies when compared with the conventional method of producing stumped buddings. Therefore, this method can be successfully adapted to immature field plantings in the Intermediate Zone of the country in order to replace weak plants where the extended dry season is prominent in every year that affect the plant growth, especially during the immature period.

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Bulletin of the Rubber Research Institute of Sri Lanka, (2023) **60**, 27-31

APPROACHES TO MANAGE THE NEWLY SPREADING LEAF FALL DISEASE OF RUBBER PLANTATIONS

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Rubber plantation industry plays a vital role in our economy. The social impacts are significant especially for the smallholder growers. Rubber (*Hevea*) plantations provide the most versatile raw material for numerous industries; supplement thousands of hectares to the forest cover, contributing to CO_2 sequestration while providing many other socio economic and ecological benefits. Unfortunately, during the recent past, the world's natural rubber production declined and this could be attributed to the low productivity level due to poor tree stand, unfavourable climatic conditions, non-adoption of recommended agronomic practices, and use of inappropriate exploitation systems and prevalence of the newly spreading leaf fall disease.

First Report of the New Leaf Fall Disease

This new leaf fall disease was first reported from Malaysia in the year 2017 and then from Indonesia. Later, the disease was reported from Sri Lanka in the month of August 2019. With the report of the new leaf fall disease condition, immediate actions were made to educate the Extension Staff and the growers regarding the disease, in order to isolate the diseased plantations and to limit further spread of the disease. Disease detection surveys were undertaken and chemical controlling programmes were also implemented to delimit further spread of the disease to new areas. Several discussions and workshops were conducted to implement the appropriate actions jointly by the Rubber Research Institution (RRI) and the Rubber Development Department (RDD).

Identification of the Disease

This has been regarded as a secondary leaf fall disease affecting the lower canopy. The disease starts with a pin point or pin head sized lesion on leaves (Fig. 1a). Later they become larger forming characteristic circular lesions (Fig. 1b). Under conducive weather conditions, the small circular lesions may coalesce to form larger necrotic areas (Fig. 1c). With time yellowing of the leaves are observed at the lower canopies of the plants (Fig. 2) leading to a leaf fall (Fig. 3).

Causative Agents

The causative agents associated with this disease show more or less variation in different countries. However in Sri Lanka, two pathogen groups have been reported to be associated with the disease: *Colletotrichum* species (four new *Colletotrichum* species) and Pestalotioides group (three genera - *Pestalotiopsis*, *Neopestalotiopsis* and *Pseudopestalotiopsis*). More than 500 numbers of disease samples were studied and approx. 70% of the isolates resulted Pestalotioides fungi. Approx. 25% of the fungi were *Colletotrichum* species (*C. siamense*, C. *fructicola*, *C. tropicale*, *C. gigasporum*). And the remaining 5% was represented by various types of fungi like *Fusarium* spp., *Botrodipoidea* spp., *Curvularia* spp. *Phomopsis* spp., and *Negrospora* spp. The pathogenicity studies have shown that even though *Colletotrichum* were found less in number, they were the most pathogenic group. Pestalotioides was more abundant but majority of the isolates were non-pathogenic or very mild in their pathogenesis. Kock's postulates were proven using both the pathogen groups.

Mixed infection conditions are very rarely reported from rubber plantations and this is the first occasion of a synergistic action made by several fungal organisms on rubber plants was noted. *Colletotrichum* leaf disease had been reported from Sri Lanka since 1903 by a scientist called T. Petch and later *C. acutatum* was reported in 1997. The present causative agents are new to all the rubber growing countries (Fernando et al., 2023). The identity of the other pathogens has also been made mainly as *Neopestalotiopsis* and hence regarded as a new pathogen. Since this is a mix infection condition, the disease has been named as the "Circular Leaf Spot Disease" – (CLSD).

Factors Affecting the Severity of the Disease

To reveal the factors affecting, a detailed survey has been carried out. Below factors have been observed affecting the incidence and severity of the disease. Weather factors such as rainfall and its distribution has influenced the disease severity level badly. The type of the clone also influenced the wintering pattern. The early wintering clones show a slight escape from the disease while the late wintering clones succumbed to the disease showing much more severity levels. The commonest clone grown in Sri Lanka, RRIC 121, succumbs to the disease severely. The prevailing low prices too have an influence since most of the growers are not following the good agricultural practices due to the low income levels. The prices of agricultural inputs like fertilizers and pesticides have gone up considerably. The overall poor condition of the cultivations and poor sanitation, coincides with the disease to make the condition serious.

Economic Significance

Although precise quantitative details related to canopy density of new rubber clones is not available nevertheless it is generally assumed that reduction in canopy due to the leaf diseases result in yield reduction. It has been reported by past physiologists that up to 25-30% canopy depletion may not affect the reduction of crops from rubber trees. The losses incurred by plantations and smallholdings in terms of lost revenue from yield decline can be substantial. This varies from location to location, since the poor yields is a result of many other factors including the incidence of the disease.

Furthermore, the incidence of disease may protract the immature period delaying the opening of trees for tapping leading to a potential loss of income. However, CLSD has not yet caused any tree death. But, these pathogens are showing alternative hosts such as tea, cinnamon, coconut, oil palm, papaya, guava and many other economically important crops. There is a high possibility for the pathogen to invade the other agricultural crops as well. Department of Agriculture and other Crop Research Institutes of the country should be vigilant on prevention of this disease invading other crops.

Management of the Disease

In order to overcome the economic losses caused by the disease, a number of strategies have been recommended. Integrated disease management protocols: agronomic practices, biological controlling and chemical controlling should be used, where necessary to manage the disease. The adoption of enviromax planting systems, proper agronomic practices, crown budding, chemical controlling, biological controlling, improvement of tree vigor and the use of disease tolerant / resistant clones will also be important. To restrict further spread of the disease, there should be a national effort. All the rubber growers, RPCs, extension staff and the researchers should take part in this programme, otherwise, the attempts will be a failure. These practices have been categorized as short-term, medium-term and long-term and the growers need to adopt them as much as possible to manage the disease.

Short term practices

- Reduce the inoculum potential: during the wintering, and during leaf fall occur at later stages - Collect all the leaves into ditches in between the planting rows for composting The biopesticide to suppress the pathogen and the acceleration of litter will be provided by the RRISL on request
- Or collect the infected leaves & carefully burn them
- Weeding and improving the sanitation of the plantations
- Remove all the runts in plantations for small holders this should be carried out with the consent of the RDO / REO
- Apply fertilizer as recommended by the RRISL
- Avoid over exploitation and non recommended tapping protocols
- Apply the fungicides where necessary (For clearings where more than 60% leaf fall was noted during the month of October, 2022)
    - Recommended Fungicides - Carbendazim 10g / L & Hexaconazole 10ml / L
- Calibration of the sprayers to make the fungicide application efficient
- Controlling of cover / ground growth

Mid term practices

- Clearing the abandoned/neglected areas
- Apply Good Agricultural practices
- Regularize the tapping protocols
- Conduct training programmes

Long term practices

- Use tolerant clones as much as possible eg. RRIC100 / RRISL2006
- Keep the clonal balance to the maximum possible level (the most susceptible clone, RRIC 121 occupies majority of our cultivations)
- Conduct training programmes

Biological Controlling

Identification of biological controlling agents for the disease is important since they will make the management strategies more environmental friendly. In Sri Lanka, native endophytic micro-organisms have been isolated and the research is in progress to test the efficacy under field conditions.

Screening of *Hevea* Clones to Identify Disease Tolerant Clones

Planting of *Hevea* clones resistant to the disease is the most economical and environmental friendly method in controlling CLSD. Unfortunately, unlike for Corynespora leaf fall disease, this disease does not show any resistant clones, based on the observations made so far. Tender leaves are highly susceptible to these pathogens. And some of the fungi are found as endophytes, showing a growth inside the plant without harming. Since these fungi are regarded as opportunistic, whenever the cultivations become poorly maintained, they have the capacity to be more pathogenic. In the natural field conditions, the symptoms are appearing after about two months of incubation period. The wet weather is highly favourable for the incidence and the severity of the disease. Identification of disease resistant rubber clones will be the most reliable and long term solution to combat the disease. The pathogen population studies and the biology of the pathogens should be completed before performing the clonal screening programme. For the matter of urgency, an intensive clonal screening programme has been launched. The research conducted for the last two years revealed that some clones like RRIC 100 tolerate the disease. Few other clones like RRISL 2004 & CEN 4 have also been identified as tolerant. Further research should be conducted and more observations should be collected before making firm conclusions. Internationally accepted protocols are available to screen the clones. There are three main steps *viz*. laboratory based techniques such as detached leaf test using conidia and toxin: screening of clones in a bud wood nursery type of experiment and screening under natural field conditions. All the Pathologists and Breeders from rubber growing countries have already made steps to screen all the available clones to be included into the breeding programmes.

The disease scenario of the rubber tree has changed with time. CLSD is a relatively new disease. The research programmes on the pathogen populations, their biology and epidemiology are limited. This knowledge is of utmost importance to formulate effective disease management strategies. Concerted efforts are on at all the Rubber Research Institutes to combat the disease and to improve currently available management strategies. At national level, many Universities have come forward for collaborative trials with the RRISL. We are facing a global epidemic condition where more cooperation is required from the industry, funding agencies, direct and indirect parties to face the dilemma.

Acknowledgement

The untiring efforts made by the staff of the Plant Pathology & Microbiology Department, RRISL, are gratefully acknowledged. The Ministry of Plantation Industries is also thanked for providing financial support.

TOWARDS A NEW ERA OF *HEVEA* BREEDING IN SRI LANKA

S P Withanage and WA D R Tharanga

Abstract

Para rubber (*Hevea brasiliensis*) provides the main source of natural rubber. The *Hevea*, tree originated in the Amazon basin and was domesticated in South East Asia in 1876, with a narrow genetic base, considered as "Wickham material" although it might be mixed with some "Cross material" derived from Lower Amazon, too (Baulkwill 1989). *Hevea* planting material, starting from unselected seedlings, has been subjected to genetic improvement, and its genetic potential has increased nearly tenfold. However, presently, *Hevea* is showing a yield plateau, which may be due to the practice of directional breeding over a long time. In order to investigate the problem of yield plateau, the total genetic and cytoplasmic composition of the clones recommended, and the hybridization (HP) progenies developed during the period 2000 - 2017 were analyzed using their pedigree records. The clone PB 86 has contributed around 16 percent, followed by RRIC 52, which contributed 12 percent to the total genetic composition of the revised clone recommendation 2013. There were cytoplasmic families with cytoplasmic uniformity within the family derived from cytoplasmic progenitors when the recommended clones/selections up to 2017 hybrid progenies were considered. The largest cytoplasm contributor was the primary clone RRIC 52, followed by PB 86. Only a very few primary progenitors are involved in the large share of the genetic composition of the current breeding pool. Therefore, the establishment of large-scale Wickham-Wickham/Non-Wickham polyclonal seed gardens for making hybrids and reciprocal crosses to change the cytoplasmic composition has been suggested to initiate a new era of *Hevea* breeding towards improving the genetic potential and to widen the genetic base.

