ISSN 1391-0051

BULLETIN OF THE RUBBER RESEARCH INSTITUTE OF SRI LANKA

Rubber Research Institute of Sri Lanka

Vol. 53 2016

BULLETIN OF THE RUBBER RESEARCH INSTITUTE OF SRI LANKA

Vol. 53 **2016**

Computer typesetting and Page formatting: Ramani Amaratunga

For spine:

BULLETIN OF THE RUBBER RESEARCH INSTITUTE OF SRI LANKA Vol. 53, 2016

BULLETIN OF THE RUBBER RESEARCH INSTITUTE OF SRI LANKA

Vol. 53 **2016**

CONTENTS

Bulletin of the Rubber Research Institute of Sri Lanka, (2016) **53**, 1-7

MAMMALIAN PESTS IN RUBBER PLANTATIONS AND THEIR MANAGEMENT

M K R Silva and B I Tennakoon

SUMMARY

Incidences of mammalian pest damages on rubber have become more frequent in the recent past due to the invasion of their wild habitats by rubber and other crops such as tea, oil palm and Cinnamon. There are several species of mammals with different modes of damage. Young rubber plants may be totally destructed while mature trees also could be lead to death due to the ring bark condition. The adaptation ability of mammalian species to human activities, the temporal nature of the damages, requirement of exclusion of the animals over a larger area and legal, cultural and religious influences are the major problems faced when adopting management strategies. There are conventional methods used to protect plants from these pests. A chemical repellant based on Tetramethyl Thiurum Disulphide (TMTD) has been developed. Several physical excluders are also recommended. The adhesive properties of the chemical repellant need improvement with less toxic active ingredients.

INTRODUCTION

Since its introduction as an agricultural crop, the rubber tree has faced hundreds of disease and pest attacks throughout the time. However, one of the interesting features of the pest and disease scenario of the rubber tree is the considerable change taken place in the relative importance of the different type of pest and disease problems. Other than the short time temporal variations due to the changing weather conditions, considerable changes have been observed in the type of maladies. The menace of mammalian pests has become an increasingly important issue over the years. Incidences of mammalian pest attacks which are less likely forwarded few decades ago have become a routine complaint of the growers of both estates and smallholder sector nowadays.

Damages caused by these animals are mainly reported from areas bordering shrub jungles. The reason for this might be the invasion of their wild habitats by rubber and other crops such as tea, oil palm and cinnamon. The animals who lived in their native habitats are now invading the cultivated lands for their food and other needs. When the damage of a certain species is prominent on rubber in some area, it is more likely have the same threat on other common crops grown in that area.

Different species

There are several species of mammals that attack the rubber tree. Wild boar, porcupine, sambar deer ("*gona*"), deer ("*olu muwa*"), rabbit, monkey and bandicoot are the main reported species causing damages on the rubber tree while most of the complaints are on damages due to wild boar and porcupine. Biology, habitats and nature of the damages caused to the rubber tree by these several species are remarkably different.

Wild boar

The wild boar is one of the most widely distributed mammals in the world (Erkinaro *et al.*, 1982). It occupies an extremely wide range of habitat types, where they feed opportunistically on plant and animal species (including crops and livestock). In addition, wild boars have the highest reproductive rates among ungulates, and their local density can double in one year. Consequently, the widespread increase in numbers and geographical range of this species might have a remarkable impact on many plant and animal species, habitat structure, and crop and livestock production (Massei *et al.*, 2004).

According to the observations, wild boar attacks the rubber tree from the time of establishment up to tapping, they attack. Incidences of wild boars attacking the trees under tapping have been reported rarely. Wild boars do not ingest any plant/tree part. However, they cause a variety of damages, most common is rooting (grubbing) the young plants causing total destruction of those plants. Severe damages are caused to the bark of the adult trees by punching with tusks due to their aggressive behavior. The damages resemble the cutting marks made by sharp equipment such as a knife (Fig.1). Consequences of the damage will some times end up with the ring barked situation causing the death of the plant. Though the wound can be recovered, the growth retardation and the increasing proneness to wind damage from the point of recovered lesion may be resulted. Moreover, the wounds will facilitate the growth of secondary invading microorganisms sometimes leading the plants to death.

Fig.1. Bark of an adult tree damaged with the wild boar tusks

It has been observed that the damage incidences are more frequent after a spell of rain in the area. However, it is difficult to use this as a rule of thumb in adopting management strategies as light rains experienced in localized pockets may also enhance the situation. The behavioral studies of the animal with reference to the changing weather factors are of practical importance.

Porcupine

Nowadays porcupines are responsible for a considerable percentage of casualties in certain immature rubber lands. They are rodents who basically attack the tree from the establishment up to tapping. In the very early stages of the rubber plant, it uproots the plant and feed on the immature underground parts. At latter stages, they feed on the bark of the rubber plants/trees. The damage exhibits the characteristic marks on the remaining wood surface (Fig. 2a). It is easily distinguishable from the wild boar damage due to these characteristic biting marks. The important feature here is that the immature plant may get total ring bark situation which definitely causes the death of the plant (Fig. 2b). As mentioned under wild boar attack, this may also cause other indirect effects.

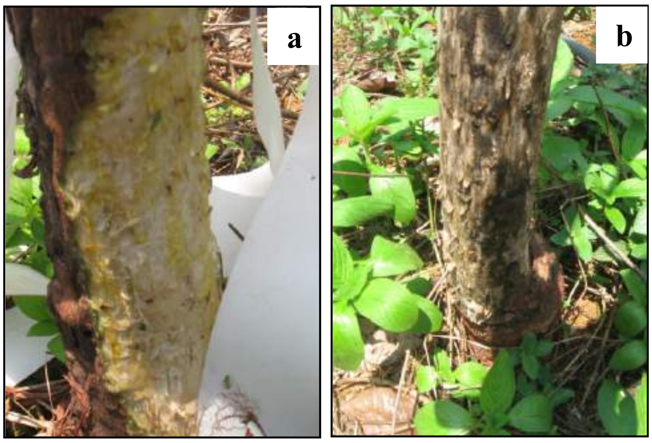


Fig. 2. Symptoms of porcupine attack on rubber. **(a)** characteristic marks on the wood **(b)** ring-barked condition

Sambar deer ("gona")

The Sambar deer eats leaves and twigs of immature rubber plants and damage the adult trees by rubbing their horns (Fig. 3). The specific feature of the Sambar deer attack is that the plant damage is done several feet above ground.

Fig. 3. Symptoms of sambar deer attack on rubber. **(a)** an immature plant damaged by sambar deer – note the height of the damage **(b)** bark damaged due to the rubbing of sambar deer

Other mammals

The rabbits and the monkeys eat leaves and twigs while the bandicoots damage the root system. However, the menaces of these creatures are limited to certain areas where the population of the certain species is fairly high.

Management of the damages

Unlike any other pest or disease management system, mammalian pest management has its own complications. Most of them are intelligent creatures so they readily modify their response to human activities and consequently, the proven management tools may fail quite frequently. The damages seem quite temporal so that the adoption of a management system should be based on the behavioral studies of the animals. Most of the management strategies which are based on exclusion of the animals are not nationally viable as they may merely cause the chasing of the animals from one field to the adjoining field. Most importantly, the adoption of different controlling systems is influenced by the legal status, cultural and religious background of the country.

Conventional methods

The conventional methods used for protecting plants from these pests include construction of border fences, keeping the clearing cleaned, employing sound producing gadgets and spreading cut hair pieces. Moreover, based on the availability, establishment of bamboo strips, plastic drink bottles, gunny bags, old buckets, old metallic roofing sheets encircling the plants and covering the animal paths with fish nets are also practiced in certain locations (Fig. 4). However, some may have there own adverse features and therefore special attention is required. Bamboo pieces may aggravate the termite problem and are not durable. Heating of the metallic roofing sheets may cause adverse effects to the growing plant and therefore care should be taken to leave enough space between the plant and the sheet.

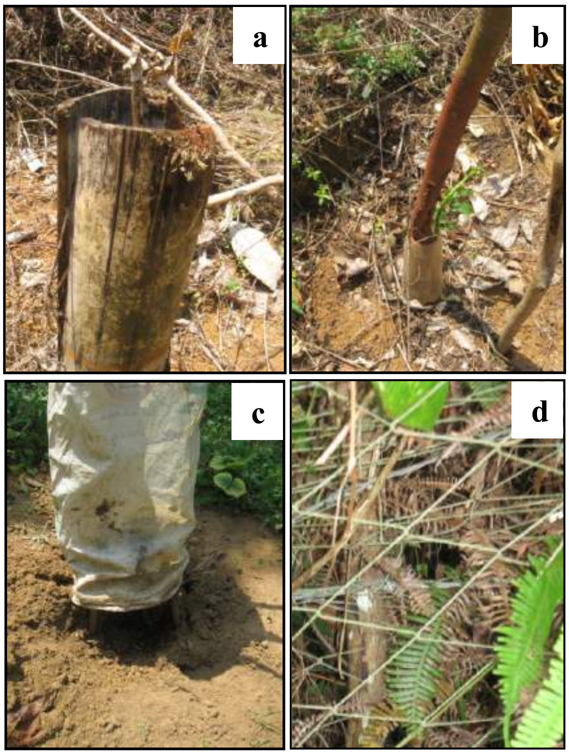


Fig. 4. Conventional methods for protecting plants. **(a)** covering plants with bamboo **(b)** covering plants with plastic bottles (c) covering plants with gunny bags **(d)** covering the fence with old fish nets

Recommended practices

Continuous efforts are made by the Plant Pathology and Microbiology Department of the Rubber Research Institute of Sri Lanka to provide efficient management strategies especially for wild boars and porcupines. A chemical repellant based on Tetramethyl Thiurum Disulphide (TMTD) has been developed (Jayasinghe *et al*, 2010). The effectiveness of the formula has been proven though it demands some improvements in its adhesive properties.

Physical methods such as grid fencing on the ground around the plant using barb wire or chicken mesh for the exclusion of these animals have also been tested (Jayasinghe *et al*, 2010).

Hanging of white polythene (as bands or strips) on fences or surrounding the plants is another methods tested for the effectiveness and the durability (Jayasinghe *et* *al*, 2010). Hanging white polythene strips around the plants is proven to be effective in protecting plants from wild boar in most of the locations. Some exceptional cases have been reported in few locations. However, it can be still used as a low-cost solution in most of the locations. The adoption of this method has to be done after ensuring that the attacking creature is not porcupine, as it is not effective against porcupine.

Furthermore, investigations on some more materials to be used for young rubber plants as excluders was carried out. A galvanized squire mesh, PVC mesh and a PVC-coated galvanized mesh are currently being tested for their durability, effectiveness and economic viability (Fig. 5). Up to the present observations, these meshes are effective against both porcupine and wild boar and durable though the cost involved is somewhat high. Therefore, the use of a mesh can be recommended in the long run.

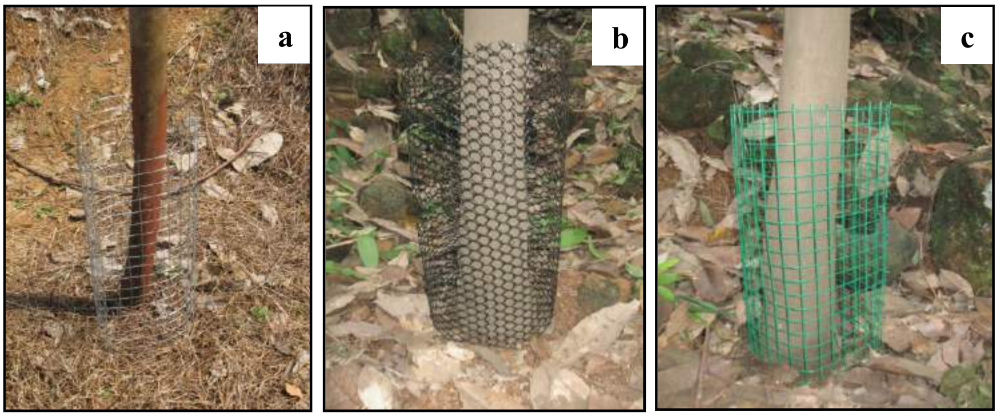


Fig. 5. Different materials used as excluders against mammalian pests (a) galvanized squire mesh (b) PVC mesh (c) PVC-coated galvanized mesh

Treatment of wounds

The recommended method of treatment of wounds is by smoothening the rough edges of the wound with a sharp blade carefully and applying the fungicide, Brunolium planetarium (15%) on the wound. This application should be followed by the application of Candarsan on top of the fungicide application. Here, it would be emphasized that merely applying Candarsan on the bark with the aim of repelling these pests is a malpractice which is frequently reported and known to cause the scorching of the bark.

The future

It is a challenge for the institute to come up with novel solutions which are effective over a wide range of animals and are less costly. It is known that meshes are effective against a wide range of creatures and the durability is also high; it is worth in the long run. However, the cost concurred is considerably high resulting a poor adaptation by the stakeholders. When hanging polythene is considered, due to its low durability of polythene, repeated hanging is needed. Though the chemical repellant is an effective solution, it has its own drawback: poor adhesiveness. However, the chemical repellent could be brought forward as a low cost solution after improvements. Less toxic active ingredients have to be looked for, as alternatives to TMTD and the adhesive properties have to be improved.

Integrated strategies including the use of locally-available materials with improved materials are cost effective. Shooting, pre-baiting and electrical fencing are some effective strategies which are not widely practiced due to various constraints. Moreover, it would be noted that an effective management of mammalian pests can only be achieved by integrated action over a large area otherwise animals will continually reinvade from the neighboring areas.

REFERENCES

Erkinaro, E, Heikura, K, Lindgren, E, Pulliainen, E and Sulkava, S (1982). Occurrence and spread of the wild boar (*Sus scrofa*) in eastern Fennoscandia. **58**, 39-47.

Jayasinghe, C K, Jayasuriya, K E, Fernando, E B and Tennakoon, B I (2010). An effective repellant for rodent management. *Proceedings of the Third Symposium on Plantation Crop Research*. 330.

Massei, G and Genov, P V (2004). The environmental impact of wild boar. *Galemys* (16), 135-145.

Bulletin of the Rubber Research Institute of Sri Lanka, (2016) **53**, 8-20

JOURNEY OF THE CLONE RRISL 203 AND ITS IMPORTANT PROPERTIES

K K Liyanage

INTRODUCTION

The primary objective of the breeding of *Hevea* is the development of genetically superior clones from the existing ones. The rubber plantations in Sri Lanka have a very narrow genetic base originated from the 1919 seedlings of Wickham collection introduced in 1876. Dr C E Ford introduced of hand pollination (HP) techniques into the *Hevea* breeding programme in the year 1932 for seedling and bud grafted trees (Baptist, 1966). Subsequently, plant breeders initiated a large-scale hand pollination programme to cross high yielding genotypes with disease resistant characters to get high growth vigour into the breeding population. From 1957 onward, attempts have been made to combine the high yield of clones such as PB 86, PB 28/59 and RRIC 7 with the vigour and leaf disease resistance of RRIC 52 resulting vigorous and high yielding clones such as RRIC 100, 101, 102, 103 (Baptist, 1966; Fernando, 1966: Jayasekara and Fernando, 1977).

Clone selection

The hand pollination programs are continued every year in order to develop superior genotypes. In the scheduled hand pollination program for the year 1974, twelve different sets of clones were crossed as shown in Table 1 and 224 seedlings were obtained from 5326 of pollinations (Fernando, 1974). After evaluation of the progenies taken from 1974 hand pollination program, 69 selections were made. Using these selections, five small-scale clone trials were established during the year 1980 for 52 different selections and RRIC 100, RRIC 103, RRIC 121 and RRIM 600 were used as control clones. Remaining 17 selections were established during the year 1982 in a small scale clone trial at Kuruwita Sub Station, where RRIC 100, RRIC 121 and RRIM 600 were used as control clones (Table 2).

