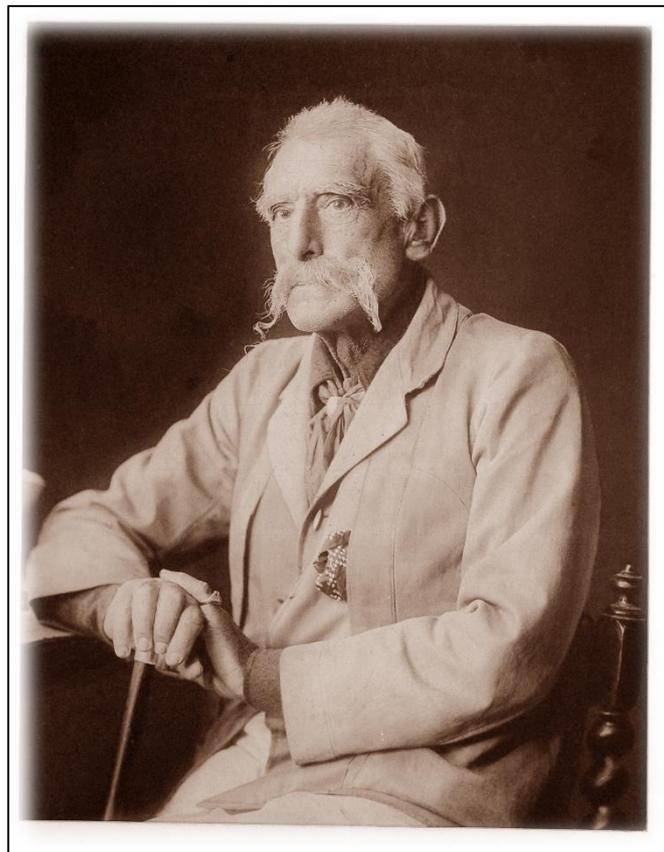


Dedication

This Handbook is dedicated to Sir Henry Alexander Wickham, who was only 20 years when he embarked on his first voyage to South America. His dedication to the rubber industry in the East was immense. He was “in the right place at the right time”



HANDBOOK OF RUBBER

Volume 1

Agronomy

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Introduction

Among the trees domesticated by man, the tropical tree, *Hevea brasiliensis* (A. Juss) Muell Arg. is one of the more recently domesticated plants. It is one of the few plants that have had a deep social, economic and environmental impact. The value of this plant was realized very early on, that rubber plantations were rapidly established. The rubber plantations in the Asian continent were first established in Sri Lanka in 1876 by Sir Henry Wickham. The Director of Kew Botanic Gardens in England provided facilities to grow rubber seeds and Sir Henry was successful in transporting the seedlings to Colombo.

From these humble beginnings the expansion of rubber cultivation saw a rise in 1883. And by 1928 the rubber extent in the country reached an incredible 214,000 ha, which is considerable when compared to the current extent of 138,000 ha. Despite the fall in the rubber extent, the rubber production has been on a continually rising trend, largely due to the usage of higher yielding varieties and the adoption of improved technology.

The first research activities related to rubber in the world was established by a group of British planters in 1909 in Sri Lanka, then Ceylon. These simple beginnings paved the way for the establishment of the Rubber Research Scheme in 1913, which was followed by the establishment of the Rubber Growers (Ceylon) Research Fund in 1914. It facilitated rubber related research by providing 60% of the funds from the government. The two bodies were then amalgamated in 1920 and a land at Nivithigalakele, a few kilometers away from the main Rubber Research Institute at Dartonfield was dedicated for the continuation of the research. Activities were further expanded through formation of an advisory section which provided the smallholders not only the technology but also quality planting materials. By 1930

all of these activities led the Rubber Research Ordinance No. 10 to become operative and allowed provisions to collect a cess on exported rubber that could then be spent on research work, under the management of a board.

It was under these circumstances that present Rubber Research Institute was established with laboratories, bungalows for the staff, land for field experiments and a factory to process rubber, on a 178 acre estate, namely Dartonfield. By 1942 this was expanded substantially with the acquisition of another 1000 acres of adjoining rubber estate in Hedigalla which provided ample area for field trials.