Keywords: Genetic Improvement, Genetic and Cytoplasmic contribution, *Hevea*, Pedigree, Polyclonal seed gardens, Sri Lanka

INTRODUCTION

Since the introduction of *Hevea* to Sri Lanka in 1876, it has been subjected to genetic improvement through various breeding processes. Hybridization and selection have mainly been practiced for more than ten decades to improve *Hevea* in all rubber-growing countries. In Sri Lanka, presently, the genetic potential of rubber yield has reached around 3,000-3,500 kg $ha^{-1}yr^{-1}$ it has been estimated the maximum physiological yield, in a mature stand of rubber, takes a value from 7,000 to 12,000 kg $ha^{-1}yr^{-1}$ (Paardekooper, 1989). In the future, almost all rubber growing countries are expected to achieve the genetic potential of rubber yield somewhere around 4000 kg $ha^{-1}yr^{-1}$(Mydin *et al.*, 2011). However, it is a well-known fact that the present Wickham genetic base has been narrow, although an unknown number of mixed cross materials is present. During past decades, a number of clones have been released and recommended under different series. Also, some clones were removed from the recommendation due to sudden disease outbreaks and newly developed high-yielding clones were introduced. With this process, although we achieved a very successful genetic improvement of *Hevea* previously, presently the new genotypes produced are not showing such yield improvement compared to their parents or control clones. The results of the recently evaluated 1998 hybrid progeny further confirm this situation, as it produced only a few genotypes that give significantly higher rubber yields than the control clone RRIC 121 (Anushka *et al*., 2019). Analysis of 1999 hybridized progeny also showed similar results (Withanage 2017).

The conventional breeding programs generally use the best performing genotypes/ clones of the previous generation as the parents for the generation and application of directional selection (or Generation wise Assortative Mating), oriented for a few objectives, mainly high yield, vigour, and resistance/tolerance to diseases. As a result of inbreeding depression, narrowing of the genetic base, buffering of the gene pool, and finally, a plateau in yield is expected. This situation led to the analysis of the pedigree of the current breeding pool to regain a new era for *Hevea* improvement for the betterment to safeguard the natural rubber industry and drive towards the expected potential of *Hevea* in the future.

MATERIALS AND METHODS

Development of pedigree flow chart:

All pedigree records and hybridization details maintained at the Department of Genetics and Plant Breeding, RRISL, were used in the present study. A pedigree flowchart was developed following the standard methodology for the previous clone recommendation (Revised 2013), which consists of 30 indigenous and seven exotic clones.

Analysis of cytoplasmic progenitors:

Both the previous clone recommendation (Revised 2013), and the new clone recommendation (Revised 2022), which includes seven new interim clones to the pool were used separately to analyze the cytoplasmic origin. According to the pedigree flow chart, the cytoplasmic progenitor of each clone is identified and taken as the percentage of the total number of clones existing under that particular progenitor out of the total number of clones in the recommendation. When carrying out the analysis of total genetic contribution**,** it is assumed that 50 percent of genetic material from each parent is passed into F1 progeny following basic genetic principles of Mendel’s independent segregation and assortment. The contribution of relevant progenitors to the total genetic composition of each clone was calculated, and the overall contribution of each progenitor was calculated as a percentage of the total contribution of the progenitors involved in developing the RRIC/RRISL recommended exotic clones included in the package of clone recommendation of Rubber Research Institute of Sri Lanka.

RESULTS AND DISCUSSION

Although the history of *Hevea* improvement goes back to the use of unselected seedlings, the pedigree analysis started from the time when the use of selected seedlings was initiated in *Hevea* improvement (Fig. 1). Most of the PB, G1, Pil, and AVROS progenitors were selected from a large seedling population raised in Malaysia during 1924 (Tan *et al*., 1996) and Mil 3/2, Wagga 6278 were raised locally as selected high yielding mother plants (Fernando, 1966). There are several clonal series, such as RRISL100, RRISL 200, RRISL 2000, RRISL Centennial, and Interim recommendations, but they could not be clearly differentiated into generation-wise categories as some clones developed later have used primary progenitors too, as their parents (*eg*: RRISL Centennial 3) (Fig. 1). When the total genetic composition of primary progenitors was considered, the contribution of 21 foreign (Bold in Black colour) and five local primary progenitors (Bold in Green colour) (Fig. 2) for the previous clone recommendation could clearly be shown (Revised in 2013).

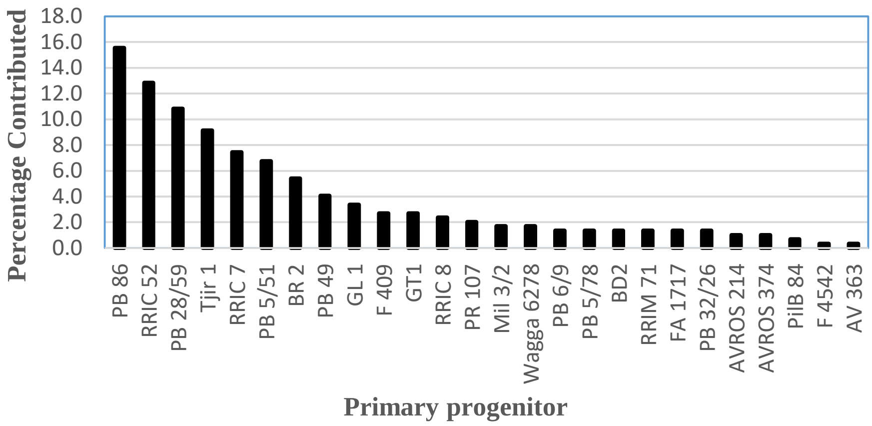

Fig. 2. Total genetic contribution of the primary progenitors (both male and female) to the previous clone recommendation (revised 2013) as the percentage of the total genetic contribution of all the 25 progenitors.

The highest genetic contribution of about 16% has been made by the clone PB 86, followed by RRIC 52 (locally selected PBIG seedling No. 183) with about 12% contribution, clone PB 28/59 (Malaysia) with about 11% contribution, and clone Tijir 1 (Indonesia) about 10% contribution (Fig. 2). About 49% of the total genetic contribution has been made by these four primary progenitors and the remaining 51% has been donated by other 21 primary progenitors (Fig. 2). This pattern is in line with the diversity pattern revealed using microsatellite molecular marker analysis of 14 selected clones representing all the series of recommended clones (Fig.1), as most of the clones belonging to different series are still grouped together indicating their genetic closeness (Kodikara *et al.*, 2011). The clone RRISL 2005, which has a non-Wickham clone IAN 45/710 as the male parent, was distinct from other clones.

The cytoplasmic contribution of each of the primary progenitors made to the previous clone recommendation (revised 2013) as a percentage of the total cytoplasmic contribution of all eight progenitors is presented in Figure 3. Primary clone RRIC 52 made about 35% cytoplasmic contribution, followed by PB 28/59 with 14% and each PB 5/51, Tijir 1, and RRIC 8 with about 11% contribution. Clones that can be traced back to the same cytoplasmic origin is a family with cytoplasmic uniformity. Based on within family cytoplasmic uniformity (Fig. 4), a few popular clones *viz*. RRIC 100, RRIC 102, RRISL 203, and RRISL 2001 belong to the RRIC 52 family and two of them *viz*. RRIC 102 and RRISL 203 are recommended to plant up to a maximum of 10% of the total extent of large plantation estates. Also, these two clones and RRISL 2001 are recommended for smallholdings that share around 70% of the Rubber plantation in Sri Lanka. The cytoplasm of the two smallest families with cytoplasmic uniformity is coming from GT 1 and BR 2, which were the donor for only two clones *viz*. BPM 24 and RRISL Centennial 3 and RRISL 210 and RRISL 211, respectively. All foreign clones, except the primary clone PB 28/59, are in two cytoplasmic families *viz*. Tijir 1 and PB 5/51 (Fig. 4). Origin of these PB, PR, RRIM and RRII clones is confirmed by the analysis given in some other studies, too (Simmonds, 1989; Priyadarshan, 2017).

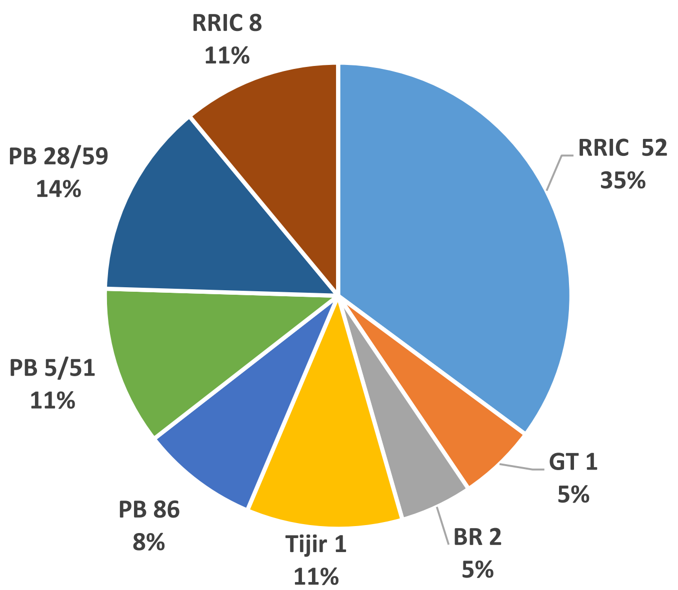

Fig. 3. Cytoplasmic contribution of each of the primary progenitors made as a percentage of total cytoplasmic contribution of all the eight progenitors in the previous clone recommendation (revised 2013).