Table 1. *Crosses made in 1974 hand pollination program*

	Parentage	Number of seedlings obtained	Progeny number
1	RRIC 103 x 8501 (RRIC 52 x FX 360)	46	74-1 to 74-46
2	RRIC 103 x RRIC 101	44	74-47 to 74-91
3	RRIC 103 x 2427 (RRIC 45 x FX 4098)	29	74-92 to 74-120
4	RRIC 103 x 418(RRIC 115) (RRIC 45 x FX 4098)	20	74-121 to 74-140
5	RRIC 103 x 2417 (RRIC 114) (RRIC 45 x FX 4098)	06	74-141 to 74-146
6	RRIC 103 x 5-90 (IAN 710 x RRIC 45)	05	74-147 to74-151

	Parentage	Number of seedlings obtained	Progeny number
7	RRIC 103 x 6-704 (IAN 710 x Ch 26)	10	74-152 to 74-161
8	RRIC 100 x 8501 (RRIC 52 x FX 360)	05	74-162 to 74-166
9	RRIC 100 x 6-704 (IAN 710 x Ch 26)	04	74-167 to 74-170
10	RRIC 100 x RRIC 101	49	74-171 to 74-220
11	RRIC 103 x IAN 45-710	03	74-221 to 74-223
12	82 (RRIC45 x RRIC 10) x 1305 (RRIC 41 x Ch 26)	01	74-224

Table 2. *Small scale clone trials established during the year 1980 and 1982*

Estate	No. of selections	No. of plants per selection	Year of planting
Yatadola Estate	18	20	1980
Perth Estate	16	20	1980
Moralioya Estate	52	10	1980
Dartonfield Estate	33	10	1980
Arappolakanda Estate	18	20	1980
Kuruwita Sub Station	17	20	1982

In each trial, annual girth measurements and yield data were recorded. After evaluation of the girth and yield data from each trial, three promising genotypes 74-141, 74-157 and 74-182 from the trial established at Moralioya and four promising genotypes 74-12, 74-41, 74-135 and 74-193 from the trial established in Kuruwita were identified.

During the period of 1986 to 1990, Sri Lanka experienced the destructive leaf fall disease caused by fungus *Corynespora cassiicola*. As a result, the breeders lost more than 50% of the genotypes that were at different selection stages, and some of the outstanding clones were also withdrawn from the recommendation.The clones such as RRIC 103 and RRIC 110 which were very well established in the country had to be removed from the recommedation. In addition clones like RRIC 104, RRIC 105, RRIC 108, RRIC 118, RRIC 122 to 129 were also removed from the recommendation. Due to this bad experience of leaf fall disease, except 74-41 and 74-193 all the other promising selections made from 1974 HP programme were also lost. These two clones showed resistance towards *Corynespora* leaf fall disease (CLF).

Yield data of Small Scale Clone Trial (SSCT)

Test tapping data collected from Kuruwita Small Scale Clone trial (SSCT) showed, RRIC 100 had the highest mean yield out of four control clones (RRIC 100, RRIC 121, RRIM 600 and PB 86) and there were four other test clones with higher means than RRIC 100. But only one clone, 74-193 had a significant difference when compared to RRIC 100. This test clone also had a good mean girth when compared with RRIC 121 which had the highest mean girth. Therefore, 74-193 was selected for further trials to test on a large scale in Estate – RRI Collaborative clone trials (ECT) (Jayasekara, 1989).

Yield data of Estate – RRI Collaborative Clone Trials (ECT)

Two Estate – RRI Collaborative Clone trails were established in Kuruwita and Galewatta for further evaluation of the performance of the selection 74-193. The data have shown that 74-193 is a promising clone for the large-scale recommendation and therefore, it has been registered as a clone RRISL 203. The commercial yields obtained from ECT trials are shown in Table 3. The incidence of Tapping Panel Dryness (TPD) in both locations was also very negligible (Attanayake, 2003).

Table 3. *Average commercial yield of the clone RRISL 203 in ECT trials*

Year of tapping	Average yield (*YPH) kg/ha/yr
1	2190
2	2515
3	1862
4	2337
5	2110
6	2495
7	2355
8	2410
9	2913
10	3380
11	2742
12	2439
13	2510
14	2610
15	2160
16	3285

*(YPH was calculated for 450 trees and140 tapping days)

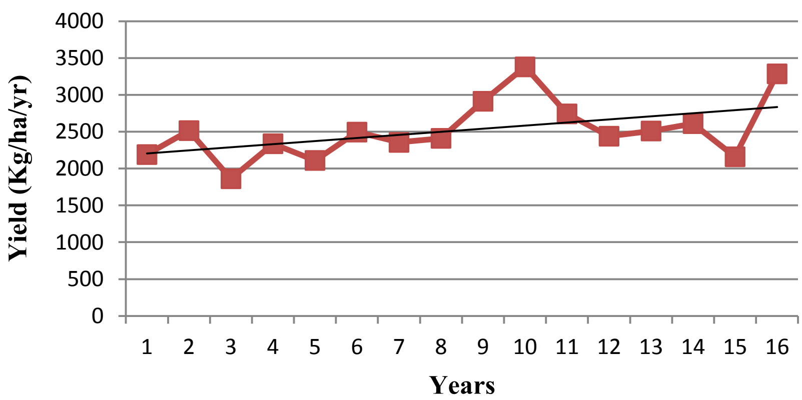


Fig . 1. Average commercial yield obtained from ECT trials for clone RRISL 203

The average commercial yield of the clone RRISL 203 is around 2500 kg/ha/yr (Fig. 1) with an increasing trend throughout the period of evaluation and with a potential of producing 3000 – 3500 kg/ha/yr. The Table 4 shows that the average girth and yield potential (g/t/t) values for the clone. According to the data, the average girth increment before tapping is around 9.24cm, and it is 2.2cm after commencement of tapping. Therefore, this clone shows a vigorous growth in both pre and post tapping periods. The yield data shows that the average experimental yield of the clone is around 61.5g per tree per tapping (g/t/t), and it is significantly high, compared to the other clones.

Table 4. *Average girth and yield potential (g/t/t) values of clone RRISL 203*

Year	Average girth increment (cm)	Average experimental yield (g/t//t)
1	8.54	64.5
2	16.0	50.8
3	28.5	49.6
4	40.5	50.6
5	46.9	63.7
6	52.2	65.9
7	55.5	55.4
8	56.5	61.4
9	59.5	57.3
10	61.2	55.4

The Fig. 2 shows that the correlation of the girth increment with its yield for the first ten-year period and it shows more or less stable trends of yield with its girth increments.

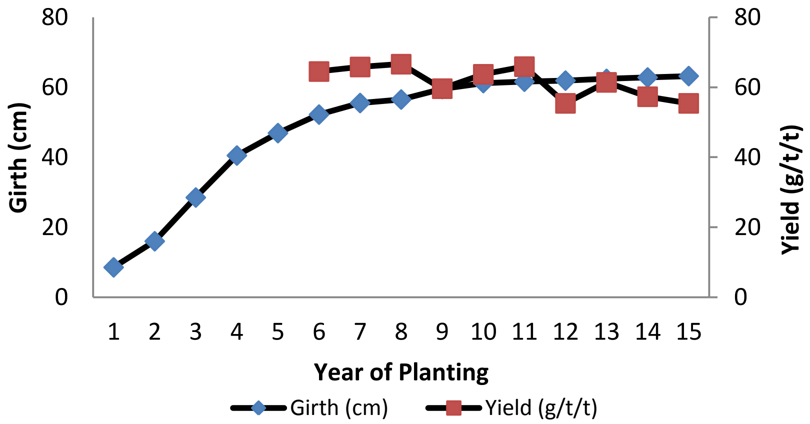


Fig. 2. Illustration of genetic variation of girth and yield of clone RRISL 203

Yield data of Smallholder Rubber Research Collaborative trials (SRT)

Two Smallholder Rubber Research Collaborative trials (SRT) were also established to evaluate the performance of RRISL 203 under smallholder level, one at Kegalle and the other at Godagama. These two trials also showed the very promising performance of the clone and therefore, RRISL 203 was recommended as a Group I clone from the year 2007.

Evaluation of clone RRISL 203 under different environments

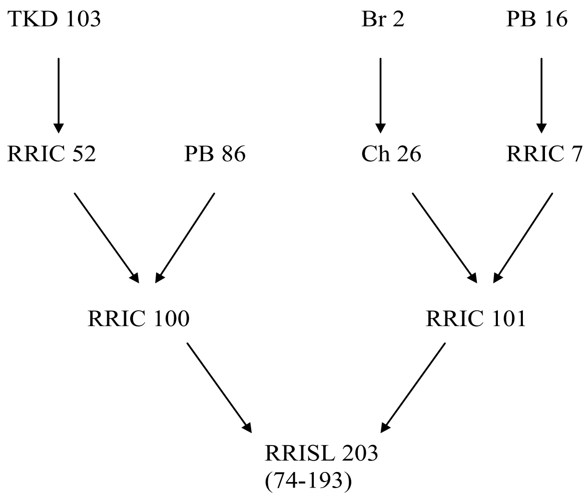
In order to monitor the performance of the clone RRISL 203 in different agro-climatic regions and to carry out further studies on environmental effect on this clone and their adaptation ability to that particular environment, several field trials were established (Table 5) (Seneviratne, 2010 – 2012).

Table 5. *Locations of the trials of clone RRISL 203, under different agro-climatic environments*

Agro Climatic Zone	District	Estate	Year of planting
Low Country Wet zone (WL)	Kalutara	Lagos Estate - Kalutara	2011
	Ratnapura	Kuruwita Substation	2009
	Galle	Katandola Estate - Elpitiya	2011
	Matara	Kamburupitiya University Farm	2010
Low Country Intermediate zone (IL)	Kurunegala	Muwankanda Estate	2009
	Monaragala	Kumarawatta Estate	2010
Mid Country Intermediate zone (IM)	Ratnapura	Ray Vikiliya Estate- Balangoda	2009
Upcountry Intermediate zone (IU)	Badulla	Dameria B Estate - Passara	2010
	Badulla	Wewassa Estate - Badulla	2011
Low Country Dry Zone (DL)	Vavuniya	Smallholders in Oddusudan and Vawuniya	2012

All these trials are still in the immature stage, but their initial growth performances are in the satisfactory level.

Parentages of Clone RRISL 203



RRISL 203 was produced by crossing two promising clones RRIC 100 as the female parent and RRIC 101 as the male parent. In the grand parentage of this clone included most promising clones in very early selection stages like RRIC 7, RRIC 52, PB 86 and Ch 26. Therefore, clone RRISL 203 possesses high yield, vigourous growth and some important disease resistant features which were also available in both parentages and grand parentages (Liyanage, 2008).

Identification of clone RRISL 203

Proper identification of this clone is vital to ensure the procurement of right clone for planting. Knowledge of relatively consistent characteristics of a clone is used to identify a clone (Liyanage *et al*., 2013). The characters of clone RRISL 203 which can be used for identification, are listed in Table 6.

Table 6. *Morphological characters of clone RRISL 203*

Descriptors	RRISL 203
01 - Axillary bud	Normal (Not sunken or protruded)
02 - Leaf scar	Protruded margin
03 - Shape of leaf scar	Heart shape
04 - Shape of leaf story	Hemispherical
05 - Separation of leaf story	Well separated
06 - External appearance of leaf story	Close canopy
07 - Size and width of leaf story	60 - 100 cm

Descriptors	**RRISL 203**
08 - Pulvinus	Swollen
09 - Petiole shape	Straight
10 - Petiole size	22 - 28 cm
11 - Petiole orientation	Horizontal
12 - Petiolue orientation	Down word
13 - Petiolule angle	48 - 55^0
14 - Petiolule size	1.8 - 2.2 cm
15 - Petiolule junction appearance	Raised
16 - Leaflet colour	7.5GY 3/4 (Yellowish green)
17 - Leaflet luster	Dull appearance
18 - Leaflet texture	Leathery
19 - Leaflet shape	Obovate (Pear shape)
20 - Leaf area	100 - 170 cm
21 - Leaflet thickness	Thick
22 - Leaf margin	Irregular wavy
23 - Degree of leaflet separation	Overlapped
24 - Cross-sectional appearance	Boat shape
25 - Longitudinal sectional appearance	"S" shaped
26 - Shape of leaf apex	Acuminate
27 - Shape of leaf base	Cuneate
28 - Colour of veins	Light green
29 - Nature of veins	Prominent

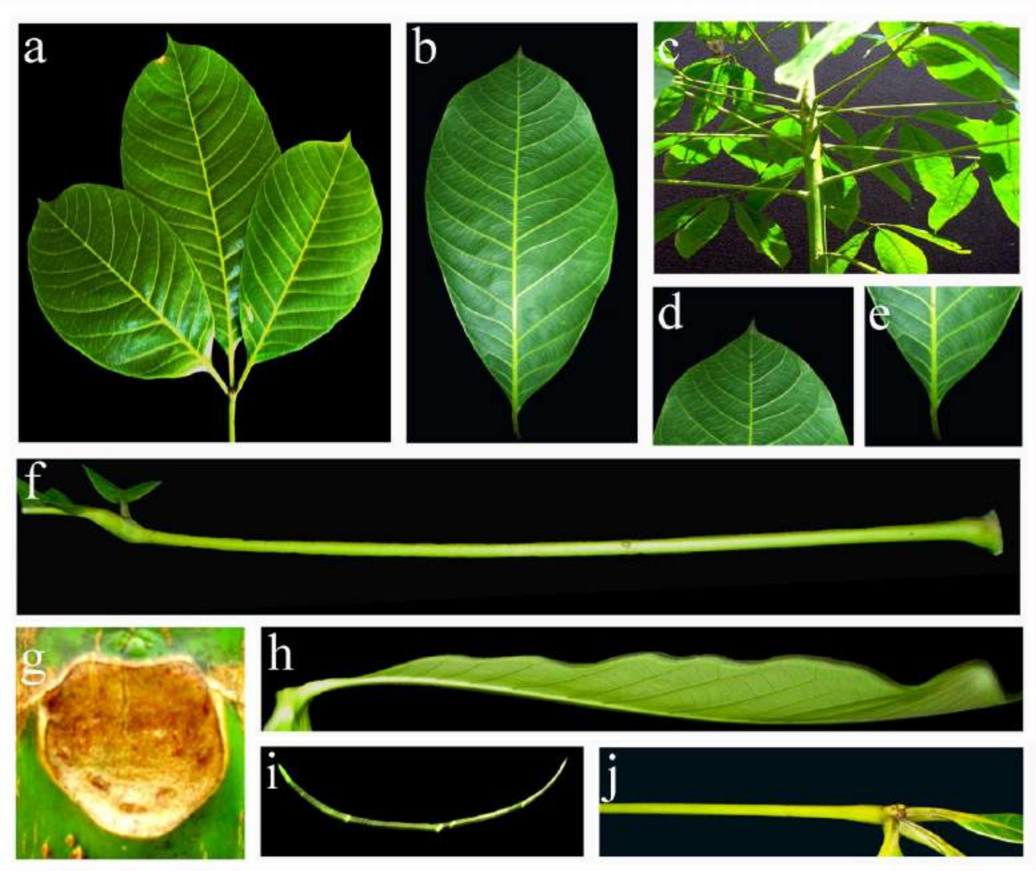


Fig. 3. Leaf and leaflet characters of clone RRISL 203

a : Leaf - Leaf is palmately compound and consists of a pulvinus, leaf stalk (petiole), three leaflets which are attached by petiolule to the distal end of the petiole. At that point, extrafloral nectaries the nectar secreting glands are present.

b : Shape of leaf blade - Leaflets are obovate in shape (pear shape) (leaf blade has its maximum width in between the middle of the leaflet and apex). Leaf margin is irregular wavy. Veins are prominent and light green in colour. Luster of the leaf is dull and leathery in texture.

c : Orientation of petiole - To describe the petiole, its shape, length and orientation are considered. Lower leaves of the story are the best to observe the petiole characters. The orientation is horizontal to upward and it describes the arrangement of petiole in relation to the stem. All the leaves of the storey may not show the same orientation, but the orientation exhibited by a majority of leaves is taken as the clonal character.

d & e: Leaf apex and leaf base - Usually, the mature middle leaflet is used to observe the character. Leaf apex is acuminate and leaf base is cuneate. Acuminate tip refers to an acute apex, sides of which are somewhat concave and tapers somewhat into an elongated tip. Cuneate leaf base appears triangular, with the narrow end at the point of attachment.

f: Petiole - The shape of the petiole is straight (there is no bending or curving of the petiole).

g: Leaf scar - The leaf scar is the mark that is left after the leaf shedding. In this clone, they normally heart shape with protruded margin and the axillary bud (the bud found at the axil of leaves that branches and flowers arise from) are normal (not sunken or protruded) and visible.

h: The Longitudinal sectional appearance of leaf - It is judged by viewing the leaflets from the side, and it is "S" shape.

i: Cross-sectional appearance of leaf - It is viewed by looking at the tip towards the direction of the base and it is boat shape.

j: Petiolule – It is the short stalk connecting the leaf lamina to the petiole. It also displays variability in size, orientation and inter petiolule angle. The orientation of petiolule is horizontal to down ward with respect to the plane of the petiole.