The country saw the need for expansion of the rubber industry and hence over the years many acts were passed to provide for it. The provision of the Rubber Research (Amendment) Act No.30 of 1951 created the present Rubber Research Institute. The Rubber Research Amendment was amended again in 1987 by Act No.39 of Parliament. It was in 1953 the Rubber Research Institute expanded greatly with the introduction of Rubber Replanting Scheme.

However, the journey of the rubber industry was not one of ease, instead it required great ingenuity and effort to overcome the many challenges in its path. Among the challenges were the dire need to enhance rubber production and productivity to ensure a sustainable rubber industry. Furthermore, owing to cyclic pattern of the rubber price, disappointed rubber farmers were driven towards crop diversification. In addition to these, many of the fertile rubber lands in traditionally rubber grown areas were acquired for other development projects.

It is when faced with challenges that more novel solutions arise. It is in keeping with this that the rubber cultivation is currently being expanded to non-traditional rubber growing areas of the country which are marginal only with regard to their climate.

With these expansions it is the expectation of the Government of Sri Lanka to see a significant increase in the rubber production which will be sufficient to cater to the demands of the local industries. Moreover, adding to the expansion of the country's rubber sector is the steady increase in the smallholders of rubber plantations which is now at 64%. However, this expansion also creates the need for better advisory programmes to guide the small holders. As a response to this growing need, the RRISL too has established several substations island wide including Kurunegala, Ratnapura and Moneragala apart from its very first location at Nivithigalakele.

The future of the rubber industry is bright and the aim is to make the rubber industry more lucrative and be able to economically compete with other plantation crops. In keeping with this aim, the objective of the Rubber Research Institute is to provide the required technologies for the rubber planters in the country through development of economically and environmentally sustainable innovation and transferring them to stakeholders while assuring decent living conditions for the plantation community.

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Preface

The Handbook of Rubber Culture & Processing edited by Dr. O.S. Peries and Mr. D.M. Fernando in 1983 was updated in 2001 along with the separation of the Agronomy and Processing sections into two separate volumes. Volume 1 contained the agronomy chapters related to rubber cultivation and was edited by Dr. L.M.K. Tillekeratne and Dr. A. Nugawela. It served as a manual for rubber planters as well as for those keen on learning more about agronomy practices of rubber cultivation. However, for the past several years the RRISL had no printed copies of this volume to fulfil the demand of the stakeholders who were thus forced to depend on only Advisory Circulars. Providing the planters with an electronic version of the Handbook did not remedy the issue, as it could not be satisfactorily utilized by them and also because the content was mostly out dated by that time. The new Chapter on Clone Identification added value to the content of the Handbook. Rubber cultivation in Non-traditional areas and Carbon trading are new additions. The Chapter on Biochemistry and Physiology is useful for students, researchers and growers. Stimulation based harvesting explains a practical and sustainable approach.

Thus 20 years after the publishing of the last Handbook on Rubber Agronomy, it is indeed a great pleasure to present the new updated Handbook for all interested stakeholders. It is an even greater pleasure to be able to present the book at a time when the rubber plantation industry in Sri Lanka is completing 140 years and when the RRISL, the first of its kind in the world, is celebrating its 117th anniversary on its original location in Dartonfield. The RRISL has contributed immensely to the progress of the rubber industry so far, not only in research and development, but also through the dynamic extension activities. Despite the ongoing research activities, a delay in adoption of these research findings has been noticed which is now felt to be a main reason for low productivity in rubber holdings in Sri Lanka. Our goal of presenting this book is to provide the stake holders with basic agronomy information along with theoretical explanations to the current recommendations, aided by figures and plates.

The book is structured to cover all agronomic recommendations required for a successful rubber plantation. It starts from an introduction to the basic requirements for a plantation, such as soil and climatic conditions and moves on to Chapters on the production of new cultivars and their genetic base. Its extent covers the wide area from the selection of rubber seeds all the way up to the production of a high quality rubber plant and explains in detail the nursery management techniques and types of planting materials. A new section on irrigation systems for nurseries is included in this Handbook for the first time.