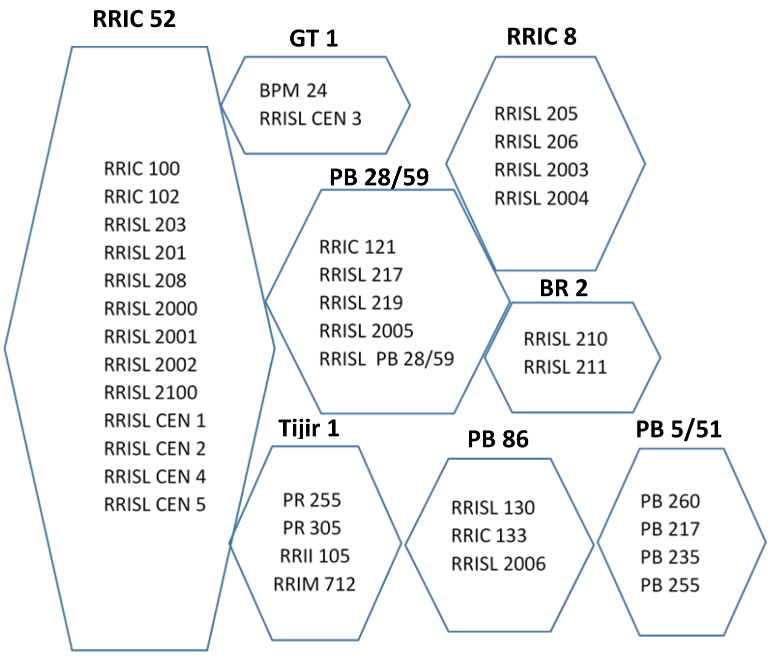

Fig. 4. Grouping of previously recommended clones (revised 2013) into families with within family cytoplasmic uniformity tracing back to eight primary cytoplasmic progenitors indicated in bold.

Once the seven interim clones including two Indian clones (RRII 430 and RRII 414) and two non-Wickham selections are included for the revised clone recommendation 2022, while removing the clones RRISL 205 and RRISL 206, the total number of recommended clones amounted to 42. Then the cytoplasmic contribution of RRIC 52 is expected to be increased up to 39% (Fig. 5). However, one genotype (1995 HP-55) out of the seven interim clones to be added has non-Wickham male parent and two non-Wickham selections (GPS III and GPS IV) (Withanage *et al.*, 2015) are expected to make a change in the genetic constitution, due to the addition of five percent cytoplasmic contribution of non-Wickham genetic base will be a great achievement.

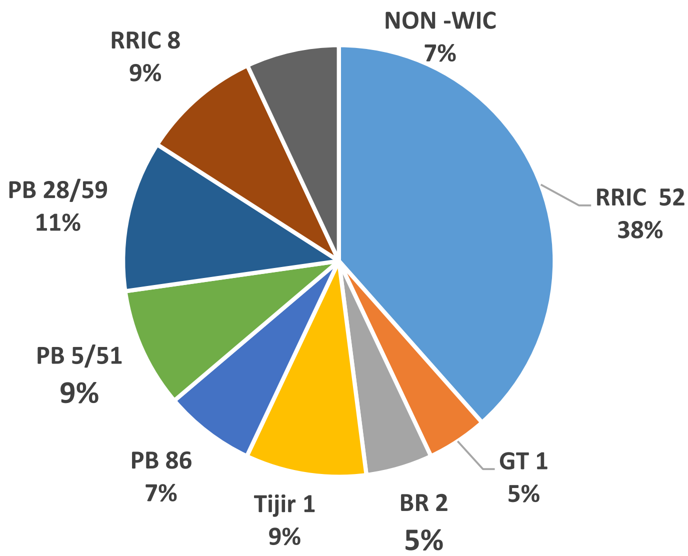

Fig. 5. Expected cytoplasmic contribution of each of the primary progenitors made as a percentage of the total cytoplasmic contribution of all the nine progenitors in the revised clone recommendation in 2022.

The present situation reveals that to date around eight to nine primary progenitors served as cytoplasmic donors and the major contributors are the primary clones RRIC 52, PB 86 and PB 28/59 and this may be the reason for the prevailing yield plateau. Because the analysis of yield records in several small scale clonal trials which have been carried out to evaluate HP progenies *ie;*1996, 1997, 1998, 2001 and 2006 showed that only a very few genotypes achieved significantly higher yields compared to their respective control clones (Withanage 2016, Anushka *et al* 2019, Withanage 2019).

It has been shown that the diversity of mitochondrial DNA (mt DNA) in the Wickham population is almost zero but high in non-Wickham accessions (Luo and Boutry, 1995) and breeding in 1999 emphasized the importance of the integration of non-Wickham cytoplasm in the breeding pool. However, the lower polymorphism in chloroplast DNA (cp DNA) indicated that the chloroplast DNA is highly conserved (Luo, 1995).

Expansion of *Hevea* Breeding garden with non-Wickham Accessions:

It is a known fact that most *Hevea breeding* programs still follow generation-wise assortative mating focusing on the Wickham selection further narrowing the genetic variation. It has experienced the continuous use of the Wickham genetic base as the female parent but incorporates the non- Wickham genetic base through the male parent. However, it was observed more polymorphism in non-Wickham genetics (1981 germplasm collection) (Lekwipat et al 2003). Therefore, the current breeding programs are focused on using non-Wickham genetics for both parents. The breeding garden has already been raised with twenty-five non – Wickham selections made after evaluating around 2000 accessions (Baddewithana *et al* 2016).Two germplasm selections as GPS III (MT 11-76 I) and GPS IV (MT 11-76 II) were used as female parents of 2022 hand-pollinated progeny and crossed with RRISL 2006 and RRISL 211 along with selfings (Withanage 2022) and raised around 68 genotypes.

Development of polyclonal seed gardens using Wickham-Wickham/Non Wickham germplasm to expand the genetic diversity and to produce *Hevea* Hybrids

The use of polyclonal seed gardens is already practiced in different countries in their breeding programs and as a result, a number of superior clones have been developed (Mydin *et al*., 2005, Mydin, 2014; Mondal *et al*., 2006, Mondal *et al*., 2016; Jacob *et al*., 2013).Even in very early established Prang Besar Isolated Gardens (PBIG), well performing PB clones have been developed (Tan *et al*., 1996).

Polyclonal seed gardens of Wickham germplasm and Wickham/NonWickham cross combinations can be established on a large scale to raise thousands of full sib (FS) and half sib (HS) families for the future evaluation process. Selection of clones having high general combining ability (GCA) that will help to increase the efficiency of parental selection will be difficult with the practice of Generation Wise Assortative breeding at the beginning as it takes a long time. However, the estimation of GCA by analyzing seedling progenies makes it possible to select the best parents for future recombination taking place in this polyclonal seed garden. Collection of seeds from Wickham clones to produce half or full sib families through controlled hybridization can be used to generate a greater genetic diversity to select genotypes for high yield, and vigour as well as suitability for different agro climatic regions, particularly for marginal areas.

In Wickham/Non Wickham polyclonal seed gardens, half sib Wickham seeds can be used to incorporate the Wickham genes into the pool. Also, collecting non-Wickham seeds helps to generate non-Wickham cytoplasmic contribution to the breeding pool. Identification of the parentage of half sibs in open hybridization can be done through informative molecular markers to reveal their pedigree information. (An *et al*., 2013). Although the construction of large scale isolated poly clonal seed gardens are costly operation, it will reduce the recurrent cost and efforts taken to conduct the annual hybridization program in the future.

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Bulletin of the Rubber Research Institute of Sri Lanka, (2023) **60**, 41-46

BIOCHEMICHAL COMPOSITION OF NATURAL RUBBER LATEX: AN OVERVIEW

N P S N Karunarathne and K V V S Kudaligama

The rubber tree (*Hevea brasiliensis*) is a commercially cultivated plantation crop for industrial production of latex. Because of the properties of natural rubber (NR), it has become an important and strategic raw material in most of the industries. NR latex is a whitish fluid produced and stored in specific tissues called laticifers in the secondary phloem of the tree. The bark of the rubber tree is periodically tapped in order to harvest rubber latex. A few hours after the incision, latex flow becomes slower and ceases mainly due to damaging of lutoids and mixing the acidic fluid with latex forming a lace on the tapping cut.

Hevea latex has a density between 0.97-0.98 g/cm^3 depending on its dry rubber content. Its pH value lies between the range of 6.5 to 7.0. Latex usually contains 25 to 50% dry matter. NR is made up of cis-1,4- polyisoprene which represents about 35% of its dry weight or 87% of its wet weight. Apart from water, latex is naturally consisted with non-isoprene molecules such as lipids, proteins, carbohydrates and minerals and their distribution in the fractions of latex is not homogeneous. In addition to cellular organelles, natural rubber latex contains lutoids and Frey-Wyssling particles dispersed in the cytoplasmic serum (C- serum) and various organic and inorganic substances (Fig. 1). The C- serum has a mass of 15- 30 % w/w in fresh rubber latex (Bottier, 2020).

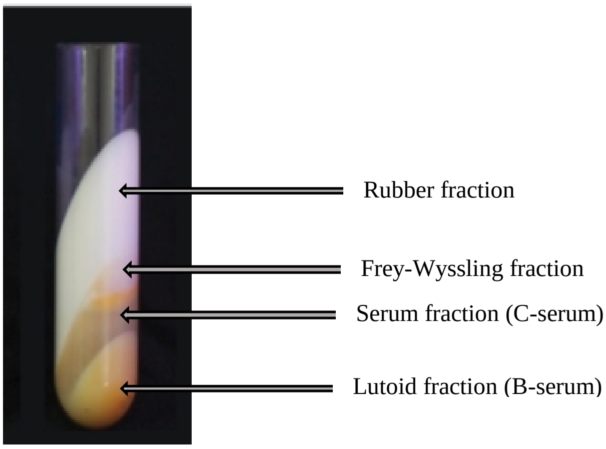

Fig. 1. Centrifuged latex sample with fractions (relative centrifugal force - x 34,000g)

Carbohydrates, proteins and lipids are mostly found as organic substances and nitrates, carbonates, sulphates and phosphates as inorganic substances. The rubber fraction of latex is the collection of cream fraction with large rubber particles and the skim fraction that consists of small rubber particles.

Lutoids are specialized vacuole based organelles within laticiferous cells of rubber tree and represent approximately 12-22% w/w of fresh latex (Cook & Sekhar, 1954; Liengprayoon *et al*., 2017). Primary and secondary lutoids are found in the primary and secondary laticifers. The hydrophilic content of lutoid fraction is called as B-serum.

Frey-Wyssling particles are the less abundant fraction in latex and present in 2-3% w/w content in fresh latex (Bottier, 2020). Frey-Wyssling fraction is yellowish color which is resulted by the presence of carotenoids. This fraction contains enzymes of the isoprenic synthesis pathway. Moreover, the polyphenol oxidase enzyme, plastochromanols and plastoquinones which play a role in oxido- reduction systems and natural process of coagulation in latex can also be found in these particles (D'Auzac & Jacob, 1989).

Latex composition

Protein content

Rubber latex is rich in various proteins. The protein content in latex varies between 1 to 2% of its fresh weight. Proteins of rubber latex are not homogeneously distributed within the latex fractions. A part of proteins is adsorbed to the surface of rubber particles (26 to 51%), whilst the rest is dispersed in the serum and the fluid of lutoids (Bottier, 2020).