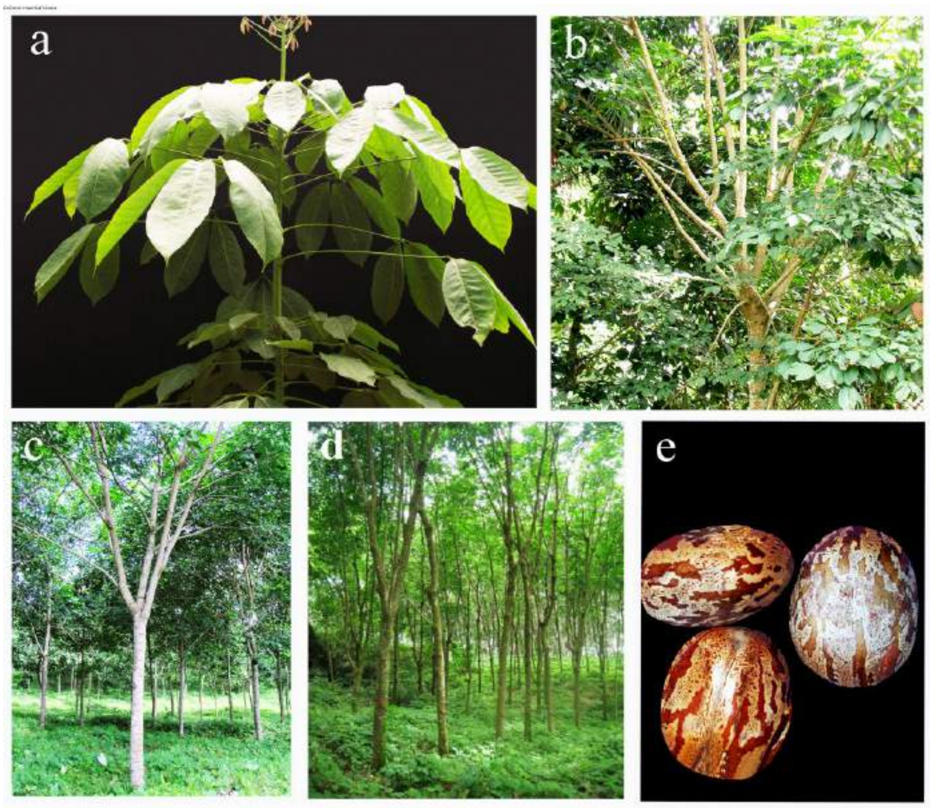


Fig. 4. Canopy (a,b,c and d) and seed (e) characters of clone RRISL 203

a: Leaf Storey - It is the leaf bearing part of the stem. It is hemispherical in shape (leaf stories look like half of the sphere), and leaf story of a plant is well separated from each other by the bare stem. The density of leaves in the storey is high and indicates as a close canopy.

b: Branching habit of the tree at its tappable stage - Few to several branches arrived at the same point giving broom-like appearance to the tree. This branching habit is similar to that in the clone RRIC 100.

c: Mature plants at its tappable stage - Bark of the main trunk is smooth and ashy in colour

d: Mature plantation - Tree trunk is more or less rounded and no nodule appearance in the main trunk as in RRIC 100.

e: Features of seeds - Seeds are oblong in shape and dorsa ventrally flat. Medium in size. The dorsal side is light brown in colour with the prominent central ridge. Lateral depression is prominent. The seed coat is shiny with large dark brown patches well distributed in both sides. The ventral side is ash brown in colour.

Latex and raw rubber properties of clone RRISL 203

Table 7 shows some of the important chemical and physical properties that are generally used in assessing the quality of raw material and its suitability in rubber product industries. High yielding clones with vigorous growth do not always produce latex and rubber of suitable properties as requested by the producers. But RRISL 203 shows more attractive latex and raw rubber properties when compared with other clones (Table 7).

Table 7. *Latex and Raw Rubber properties of clone RRISL 203 and RRIC 121*

Property	Average value	RRISL 203	RRIC 121
Initial Wallace Plasticity of Rubber (P_0)	30 (min)	56.1	41.1
Plasticity Retention Index (PRI)	60 (min)	62.5	55.0
Mooney Viscosity (V_R) (ML 1+4@100C^0)	75 -85	102.1	84.8
Ash Content % (w/w)	0.2 (max)	0.10	0.15
Lovibond Colour	1.5 units (max)	1.0	1.0
Nitrogen Content %	0.35 (max)	0.33	0.33

(**Source:** Attanayake, 2011)

Initial Wallace Plasticity (P_0)

The P_0 test is a measure of the original plasticity (before aging). It influences the processability of rubber in the factory. This measures the hardness or the softness of rubber to process, and it highly depends on the molecular weight of rubber. When the molecular weight is high, P_0 value is also high. If P_0 value is less than 30, it is generally considered as a rejectable lot. The clone RRISL 203 also has P_0 value of 56.1, and it is a considerably high value compared to other clones. But on the other hand, higher P_0 values increase the cost of compounding.

Plasticity Retention Index (PRI)

This is usually expressed as a percentage, and it is a measure of the resistance of raw rubber to oxidation, on heating. The latex grades usually have PRI values above 60%. Higher PRI value shows higher resistance to the oxidation, and it corresponds to good heat resistant character. PRI of RRISL 203 is above 60 and therefore it provides quality latex for the rubber product industry.

Mooney Viscosity (V_R)

This property is commonly used as the test to characterize and monitor the quality of rubber. It measures the resistance to the flow of rubber at a relatively low shear rates, and it gives the plasticity or viscosity of rubber or their compounds. The clone RRISL 203 has a significantly higher mooney viscosity value when compared with other clones. Higher mooney viscosity values again increase the cost of compounding.

Ash content %

This gives an indication of the amount of inorganic chemical substances (metals) present in the rubber. If the ash content of rubber sample is high, it indicates higher deterioration of manufactured product due to the oxidation of the metal contaminant. In clone RRISL 203, ash content is low and meets with the specification requirement.

Nitrogen content

It is the measure of non-rubber components usually the proteinaceous matter present in the rubber phase. Also, the minor content of non-protein nitrogen containing substances are also included. It is an important determinant as higher nitrogen contents increase the storage hardening and reduce the dynamic and aging properties. The clone RRISL 203 also meets the specification requirement of nitrogen as per other clones for rubber product manufacturer industry.

Assessment of disease resistance:

Corynespora leaf fall disease (CLF)

A scoring system adopted by the RRISL for evaluation of clones in bud wood nursery and in mature fields, indicates that the clone RRISL 203 had 0 values for the last 10 years and it means that RRISL 203 is resistant to CLF disease (Jayasinghe, 2002 - 2006; Silva, 2007 - 2011).

Phytophthora leaf disease

Annual screening of clones for *Phytophthora* leaf fall disease shows that RRISL 203 is a susceptible clone, under bad weather conditions. Therefore, it is necessary to take precautionary measures to protect the clone from *Phytophthora* leaf fall disease in both immature and mature fields (Silva, 2010).

Powdery mildew and Colletotrichum leaf disease

Clone RRISL 203 shows resistance to powdery mildew but susceptible to *Colletotrichum* leaf disease. Therefore, it is necessary to take precautionary measures when *Colletotrichum* leaf disease is evident.

Other important characteristics of clone RRISL 203

When RRISL 203 is in tappable stage (50cm girth at 120cm above) they have a bark thickness of average 6 to 7mm and it is greater than the clone RRIC 121. Therefore, it should be tapped somewhat deeper to get its maximum potential yield when compared with the clone RRIC 121. The clone RRISL 203 is recommended as a d_2 clone and therefore it should be tapped on every other day.

Another important feature is that RRISL 203 is highly fertilizer sensitive. Therefore, it is essential to add recommended dosage of fertilizer at recommended intervals to get its maximum potential yield.

Based on all these factors, the clone RRISL 203 is considered as a very promising clone with good latex properties and timber value for both estate sector and smallholder sector. Therefore, clone RRISL 203 is highly recommended for planting to maintain the correct clone balance in the country.

REFERENCES

Attanayake, D P S T G (2003). Review of the Genetics and Plant Breeding Department, *Annual Review 2003*. Rubber Research Institute of Sri Lanka, 4-23.

Attanayake, A (2011). Raw rubber properties of new clones. Presentation made at the 31st Scientific Committee Meeting held at RRISL.

Baptist, E D C (1966). Breeding for high yields and disease resistance in *Hevea. Proceedings of the Natural Rubber Conference*. Kuala Lumpur. Pp.430.

Fernando, D M (1966). An outline of breeding selection and propagation of rubber. *RRISL Quarterly Journal* **42** (1 & 2). 9-2.

Fernando, D M (1974). Review of the Genetics and Plant Breeding Department, *Annual Review 1974*. Rubber Research Institute of Sri Lanka. 48-60.

Jayasekara, N E M and Fernando, D M (1977). *Hevea* introductions (Non Wickham) into Sri Lanka. Workshop on International Collaboration in *Hevea* breeding and Collection and Establishment of Materials from Neo-tropics, Kuala Lumpur.

Jayasekara, N E M (1989). Review of the Genetics and Plant Breeding Department. *Annual Review 1989.* Rubber Research Institute of Sri Lanka, pp 5-60.

Jayasinghe, C K (2002 - 2006). Review of the Plant Pathology and Microbiology Department, *Annual Reviews (2002-2006)*. Rubber Research Institute of Sri Lanka.

Liyanage, K K (2008). Role of PB and Tijikado clones in rubber breeding in Sri Lanka - A analysis of the pedigree of Sri Lankan Rubber Clones. *Bulletin of the Rubber Research Institute of Sri Lanka* **49**, 50-58.

Liyanage, K K, Sumanasinghe, V A, Attanayake, D P S T G and Baddewithana, B W A N (2013). Phenotypic diversity of rubber clones grown in Sri Lanka at their immature stage based on the available morphological descriptors. *Tropical Agricultural Research* **24** (2), 112-127.

Seneviratne, P (2010-2012). Review of the Genetics and Plant Breeding Department. *Annual Reviews 2010 - 2012*, Rubber Research Institute of Sri Lanka.

Silva, W P K (2007 – 2011). Review of the Plant Pathology and Microbiology Department, *Annual Reviews (2007- 2011),* Rubber Research Institute of Sri Lanka.

Bulletin of the Rubber Research Institute of Sri Lanka, (2016) **53**, 21-28

GUIDELINES FOR PROTECTION AGAINST SOUTH AMERICAN LEAF BLIGHT OF RUBBER (*HEVEA BRASILIENSIS*)

T H P S Fernando, N Nishantha and C Wijeratne

Hevea brasiliensis is a member of the family Euphorbiaceae and is the main source of natural rubber which is one of the versatile industrial raw materials and also an important commodity to the economies of many countries. Further, the natural rubber plantation industry makes export earnings and provides livelihood to over thousands of people. Rubber plantations supplement thousands of hectares to the forest cover and provide many other socio-economical and ecological benefits. The Asian rubber growing countries produce more than 90% of the world's natural rubber. This important industry is under the threat from a deadly disease known as, South American Leaf Blight (SALB). It is a disease, of great historical interest since it is the factor which is hindering the development of natural rubber plantation industry in its region of origin, South America. SALB is caused by the fungus *Microcyclus ulei* (P. Henn.) V. Arx and regarded as the most destructive disease of rubber. Introduction of this disease can cause great economic losses to the rubber growing countries of Asia and the Pacific region.

This threat of SALB was recognized by the rubber growing countries of the region when establishing the Plant Protection Agreement for the Asia and Pacific region in 1956. This obliged member countries to prohibit import of plants or the seeds of the *Hevea* genus, plant materials of *Hevea* genus not capable of further growth or propagation such as fresh or dried herbarium specimens and any plants of other than genus *Hevea* from SALB endemic areas into their countries unless certain stringent phytosanitory import requirements were met.

This agreement was brought in line with the World Trade Organization Agreement on the application of sanitary and phytosanitory measures in 1999. Due to the inconsistent provisions in 1956 agreement, Asia Pacific Plant Protection Committee (APPPC) decided that a pest risk analysis (PRA) on SALB should be developed by member countries. Based on this requirement, PRA for SALB was completed and accepted by the 25th session of the APPPC in August 2007 and the PRA is the guideline used to develop this standard on SALB.

This standard provides guidelines for APPPC member countries that grow rubber to prevent entry, spread and establishment of SALB taking SALB PRA into account. The guidelines cover five major areas:

- Prevention of the introduction of SALB into Asia and Pacific region using import requirements, and systems of points of entry inspections, laboratory diagnostics and surveillance
- Establishment of eradication or control programmes in case of entry of SALB
- Development of training programmes on inspection and diagnostic methods, surveillance, eradication and control measures

- Minimum resources in terms of personnel and facilities, for protection against SALB
- The establishment of coordination activities for SALB programmes

Requirements

Prevention of the introduction of SALB

Integrated systems should be employed by strict phytosanitory import requirements to reduce any potential risk from imports to a level acceptable to the importing country, inspection system at the entry point, laboratory diagnostic systems and also an efficient surveillance system.

Import requirements

This should be determined based on SALB PRA. Attention should be paid to pathways of entry and the relative risks taking the consequences and the appropriate level of the protection of individual country into account. Pathways for the entry of the pathogen based on the SALB PRA;

- Budded stumps and bud wood
- Foliage
- Flowers, fruits and seeds
- Plants *in vitro*
- Rubber wood
- Travelers inanimate goods or non-host organic materials (contaminated by spores)
- Inanimate goods or non-host organic material contaminated by host plant material

The National Plant Protection Organization of each rubber growing country should consider import requirements as follows;

Host materials

Planting materials of *Hevea* from SALB endemic countries is considered as "high risk. Importing countries" should apply measures as necessary and should limit the entry. Measures are given as follows;

- Prohibition of imports, if an importing country does not have the capacity to apply effective measures to mitigate risk to an appropriate level of protection
- Restriction of the quantity based on the capacity of the post entry quarantine station
- Restriction of the length of the bud wood sticks
- Pre export inspection and treatment
- Measures applied on arrival
- Restriction of imports to government research institutes only using Plant Entry Quarantine stations

- Fascilities at the intermediate quarantine for at least one year and SALB free certification by SALB specialist

For seeds

- Restriction on the quantity
- Only healthy seeds be imported
- Washing with a surface sterilant and dressing with a fungicide prior to export

***In vitro* plants**

- Growing the plants aseptically on agar for more than three months followed by appropriate inspection and testing

For foliage

- Should be treated to remove the risk

Non host materials – travelers/inanimate goods/non host organic materials
Travelers from SALB endemic countries

- Travelers should declare to the NPPO if they have visited a SALB endemic country during the last 21 days and have visited a rubber plantation.
- Special care should be taken of camping equipment, hiking boots, farm equipment and decorative planting materials that may be contaminated with SALB.
- Measures to remove possible contaminations include cleaning, dis-infection or destruction.

Inanimate goods

- Cargo such as machinery that has been used in rubber plantations in SALB endemic countries can be contaminated with non viable host materials carrying the pathogen. The materials should be well cleaned, should be heat treated for 30 minutes at 56˚C.
- Planting materials and foliage of non- SALB hosts may need to be assessed for possible SALB contamination and phytosanitory procedures and appropriate treatments that should be adopted.

Non-host organic materials

Planting materials and foliage of non SALB hosts may need to be assessed for possible SALB contamination and phytosanitory procedures and appropriate treatments that should be adopted.