Certain Chapters such as those on control of diseases may require reference to other Chapters like those on nursery management to fully grasp the concept. However, many Chapters stay independent and give the freedom to the reader to select a topic of their choice.

Every effort has been taken to explain the theory behind the recommendations in simple and easy to read language for the benefit of the reader. Undoubtedly, this Handbook will be invaluable to all those who are directly and indirectly involved in the rubber cultivation industry, in both large estates and smallholdings. During our long period of service to the rubber industry we have come to see that correct knowledge has always helped to adopt the recommendations properly. Thus we strongly feel that this Handbook will be an important source of information that will eventually help in the proper application of recommendations at the grassroots level. It is the expectation and the wish of the contributors that the content of this book be of benefit to the rubber industry by increasing its productivity which will lead to a sustainable rubber industry in Sri Lanka.

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Acknowledgements

First of all, I wish to thank many Planters who continuously told us the importance of having this book published for the benefit of the stakeholders. The Handbook of Rubber, Volume 1 on Agronomy published in 2001 was the model for this version, for which I am very much grateful to authors as well as to editors.

All contributors to this volume, who did a wonderful job in presenting their knowledge and experience in to small book chapters which made this Handbook a reality are appreciated. This is a collective effort of many at the Rubber Research Institute and perhaps too many to name. However, type setting of the Chapters were done by Mrs H.D.D.E. Jayawardena, Mrs M.K.A.D.Y. Madushani Lanka, Mrs H.A. Manoji Erandika and Mrs S.D.P.K.L. Peiris and their dedicated work is appreciated.

The dedicated, efficient and patient service of Mrs Ramani Amaratunga in compiling this book and the assistance given by the staff of the Library are deeply appreciated.

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Chapter 1

Land suitability evaluation and soil conservation

R.P. Hettiarachchi

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1. INTRODUCTION

Rubber (*Hevea brasiliensis*) is a fast growing tree crop, a native of Amazon tropical forests, can grow in a wide range of climate and soils. In order to achieve the best possible results the land selected for planting should follow certain standards.

2. LAND SUITABILITY FOR RUBBER

2.1 Physiography

Hevea is currently cultivated as far as North of the 25° N latitude and as far as South of the 21° S latitude. However, the main production zone, worldwide, is concentrated between 15° N latitude and 15° S latitude. Most of the world's rubber expansion occurred at altitudes of less than 900 m. The Sri Lanka rubber plantations lie within 8° of the equator and are situated between 80° 09' and 81° 04' E longitudes and 6° 50' and 7° 38' N latitudes.

Rubber is normally grown in Sri Lanka on lands varying from flat to very steep terrain. Between these two extremes, most of the rubber plantations are located in Sri Lanka on lands ranging from undulating to moderately steep terrain. Steep slopes have been recognized as a limitation for growth and productivity of rubber. Most of the rubber lands in Sri Lanka have rock outcrops on the surface in

addition to their occurrence on very steep slopes. Moreover, poor drainage and stagnation of water on the soil surface after rain can result from lands with low lying terrain or hard pan and high water table. These conditions may affect the performance of the rubber tree, causing slow establishment and significant casualties at planting.

2.2 Climate

There are three major climatic zones in Sri Lanka, viz. Wet, Dry and Intermediate zones. Rubber is grown in almost the entire Wet Zone and certain regions of the Intermediate Zone and Dry Zone. Climatic factors of importance for the successful establishment of rubber are rainfall, temperature, evaporation, relative humidity and wind.

2.2.1 Rainfall

The ideal annual rainfall for rubber should fall within the range of 2000 mm - 3000 mm with 150 to 200 rainy days per annum and uniformly distributed without any marked dry season. Both foliage and panel diseases are favoured by high rainfall and growth and yield tend to be depressed if rainfall is low. The time required for low rainfall to influence tree growth rate and yield performance depends on the moisture retention properties of the soil; this may be less than one month in free-draining sandy soils and up to two months in well structured clay soils which permit satisfactory root development to the desired depth. Although precise limits have not been established, it is generally accepted that tree performance will be severely affected if rainfall over a six month period is less than 500 mm, especially when it is not uniformly distributed throughout that period. The distribution of rainfall also influences the quantity and quality of latex harvested by interfering with tapping operations and by contact with latex. Ideally, rainfall should occur in the late evening and should cease before 03.00 hours to permit tapping from dawn, because trees are yielding best during cool mornings. Unless special guards are provided, heavy rain after tapping will reduce total crop by preventing completion of tapping and by displacement of latex from cups. The tapping of wet trees is known to spread bark rot or black stripe, a *Phytophthora* disease.