Proteins are important as a protective layer of the rubber particles. Due to the isoelectric pH of 4.55 which is identical to that of latex, some proteins easily adsorbed on rubber particles leading to their colloidal stability. Enzymes involved in rubber biosynthesis and other metabolic activities in laticifers are the most important proteins. Proteins have been considered to be essential components of NR for their characteristic properties. Several proteins in NR have been found to cause type I allergic responses in humans and hence extractable proteins need to be removed during rubber products manufacturing (e.g. gloves and condoms).

Proteins in C-serum fraction: The C- serum fraction is rich in various proteins. Many of these proteins are acidic and water soluble. About 50% of the rubber latex enzymes involved with glycolytic pathway and rubber synthesis are dispersed within C- serum (Bottier, 2020).

Proteins in lutoid fraction: Out of the proteins of the lutoid fraction, B- serum has nearly 80% whilst the remaining 20% is associated with lutoid membranes (Tata, 1980). Proteins found in B- serum are mostly water soluble and have acidic or basic properties. B-serum is twice richer in proteins than C-serum, however has a lesser diversification among the proteins compared to the C- serum (Archer *et al*., 1969). Some important enzymes are also found in lutoid membrane such as ATPase which functions as an influx proton pump, NADH-cytochrome c reductase and pyrophosphatase (Bottier, 2020).

Proteins in rubber fraction: Out of the proteins found in rubber fraction, rubber elongation factor (REF1) and small rubber particle protein (SRPP1) play a major role in the rubber biosynthesis machinery (Chow *et al*., 2007).

Carbohydrate content

The carbohydrate content of *Hevea* latex is about 1.5% of its fresh weight. Carbohydrates are mainly confined to the serum fraction where they serve as substrate for the numerous enzymes which are present in serum.

Carbohydrates in C-serum fraction: Quebrachitol and sucrose are the most abundant carbohydrates in C- serum of latex. Sucrose is the main glucide in latex and accompanied by smaller amounts of glucose, fructose and raffinose. It is important as the primary source of rubber biosynthesis and glucose and fructose as the intermediates in the biosynthetic pathway. Sucrose is the main soluble sugar in latex and an important precursor of rubber biosynthesis. Degradation of sucrose results the production of pyruvate which subsequently produces isopentenyl pyrophosphate (IPP) and then cis-1,4-polyisoprene. The concentration of sucrose in latex is used to determine the metabolic activity of laticiferous cells.

Quebrachitol is the most abundant and the earliest known polyol in *Hevea* latex. Quebrachitol and inisitols play a major role in regulating the osmolarity of laticifers and maintain the turgor pressure and as a result keeping latex flow after tapping (Sheldrake, 1979). Quebrachitol has been found at a high concentration in clones showing a rapid coagulation *i.e.* Tjir 1 and at lower concentrations in clones having a delayed coagulation *i.e.* RRIM501. Therefore, it was suggested that quebrachitol negatively impacts the colloidal stability of the latex (Low, 1978). In addition to sucrose and quebrachitol, other carbohydrates such as myo-inositol, glycerol, sorbitol, mannose, glucose, galactose and fructose can be found in C- serum.

Carbohydrates in lutoid and rubber fractions: Lutoid fraction mainly contains glucose as carbohydrates. Carbohydrate content in lutoid fraction is less studied compared to C- serum. The carbohydrates are almost absent from the rubber fraction.

Lipid content

Because of their hydrophobicity, lipids are the main non-isoprene molecules found in dry rubber. The lipid content in *Hevea* latex varies from 1 to 2% of its fresh weight (Bottier, 2020). These lipids fall into various lipid classes including neutral lipids, phospholipids and glycolipids. Lipids are non-homogeneously distributed within latex fractions and are almost absent in the aqueous C-serum fraction. Neutral lipids can be found at 0.7% of fresh latex and 40% out of it are triacylglycerols (D’Auzac & Jacob, 1989). Phospholipids are much more dominant compared to galactolipids. Among the nine classes of phospholipids, phosphatidylcholines (PCs) are the most abundant in *Hevea* latex.

Lipids in lutoid fraction: Although lipids are absent from the lutoid aqueous fraction, they are components of lutoid membranes, and thus represent a significant amount of the lutoid fraction representing up to 10% w/w of the lutoid dry matter.

Lipids in rubber fraction: The lipids of the rubber fraction are localized in the monolayer membrane surrounding the rubber particles. On a dry weight basis, the lipids represent 2-3% of large rubber particles (cream) and 4-6% of small rubber particles (skim), respectively (Liengprayoon *et al*., 2017).

Mineral content

About 0.5% of fresh *Hevea* latex weight is composed of inorganic ions. Minerals are present in the main latex fractions, including the rubber cream containing rubber particles. The main minerals identified in latex are potassium, sodium, magnesium and phosphorus. Their concentrations can vary depending on the clone and the season. It has been observed that the impact of seasonal and clonal variation significantly affected on potassium and magnesium contents in rubber latex (Gopalakrishnan *et al*., 2010). Mineral concentrations in the rubber fraction, C-serum and lutoids are about 0.1-0.2%, 7-8% and 7-9% w/w dry matter respectively (Liengprayoon *et al*., 2017).

Potassium which is considered as the most abundant mineral of latex accounting for 1000-5000 ppm is evenly dispersed between the cytosol and lutoid serum and helps to form the principal mineral osmoticum of latex. In addition, sodium (70-1000 ppm), magnesium (10-1200 ppm), phosphorus (100-700 ppm), calcium (0.5-300 ppm), iron (10-120 ppm), rubidium (7-40 ppm) and copper (2-5 ppm) can be found in *Hevea* latex (Rolere *et al*., 2016).

Minerals have the ability to influence on the colloidal stability of latex. High levels of magnesium and low levels of potassium and phosphorus may cause the low stability of rubber latex. On the other hand low Mg/P ratio is also associated with high latex stability (Gomez, 1980).

Minerals in C-serum fraction: Potassium is the most abundant mineral element in C-serum. Phosphorus, magnesium, sulfur and traces of calcium, iron, manganese and zinc have also been observed in the C-serum.

Minerals in lutoid fraction: When compared to C-serum and rubber fractions, the lutoid fraction has the highest level of minerals. The two most abundant mineral elements in lutoids are magnesium and phosphorus followed by potassium, sulfur and calcium (Liengprayoon *et al*., 2017).

Minerals in rubber fraction: Considering the dry weights, mineral content in the rubber fraction is extremely lower than C-serum and lutoids. The two major minerals of the rubber fraction are phosphorus and potassium, followed by sulfur, magnesium and calcium (Liengprayoon *et al*., 2017).

Even though the non- isoprenic substances are present in low values in latex, some of them play a crucial role on NR properties. They are also responsible for the high variability of the quality of NR. Latex composition and various biochemical and physiological parameters directly link to the variability of quality of NR. Therefore, better understanding on latex composition, biochemical and physiological parameters is significant for NR industry to meet the customer needs.

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Bulletin of the Rubber Research Institute of Sri Lanka, (2023) **60**, 47-52

EFFECT OF OVEREXPLOITATION ON THE YIELD OF HIGH YIELDING CLONE RRISL 201: A CASE STUDY

P Seneviratne, R K Samarasekera and P K W Karunathilake

INTRODUCTION

The potential yields of rubber clones recommended for planting in Sri Lanka in early days were comparatively lower to that of the clones recommended during the past 2-3 decades. Clones with low yield potentials can withstand high frequency harvesting simply due to the small amount of latex give out from the tree at a tapping. The use of rain guards was not very familiar among smallholder farmers in the past and therefore though they were to tap daily the trees got some rest at least during wet days. The widely planted clone by the smallholder sector in the past was PB 86, which can be tapped daily, but it was removed from the list of clone recommendation in 1983 due to over usage and also to give room for the new clones. The next popular clone among the smallholders was RRIC 100. That was a d2 clone, that means it should be tapped on every other day only. But the farmers who used to tap the clone PB 86 daily, tapped RRIC 100 too daily, and a high incidences of tapping panel dryness was resulted. A majority of rubber farmers unaware of the differences among clones and many cannot identify clones. Therefore, even at present the clones recommended for the smallholder farmers should have the ability to tolerate high frequency harvesting. The breeder's main objective is to produce high yielding clones and increase the usage of high yielding clones by the farmers to balance the increasing cost of production in rubber plantations. Though the Rubber Extension Officers conduct awareness programs on the potential yields of different clones and the harvesting frequencies, it is a difficult task to convince the farmers of the differences between clones as for them all are rubber trees. Majority of present-day clones are recommended to harvest every other day known as S/2d2 system and clones like RRISL 217 was later recommended to tap at d3 frequency, *i.e.* harvesting every third day. Tapping is the most costly item in the cost of production of rubber and also requires skills and skilled tapper shortage is a common problem in the rubber sector.

A majority of the smallholders especially those who have very small lands of about half to one acre *etc.*, use family labour for many agronomic practices, especially harvesting. In such cases they prefer to tap daily and get some crop than getting the same crop by tapping every third day. Perhaps due to no other work to attend to on regular basis or not believing in the d3 system to get the same yield that they get by d2 tapping. Accordingly, even the d2 clones are tapped at d1 in many cases in the smallholder sector resulting high incidences of Tapping Panel Dryness (TPD).

Daily tapping provides a daily income to the farmers and tappers. If a farmer has at least two tapping blocks this is solved to a greater extent. The recommended tapping frequency is given with clone and current list of recommended clones has all d3 clones marked and the balance is d2 clones. Once the clone PB 86 was withdrawn in 1989 for the second time, there were no d1 clones but from 2022 PB 86 was added to the list for smallholder sector with the restriction that it should be withdrawn again once it covers 5% of the total rubber extent in the country.

This trial was done to assess the suitability of clone RRISL 201 which is a d/2 clone, for rubber smallholder farmers. Knowing that it would be tapped at d1 frequency it was tested as the most important factor to look into.

MATERIALS AND METHODS

The trial was done in Sapumalkanda Estate, Clunes Lower division. One tapping block of clone RRISL 201 planted in 2001 was selected. Trees have been tapped on panel 'A' when the trial was started.

Initially two treatments were introduced with the control which is S/2 d2 with rain guards. Twenty five trees were allocated for each treatment. Treatments are as follows.

T1 - S/2 d/1 with rain guards
T2 - S/2 d/2 with rain guards
T3 - S/2 D/3 with rain guard and 2.5% ethaphone applied quarterly

Latex yield was collected and monitored in each tapping and DRC% was measured using metrolac. Scraps were collected, weighed and recorded. The girth, bark consumption and the number of dry trees were taken.

Data recording was started in March 2009 and continued up to 2012. Before commencing the experiment pre treatment data were recorded for a period of one month.

RESULTS AND DISCUSSION

Girth measurements of the trees 150 cm above the ground level was collected and average values and the percentage increase of girth from 2009 to 2012 are given in the Table 1.