Inspection systems - at the points of entry

Consignments and travellers hand carried items should be subjected to inspection by NPPO inspectors at point of entry.

NPPO should follow the general guidelines provided in International Standard for Phytosanitory Measures No.23 – Guidelines for Inspection.

Specific points related to risk items

- Examination of documents to ensure that all planting materials have correct certification
- Examination of manifests to identify any inanimate goods or no host organic materials that might be contaminated with the spores of the pathogens
- Trained personnel to be stationed at entry points to recognize live and dead plant material of *Hevea*
- Inspection of consignments to detect any goods or machinery that have been in the rubber plantations of SALB infected countries
- Equipments and chemicals for disinfection and disposal of any suspect materials should be available to the inspectors
- To ensure appropriate security, diagnostic laboratories are available
- Phytosanitary action, as noted in ISPM No.20 Guidelines for an import a phytosanitary import regulatory system should be taken into account where non- compliance occurs or SALB is detected.

Laboratory diagnostic system

Countries should have access to appropriate laboratory diagnostic systems. Diagnostic facilities for the identification of suspect fungal isolates and also they should be located close to the designated entry points. The laboratories should follow standard procedures for the diagnosis of the pathogen.

SALB surveillance systems

NPPOs in rubber growing countries should establish and maintain national system for surveillance for SALB (ISPM No. 6). It is essential that any incursion of the pathogen is detected before it establishes and widespread. Additional surveillance systems should be implemented in countries if the disease occurs in neighbour countries or specific surveillance systems should be employed.

Eradication or control programmes

The NPPOs of APPPC rubber growing countries should develop and establish contingency plans for eradication or control programmes according to ISPM 9 to be prepared in the event that the disease is found in a country. The plans should include a system for prevention the movement of potentially infected or contaminated material within and out of infected areas. The plans should include following components,

Operational procedures would include:

- Undertaking of a delimiting survey of the affected area
- Undertaking other surveys as necessary
- Documenting records of occurrences
- International notification

- Carrying out an eradication feasibility study
- Establishing and undertaking the eradication programme or control measures including surveillance, containment and treatment
- Disinfection and destruction procedures
- Systems for the prevention of the movement of possibly infected or contaminated material within and out of infected areas
- Verification of eradication

Required resources would be as follows:

- Identifying the disease in the field with a diagnostic laboratory support for confirmation of identifications
- Identification of appropriate eradication methodologies and administrative systems including a management structure and documentation procedure
- Trained operational staff
- Regulations providing authority for procedure implementation (movement prohibitions, setting up check-points, *etc*.)
- Information management system
- Communication programme, including media and public awareness
- Financial support

Training programmes

NPPOs of rubber growing countries should establish training programmes for the staff on inspection, diagnostic and disinfection procedures; surveillance; eradication and control measures; and management of programmes for SALB. The components of such programmes are listed below:

Inspection, diagnostic and disinfection procedures would include:

- Procedures of inspection
- Procedures of clearance
- Inspection of document and import requirements
- Recognizing the symptoms of SALB and its pathogen
- Recognizing host plants and host plant parts
- Laboratory diagnostic protocols and procedures for identification of the pathogen
- Disinfection or destruction of infected or non-compliant materials
- Disinfection procedures for personnel handling diseased material

Surveillance programmes would include the following:

- Early detection systems
- Identification of symptoms and the pathogen

- Surveillance procedures and sampling techniques
- Documentation and reporting

Eradication and control measures would be based on:
- Knowledge on eradication and control procedures
- Safe handling of chemicals and equipment
- Use of a geographical information system (GIS) to map affected areas
- Application of fungicides
- Eradication programmes (including simulated outbreak exercises).

Management of Programmes would include the following:
- Eradication programme management
- Programme documentation and recording
- Communication with growers, industry representatives, government departments, NGOs and public
- Communications/media.

Minimum requirements for personnel and facilities

The NPPO of each rubber growing country should have the following minimum resources for protection against SALB:
- Designated experts on SALB
- Trained inspectors for consignment inspection and for surveillance programmes
- Diagnostic capabilities to detect and identify the pathogen
- PEQ facilities
- Access to aerial spraying organizations or companies
- Disinfection facilities including:
  - Dipping tanks with sodium hypochlorite
  - Hot water jet systems for disinfection
  - Incinerators
  - UV Chambers
  - Access to chemicals and any necessary registration for use

National and regional coordination and cooperation

National

The NPPO of each rubber growing country should coordinate the activities of the SALB programme or, where appropriate, establish a centralized body or committee (if one does not already exist) to do this. The activities of such a body or committee could cover the following areas:

- Resource management
- Programme documentation, evaluation and improvement procedures

- Centralized communication with growers, industry representatives, government departments and NGOs
- Establishment and maintenance of a national focal point
- Surveillance planning
- Public awareness initiatives and programmes

Regional

The NPPO or the committee would also establish links with related bodies or committees in other rubber growing countries to exchange information and establish regional programmes where necessary to:

- Seek technical resistance
- Seek financial resistance
- Ensure availability of technical expertise through regular regional and international workshops, training and seminars on SALB
- Provide training on SALB
- Cooperate with other regional and international organizations that deal with rubber and with the NPPOs of non-rubber growing countries (that could, for example, supply opportunities for intermediate quarantine, undertaking research)
- Cooperate with SALB endemic countries in training, research, the safe transfer of rubber plant germplasm including the verification of phytosanitory systems and information exchange.

The Commission may consider the establishment of an SALB Cooperation Committee to oversee and coordinate various regional activities for the prevention of the introduction of SALB into the region. The NPPOs of all member countries should support regional activities for the prevention of the entry of the disease into the area where this is appropriate.

PRA (2007): Summary of the assessments of introduction, spread and consequences to rubber growing countries

Vector	Probability of entry	Probability of establishment	Probability of spread	Likely impact	Level of risk
Host material (*Hevea* species)					
Budded stumps or budwood	High	High	High	High	High
Foliage (stem and leaf material not for planting)	Low	High	High	High	Moderate
Flowers, fruit and seeds	Low	High	High	High	Low
Plants *in-vitro*	Negligible	N/A	N/A	N/A	Negligible

Non-host material					
Inanimate goods or non-host organic material	Negligible	N/A	N/A	N/A	Negligible
Inanimate goods or non-host organic material contaminated by host plant material	Low (if <1 cm^2)	High	High	High	Low (if <1 cm^2)

The following countries have been identified as
SALB Endemic Countries

1. Belize 2. Bolivia 3. Brazil 4. Colombia 5. Costa Rica 6. Dominican Republic 7. Ecuador 8. El Salvador 9. French Guiana 10. Guatemala	11. Guyana 12. Haiti 13. Honduras 14. Mexico 15. Nicaragua 16. Panama 17. Paraguay 18. Peru 19. Surinam 20. Trinidad & Tobago 21. Venezuela

ACKNOWLEDGEMENTS

This article in based on information gathered during a workshop on SALB in Thailand using the publications provided. Authors are grateful to the Plant Protection Specialist of the Food and Agriculture Organization of the United Nations Regional Office for Asia & the Pacific, Dr. Piao Yongfan for the valuable publications.

Bulletin of the Rubber Research Institute of Sri Lanka, (2016) **53**, 29-34

INCIDENCE OF BROWN ROOT DISEASE IN RUBBER PLANTATIONS OF SRI LANKA

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

In Sri Lanka, there are three important root affecting fungi on rubber: *Fomes lignosus* (currently known as *Rigidoporus microporus*) which causes white root disease, *Fomes noxious* (currently known as *Phellinus noxius*) which causes brown root disease and *Xylaria thwatsii* (causative agent of black root disease) which can grow on living as well as dead wood. Brown root disease is distributed in tropical and sub-tropical regions in Asia (including Southern Japan, Mainland China, Hong Kong, Taiwan and Malaysia), Central America, Africa and Oceania (Larsen *et al.* 1990; CABI/EPPO, 1997; Chang and Yang 1998; Ann *et al.,* 2002). A total number of 427 records (310 species, 06 sub-species, 42 varieties and 69 forms) of *Phellinus* have been reported worldwide (Ranadive *et al.,* 2012). Most of the economically-important plantation and other crop species including, *Camellia sinensis* (tea), *Coffea spp.* (coffee), *Artocarpus altilis* (breadfruit), *Cinnamomum spp*. (cinnamon), *Theobroma cacao* (cocoa), *Cocos nucifera* (coconut), *Garcinia mangostana* (mangosteen), *Citrus spp*. (citrus), *Mangifera indica* (mango), *Artocarpus heterophyllus* (jack), *Tectona grandis* (teak) and *Swietenia mahagoni* (mahogany) have been reported to be affected by this disease (Ranadive *et al.,* 2012).

Disease development and mortality are most rapid during the first few years after planting and during which, the areas of the initial disease centers increase and new centers appear (Nandris *et al.,* 1987). The above ground symptoms of brown root disease are similar to those caused by other root rot pathogens as symptoms are caused by a root and butt rot that hinders uptake and transport of water and nutrients from the soil. Slow plant growth, yellowing and wilting of leaves, defoliation, branch dieback and plant death are the usual symptoms. Roots infected with *P. noxius* initially exhibit a brown discoloration of the wood just beneath the bark. Tawny brown gummy rhizomorphs firmly fixed to the outer bark surface with an encrustation of sand and stones on the root surface are the characteristic diagnostic feature of the disease (Plate 1a). The inner bark is covered with the white to brownish mycelial mat. Although dead wood is initially discolored into reddish brown (Plate 1b), it later becomes white, dry, and honey-combed (Plate 1c). Occasionally, brownish-black/dark greyish-brown colored bracket like fruiting bodies are formed on the basal trunks or exposed roots of diseased trees (Plate 1d).

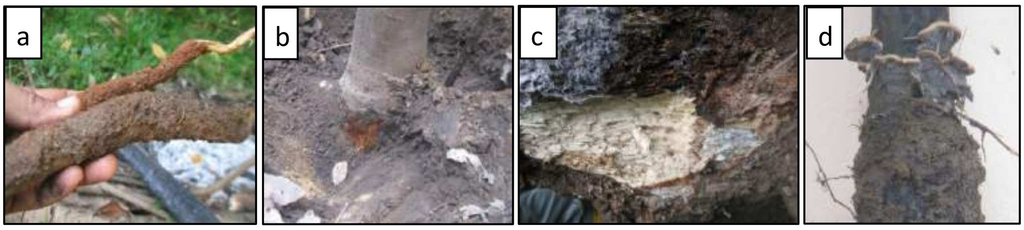


Plate 1. Symptoms of the brown root disease of rubber plants a) Encrustation of sand and stones on the root surface b) Reddish brown discoloration of dead wood at the collar region c) Honey-combed wood d) Fruiting bodies on the basal trunk

As far as other countries are concerned, the economic impact of *P. noxius* is highly variable due to extremely diverse host range and geographical distribution and a loss of up to 60% can occur in rubber plantations (Nandris *et al.,* 1987). According to T. Petch an eminent Pathologist, brown root disease was first recorded on *Hevea* in Ceylon in 1905, and it was probably the most common root disease of the rubber tree in the country at that time (Petch, 1911 and 1921). However, the significance of the brown root rot was recognized only recently in Sri Lanka. During the recent past, frequent complaints on this disease were received by the Department of Plant Pathology and Microbiology. Moreover, it can be noted that the disease occurrence is high in certain parts of the country. Generally, the traditional rubber-growing area in Low Country Wet Zone is concerned, the incidence of the disease is restricted to certain locations. It is quite often reported in Moneragala, Badalkumbura and Medagama, in non-traditional rubber growing areas and Galagedara and Galigamuwa in traditional rubber growing areas. Incidences have also been reported from Ginigathhena, Kithulgala, Passara, Padiyathalawa, Warakapola, Yatiyantota, Dehiowita, Meerigama and Attanagalla areas. When reviewing the reasons for the recent rise in the disease occurrence in these areas, several factors can be identified.

Expansion of the rubber industry to non-traditional rubber growing areas

When Corner (1932) described *Fomes noxius* (currently *Phellinus noxius*) as a new species, he said that it was usually found in cleared or disturbed areas. Since the beginning of the 20th century, many plantations of rubber, tea, cocoa, coffee, oil palm, and mahogany established on cleared forests sites had been damaged or destroyed by *P. noxius* (Pegler and Waterston, 1968). It can be therefore be expected that the innoculum is present in native tropical forests and plantations on infected roots, stumps and in woody debris and new infection centers may be initiated when roots of the newly planted trees make contact with infected stumps or other woody debris of cleared native forest.

As there is no more cultivable land available in the traditional rubber-growing areas in Sri Lanka, the rubber industry is being extended to non-traditional rubber growing areas in Uva, Northern and Eastern provinces where land and labour are not limited. Most of the rubber lands in non-traditional areas have been established in cleared native forests and are now at the immature phase or at the beginning of tapping. These have been established after a minimum land preparation and consequently, roots of forest species are frequently observed unuprooted and kept *in situ* (Plate 2 a,b,c). Some clearings are having agro-forestry type cropping systems where rubber is planted with other forest species. Therefore, more incidences of this disease may be reported from these non-traditional areas in the future.

Plate 2. Unuprooted infected roots of forestry species in rubber clearings: **a)** Stumps of an infected forest species in an immature rubber land (Note the fruiting bodies) **b)** A dead immature rubber tree in the lower terrace, having contacts with the infected roots of the forest tree in the upper terrace **c)** A root of an infected forest tree uprooted after the infection of the rubber trees in contact

Preference of the fungus under dry soil conditions

During the surveys carried out by Chang (1996), *Phellinus noxius* occurred more frequently in fields with sandy soils, probably because sandy soils drain better and are less likely to become submerged for any significant length of time, even during high rainfall. On the other hand, clay soils drain poorly; therefore these soils are more likely to be submerged, a situation that is detrimental to the survival of *Phellinus noxius* (Chang, 1996). Out of the few areas where the disease incidence was high, Moneragala, Badalkumbura, Medagama, and Galagedara are in the Intermediate Zone. Therefore, it is obvious that the probability of brown root disease incidence is higher in such areas.

Poor land preparation and sanitation

In Sri Lanka, brown root disease has been frequently reported from small holders, where rubber is planted after leaving woody debris of the prior stand, either forest, rubber or some other crop species. In most incidences, stumps of forestry or some other species left behind at the time of land preparation have been observed to be in contact with the original diseased plant of the current disease patches (Plate 03). The initial infection occurs when roots of the newly planted trees make contact with stumps or other woody debris that contain the fungus (source of inoculum). Further spread from the initial infection centers is through root contact. *P. noxius* can persist in the roots and stumps of infected plants for more than ten years after the death of the host (Chang, 1996).

Plate 3. Source of inocula left from the previous plantations has spread the disease to the plants from the new clearing

Land use pattern

In Sri Lanka, this disease is frequently reported from the small holders, who are not practicing monoculture rubber cultivations. Frequently, rubber is planted in mixed cropping systems especially in the non-traditional rubber growing areas (Plate 4). Some clearings are having agro-forestry type cropping systems where rubber is present with other forest crop species.

Plate 4. Rubber is planted with other tree crops

The future

It is evident that there is an increasing trend in the occurrence of the brown root disease in Sri Lankan rubber plantations. When non-traditional areas are concerned, there are several facts to be taken into consideration. As these areas include parts of Low/Mid Country Intermediate and Dry Zones, the crop may face different agro-climatic conditions. The prevailing climatic conditions not only influence the crop growth and development but also affect pathogen development and host-pathogen interactions. Moreover, the inherent flora and fauna are different from that of the traditional Wet Zone. Increasing pressure on the conventional agricultural systems in these areas may disturb the balance between the crops and the pathogens. Hence, the increased occurrence of the brown root disease in these areas should be thoroughly looked into and attempts should also be made to develop improved management strategies for this disease in all areas in order to avoid low productivity levels resulted by unproductive bare patches.

REFERENCES

Ann, P J, Chang, T T and Ko, W H (2002). *Phellinus noxius* brown root rot of fruit and ornamental trees in Taiwan. *Plant Disease* **86**, 820–826.

CABI/EPPO (1997). *Phellinus noxius*. *Distribution Maps of Plant Diseases* No. **104.** Wallingford, UK, CAB International.