The main climatic factor affecting rubber cultivation in Sri Lanka is the incidence of rainfall. The wetter districts can benefit from both the Southwest and the Northeast monsoons, whilst the drier districts have to rely on the Northeast monsoon, which can be irregular in most occasions.

2.2.2 Temperature and altitude

Being an island nation, the temperature conditions in different physiographic regions in Sri Lanka do not show much variation. The annual average temperature in the lower peneplain is more or less uniform, approximately 27.8 °C. In the transitional area, somewhat cooler conditions are found; with temperature lower by about one or two degrees Celsius. The mean annual

temperature in the Wet Zone is about $28^{\circ}\text{C} \pm 2^{\circ}\text{C}$. The temperature ranges from $20^{\circ}\text{C} - 25^{\circ}\text{C}$ during night to $30^{\circ}\text{C} - 35^{\circ}\text{C}$ during the day in the months of December - February.

The ideal mean annual temperature for rubber should be within the range $23^{\circ}\text{C} - 28^{\circ}\text{C}$ and temperatures should not fall below 20°C for more than a few weeks. The temperature decreases by about 0.6°C per 100 m in height increase. In such conditions, Hevea will grow most rapidly below 200 m, and trees require approximately 3 - 6 months longer to reach tappable size with each rise of 200 m above sea level. Moreover, at lower temperatures potentially damaging diseases, such as Phytophthora secondary leaf fall and Oidium leaf disease, are more common. Very high temperatures, in excess of 30°C over a prolonged period, also adversely affect tree performance by increasing evapotranspiration to the extent that physiological processes are impaired.

2.2.3 Relative humidity

The relative humidity ranges are generally uniform except in the high elevation area with the afternoon values being generally less than the morning values.

High relative humidity favours crop growth with reduced evapotranspiration and consumptive use of water. However, high incidence of diseases can be a problem for rubber production under high humidity conditions.

2.2.4 Sunshine

The duration and intensity of sunshine should have a significant influence on latex sucrose levels. An increase in sunshine duration towards the end of the rainy season is often associated with an increase in latex production. Also, lower latex production during the rainy season can be attributed to reduced sunshine hours. High radiation and its long duration from December to May cause scorching of bark in young rubber plants. The optimum annual sunshine requirement is about 2000 hours, at the rate of six hours per day in all months.

2.2.5 Wind

Rubber trees are susceptible to damage by strong winds and clones differ in their susceptibility. The most wind-prone clones may suffer severe damage in gales of over 40 knots, but even the most wind-resistant clones suffer severe damage in windstorms of force exceeding 10 on the Beaufort scale (upto 56 knots). The extent of wind damage depends on the timing of winds; trees devoid of foliage suffer least damage whilst trees bearing dense canopies of moisture laden foliage shortly following refoliation are at the greatest risk.

Recognizing that climate forms the first major part of any land evaluation exercise, a method to assess the suitability of climate for rubber is given in Table 1.1. The evaluation of the climate should be used in combination with the evaluation of the soils and landscape features.

Table 1.1. Climatic requirements for Hevea cultivation.

Climatic characteristics	Degree of limitation*				
	0	1	2	3	4
Mean temperature (°C)	28 - 25	24 - 22	21 - 20	19 - 18	< 18
		29 - 30	31 - 32	33 - 34	> 34
Mean daily maximum temp. (°C)	34 - 29	28 - 27	26 - 24	23 - 24	<22
Mean daily minimum temp.(°C)	> 20	20 - 19	18 - 17	16 - 15	< 15
Mean annual rainfall (mm)	>2000	2000 - 1750	1749 - 1500	1499 - 1250	< 1250
Expected total rain interference (days/yr)	0 - 30	31 - 60	61 - 90	> 90	
Sunshine (hours/yr)	2100	2100 - 1800	1799 - 1400	1399 - 1000	> 1000
Mean annual R.H. (%)	< 80	80 - 100			
Length of dry season (months/yr)	0 - 1	2 - 3	4	5 - 6	> 6