Table 1. *Average girth values of the trees and percentage girth increase from 2009 to 2012.*

Treatment	**Average girth (cm)**				**Percentage increase**
	2009	**2010**	**2011**	**2012**	
T1- S/2 d/1 with rain guards	69.9	70.8	81.1	83.4	19.3
T2- S/2 d/2 with rain guards	66.2	74.8	72.8	74.1	11.9
T3- S/2 D/3 with rain guard and 2.5% ethaphone	65.2	66.7	70.6	72.7	11.5

The initial and the final average girth values and the percentage girth increase over the period of four years are highest in the trees tapped at d1. The average girth at the end of four years is lowest in the trees tapped at d3 with ethaphon but the percentage increase is comparable in trees tapped at d2 and d3 with ethephon.

The average yield as grams per tree per tapping (g/t/t) and percentage of tapping panel dryness of the trees (within brackets) tapped at d1, d2 and d3 systems are given in Table 2.

Table 2. *The average yield as grams per tree per tapping (g/t/t) and percentage of tapping panel dryness of the trees (within brackets) tapped at d1, d2 and d3 systems*

Treatment	Yield measurements (g/t/t) and TPD%			
	2009	**2010**	**2011**	**2012**
T1- S/2 d/1 with rain guards	23.56	20.11 (33)	-	32.3 (100)
T2- S/2 d/2 with rain guards	21.65	25 (13)	14.5 (4)	26.1 (12)
T3- S/2 D/3 with rain guard and 2.5% ethaphone	47.26	38.6 (7)	30.4 (0)	35.7 (7)

The highest g/t/t has been recorded for the trees tapped at d3 with ethaphone throughout. This is a general observation in the rubber industry in almost all the high yielding clones. Tapping at d3 system always results in high g/t/t even without ethaphone application. The lowest g/t/t was observed with d2 system. In 2011, more and more trees tapped daily (T1) started to show early TPD symptoms such as late dripping and dry patches on the tapping cut. Therefore, the no tapping was done during 2011 on T1 trees. In 2012, they were tapped again average g/t/t was higher than d2 system, but at the end of the year, in almost all the trees TPD symptoms were seen. However, d3 tapping with ethaphon showed minimum TPD.

The main objective of the trial was to see the effect of daily tapping on tapping panel dryness and the trial was discontinued in 2012 when all the trees tapped daily showed TPD symptoms.

The average yield per tree per year for the treatments from 2010 to 2012 are given and the average for the three years are given in Table 3.

Table 3. *The average yield per tree per year (kg) for the treatments from 2010 to 2012 are given and the average for the three years*

Treatment	Average yield per tree per year (kg)			
	2010	**2011**	**2012**	**Average for 3 years**
T1- S/2 d/1 with rain guards	5.7	-	7.3	4.33
T2- S/2 d/2 with rain guards	3.9	1.9	3.7	3.17
T3- S/2 D/3 with rain guard and 2.5% ethaphone	4.1	2.9	3.4	3.2

The crop per tree per year is the most important figure, as far as the economy of the field is concerned. Though tapping was not done during 2011, when calculating the average crop for the three years, the total crop for 2010 and 2012 was divided by 3 as it was the crop received for the three years. Still, the crop is highest at d1 tapping though not sustainable due to high incidence of TPD. The important observation is the comparable crop received from both d2 and d3 with ethaphone. For TPD incidences also d2 and d3 systems show 12 and 7 percent TPD respectively.

The number of tapping days under d1, d2 and d3 and the annual bark consumption are given in Table 4.

Table 4. *The number of tapping days and the annual bark consumption under d1, d2 and d3 tapping systems.*

	Tapping System		
	d1	d2	d3
Number of tapping days per year	320	160	120
Annual bark consumption (inches}	16	8	6

As mentioned earlier, the tapping cost is the highest contributary factor in the cost of production. Higher number of tapping causes higher tapping cost. The next important factor is the annual bark consumption under the three tapping systems. Daily tapping consumes 16 inches of the bark where as only 6 inches is required if tapped under d3 system. However, three years tapping is not sufficient to conclude the sustainability of the tapping systems as d3 tapping uses ethaphone.

Though low yielding clones such as PB 86 can withstand daily tapping, it is not suitable for high yielding clones. When PB 86 was tapped daily, the rain guard application was not popular among small holder farmers and trees had no tapping at least during rainy days which is a relief for the trees. The high crop of the trees become immaterial when they succumb to TPD in panel A or B in some cases and which is irrecoverable in most of the cases. In other words, if the trees get TPD conditions in early years the rest of the life span will be unproductive, despite their high yield potentials.

At present, the high incidence of TPD is one of the key reasons for the low productivity. In order to obtain the potential yields economically, each panel should be exploited for at least 6 years i.e. under every other day tapping generally termed as “d2 tapping”. But the average bark consumption rate, according to the data gathered so far is about 4 years per panel as reported by Seneviratne *et al* (2018). It is also highlighted in the paper that, a gradual increase in “brown bast” with the increase of the age of the clearing is acceptable, but to be around 5-10%. In clearings where the tapping frequency is very high, the percentage of brown bast affected trees has well exceeded the accepted levels, as reported in this paper. Is is recommended for the management of estates to understand properly and to take remedial actions with no further delay. Therefore, when clones are recommended for the small holder sector, the important criteria to be concerned should be the ability to withstand daily tapping as so far there is no fool proof mechanism to control tapping in the small holder sector. What is experienced today is the amount of the rubber harvested from high yielding clones is comparable to the crop received from low-yielding clones due to the fact that a high percentage of high-yielding trees are affected with TPD.

Also, availability of only a limited number of clones for the smallholder farmers is a problem but due to the issue of daily tapping in this sector, release of high-yielding clones for them is problematic. As a result of the usage of limited number of clones, at present one clone namely RRIC 121 covers more than 73% of the total rubber extent which is a very unhealthy situation as far as disease outbreaks are concerned. Accordingly, this clone was withdrawn from the list of recommended clones from the year 2022. As mentioned in the introduction, the clone that can withstand daily tapping, PB 86 was re-introduced to the list while limiting to the smallholder sector and also only up to planting of 5% of the total rubber extent in the country. Re-introducing RRIC 100 to the list, again restricting it for the small holder farmers is a relief but it is sensitive to daily tapping.

It should be emphasized that the damage to the tree due to over exploitation is permanent. Therefore, the rubber production in the country is severely affected due to over exploitation while the rubber industry, in particular the local consumers compelled to import more and more rubber to the country to maintain the production in their factories.

Though it is not discussed in this paper, maintaining the tapping quality in rubber fields is also a key requirement to obtain potential yield with minimum harm to the tree. It also determines the productivity and the economical lifespan of 30 years. The length of the tapping cut, the depth, thickness of the bark shaving and slope of tapping cut are the main factors determining the tapping quality and this is discussed in detail by Seneviratne, *et al*, (2018).

The way forward would be to identify clones that can withstand daily tapping, for the simple reason that the productivity cannot be increased with high incidences of tapping panel dryness prevailing in rubber fields with high-yielding clones. Further, clear identification of clones for the small holder sector and for estates under Regional Plantation companies should also be done for strict complying.

Acknowledgements

Authors wish to acknowledge Lalan Rubbers, and specially Mr. Albert Peries for providing the rubber field and other the facilities at Sapumalkanda estate to conduct this trial.

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Bulletin of the Rubber Research Institute of Sri Lanka, (2023) **60**, 53-55

THE PHYSICAL WELLBEING OF ELDERLY LATEX HARVESTERS: A CASE STUDY IN KEGALLE DISTRICT IN SRI LANKA

P K K S Gunarathne, P H U Ranasinghe, K K I Jayasundara

INTRODUCTION

Population of low and middle-income countries are aging rapidly. Aging population (>60 years) was 13.9%, in 2019 and this is projected to increase to around 21.2% by 2030 and 25.6% by 2040 in Sri Lanka. Aging population also has caused sudden demographic change in the world at (Tilakaratna *et al*., 2019). Latex harvester is a person who extracts (harvesting/tapping) latex from the mature rubber (*Hevea brasiliensis*) tree. Latex harvesting is considered a skilled job which should be performed in an efficient manner according to the harvesting recommendations formulated by the Rubber Research Institute of Sri Lanka, to obtain the potential yield from the rubber plant. Although this is not a white-collar job, it can be considered as the backbone of the rubber industry, as latex extraction is the initial step of the manufacturing cycle of all the rubber products (Gunarathne *et al.*, 2019).

Globally and locally, there are many studies conducted on the aging population, still no studies have been undertaken on Elderly Latex Harvesters (ELHs) in Sri Lanka. According to the contribution of LHs into the smallholder rubber sector during their working lifespan, it is necessary to investigate their livelihoods and issues to boost their socio-economic status. The main objectives of the study were exploring the Physical Well-Being of ELHs (PWBELHs) in order to fill the research gap. Such findings will be useful for the policy makers to make decisions and arrangements to develop the PWBELHs for better performance of their life.

METHODS AND MATERIAL

The study was conducted in Kegalle District in Sri Lanka, during 2019. Random sampling procedure was employed in the study with a sample size of 128 ELHs. Pre-tested questionnaire (with 20 in number) was used. The key socio-demographics and the PWBELHs were measured. Index of Assistance of Daily Livings (IADLs) was developed using Katz Scale (Katz,1983) to measure PWBELHs. The11variables based on disabilities that reflect the status of PWBELHs were selected and incorporated in the questionnaire to develop IADLs. The construction of the IADLs was based on binary indicators, which are able or unable, of 11 disabilities for a period of 12 months. Variables were re-coded into binary variables (yes=1, no=0). Principal Component Analysis (PCA) was applied for weighing the IADLs (Vyas and Kumaranayake, 2006). The respondents were separated into three categories of PWELHs which are the most well-being, well-being and the least well-being based on the confidence interval method. The suitability of the data for the PCA was checked using the Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) statistics.

RESULTS AND DISCUSSION

Seventy-two percent of the sample were females. The average age was 71 years (SD = 6.4). The majority of ELHs (76%) lived in villages, while the rest lived in plantation communities. More than half (73%) of the ELHs lived in households of four or more members, while 20% lived with the spouse and only 7% lived alone. Around two thirds of the sample were married, while 32% were widowed (15% of men and 58% of women), 5% had never married and three had divorced or separated. The majority of the sample attained schooling only up to 5-7 grades. The majority (91%) of ELHs were dependent on the monetary support provided by their children. Six percent received government poverty alleviation programme named *Samurdhi*. The rest of them were still engaging in jobs such as daily paid labours in agriculture sector (90%), security officers (7%) and drivers (3%). ELHs had many leisure-time activities like home-gardening, visiting religious places and looking after grandchildren. These factors keep them feeling that they are worthy members of the society. The result of KMO of IADLs was greater than 0.6 which suggests that the adequacy of input variables for the PCA was excellent. The results of Bartlett's test of IADLs were significant at 0.001 level which suggests that there was a relationship between the variables. PCA was therefore a suitable method for the extraction of measurements of IADLs of physical wellbeing of the ELHs.