Chang, T T (1996). Survival of *Phellinus noxius* in soil and in the roots of dead host plants. *Phytopathology* **86**, 272-276.

Chang, T T and Yang, W W (1998). *Phellinus noxius* in Taiwan: distribution, host plants and the pH and texture of rhizosphere soils of infected plants. *Mycological Research* **102**, 1085–1088.

Larsen, M J and Cobb-Poulle, L A (1990). *Phellinus* (Hymenochaetaceae). A Survey of the World Taxa. Synopsis Fungorum 3. Oslo, Norway, *Fungiflora*, 609.

Nandris, D, Nicole, M and Geiger, J P (1987). Root rot disease of rubber trees. Plant Disease. 71. 298-306.

Pegler, D N and Waterston, J M (1968). *Phellinus noxius, CMI Descriptions of Pathogenic Fungi and Bacteria*, No. **195**. Commonwealth Mycological Institute, Kew, Surrey, England.

Petch, T (1911). *The Physiology and Diseases of Hevea brasiliensis the premier plantation rubber tree.* Dulau and Co. Limited, London.

Petch, T (1921). *The Diseases and Pests of the rubber tree***.** Macmillan and Co. Limited, London.

Ranadive, K, Jagtap, N and Vaidya, J (2012). Elixir. *Applied Botany* **52**, 11402-11408.

Bulletin of the Rubber Research Institute of Sri Lanka, (2016) **53**, 35-39

OCCURRENCE OF DRY SPELLS IN RUBBER GROWING AREAS IN EASTERN, NORTH CENTRAL AND NORTHERN PROVINCES OF SRI LANKA

Wasana Wijesuriya, P W Jeewanthi and Vidura Abeywardene

INTRODUCTION

An understanding of the occurrence of dry spells is important in producing optimum outputs from any agricultural crop, and rubber is not an exception. A proper understanding reduces the risk of any adverse impacts of drought conditions by adopting appropriate management practices at the correct time. Studies on dry spells and rainfall are mainly limited to the Wet Zone and Intermediate Zone areas (Wijesuriya *et al*., 2005 and 2010). However, through different Government policies in the recent past, the rubber cultivations have been introduced to Eastern and Northern provinces which come under Intermediate and Dry Zone areas, respectively (Rodrigo *et al.,* 2009). This move required more detailed analysis of rainfall and dry spells in Northern and Eastern regions of Sri Lanka for better decision making to ensure sustainable rubber farming.

The ideal annual rainfall for rubber falls within the range of 1650 mm to 3000 mm. The tree performance is severely affected by prolonged periods of dry weather when rainfall over consecutive six months period recorded less than 500 mm, and also when rainfall is not uniformly distributed over the year (Yogaratnam, 2001). It has been observed that ideal rainfall conditions do not exist in non-traditional rubber growing areas in the drier areas (Wijesuriya *et al.,* 2010). Vulnerability of different agro-ecological regions for droughts has been identified by Chithranayana & Punyawardene (2008). According to them, almost all regions of the island have a potential threat to droughts. However, the degree of vulnerability is more in the Dry Zone. Hence, rubber farming in drier areas is a challenge and needs careful handling to avoid detrimental effects due to adverse environmental conditions. A proper understanding on occurrence of dry spells therefore provides a useful guidance for effective management of rubber plantations in those areas.

METHODOLOGY

Selection of sites and collection of data

Selection of sites was done to represent the Agro Ecological Regions (AERs) where rubber has recently been introduced as listed in Table 1. Daily data on rainfall in the stations listed in Table 1 were collected from the Department of Meteorology. The rainfall data availability in most cases ranged from 1980 to 2012 but in some stations the record availability is limited to less than 20 years.

Table 1. *Details of the meteorological stations selected for the study*

District	Station	Agro-ecological region	75% expected value of annual rainfall (mm)	Data availability
Apura	Anuradhapura	DL_{1b}	> 900	1980 - 2012
	Medawachchiya	DL_{1b}	> 900	1995 - 2012
Vavuniya	Pawatti Kulam	DL_{1b}	> 900	1993 - 2012
	Vavuniya	DL_{1b}	> 900	1980 - 2012
Ampara	Ampara Tank	DL_{2b}	> 1130	1980 - 2012
Kilinochchi	Akkarayan Kulam	DL_{1f}	> 800	1980 - 2012
	Iranamadu Tank	DL_{3}	> 800	1980 - 2012
Mullaitivu	Muthuiankadu Kulam	DL_{1e}	> 800	1989 - 2012

Organization of data and analysis

Daily data were summarized into yearly, monthly and standard week bases for all the stations. Descriptive analyses were mainly employed in the analyses. A threshold value of rainfall <0.5 mm day^{-1} was taken to define a dry day. For different months of the rainfall series, the occurrence of dry spells of different lengths, *viz.* 10, 15 and 20 days were counted. Subsequently, the occurrences were presented as probability of occurring dry spells of different lengths for different months.

RESULTS AND DISCUSSION

An understanding on the probability of occurring a dry week (<10mm) is very useful in planning cultural operations to withstand any adverse effects on growth or yield of rubber. A high variation is observed in all locations as indicated by the high CV value.

The probability of occurrence of dry spells of different lengths in different months is depicted in Fig. 1 to Fig. 5. It is evident that probability of having long dry spells is less than 20% in all the sites during October, November and December. The chance of having dry spells more than 20 days is also less than probability of 0.2 (20%) in April for stations located in agro-ecological region DL_{1b}, in Ampara located in DL_{2b} and in Iranamadu in DL_{3}. There is only a chance of 20% to occur dry spells more than 20 days during January and September too, for Ampara area.

The driest month is June in all the locations considered in this study, except for Anuradhapura where August has more chance to receive dry spells greater than 20 days. The chance exceeds 80% in Medawachchiya, Pawatti Kulam, Akkarayan Kulam, Iranamadu and Muthuiankadu Kulam (Fig. 1 to Fig. 5).

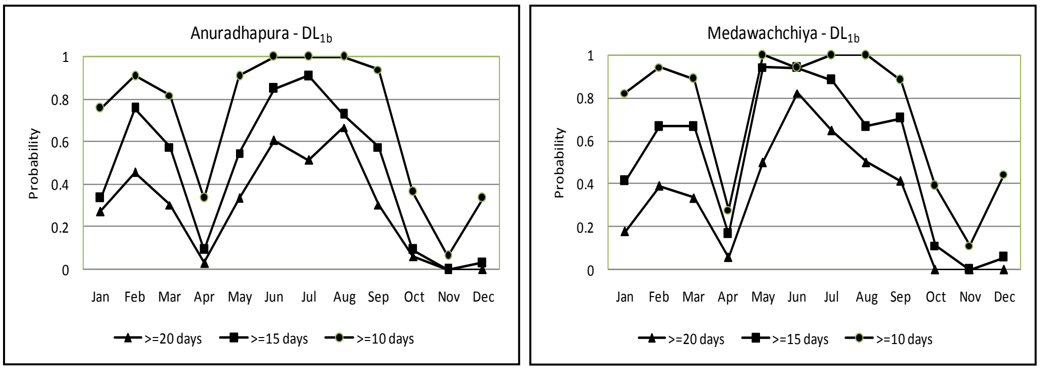


Fig. 1. Monthly distribution of frequency of dry spells of different lengths in Anuradhapura district

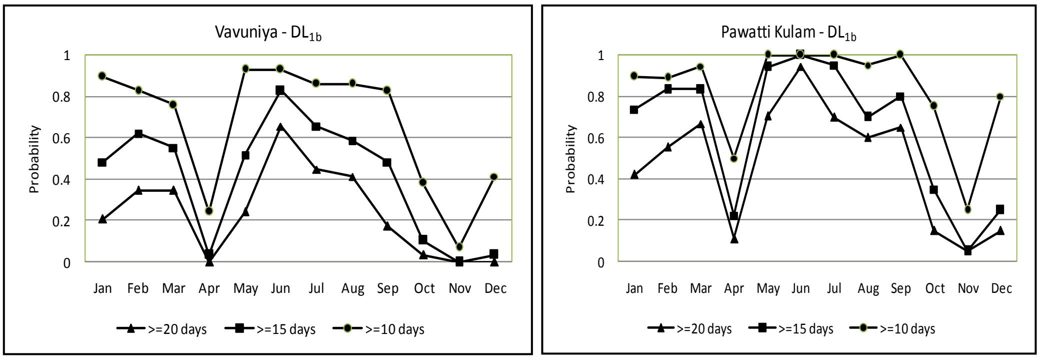


Fig. 2. Monthly distribution of frequency of dry spells of different lengths in Vavuniya district

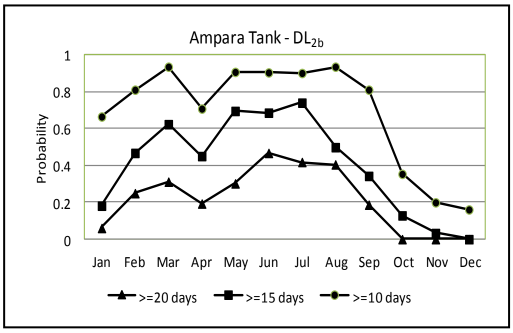
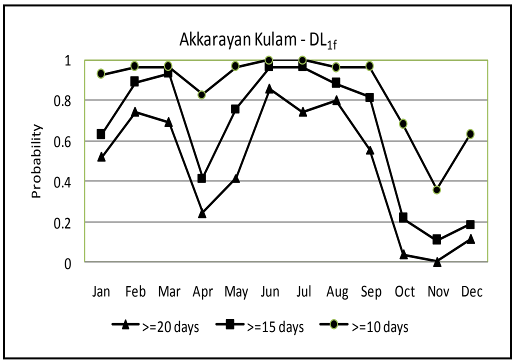


Fig. 3. Monthly distribution of frequency of dry spells of different lengths in Ampara district



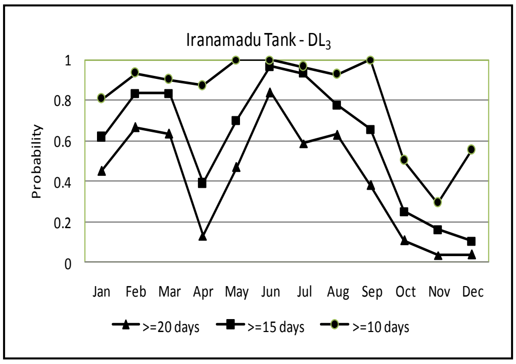


Fig.4. Monthly distribution of frequency of dry spells of different lengths in Kilinochchi district

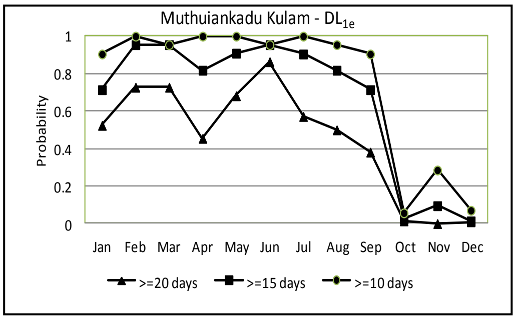


Fig. 5. Monthly distribution of frequency of dry spells of different lengths in Mullaitivu district

As stated by Chithranayana and Punyawardene (2008) DL_{1f} and DL_3 regions exhibit mild drought during the Maha season with Moisture Availability Index (MAI) less than or equal to 0.33 in January and February. The areas that belong to DL_{1e} are vulnerable to drought conditions during February. The agro-ecological regions DL_{2a} and DL_{2b} to which Uhana and Ampara areas belong to have no threat of drought during September to February. However, these areas are vulnerable to severe drought conditions during March to August (Fig. 4).

The AERs in the Dry zone are vulnerable to droughts especially during March to August. However, if cultural operations are carried out in a timely manner the repercussions of dry spells can be minimized to a considerable extent. Holing operation which requires a moist soil is best be done during 38th or 39th standard weeks (17th September to 30th September). Planting of rubber should coincide with 43rd and 44th weeks (22nd October to 04th November) to catch the maximum possible length of the wet season to assure optimal establishment success. First, second and third fertilizer applications in the first year of planting need to be done respectively, during 51st/52nd (17th to 31st December), 13th/14th weeks (26th March to 8th April) and 39th/40th weeks (24th September to 7th October) to avoid heavy rains and dry spells. All these dates have been computed using the probability theory in various ways. Hence, it should be noted that it is impossible to prevent any departures from these stipulated dates.

Through proper cultural operations and moisture management practices in rubber plantations, *viz*, irrigation, mulching and intercropping throughout the immature phase of rubber, one can assure a healthy rubber plantation with minimum vacancies to reach the tappable status despite the occurrence of dry spells.

ACKNOWLEDGEMENTS

The work connected with this article was carried out under the project "Empowering rubber farmers in non-traditional rubber growing areas through knowledge on combating adverse impacts of environment for better productivity" funded by National Research Council (NRC) grant No. 11-125. The authors are grateful to NRC for the financial assistance.

REFERENCES

Chithranayana, R D and Punyawardene, B V R (2008). Identification of drought prone agro-ecological regions in Sri Lanka. *Journal of the National Science Foundation of Sri Lanka* **36**(2), 117-123.

Rodrigo, V H L, Iqbal, S M M and Munasinghe, E S (2009). Rural livelihood and rubber cultivation in eastern province of Sri Lanka. *Journal of the Rubber Research Institute of Sri Lanka* **89,** 58-69.

Wijesuriya, W and Herath H M L K (2001). *Effects of climate change on rubber plantation in Sri Lanka.* A report submitted to the Center for Climate Change Studies of the Department of Meteorology, Sri Lanka.

Wijesuriya, Wasana, Herath, Keminda and Karunaratne, Senani. (2010). Use of rainfall patterns for efficient operation of agronomic practices in rubber plantations: The case of Moneragala district. *Bulletin of the Rubber Research Institute of Sri Lanka* **51,** 70-80.

Wijesuriya, Wasana, Herath, Keminda and Abeywardene, Vidura (2005). Characteristics of rainfall in the Moneragala district. *Bulletin of the Rubber Research Institute of Sri Lanka.* **46,** 1-9.

Yogaratnam, N (2001). Land suitability evaluation, selection and soil conservation. In*: Hand Book of Rubber, Volume 1 (Agronomy*), (Eds.) Tillekeratne, L M K and Nugawela, A., Rubber Research Institute of Sri Lanka.

Bulletin of the Rubber Research Institute of Sri Lanka, (2016) **53**, 40-47

EXPORT PERFORMANCE OF THE NATURAL RAW RUBBER SECTOR IN SRI LANKA

J K S Sankalpa and Wasana Wijesuriya

SUMMARY

This paper reviews the performance of Natural rubber (NR) exports during the period of 2007 to 2013. Although the raw rubber exports sector in general, has shown less growth in the year 2013, the sector showed satisfactory growth in the years 2010 and 2011 with global financial recovery. Fall in sale of vehicles is one major factor that caused decline in demand for Ribbed smoked sheet (RSS) which accounted for 57% of NR consumption globally. Quantity of Sri Lankan raw rubber export decreased by 25% in year 2013 which can be attributed to 2% reduction in world rubber consumption. Domination by crepe rubber in Natural raw rubber exports is seen throughout the seven years period while Technically specified Natural Rubber (TSR) and RSS were the other major contributors. Crepe rubber had an export value share of 66% while RSS rubber had a share of 19%. Crepe rubber earned US $ 47 million in 2013 and was the largest contributor in raw rubber exports earnings in the last 7 years. Malaysia is the largest importer of raw rubber from Sri Lanka while Pakistan, India and USA are the other major importers of raw rubber from the year 2011 to 2013. A strong growth in RSS exports is expected as a result of increased vehicle production in the future. Replacement car tyre sales are expected to move from 786 million units in 2012 to 1.3 billion units by 2022. Non tyre sector shows strong growth in the world market.