*0 - No limitation, 4 – very serious limitation

2.3 Soil factors

Many soils of different origin as well as morphological characteristics can support a viable rubber plantation. However, its performance and economic viability can be controlled by the limitations of particular land or soil characteristics. Under such limiting conditions, to ensure high growth and yield levels by the establishment of intensive and costly soil management practices. The performance of rubber tree is affected severely by adverse soil conditions of physical, chemical, physicochemical and physiographic features of soil and influence the growth and productivity of rubber to a considerable extent. Physiographic factors such as soil depth, degree of slope, rockiness *etc.* have been identified as factors affecting growth and yield of rubber. Minimum depth of 100 cm, slope up to 20% and less than 50% rock out crop on the surface have been identified essential for successful establishment of rubber.

A land suitability evaluation system for rubber cultivation is made up of a framework of the best soil and physiographic features which are considered as suitable range for optimal growth of rubber.

The poorer soils have properties which limit the optimal growth and performance of rubber and these are recommended as suitable range with corrective measures and not suitable range.

The criteria considered in the evaluation system are as follows:

2.3.1 Suitable range of physical properties

- Soil depth up to 100 cm, free of pan/rock outcrop hindrance
- Well drained
- Good soil aeration
- Good soil structure
- Good water-holding capacity

- Soil texture with sufficient clay (preferably a minimum amount of 20% clay to retain sufficient moisture and nutrients and about 65% - 70% sand to allow for expression of good physical soil properties like aeration and drainage).

2.3.2 Suitable range of environmental and physiographic features

- Gently sloping or rolling terrain with between 0-20% slopes and minimal soil erosion and surface run-off
- Less than 50% rock outcrop in a unit area
- Water-table should be deeper than 100 cm.
- No stagnation of water on soil surface

2.3.3 Suitable range of chemical properties

- At least medium levels of total nutrient contents of nitrogen (N), phosphorus (P), potassium (K), and magnesium (Mg) with no deficiency of trace elements
- A pH of around 4.5 - 6.0
- Soil organic carbon of about 2-3%
- Absence of saline/acid sulphate conditions

Limitations of the properties influence good crop performance and can be graded as suitable range with corrective measures and not suitable range

2.3.4 Suitable range with corrective measures

- Slopes steeper than 20% but less than 45%
- Water-table should be lesser than 100 cm.
- Weak soil structure
- Soil organic carbon less than 2%
- Moderate drainage conditions, susceptibility of flooding and stagnation of water from 1-3 days at the surface even after light rain
- Susceptibility to soil erosion
- Sub-optimal soil nutrient status, reflected by low contents of nitrogen, phosphorus, potassium and magnesium

2.3.5 Not suitable range

- Slopes steeper than 45%
- Massive thick hard-pan at or very close (within 20 cm) to the surface
- More than 50% of rock outcrop in a unit area
- Permanent water-table at or near (within 20 cm) the surface

- Strong compaction influencing permeability and infiltration
- Prolonged water logging more than 3 days at the surface with light rain
- Poor structure (too sandy with more than 90% sand)
- Poor nutrient status.

3. LAND PREPARATION

Rubber plantations are no longer raised in virgin forests and most of the rubber growing soils are either in the third or the fourth cycle of replanting. They are generally situated on sloping lands with varying degrees of steepness and the intensity of rainfall recorded in these areas had also been very high. At the time of replanting the old stand of rubber is cleared and it results in bare patches of soil. These conditions may create deteriorated nutrient reserves, change their hydrological parameters and productive potential of the site unless it is carefully managed. Exposure of the bare soil to the environment and the impact of rain drop results in accelerated decomposition of the organic matter, leaching of the nutrients, breakdown of the aggregate structure of the surface soil, decreased infiltration of the rainfall water. Except on flat lands, surface layer of fertile top soil could easily be washed away with runoff water and leave behind less fertile sand and stone. To avoid these ill effects as far as possible, exposure of the bare land should be minimized and the clearing and cultivation methods employed should disturb the soil as little as possible and those conditions may leads to less damage of soil structure.