Distribution of the PWBELHs based on the IADLs of ELHs were under the category of the most well-being (73%), where 26% were included in well-being category and only 1% is in the least well-being category, in this study area. Under the physical well-being activities of daily living, eat (97%), dress (97%), wash (95%), use the toilet (95%), get in and out of bed without assistance of others (97%), able to travel using public transportation (70%), engage in day to day activities at home (85%), go on shopping to buy essentials (86%), go for treatments alone during mild illness (76%), perform money transactions alone (67%), visit to children' places (76%) and that of relatives and (82%) go to a religious place. The ELHs are more physically active population compared to their colleagues, as their previous job task was more physically active. Previous studies have shown that physical inactivity of elderly people were related with individual characteristics (Pascual *et al*., 2005) and socioeconomic status (Koster *et al*., 2006). However, the linkage of physical activity levels to wellbeing was not always positive (Morgan *et al*., 1991).

CONCLUSION

Index of assistance of daily livings can be used to measure physical well-being of the elderly latex harvesters. The most of elderly latex harvesters are in the most well-being category. The majority were able to perform their daily activities themselves without any family support. Further, advance research on the aspects of social and mental wellbeing should be focused.

Acknowledgements

The authors are grateful to the Rubber Extension Officers of Kegalle district under the Advisory Services Department of RRISL and elderly latex harvesters in Kegalle district for their valuable support.

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Bulletin of the Rubber Research Institute of Sri Lanka, (2023) **60**, 56-60

ADOPTION LEVEL OF PRACTICES OF MANURING OF MATURE STAGE RUBBER SMALLHOLDINGS IN MONERAGALA DISTRICT

P K K S Gunarathne

INTRODUCTION

The Rubber Research Institute of Sri Lanka (RRISL) has developed and recommended the Manuring Practices (MPs) of Rubber (*Hevea brasiliensis*) Farming (RF) which play a key role in increasing the rubber productivity in Moneragala District (Moneragala) which was one of the newly rubber introduced areas in the country (RRISL, 2021). At present, the total extent of rubber smallholdings in Moneragala is about 4,402 ha, while economically productive harvesting extent is only 689 ha which accounts for 20% (MPI, 2020). The average yield was 890 kg/ha/year on dry rubber basis (Gunarathne *et al*., 2021). With this background, there is a great necessity to study MPs of rubber tapping (mature) stage holdings in Moneragala to improve the rubber productivity. There were no planned studies undertaken so far, to assess the adoption level of MPs of the smallholder rubber sector in Moneragala which is the objective of this study. This study therefore, has attempted to assess the level of adoption and to find reasons for non-adoption of MPs by Rubber Smallholders (RSs) in order to suggest possible means of improving adoption MPs among RSs.

METHODOLOGY

Sampling procedure and data collection

The study was conducted in Moneragala in Sri Lanka during 2020. A questionnaire survey was conducted with 202 RSs in 8 rubber growing DS divisions where stratified sampling technique was applied according to the distribution of RSs in each DS division. Pre-tested questionnaire and field observations were used to collect data from the respondents. The questionnaire consists of questions on key general information of smallholdings and RSs, level of adoption on recommended MPs and reasons for less/non-adoption on MPs.

Testing for adoption and finding the reasons for non-adoption of harvesting practices

Rogers and Shoemaker (1971) defined adoption as a decision to make full use of a new idea as the best source of action available. Accordingly, adoption in this study refers to utilization and application of five critical areas of MPs recommended by the RRISL (RRISL, 2021). They were: 1. Type of fertilizer mixture (R/SA 8:8:7 mixture), 2. Distance from plant to manuring circle (circle with 3 feet radius), 3. Time of application (After refoliation), 4. Quantity of fertilizer per plant (900g/plant), and 5. Method of application (By forking).

Scores of adoption were developed in order to measure the RSs' adoption level in each recommended MPs which was measured using an adoption scale which comprises two different levels of adoption, to which marks were given (1 - Adopted and 0 – Not adopted), to result in a score for each recommended practice.

The reasons for non-adoption in each MPs were listed out by discussing with RSs prior to the survey and the list was then administrated for response at the time of survey. Descriptive methods were employed in the area of examining the reasons for non-adoption in each practice of MPs analysis. The percentage of adoption of each practice of the study sample was calculated by the following formula (Eq. 1);

The percentage of adoption of the recommended practice of the study sample $= n_i/N*100$ ....Eq. 1

n_i = Total number of rubber smallholders who adopted for i^{th} recommended practice

N = Number of study sample

RESULTS AND DISCUSSION

Key information of study sample

Male RSs (98%) dominated. The age of RSs varied from 20 to 79 years. The majority of RSs belonged to the age category of 46-55 years. Nearly 6% of the respondents was above 65 years in category, while only 32% was found below 35 years. No one obtained higher education (Diploma and degree level) and 1% of RSs had not attended schools. Further, only 2 % of RSs had attended tertiary level education (GCE A/L). The majority of RSs (53%) have achieved more than ten years of RF experience.

The majority of the smallholdings (89%) falls into the size of 1-1.5 acres (Range = 0.4 – 0.6 ha). The clone RRIC 121 occupies 85% of the smallholder units. The prominent current harvesting panels are B0-1 and B0-2. The average harvesting stand (no. of trees) was 170 trees/acre (Range = 129-208). The average number of harvesting days was reported as 104 per year (Range = 65-175) and average yield was 990 kg/ha/year (Range = 340-1100) on dry rubber basis.

Adoption on weeding and soil conservation

The recommended method of weeding in rubber smallholdings is around the trees (RRISL, 2021), when necessary. Weeding was practiced by 69% RSs in regular basis, where the rest of the others do not practice weeding, either because of the cost of weeding (89%) or negligence (11%). However, recommended method of weeding was practiced by 48% of the RSs. Around one third of the sample (32%) have cleared the whole land, while 20% have practiced stripe weeding, where both of the methods are not encouraged by the RRISL since it causes land degradation and additional cost to the RSs. Further, absence of soil cover increases soil erosion during the rainy season reducing the land productivity of smallholdings (Samarappuli, *et al*., 2005). The most of RSs (99%) practiced manual weed control, while only 1% used chemicals. With respect to weeding practices, 78%, 12% and 10% practiced family labour or, hired labour or both types, respectively. The average cost of hired labour for weeding was LKR 45,000.00 per acre/round.

Practice of soil conservation methods in rubber smallholdings is essential to avoid extensive soil loss during high intensity showers (Samarappuli *et al*., 2005). In *Moneragala*, around 25% of rubber smallholdings are flat lands which permit lesser necessity of extensive soil conservation measures (Samarappuli *et al*., 2005). Drains were found in 63% of the rubber smallholdings, while terraces were found in 23% of the rubber smallholdings. Maintenance of existing terraces and drains was good in 64% of the sub sample which had drains and terraces in their rubber smallholdings while others had not pay any attention to maintain neither drains nor terraces. Therefore, RSs should be motivated further on soil and moisture conservation practices to increase the land productivity. According to Asrat *et al*., (2004); Tenge *et al.,* (2004); Tadesse and Belay, (2004), it was revealed that a sound knowledge of farmers about the problem of soil erosion contributes significantly to sustainable use of introduced soil and water conservation practices.

Adoption level on manuring practices

Manuring (fertilizer application) is crucial to maintain the level of productivity of rubber smallholdings (RRISL, 2021). However, emphasis should be given to maintain the efficiency of manuring as this implicates a considerably large expenditure and also it is one of the important cultural practices especially in *Moneragala*. For rubber the recommended quantity of fertilizer should be applied in single application within one month after refoliation before the month of June and with the rain either in March or April (Samarappuli *et al*., 2005). Therefore, the level of adoption of MPs of RSs is important to utilize fertilizer efficiently to maximize profits.

Figure 1 indicates the level of adoption of RSs on MPs. The overall adoption of RSs on MPs was 32%. Fertilizer application was not practised in 55% of the rubber smallholdings. Among the rest of the RSs who applied fertilizer, only 8% had adopted to the correct fertilizer mixture (R/SA 9:9:9:7) in *Moneragala*, while others used to apply immature fertilizer mixture. However, the correct amount was applied (900g/tree) by 41% of the holdings, while recommended method of fertilizer application was found in 34% of the rubber smallholdings. Fifty-nine percent of holdings applied fertilizer around the trees and 7% in between the trees. The adoption rate on correct time of fertilizer application was 32%.

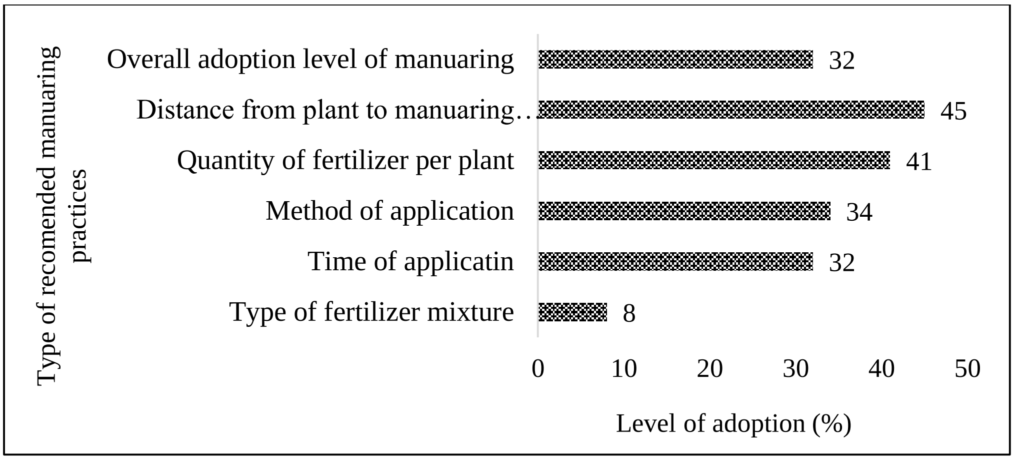

Fig. 1. The level of adoption of rubber smallholders on practices of manuring

Reasons for non/partial adoption of harvesting practices

Table 1 shows reasons for non-adoption on MPs. An attempt was made to explore the reasons for non-adoption in MPs from the perspective of RSs. The lack of awareness was the main reason which was prominent in MPs. There were several reasons other than no awareness of MPs for non-adoption on MPs, according to the respondents. Among other reasons, non-availability of fertilizer, not given the due recognition and bad weather condition were the major reasons for non-adoption on MPs (Table 1).