Background

Total Natural raw rubber export value was almost USD 71 million in 2013 while it was USD 123.24 million in year 2012. Although, this is a significant figure to the country, it accounts for a very little portion when compared to world rubber industry. Therefore, certain innovations are necessary in the rubber sector to attain global competitiveness. Due to rapid increase in demand for Natural Rubber (NR) products in the world, investment in rubber sector is highly profitable. Estate crop commodities provided a significant contribution to Gross Domestic Product (GDP) in Sri Lanka. The rubber industry is one of the key sectors of the Sri Lankan economy. Share of the Agriculture sector in GDP decreased to 10.8% in 2013 from 11.1% in 2012, while the contribution of the rubber sector has remained unchanged within 0.2% share within agriculture sector (Central Bank, 2013). Sri Lanka is the thirteenth largest exporter of natural rubber (NR) in 2013 (IRSG, 2014).

There have been several studies undertaken on NR sector performance by Tillekeratne (1998), Samarappuli (1995) and Tillekeratne and Samarappuli (1995). However, comprehensive studies focused on export performance of the rubber industry are limited. This study is based on export data collected from Sri Lanka Customs and was carried out with the objective of investigating the export performance of Natural raw rubber sector in Sri Lanka.

Raw rubber categories and their contribution

The main types of raw rubber produced and exported from Sri Lanka are Ribbed Smoked Sheets (RSS), Latex crepe, Sole crepe, Centrifuged latex and Technically Specified Natural Rubber (TSR). A considerable amount of compounded rubber (a semi processed product) is also exported. Other categories of rubber include various forms of unvulcanized rubber, reclaimed rubber and wastes.

The quantities of raw rubber exported to different countries are shown in Figure 1. The major destinations of Sri Lanka's raw rubber are Malaysia, Pakistan, India, Japan, Germany, USA and Italy. Nearly 74% of raw rubber produced in Sri Lanka was exported to these countries in 2013. Among them, Malaysia had the highest share with 21%. Pakistan had a share of 19% and India had a share of 11%. Share percentage of exports change from year to year depending on the industry demand in respective countries.

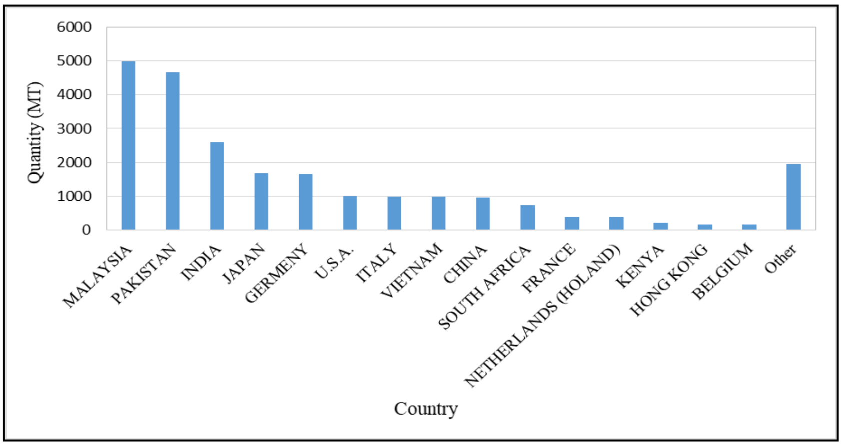


Fig. 1. Natural Raw rubber exported to different countries in 2013

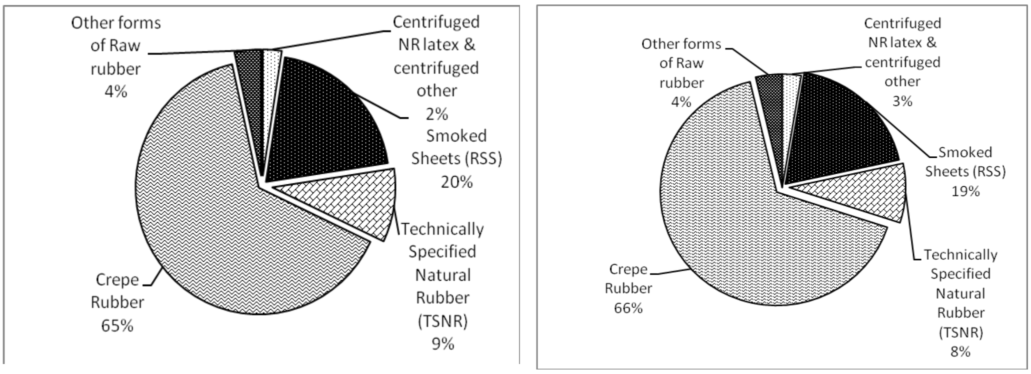
The export earnings from raw rubber exports accounted for USD 71 million in 2013. Further productivity improvements in the rubber sector could enhance the benefits from NR in the rubber products industry. USD 206.3 million was recorded in raw rubber export earnings from the rubber sector in terms in year 2011 and this is equivalent to LKR 22,811Mn. However, 2013 recorded a reduction in earnings by Rs.13,617 million from the value in 2011 mainly due to low FOB prices recorded during the year 2013 for all grades of NR and decrease in quantity produced in the year 2013.

Table 1. *Export earnings from natural raw rubber*

Year	Export earnings (Nominal values, US$ Mn)
2007	109.1
2008	124.9
2009	98.5
2010	173
2011	206.3
2012	123.2
2013	71.2

Source: Sri Lanka Customs

The total export volume of rubber in 2013 accounted for 23,586 MT, which brought foreign exchange worth of USD 71 million to the country. As can be seen from Fig. 2, crepe rubber dominates the exports with a share of 64.5% in quantity and 66% in value. Export earnings from crepe rubber was USD 47 million in year 2013. There was a reduction in both export quantity and value of crepe rubber in 2013 compared to against the previous year (Fig. 3 & Fig. 4). Brown crepe and pale crepe were the most prominent types of crepe rubber exported during 2007 to year 2013. There weren't any exports of scrap crepe recorded in year 2011 and 2012, while it contributed 2 to 3% during 2007 to 2010.



a) Quantity (MT) **b)** Value (US$ Mn)

Fig. 2. Export volumes and values of different types of rubber in 2013

The contribution from RSS is also considerable, with 20% and 19% share on the quantity and value, respectively (Fig. 2). RSS exports have shown a remarkable decline in 2013 which accounted for nearly 60% reduction compared to 2012. This amount was further reduced by 30% when compared to the value in 2010 and 2011. Crepe rubber exports were also reduced by 20% in 2013 compared to 2012. Although TSR quantity showed an increasing trend from 2010 to year 2012, it has decreased remarkably by 50% in year 2013. It has taken 5000 MT range in year 2007 and 2009.

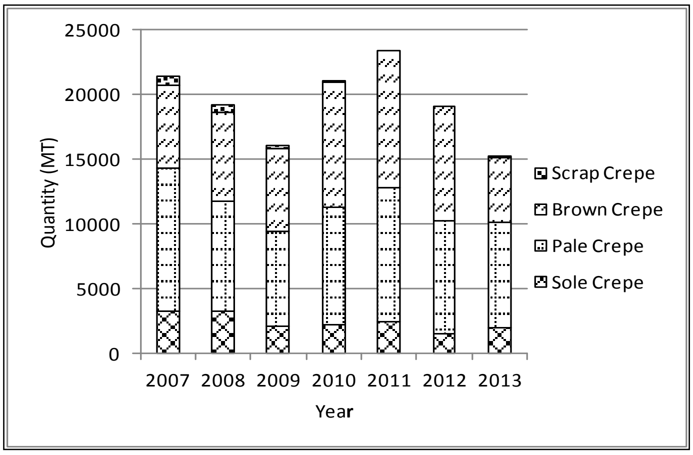


Fig. 3. Export volumes of different grades of Crepe from 2007 to 2013

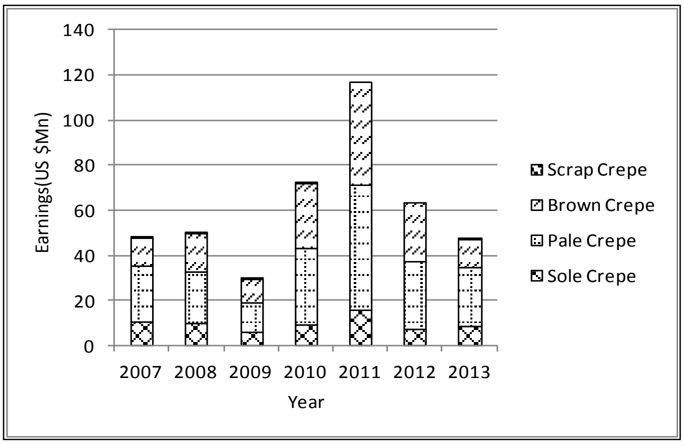


Fig. 4. Export earnings from different grades of Crepe from 2007 to 2012

Export earnings from RSS were USD 13.5 million in the year 2013. There was a reduction in both export quantity and value of RSS as in the case of crepe rubber in 2013 compared to previous year (Fig. 5 & Fig. 6). RSS- 3 and RSS-5 are the major types of sheet rubber exported in 2013.

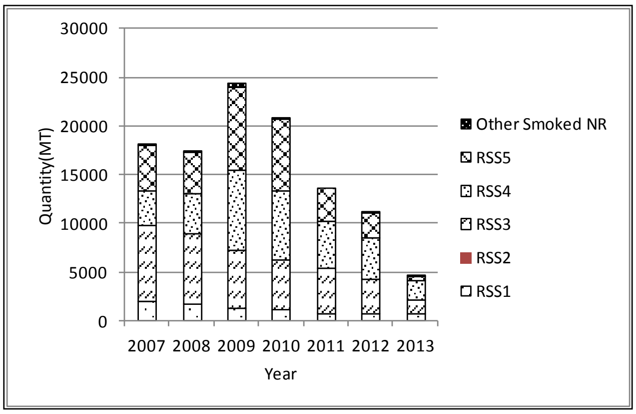


Fig. 5. Export volumes of different grades of RSS from 2007 to 2013

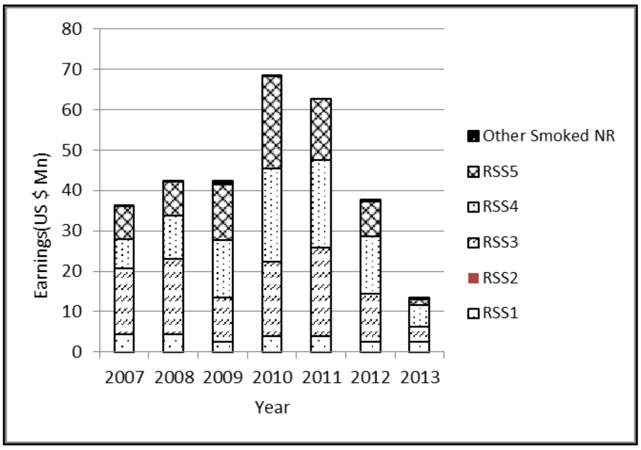


Fig. 6. Export earnings from different grades of RSS from 2007 to 2013

Raw rubber supply demand scenario

World demand for RSS is predominantly driven by the tyre sector. According to International Rubber Study Group (IRSG), percentage growth of passenger car tyres was -3.9% and growth of commercial vehicle tyres was -3.5% in 2009. This has been reflected by the low level of exports earnings in year 2009. Total vehicle production in Europe has decreased from 19.4 million units to 17.9 million units in year 2010. European tyre production growth rate was -24.7% in year 2009. It has increased up to 26.1% in year 2010 on volume basis (Anon, 2011). Nearly 60% of rubber used in the tyre industry is Synthetic Rubber (SR), produced from petroleum-derived hydrocarbons. Hence the contribution of natural rubber is 40% (Anon, 2014a). World Synthetic rubber consumption slightly increased by 6% in year 2010 while it was 4% in year 2013. The world SR consumption is generally affected by the world crude oil prices. World crude oil spot prices have decreased by about USD 37 per barrel during the year 2008 to 2009. Lowest crude oil price was recorded in the year 2009 during the review period. SR consumption has increased in year 2011 since it has benefited from the world crude oil price reduction in previous years (Fig. 7). Average world crude oil price was increased again up to USD 93 per barrel in 2013 (Anon, 2013a). Annual average synthetic rubber consumption was 1290 thousand tonnes in year 2013, while it was 1170 MT in 2010 (IRSG, 2013).

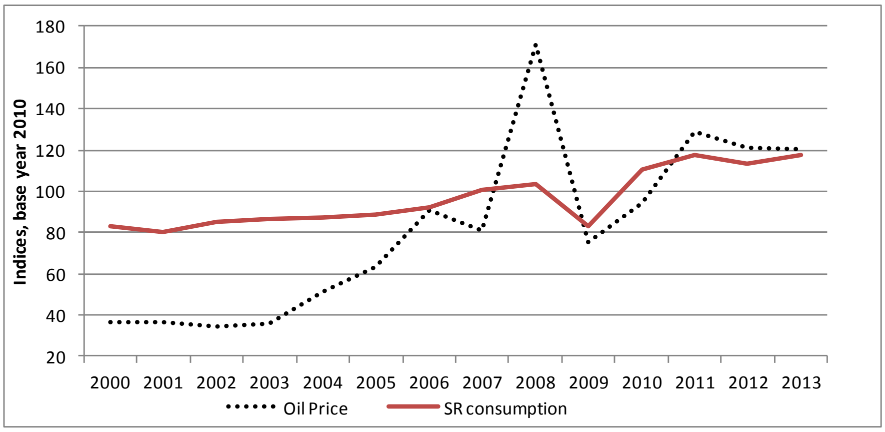


Fig. 7. Temporal variation in SR consumption and crude oil price

Both RSS and crepe exports have shown an increase in the year 2010. This income can be attributed to favorable conditions in international trade following an easing of the global recession. It had been reported that the year 2011 was the most favorable for crepe rubber while the year 2010 was most favorable for RSS. World NR production has increased by 7.6% as against 2009. Total export quantity has remarkably decreased in year 2013. This shock decrease was the result of drop in NR FOB prices due to excess supply in the market. Most of the Asian countries like India, Indonesia and Thailand were also affected by the downward trend of NR prices in the 2012 - 2013 period. Natural rubber consumption of Malaysia, USA and India has decreased by 2%, 4% and 3% respectively in year 2013 (IRSG, 2013). Since those countries were the major importers of Sri Lankan raw rubber, it adversely affected on raw rubber exports of Sri Lanka during this period.

The export value of Technically Specified Natural Rubber (TSR) was USD 6 million in year 2013. TSR exports earnings have decreased by about 50% compared to previous year. Asia's TSR prices have decreased by 20% in 2013. Singapore market price of TSR was USD3.16 per kilogram in 2012 which changed to USD 2.51 per kilogram in 2013 (Anon, 2013b).

With respect to the world main natural latex rubber goods such as gloves, threads and cords recorded a growth rates of 23.3% 4.3% and 82.7%, respectively, while the growth rate of condom production decreased by 4.5% (IRSG, 2013).

Weaker market activities were one of the major factors for decreasing NR earnings from year 2010 to 2013. NR prices have been continuously falling during the year 2013 (Fig. 8).

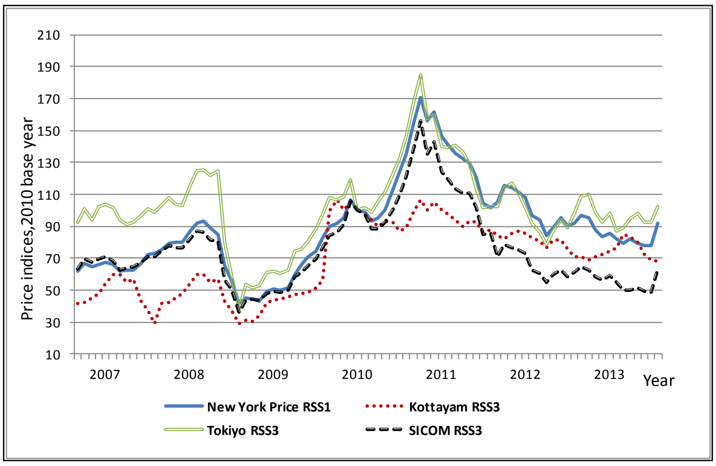


Fig. 8. RSS price change in selected market

Future outlook

Exports earnings from Natural Raw Rubber has sown a decreasing trend during the last few years period mostly due to weak rubber prices in the world market. Thailand has planted about 383 thousands hectares of rubber and 112 thousands hectares by Vietnam in year 2007 – 2008 period (ANRPC, 2014d). Increasing trend in new planting will be resulted a higher raw rubber supply in the market. Further, the observed trends were in close agreement with the changing pattern of world demand for rubber and global financial situation. Slowdown in China and European economy will be negatively affected on the Sri Lankan raw rubber exports earnings.