Table 1. *Reasons for non-adoption of manuring practices*

Recommendation	% of smallholders	Reason/s for partial or non-adoption
Type of fertilizer mixture	78	Lack of awareness
	12	Non-availability of fertilizer
	10	Not given the due recognition
Distance from plant to manuring circle	98	Lack of awareness
	02	Not given the due recognition
Time of application	63	Lack of awareness
	37	Bad weather condition
Quantity of fertilizer per plant	90	Lack of awareness
	10	Not given the due recognition
Method of application	81	Lack of awareness
	19	Not given the due recognition

CONCLUSION

Findings of the study reveal that the level of adoption on recommended manuaring practices are not in satisfactory in smallholder rubber sector in Moneragala

District. Reasons for non-adoption suggest the necessity in improving the knowledge, attitude and awareness of manuaring practices mainly type of fertilizer mixture, distance from plant to manuring circle, time of application, quantity of fertilizer per plant and method of application through present extension and advisory system. The policy changes with regard to distribution of recommended fertilizer type should be organized in more efficient way.

Acknowledgement

The authors are grateful to the Rubber Development Officers of Moneragala of the Rubber Development Department and the rubber smallholders in Moneragala for their valuable support.

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Bulletin of the Rubber Research Institute of Sri Lanka, (2023) **60**, 61-70

POTENTIAL FOR SMALLHOLDER RUBBER FARMING BASED AGRO-TOURISM DEVELOPMENT: EVIDENCE FROM MONERAGALA DISTRICT IN SRI LANKA

P K K S Gunarathne

INTRODUCTION

Many terms have been used to convey the meaning of agro-tourism; agricultural tourism, agri-tourism, farm tourism, farm vacation tourism, wine tourism and agri-entertainment. Agro-tourism, farm tourism or agricultural tourism is the process of attracting visitors and travellers to agricultural areas, generally for educational and recreational purposes (Lamb, 2008; Veeck *et al*., 2006). Agro-tourism provides “rural experiences” to travellers with the goal of generating revenues for farmers and surrounding communities. These experiences typically include a wide range of attractions and activities that take place in agricultural areas. Important ingredients of “rural experiences” of agro-tourism include open spaces, low levels of urban or industrial development, and opportunities for visitors to directly experience agricultural, rural, and natural environments (Senanayake and Wimalaratana, 2010). Agro-tourism is considered to be a specific type of rural tourism and refers to activities in which tourists visit agricultural facilities and landscapes or actively participate in agricultural processes for recreation or leisure. Also, farmers selling products directly to tourists can be identically categorized as agro-tourism (Tew and Barbieri, 2012).

Tourism is one of the largest industries in the world (WTTC, 2019) as well as in Sri Lanka and is the fourth largest earner of foreign exchange, which contributed to GDP of 4.3% of the GDP of the country in 2022 (CBSL, 2022). Being, Sri Lanka is the oldest rubber (*Hevea brasiliensis*) producing country in the world, with commercial production having commenced more than 125 years ago, and there is an unlimited potential to establish agro-tourism. Rubber Farming based Agro-Tourism (RFAT) is an important alternative source of income for Rubber Smallholders (RSs) and sustainability of Rubber Farming (RF) in Moneragala. But, it is still in the infant stage in Sri Lanka as well as other RF countries in the world. Therefore, the main aim of the study was to figure out the developing strategies via studying strengths, opportunities, weaknesses and threats to promote the RFAT sector with the aim of livelihood development of RSs.

METHODOLOGY

A questionnaire survey based on a stratified random sampling technique was used to gather primary data from RSs during 2019 in Moneragala District. The interview method used in this study was semi-structured interviews and informants were determined using a purposive sampling technique. Field observations were performed to match the data obtained from the literature review and information gained from the questionnaires supported by the facts in the fields.

Profile of the study sample

The sample consists of 253 respondents and out of all, 87% were male. All were married. 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 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 an advanced level. Around 30 % of smallholders had less than 15 years of experience in farming, while 36% was reported to have more than 36 years of experience. The mean land size was 1.5 ac. The largest smallholdings were about 1-1.9 ac. About 50% of the lands were less than 2 ac. in size. The majority of RSs (82%) had 4-6 memberships in village level societies.

Table 1 indicates the average extent of cultivated land by RSs. The majority of RSs utilized the land for cultivation of rubber (31%) while 21% of their land was for chena cultivation. The average cultivated extent of land was 6.4 ac. RSs have not utilized the land for animal husbandry.

Table 1. *Average extent of land cultivated by smallholders*

Type of farming system	Average extent of land (ac)	%
Paddy farming	0.68	11
Cash crop farming	0.74	12
Chena cultivation	1.32	21
Home gardening	0.68	11
Perennial (Rubber)	2.00	31
Perennial (Non-rubber)	1.00	16
Animal husbandry	0.00	00
Total cultivated land	**6.42**	**100**

Source: Field Survey, 2019 – 2020

RSs or/and their family members were engaged in agricultural and non-agricultural labour, permanent employment, letting of agricultural machineries, other family business (e.g. shop, boutique) and provision of transport for publics, goods and chattels. Agricultural labouring (33%), non-agricultural labouring (20%), letting of agricultural machineries (15%), provision of transport for publics (12%), goods and chattels by three wheelers (10%) and other family business (4%) were prominent in the sample.

The potential of agro-based tourism in Moneragala

Moneragala (6.7563° N and 81.2519° E) was a district in Uva Province in Sri Lanka with people of multiple cultural and ethnic groups. It is located in the South eastern quadrant of Sri Lanka, bordering the districts, namely, Ampara from the North and East, Badulla from the West and North, Hambantota from the South, and Ratnapura from the South West. The total land area is 565,930 ha, representing approximately 13% of the country's total land area. The population of the district was predominantly distributed in rural areas, approximately 83%. Moneragala was the district of which the highest percentage (52.3%) of the population was employed in agriculture in Sri Lanka. The majority of them adopted subsistence agriculture (65%) as the mainstay of their livelihood. There were 95,718 farmers within 21,817 households and the agricultural household population was 343,037. The rural agriculture entered artificial irrigation tanks and complex irrigation canal systems with smiling tracks of paddy fields, especially during the great season that coincides with the tourist season of the country. It also consists of fruit and vegetable gardens, mixed home gardens, shifting cultivations, and many other closely and distantly related activities. The harvesting period of the most of these crops, vegetables, and fruits also falls during the tourist season, making the sector more attractive to tourists (Silva and Wimalaratana, 2012).

Malkanthi and Routry, 2011 discovered the tourist attractive features in Moneragala which had 92 religious places, 27 natural attractions and 28 cultural attractions. Among them, the presence of various religious places such as Temples, Kovils, Churches, Mosques are very common. Natural attractions such as rivers, waterfalls, hills, forests, caves and parks are predominant. When the cultural attractions are concerned various festivals, ruins of civilizations and kingdoms and ancient livelihood strategies are important. The combination of three agro-ecological regions has made the region rich in biodiversity, gorgeous natural forests, greenish paddy fields, beautiful mountain ranges and conspicuous sanctuaries, sacred places of deities, heterogeneous climate and landscapes, talented and skilful village communities with courteous disposition. Silva and Wimalaratana (2012) highlighted that there was potential for tourism with the nature-based, cultural, heritage, spiritual, health, sports, agro and adventure tourism in Moneragala. Since a large number of these attractions and other tourism destinations, there is a very high potential to attract visitors to Moneragala.

The potential of rubber-based agro-tourism in Moneragala District

Among the perennials, RF is prominent in Moneragala, within the agro-ecological regions, namely, DL1b, IL1C, and IM2b. There are about 5,087 ha of rubber lands and 9,514 RSs (MPI, 2019) in Moneragala. The distribution of the rubber lands and RSs in the DS Divisions and agro-ecological regions in Moneragala District is listed in Table 2.

Table 2. *Distribution of rubber lands in DS Divisions of Moneragala District*

DS Division	Agro-ecological region	Number of smallholders	Rubber extent (ha)
Badalkumbura	IM2b,IL1c	3607	1877
Moneragala	IM2b,IL1c	1421	869
Medagama	IM2b,IL1c	1517	695
Bibila	IL2,IL1c	919	469
Madulla	IL2	831	427
Buttala	IL1c	658	421
Wellawaya	IM2b,IL1c	405	221
Siyambalanduwa	IL2	156	109
Total		**9,514**	**5,087**

Source: MPI, 2019

According to the RF system, two basic potential RFAT phases could be identified, which had the qualities and abilities that may develop and lead to success in the trade namely; 1. Immature stage RF with intercropping and 2. Mature stage RF with rubber processing/sheet making. The potential activities of RF can be utilized for RFAT, and the seasonal calendar of the RF is shown in Table 3 (Gunarathne *et al*., 2022). Basic agronomic practices of mature rubber smallholdings such as weeding and manuring, were identified as potential RFAT activities which could be practiced throughout the whole year from April to July. Activities such as tapping, sheet rubber making and smoking were identified as potential activities of the mature stage RF which could be practiced throughout the year. In general, tapping started early in the morning around 5.30 a.m. which aroused the necessity of provision of accommodation facilities for tourists. Only 45% of RSs had processing and smoking facilities for making sheet rubber. Both diamond and smooth rollers and smokehouse are required to produce sheet rubber. But, nearly 40 % of the sample had rolling facilities to make RSS and 65% of the sample used their own smokehouses for drying of sheets.

Table 3. *The potential elements that can be offered to a tourist in agro-based smallholder rubber farming in Moneragala District*

Activity	**Time period (month of the year)**											
	J	F	M	A	M	J	J	A	S	O	N	D
Immature stage of rubber farming												
Rubber planting										■	■	■
Watering	■	■	■	■	■	■	■	■	■	■	■	■
Weeding			■							■		
Manuaring			■							■		
Branching induction	■	■	■	■	■	■	■	■	■	■	■	■
Soil conservation	■	■	■	■	■	■	■	■	■	■	■	■
Intercropping of rubber farming												
Planting										■	■	■
Weeding	■	■	■	■	■	■	■	■	■	■	■	■
Manuaring	■	■	■	■	■	■	■	■	■	■	■	■
Harvesting	■	■	■	■	■	■	■	■	■	■	■	■
Processing	■	■	■	■	■	■	■	■	■	■	■	■
Bee-keeping	■	■	■	■	■	■	■	■	■	■	■	■
Mature stage of rubber farming												
Tapping	■	■	■	■	■	■	■	■	■	■	■	■
Weeding				■	■	■						
Manuring				■	■	■						
Sheet making	■	■	■	■	■	■	■	■	■	■	■	■
Sheet smoking	■	■	■	■	■	■	■	■	■	■	■	■
Bee-keeping	■	■	■	■	■	■	■	■	■	■	■	■

Source: Gunarathne *et al*., 2022

In the immature stage of RF, agronomic practices of watering, weeding, branching, and soil conservation could be practiced throughout the year, while planting and manuring were seasonal practices. Most of RSs (97%) practiced intercropping during the immature stage, and prominently cultivated crops are Banana (*Musa acuminate*) (51 %), Maize (*Zea mays*) (19 %), Cowpea (*Vigna unguiculata*) (8%), Passionfruit (*Passiflora edulis*) (1%), Groundnut (*Arachis hypogaea*) (12%) and vegetables (9 %). Two percent of RSs adopted Cocoa (*Theobroma cacao*) as mix cropping with mature rubber plantations. Therefore, basic agronomic practices of intercropping, such as planting, watering, weeding, manuring, harvesting and processing, were identified as potential agro-tourism activities during the whole year (Table 3). Bee-keeping was practiced by 2% of RSs both in immature and mature rubber plantations and which could be considered in agro-tourism. Figure 1 indicates the agricultural farming systems practised by RSs. There were six farming systems that were identified in the study area, namely, 1. Paddy farming, 2. Cash crop farming, 3.

Chena cultivation, 4. Animal husbandry, 5. Perennial (Non-rubber) farming and 6. Home gardening.

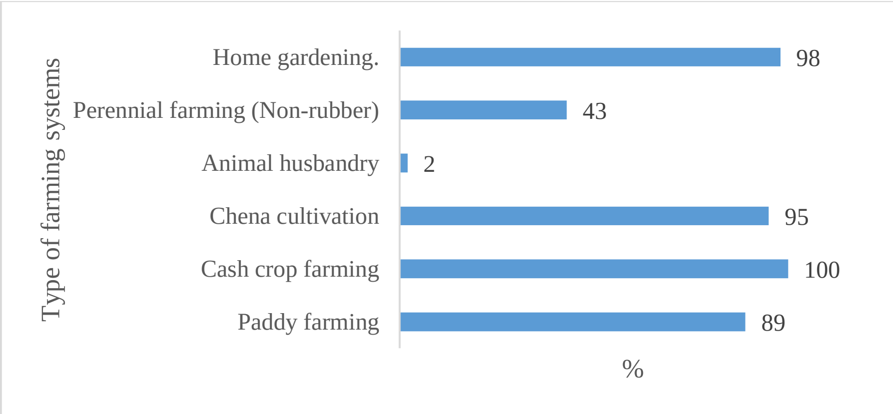

Fig. 1. Farming systems practised by smallholders' households

Table 4 shows the type of crops cultivated by RSs. It was found that RSs practiced perennial (Non-rubber) farming systems, home gardening, paddy (*Oryza sativa*) farming in low land, cash crop farming and chena cultivation in the study area. Both commercial and subsistence crops were cultivated by RSs in the study area. Maize (*Zea mays*) was the prominent cash crop among RSs (80%), while it was a popular Chena crop among RSs (78%). Many crops were cultivated in the home gardens and coconut (*Cocos nucifera)* was the least prominent perennial crop in farm lands of RSs (4%) as plantation crop, but it was prominent in home gardening among RSs. Pepper (*Piper nigrum*) was the most prominent perennial crop of RSs where it is grown either in combination with other crops in home garden or as a monocrop in a separate plot of land. About 4% of RSs were practising cattle farming to obtain milk as a source of income and for household consumption. While 2% of respondents were practising poultry to obtain eggs as a source of HI and for household consumption. Water buffaloes (*Bubalus bubalis*) (<1%) were used in the ploughing of paddy lands and producing curd by RSs.

Table 4. *Type of crops cultivated by smallholders*

Type of farming system	Type of crop/animal	Rubber smallholders (%)
Paddy farming	Low land rice (*Oryza sativa*)	93
Cash crop farming	Maize *(Zea mays)*	80
	Cowpea *(Vigna unguiculata)*	78
	Manioc (*Manihot esculenta)*	77
	Water melon (*Citrullus lanatus)*	67
	Groundnut (*Arachis hypogaea)*	78
Chena cultivation	Pumpkin (*Cucurbita pepo)*	76
	Millet (*Panicum miliaceum)*	65
	Mung bean (*Vigna radiata)*	73
	Sesame (*Sesamum indicum)*	77
	Eggplant (*Solanum melongena)*	74
	Water melon (*Citrullus lanatus)*	72
	Groundnut*(Arachis hypogaea)*	76
	Marrow (*Cucumis melo)*	78
	Bitter guard (*Momordica charantia)*	75
	Maize(*Zea mays)*	65
	Kurakkan(*Eleusine coracana)*	60
Home gardening	Lime (*Citrus aurantiifolia)*	13
	Maize *(Zea mays)*	88
	Vegetables	88
	Mango (*Mangifera indica)*	7
	Tamarind (*Tamarindus indica)*	13
	Arecanut (*Areca catechu)*	18
	Coconut (*Cocos nucifera)*	88
	Banana (*Musa acuminate)*	56
Perennial farming	Coconut (*Cocos nucifera)*	4
	Pepper (*Piper nigrum)*	88
	Cocoa (*Theobroma cacao)*	16
	Mango (*Mangifera indica)*	22
Animal husbandry	Cattle	4
	Poultry	2
	Water buffaloes (*Bubalus bubalis)*	<1

Attitude level of the rubber smallholders on rubber farming based agro-tourism

The level of attitude of RSs on RFAT is shown in Figure 2. The majority of the RSs answered it as an extremely good idea (62.5%), whereas an extremely poor idea was highlighted by the least number of RSs (4%). The following responses, namely, good idea, moderate and poor idea, were indicated by 18%, 10.5%, and 5 % of RSs, respectively.

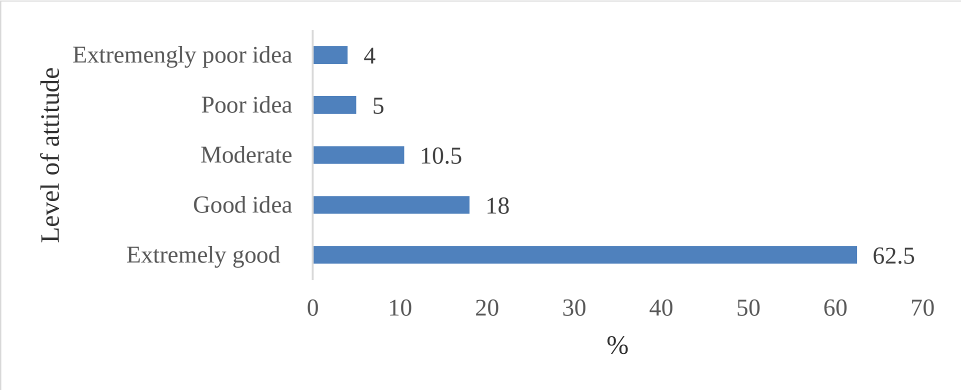

Fig. 2. Farmer's level of attitude on rubber farming based agro-tourism

SWOT analysis for the initiation of rubber farming based agro-tourism

SWOT analysis shows strengths and weaknesses and the potential opportunities and threats viewed as essential for the development of RFAT in Moneragala District. When the strength points are concerned, some of RSs have farm land/s and other requirements for farming on their own. These farms have area specific crops, trees and livestock species contributing to a unique agricultural landscape for the area. Beautiful natural landscapes consisted of forests, mountains, and grasslands provide a high value for the environment. RSs of these areas have good knowledge about farming activities. These young farmers can work hard throughout the year without any problem as there is no seasonal difference in the country. The availability of family labor at a significant level is also a positive point for agro-tourism. Farmers practice both traditional farming activities together with new farming techniques. Currently, there is a trend towards organic farming. Moreover, these areas are rich in traditional (cultural) such as pottery making, cane weaving, art and craft industry as well as, Sri Lankan cookery with various spices. Still, these rural areas have a clean environment and relatively low pollution due to the absence of industrial emissions.

A few weaknesses of Moneragala District were also found. Most of the farmlands are small in size (it needs at least three acres to start an RFAT destination including basic agricultural activity with some livestock and accommodation facilities for 6-8 visitors. RSs have low awareness of the benefits of RFAT and related aspects. Especially they have poor levels of entrepreneurship, leadership, management and decision making skills that are important in agribusiness activities. They don't produce value added farm products. No coordination between agencies responsible for rubber and agencies responsible for promoting tourism, lacking of new innovative ideas when creating tourism products, working independently rather than working as a team by the respective stakeholders in tourism as well as in the RFAT, no proper marketing and product development, strategy in RFAT, lack of research undertaken by focusing RFAT, no proper infrastructure facilities, no awareness on this new market segment especially for the plantation and local community, lack of tourism literature available for tourists on RFAT and lack of promotional opportunities in RFAT were identified as weaknesses with regards to the development of RFAT. No proper facilities for the communities in the rubber plantation areas, lack of coordination between respective authorities in rubber, travel and tourism sectors, no government priority for RFAT development, lack of research undertaken focusing on RFAT product development, lack of infrastructure development, no proper promotion and marketing programme for RFAT, lack of financial support to start the new income generation opportunities in tourism for RSs and lack of awareness on RFAT were highlighted by this study as main threats which will affect to RFAT development in the country.

The following factors can be considered as main opportunities. It is easy to attract visitors, due to the presence of a large number of tourist attractive locations in these areas (Moneragala, Ampara and Badulla Districts). They are rich with religious, cultural and natural attractions. Moreover, mutual co-operation among farmers and other organizations in these areas shows the social capital that can be used for the development of the agritourism industry. Owing to the presence of lots of other tourism destinations in these areas (ecotourism, culture tourism, adventure tourism, sports tourism etc.). Since the unemployment of the youth of these areas is high, these unemployed people can be employed by RFAT. Other identified opportunities were minimum competition in the rubber-tourism market segment with other destinations, availability of many tourism attraction places in rubber plantation areas, beautiful rubber landscapes, unique climatic conditions, quality accommodations facilities in rubber plantation areas and diversified geographical areas. Foreign visitors will view this as a new niche market segment since this is a new experience for them.

A few threats for RFAT were also identified. Although the government plans for the development of agriculture in these areas, a lack of commitment at the provincial and central levels is obvious. Waste management, careful use of forest cover, management and protection of catchments are very crucial factors at present, even in rural areas. Unnecessary urbanization can affect the rural culture badly. Dressing patterns, food habits, language, behavior etc., of urban visitors are different from local people.

CONCLUSION

Moneragala District had an enormous potential for developing mass tourism as well as rubber farming based agro-tourism. Comparatively, positive impacts of rubber farming based agro-tourism were evident in this study. It would provide farmers a considerable revenue, offering an opportunity for an alternative approach to retail RSs' products and services. The development of rubber farming based agro-tourism makes the rubber industry a profitable, socially acceptable and environmentally friendly approach for the betterment of the nation.

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