The non-tyre products sector should be given high priority since high value addition and he presence of a steady increase in global demand. Negative growth of NR latex production severally affected the earnings from this sector.

Looking at the global tyre industry, one can see that it is set to record close to 5% yearly growth in volume demand through 2015 to reach almost 3.5 billion units (Anon, 2014c). The large motor vehicle tyre market will see acceleration in growth through 2015. In value terms, the tyre market is projected to advance 6.5% annually over the same span to USD 220 billion. Global rubber consumption will grow at an average of 3.6% a year through 2018 as demand increases for replacement tyres, supporting prices of the commodity (Stapleton, 2013). World crude oil reference price in year 2018 is projected to 4.5% higher than the year 2013. Synthetic Rubber (SR) consumption will almost steady throughout the period. Therefore, the income from raw rubber exports can be capitalized especially through exports of RSS.

REFERENCES

Anon (2011). European tyre industry report 2011. Accessed on 28th January 2014. Retrieved from www.etrma.org

Anon (2014a). Materials in tyre. Accessed on 28th January 2014. Retrieved from http://thetiredigest.michelin.com/an-unknown-object-the-tire-materials

Anon (2013a). Cushing, OK WTI Spot Price (FOB) Crude Oil Prices and Price Charts. Accessed on 28th January 2014. Retrieved from http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=RWTC&f=D

Anon (2014b). World Rubber Consumption Seen Climbing As Tire Demand Grows. Accessed on 29th April 2014. Retrieved from www.rubberworld.com/RWmarket_report.asp?id=1052

Anon (2014c). Tire Industry: Market Research Reports, Statistics and Analysis. Accessed on 2nd of May 2014. Retrieved from http://www.reportlinker.com/ci02307/Tire.html

Anon (2014d). Monthly Statistical Tables Natural Rubber Trends and Statistics. Association for Natural Rubber Producing Countries. Kuala Lumpur, Malaysia.

Stapleton, G (2013). World Rubber Consumption. Accessed on 2nd of May 2014. Retrieved from http://www.bloomberg.com/news/2013-10-24/rubber-demand-to-grow-3-5-a-year-on-replacement-tires-lmc-says.html

Central Bank (2013). Annual Report. Central Bank of Sri Lanka, Colombo, Sri Lanka. International Rubber Study Group (2013). Industry Report.

Samarappuli, I N (1995). The need to supplement the research cess on raw rubber exports and investigation of alternative policies. *Bulletin of the Rubber Research Institute of Sri Lanka*. **32**, 22-34.

Tillekeratne, L M K (1998). Improvements to be done in the raw rubber industry to improve occupational safety and hygiene. *Bulletin of the Rubber Research Institute of Sri Lanka* **37,** 71-74.

Tillekeratne, L M K and Samarappuli, I N (1995). Effects of Asian currency crisis on the rubber industry of Sri Lanka. *Bulletin of the Rubber Research Institute of Sri Lanka* **39**, 40-44.

Bulletin of the Rubber Research Institute of Sri Lanka, (2016) **53**, 57-65

TOWARDS IMPROVEMENT OF GENETIC DIVERSITY OF FUTURE RUBBER CLONES: EVALUATION OF 2008 HAND POLLINATED GENOTYPES

P V A Anushka, S P Withanage, L A R Amarathunge, K K Liyanage, P K G S S Bandara and A K Gamage

INTRODUCTION

Hevea brasiliensis Muell. Arg. is a forest tree belonging to the family Euphorbiaceae (Lam *et al.*, 2012). The rubber tree is native to the tropical rain forests of Central and South America and it was introduced to South East Asia by Sir Henry Wickham in 1876. From the "Wickham collection" 1919 seedlings were cultivated in Sri Lanka (Lam *et al.*, 2012 & Liyanage, 2007). Therefore majority of *Hevea* clones have been derived from relatively a few number of trees surviving from Wickham's collection through selection or breeding. Also, Wickham clones showed less variation due to their female progenitors which consist of primary clones naturally bred under the same environmental conditions of Malaysia and Indonesia. Therefore, *Hevea brasiliensis* grown in South East Asia comprises a very narrow genetic base (Liyanage, 2007).

Possible reasons for the genetic erosion

In commercial practice, *Hevea* breeding mainly aims to produce high yielding rubber clones through introduction, Ortet (plus tree) selection and hybridization (Gonçalves *et al*., 2011). Continuous propagation through directional selection for yield has led to further reduction in the genetic diversity.

Also in hybridization programme, parental trees are selected mainly based on the yield and then on disease resistance. This directional selection also lead to the genetic erosion due to the ignorance of genetic variability for other secondary characters such as drought/cold tolerant ability, *etc.* (Liyanage *et al*., 2014).

The high yielding genotypes produced from hybridization procedure are used as parents for the next cycle of breeding. This has lead to the production of high yielding clones which originated from a few prominent parents. Most of the present day popular clones in Sri Lanka originated from few numbers of parents such as RRIC 100, RRIC 121, PB 86, and PB 28/59; and hence the genetic diversity is low (Table 1). Therefore, it is necessary to widen the genetic base during *Hevea* breeding program.

Table 1. *Pedigree of the clones presently recommended for cultivation in Sri Lanka*

No.	Recommended Sri Lankan clones	Parentage
1	RRIC 100	RRIC 52 x PB 86
2	RRIC 101	CH 26 x RRIC 7
3	RRIC 102	RRIC 52 x RRIC 7
4	RRIC 121	PB 28/59 x IAN 45/873
5	RRIC 130	IAN 45/710 x RRIC 45
6	RRIC 133	IAN 45/710 x RRIC 52
7	RRISL 201	RRIC 103 x 85 – 01
8	RRISL 203	RRIC 100 x RRIC 101
9	RRISL 205	82 x 82
10	RRISL 206	82 x RRIC 101
11	RRISL 208	RRIC 101 x RRIM 600
12	RRISL 210	RRIC 101 x RRIM 600
13	RRISL 211	RRIC 101 x RRIM 600
14	RRISL 217	PB 28/59 x RRIC 121
15	RRISL 219	PB 28/59 x RRIC 102
16	RRISL 2000	RRIC 100 x RRIC 101
17	RRISL 2001	RRIC 100 x RRIC 101
18	RRISL 2002	RRIC 100 x RRIC 101
19	RRISL 2003	82 x RRIC 101
20	RRISL 2004	82 x PB 86
21	RRISL 2005	PB 28/59 x IAN 45/710
22	RRISL 2006	IAN 45/710 x PB 28/59
23	RRISL Centennial 1	RRIC 100 x GT 1
24	RRISL Centennial 2	RRIC 100 x GT 1
25	RRISL Centennial 3	BPM 24 x RRIC 121
26	RRISL Centennial 4	RRIC 100 x PR 255
27	RRISL Centennial 5	RRIC 100 x PR 255
28	RRISL 2100	RRIC 100 x PR 309

The present day high yielding clones are limited in number and extensively cultivated in traditional rubber growing areas (Table 2). The situation is more or less similar in other rubber producing countries also.

Table 2. *Clonal composition of the rubber cultivation industry in Sri Lanka*

Clone	Percentage
PB 86	43%
RRIC 100	26%
RRIC 102	4%
RRIC 121	22%
RRISL 203	5%
RRISL 2000	0.1%
Other	0.4%

Source: Rubber Development Department/Census of Rubber Lands 2010

IRRDB 1981 germplasm collection to overcome the problem

In 1981, action was taken to improve the genetic variability of *Hevea* by the International Rubber Research and Development Board (IRRDB) through organizing a major collection expedition to the Amazon rain forests. This was considered as a major event in the rubber history to ensure a bright future for rubber plantation industry. This expedition covered the three Western states of Brazil, called Acre (AC), Rondonia (RO) and Mato Grosso (MT), in 16 different districts and 60 different locations to collect wild *Hevea* germplasm. As a result 63,768 seeds, bud wood from 194 high yielding trees and 1,160 seedlings were collected (Lam *et al*, 2012). Acre and Rondonia are famous for vigorous high yielding characters and Acre genotypes produced superior quality rubber. The three states having different ecological characters led to the selection of materials which are suitable for diverse situations. About 50% of the seeds and clones were retained in Manaus, Brazil and the other 50% was sent to Malaysia and Ivory Coast (Sethuraj *et al.*, 1992). The genotypes produced by the bud wood collection were also brought to Malaysia and Ivory Coast and finally the collection was distributed among all the IRRDB member countries (Fig. 1).

Fig. 1. IRRDB 1981 germplasm collection in Neuchatel estate, Sri Lanka

Breeding objectives for the crop improvement

For the crop improvement, breeding objectives should be focused on high productivity potential along with the desirable secondary characters. Vigorous growth, a thick bark with a good latex vessel system, high growth rate, ability to tolerate diseases, drought, cold and wind, low Tapping Panel Dryness (TPD) incidences could be recognized as some of the secondary characters. Breeding objectives vary from country to country. For an example in Sri Lanka, rubber cultivation in traditional area is limited for further extension. But Sri Lanka has plenty of land available for new cultivation in dry areas. Therefore any clones to withstand conditions in those areas, drought tolerance, vigor, high yields under low level of soil moisture and relative humidity are to be considered in breeding programmes.

Present day involvement for the crop improvement

The Department of Genetics and Plant breeding of the Rubber Research Institute of Sri Lanka has taken steps to incorporate such non Wickham genetic characters to their breeding pool since early 1990s through hand pollination programme focusing the fulfillment of the above objectives; *i.e.* the improvement of rubber genetic diversity. In 2008, a special hybridization programme was launched as described below.

Hybridization programme in 2008

In the hand pollination/hybridization programme in 2008, Wickham's originated female parents RRIC 100, RRIC 121 and PB 28-59 were used with eight different male parents which were originated from non Wickham germplasm (IRRDB 1981 germplasm collection). Both female and male parents were artificially cross pollinated as shown in Table 3 and resulted seeds (F1) were placed in a sand bed for germination. From the 2008 HP progeny, 354 numbers of F1 genotypes were obtained and these genotypes were established in a nursery for further evaluation (Fig. 2).

Table 3. *Parentage of the 2008 HP progeny*

Female parent	Male parent	
RRIC 100	PB 28-59 (Control)	Category 01
RRIC 121	PB 28-59 (Control)	Category 01
RRIC 100	36-47	Category 02
RRIC 100	1-4	Category 02
RRIC 100	22-271	Category 02
RRIC 121	21-136	Category 02
RRIC 121	1-4	Category 02
RRIC 121	36-160	Category 02
RRIC 121	1-47	Category 02
PB 28-59	45-873	Category 02

The entire seedling plants were divided into two categories where category 01 comprises the seedlings obtained from the parents, who were originated from Wickham's collection and category 02 comprises the seedlings obtained from the mother, who originated from Wickham's collection and the father, who is belonging to non Wickham's collection (IRRDB 1981 germplasm collection).

Fig. 2. Seedling nursery (2008 HP) established at the Genetics and Plant Breeding Department premises

Analysis of growth and yield performances

During a period of 4 years, yield (micro tapping), girth and the bark thickness were measured. The trees were opened for micro tapping at the third year. Micro tapping was done at 45cm height above the bud union of the rubber tree on half-spiral, with two daily tappings. Collection of latex into 50ml tubes was done after 4^{th} day of tapping. Latex from five tappings was collected into the same tube and coagulated using 2% acetic acid, and then dried coagulum was weighed for calculation of dry rubber content as g/t/t. This procedure was repeated three times to get the average yield. The girth was measured once a year at 90cm height above the bud union using a measuring tape. The first measurement, at 12 months, consisted of diameters; because the plants were too small to measure the girth. Using a slide caliper the plant diameters were measured and converted to girth by assuming that the stem was cylindrical. Bark thickness was measured with a Schleiper gauge.

Finally, the average girth, yield and bark thickness of the genotypes belong category 01 were compared with those of the category 02 genotypes.

Molecular analysis

From all genotypes, 23 numbers of genotypes were selected based on girth, yield and disease tolerance ability to find genetic diversity by using SSR markers.

Genomic DNA was extracted from apple green stage leaves of the selected genotypes using the mini preparation method (Amarathunge *et al.*, 2014). Extracted DNA was mixed with 1 µl of RNAse to each DNA pellet by shaking gently before subjecting to agarose gel electrophoresis. The Quantification of extracted DNA was done according to visual observation of the intensity. Eight primer pairs- HB 1, HB 2, HB 3, HB 4 hmac 4, hmac 5, hmct 1 and hmct 5 – that could amplify polymorphic products were used for the analysis. For PCR (polymerase chain reaction) amplification, samples were prepared in 25 µl reaction volumes containing approximately 100 ng of genomic DNA, 200 µM dNTPs 1X PCR buffer with 2.5 mM $MgCl_2$, 5 mM primer and 0.5 units *Taq* DNA polymerase in Multigene DNA thermal cycler (ver.1.7). Specific annealing temperature of each primer pair was used for program according to the used primer. The amplified PCR products were resolved on 1.3% Agarose gel.

Power Marker software program, version 3.25 was used to develop genetic distance matrix and consequently phylogenetic tree based on the Unweighted Pair Group Method with Arithmetic Averages (UPGMA).

Results of growth and yield performances

In the comparison of 01 and 02 categories; both did not show a significant difference on girth and bark thickness; but in the category 02, yield was significantly different from category 01 (Fig. 3). Category 01 genotypes showed higher yield due to the fact that they arouse from high yielding promising parents with Wickham base, while category 02 genotypes arouse from non Wickham (1981 IRRDB germplasm) male parents. But the category 02 was also a vigorous group having proper girth and bark thicknesses.

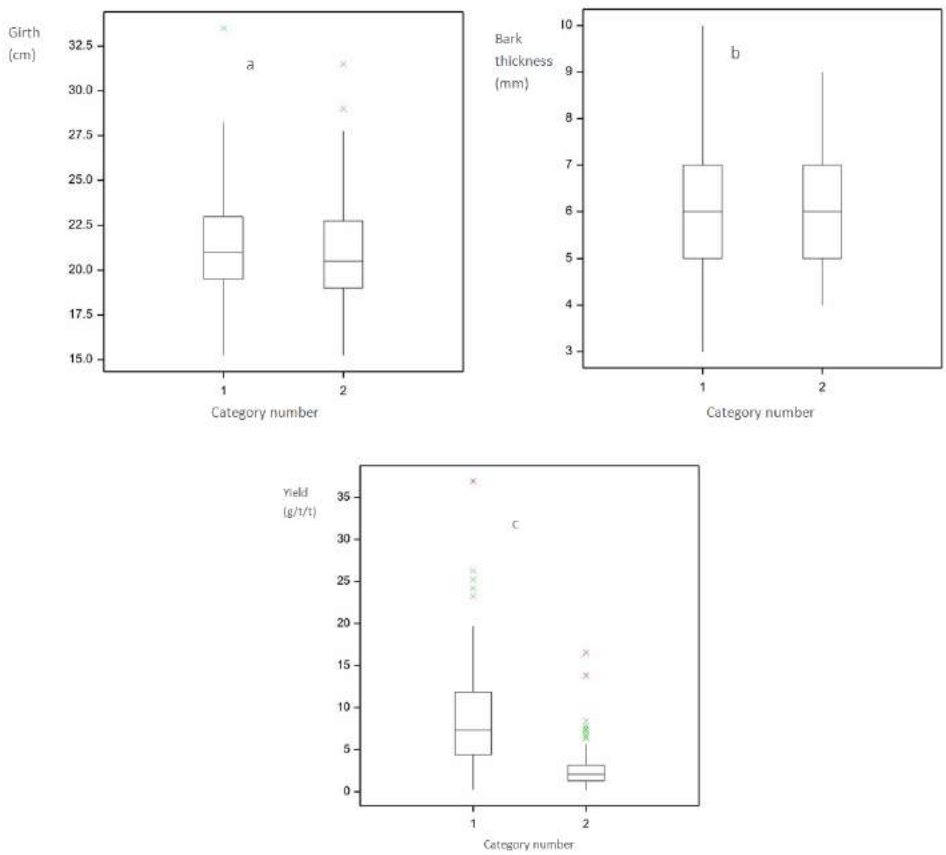


Fig. 3. Growth and yield performances of the trial to improve genetic diversity a) Girth (cm), b) Bark Thickness (mm) and c) Yield (g/t/t)

Results of molecular analysis

Two noticeable alleles were produced from each of the SSR marker. Through visual observation of gel images, the genotypic score was recorded and then derived the phylogenetic tree (Fig. 4).

Phylogenetic tree was divided mainly into two clusters (X and Y). Ten numbers of genotypes belonging to five different families grouped into cluster X which indicates higher level of genetic diversity. The selected three genotypes from the family RRIC 100 X PB 28/59 and the RRIC 121 X PB 28/59 were also grouped in the cluster X though they have both parents from Wickham genetic base. This indicates that there is a possibility to develop genetic variability through recombination of Wickham genetic base.

Again cluster Y grouped into two sub clusters where one sub cluster comprises six genotypes from the progeny having non Wickham based male parents. The Female parents were grouped together in other sub cluster due to their origin from the Wickham base. The clone RRIC 100 and RRIC 121 showed narrow genetic relationship of 0.073 distance value. There were seven genotypes from the progeny grouped with female parents. Eight genotypes from the progeny showed genetic distance values higher than to 0.5 from all three parents.

CONCLUSION

According to the growth performances, the genotypes in category 01 showed higher yield since they are coming from Wickham base promising parents. But there was no significant difference in between the category 1 and category 2 on girth and bark thicknesses. These results showed the possibility of improvement on genetic diversity while maintaining a vigorous growth.

The molecular experimental results showed parents (promising clones; RRIC 100, RRIC121 and PB 28-59) of genotypes having close genetic relation due to the fact that they are originated from the Wickham base; while16 number of genotypes out of 23 were grouping separately from the female parents (RRIC 100, RRIC121 and PB 28-59). The eight genotypes showed more than 0.5 genetic distance values from the female parents, representing a higher genetic diversity.

Future actions

Identification of genetically diverse genotypes will be continued using further growth and molecular parameters. In order to produce genetically improved new clones for different climatic regions, further experiments on 2008 HP progeny will be designed. And also the selected best genotypes will be used as parents in future breeding programmes.

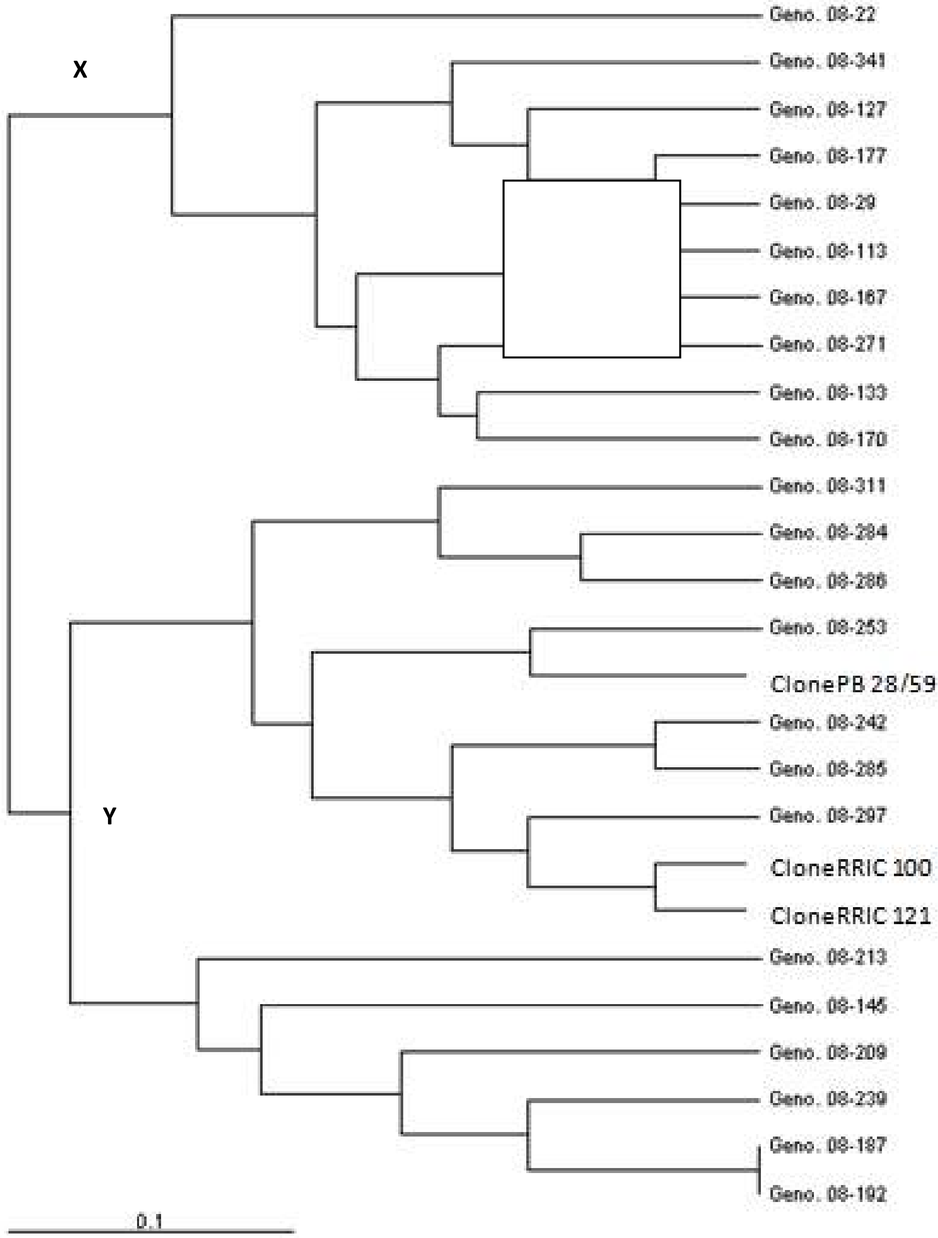


Fig. 4. Phylogenetic tree constructed using UPGMA genetic distance (Power Marker V3.25)

REFERENCES

Amarathunge, L A R, Sumanasinghe,V A and Withanage, S P (2014). Genetic diversity of selected genotypes from year 2008 hand pollination progeny of *hevea brasiliensis* using SSR markers. *Proceedings of the Peradeniya University. International Research Sessions, Sri Lanka* 18, 4.

Gonçalves, P D S, Júnior, E J S, Martins, M A, Moreno, R M B, Branco, R B F and Gonçalves, E C P (2011). Assessment of growth and yield performance of rubber tree clones of the IAC 500 series. *Brasília* 46, n.12, 1643-1649.

Lam, L V, Thanh, T, Trang, L T T, Truong, V V, Lam, H B and Tuy, L M (2012). *Hevea* germplasm in Vietnam: conservation, characterization, evaluation and Utilization, Genetic Diversity of Plants. Rubber Research Institute of Vietnam, Ho Chi Minh City 22,433-456.

Liyanage, K K (2007). *Hevea* germplasm and its potential. *Bulletin of the Rubber Research Institute of Sri Lanka* **48**, 16-26.

Liyanage, K K, Sumanasinghe, V A, Attanayake, D P S T G and Baddewithana, B W A N (2014). Identification of recommended *Hevea brasiliensis* (Willd. ex A. Juss.) Müll. Arg. clones grown in Sri Lanka by RAPD analysis. *Tropical Agricultural Research*, Postgrduate Institute of Agriculture, University of Peradeniya, **25**(2), 188-200.

Sethuraj, M R and Mathew, N M (1992). Natural Rubber: Biology, Cultivation and Technology. *Rubber Research Institute of India, Kottayam - 686009, Kerala, India*, 88-109.

Bulletin of the Rubber Research Institute of Sri Lanka, (2016) **53**, 66-70

CHEMICAL TREATMENT ENHANCES BRANCH INDUCTION

P Seneviratne and G A S Wijesekera

INTRODUCTION

Hevea brasiliensis, commonly known as rubber tree, is a deciduous open pollinated perennial tree that belongs to the family Euphorbiaceae. Seedling trees grow up to more than 30m in height with well-balanced branches starting from about 2-3m from the base. The trunk shows a tapering shape which is unique to seedlings of many tree species. Due to high variation among seedling populations, bud grafting was introduced to propagate rubber trees far back in 1917.

Since then, the planting material widely used for propagation of rubber was budded plants and at present budded plants are produced in the form of young buddings. As far as budded plants are concerned branching pattern is a characteristic of the clone from which the bud patch was taken. Some clones like PB 86 and RRIC 100 naturally show substantial branching whereas clones like RRIC 121 and RRIC 217 show very thin canopies (Fig. 1). Furthermore, some clones lead to a condition of very poor branching and even the growth or the tree girth seems to be affected. As a solution to this, branch induction is recommended for budded rubber plants at the age of 1½ -2 years when the top of the tree is reachable.


RRIC 100 **RRIC 121**


PB 86 **RRISL 217**

Fig. 1. Canopy architecture of different clones

Removing the apex of the tree is the most effective method to induce branches but it is not recommended for rubber, as the apex seems important to control the canopy architecture. Removing all the leaves of the top most whorl is recommended in Indonesia. In Sri Lanka two methods have been recommended for rubber to induce branches. In leaf cap method, a cap is formed to cover the apex with 4-5 detached leaves from another leaf whorl. In the leaf folding method, which can be practiced if only the top most leaf whorl is mature, the leaves are gathered with hands to cover the apex. Accordingly, the two techniques are for the two different growth stages of the tree that is with mature leaves at the top whorl and without mature leaves. In both methods, apex of the tree, where the branch inhibiting hormones are produced is covered from the sunlight temporarily for about 1-2 weeks. It is also important to use materials such as rubber leaves and rubber bands which are short lived under natural environmental conditions.

Branching pattern and tree girth has shown a positive significant correlations (Senevirtne and Wijesekera, 2011). The recommended method to induce branching is different from one country to another. But in Sri Lanka, as mentioned before the recommended techniques are either leaf folding or leaf cap. The method practiced will depend on the growth condition of the top most leaf whorl. When the top most whorl has partially or fully matured leaves on it (Fig. 2) the same leaves are used to cover the apex of the main shoot which is called leaf folding method. When the top whorl is only a tender shoot with no expanded leaves, then some detached leaves from a whorl below are used to make a temporary cover in leaf cap as explained earlier (Fig. 3). In both methods the apex is covered to prevent sun light reaching the apex which then synthesizes auxins to prevent induction of branches at axillary buds, below. This is called apical dominance and in case of rubber strong apical dominance is observed during the first 1-1½ years of growth, both in seedlings as well as in budded plants. Therefore, no branching is seen during this period.

In the present study Zinc Sulphate ($ZnSO_4$) and urea solutions were used to induce branches which are more effective and also easy to perform under field condition.

MATERIALS AND METHODS

Trial was conducted at Dalkeith Estate under Kotagala Plantation PLC in Kalutara district. Ten month old rubber trees of the clone RRIC 121 with initial average height of 2-3 m and girth of 7.22cm at 120cm height were selected. The trees had about five leaf whorls at the time of commencement of the trial.

Commercial grade $ZnSO_4$ and urea solutions as given below were used to treat the trees to induce branches. General purpose plastic hand sprayers were used to apply chemicals. Currently recommended leaf cap method was used as shown in Figure 2.

Fig. 2. Leaf folding method **Fig. 3**. Leaf cap method for branch induction

In the preparation of chemical solution, 100g of urea and $ZnSO_4$ were weighed separately and dissolved in water to make 01 litre solutions for treatment 1 and 2. Similarly, 250g were weighed and dissolved in 01 litre to prepare solutions for treatment 4 and 5. Chemicals were sprayed once on to the top most leaf whorl.

Treatment No.	Treatment
T1	10% (W/V) - Urea Solution
T2	10% (W/V) - $ZnSO_4$ Solution
T3	Leaf cap method
T4	25% (W/V) - $ZnSO_4$ Solution
T5	25% (W/V) - Urea Solution
T6	Control

Observations were made after 3 days, 3 weeks and 7 weeks and the observations are given in the Table 01.

As per the results, higher concentrations of urea and $ZnSO_4$ performed better than lower concentrations. However, the results after 7 weeks show that leaf cap method is as good as spraying with $ZnSO_4$ and Urea at 25% (W/V) concentration though they are not significantly different (Table 1).

Table 1. *Percentage of branched trees after imposing the treatments*

Treatment	After 3 days	After 3 weeks	After 7 weeks
T_1	9.52	42.8	61.9
T_2	12.5	20.8	54.2
T_3	11.1	66.7	88.9
T_4	26.3	63.2	73.7
T_5	35.0	50.0	85.0
T_6	26.1	30.4	39.1

Mean number of branches per tree is given in Table 2a & b for different treatments. As far as mean number of branches is concerned, $ZnSO_4$ at 25% (W/V) has given the best results after 3 days of spraying. However, results after 7 weeks confirmed that the leaf cap method, which is one of the current recommendations was the best. Further, the control too shows branching, though it is only 39%.

When only the branched trees are considered, the mean number of branches per tree is shown in Table 2a. Except treatment 5 (25% urea) all other treatments show comparable results. But when the total number of trees treated are considered, the control gives the lowest (Table 2b).

Table 2a. *Mean number of branches per tree (only the branched trees are considered)*

Treatment	After 3 days	After 3 weeks	After 7 weeks
T_1	2.00	4.00	4.77
T_2	1.67	2.00	4.15
T_3	4.33	4.61	5.14
T_4	6.00	4.25	4.21
T_5	2.70	3.00	2.59
T_6	4.17	3.71	4.11

Table 2b. *Mean number of branches per tree (when the total number of treated trees are considered*

Treatment	After 3 days	After 3 weeks	After 7 weeks
T_1	0.19	1.14	3
T_2	0.21	0.42	2.35
T_3	0.48	3.07	4.59
T_4	1.5	2.25	4.15
T_5	0.95	1.5	2.2
T_6	1.09	1.13	1.61

When the length of the branches were measured, leaf cap method showed the best results followed by urea at 10% (W/V) as given in Table 3.

Table 3. *Mean length of branches (cm)*

Treatment	After 3 weeks	After 7 weeks
T_1	9.4	41.3
T_2	13.7	26.4
T_3	18.2	45.1
T_4	13.7	33.7
T_5	19.2	31.2
T_6	31.2	30.7

Percentage of trees showing apical elongation is given in Table 4. The control plants showed the highest percentage of apex growth after 3 days. But after 3 weeks $ZnSO_4$ at 25% (W/V) and urea at 25% (W/V) recorded the highest percentage of apex elongation and the control also showed a higher percentage of apex elongation after 7 weeks.

Table 4. *Percentage apex growth of trees of different treatments*

Treatment	After 3 days	After 3 weeks	After 7 weeks
T_1	14.3	57.1	66.7
T_2	20.8	50.0	54.2
T_3	3.7	55.5	44.4
T_4	36.8	78.9	78.9
T_5	25.0	70.0	90.0
T_6	43.5	52.2	82.6

It is expected for the leaf cap to get released automatically after a few weeks and as expected about 96% of the trees, leaf cap got automatically released after 7 weeks.

DISCUSSION

As per the results of the present study spraying with either $ZnSO_4$ or urea can be considered in branch induction when the trees are about one year old and practically difficult to perform branch induction by leaf cap or leaf folding method. Spraying the apex with the chemicals seems economical, ergonomical and effective.

One person can spray about 250 trees per day whereas he can perform either leaf cap or folding method only on about 75 trees per day.

Though a second application was also planned after three days of the first application, it wasn't done due to some trees which had immature leaves showed scorching symptoms after the first application of urea and $ZnSO_4$ at 25% (W/V).

A similar trial with more treatments was conducted in the following year and the results indicated similar effects of urea and $ZnSO_4$.

REFERENCES

Senevirtne P and Wijesekera G A S (2011). The growth pattern of rubber tree to improve the performance of clearing. *Bulletin of the Rubber Research Institute of Sri Lanka* **52**, 26-30.