At the earliest opportunity after clearing, it is necessary to practice various soil conservation measures, in order to protect and preserve native soil fertility.

The importance of employing appropriate clearing methods and other, well-tried laborious measures designed to conserve soil, water and nutrients are nowadays generally appreciated, but, partly because of the cost, the required procedures are not always fully implemented. However, prevention of the capital loss represented by the erosion of valuable, and non-renewable resource of surface soil is normally well worth than the initial expenditure on effective soil conservation.

3.1 Soil conservation

Erosion is one of the most serious detrimental effect that can occur in soil. It can be defined as the removal of soil by the forces of water or wind. Rubber plantations in Sri Lanka are generally situated on sloping land with varying degrees of steepness and the intensity of rainfall recorded in these areas is also very high. Over half of the rubber lands in Sri Lanka are losing productivity because top soil is being washed away faster than its replacement by natural forces.

Improper soil conservation practices cause (1) dispersion of soil aggregates through direct rainfall impact and removal of the binding substances, (2) soil particles to be washed into the cracks and pores of the soil body and making it less pervious to air and water, (3) decreased infiltration rate and aeration capacity

through exposure of clay plan, (4) removal of fertile top soil, (5) differential removal of the more valuable constituents of the soil, such as clay, organic matter and plant nutrients leaving behind sand and stones and (6) sedimentation of ponds, reservoirs and streams and covering flood plains with increasingly worse soil materials. Therefore, proper use of land must be ensured in order to preserve the productivity and fertility of the soil. This can be brought about by introducing appropriate soil conservation and agro-management practices, which may be grouped under three headings: 1. agricultural, 2. biological and 3. mechanical.

3.1.1 Agricultural

- (i) *Land preparation:*
Land preparation should be completed before the monsoon.
- (ii) *Contour planting:*
Planting should be done on the contour on steep or undulating land.
- (iii) *Maintenance of embankment and fences:*
Weeds on embankments and on areas close to the fences should not be completely removed. They should be kept under control by slashing or chemical weeding, because clean weeding not only exposes the soil surface, but also leaves behind a layer of loose soil that can be easily washed away by run-off water.

3.1.2 Biological

- (i) *Ground covers:*
It is essential to establish a suitable leguminous ground cover that will not compete with rubber for nutrients and moisture, to serve as live mulch after clearing the land (Plate 1.1a). In the wet zone regular showers are experienced in March, which permit the establishment of ground covers. These help to conserve the soil in the following manner:
 - Direct protection of the soil surface by the leaves and stems from wash by rain or blowing by wind
 - Binding the soil together by the root system of the cover plant
 - Formation of miniature bunds, which help to prevent surface wash
 - Breaking up the movement of water over the soil
 - The soil is opened and kept porous by the roots.
- (ii) *Hedges:*
Vetiver grass is a well-known plant that can be grown as hedges to prevent soil erosion and increase moisture conservation (Plate 1.1b). This system must form a continuous hedge along the contour to be effective, and takes 2-3 growing seasons to establish as a dense hedge. Vetiver grass helps to conserve the soil by

- binding the soil along the contour by its deep, strong, dense root system
- slowing down the runoff water, filtering out the soil it is carrying and spreading it out down the slope
- forming natural terraces
- forming a good mulch by death and decay of leaves.

Apart from these, this conservation system

- is extremely cheap and fits well into low technology planting systems
- does not require maintenance for many years
- disturbs very little soil during establishment.

(iii) *Mulching:*

Mulching with plant residues had been found to be very effective in not only avoiding evapotranspiration losses but also in providing more nutrients and preventing run off and soil erosion losses.

Soil losses likely to occur due to erosion from bare land which are in the region of 60-65 MT/ha/yr could be eliminated by mulching. Any cover treatment other than mulching normally takes 6-12 months before providing sufficient protection to the soil. Therefore, it is a good practice to mulch the soil, at least around the base of the rubber tree, immediately after planting and at least until the legume covers are fully established (More details in Chapter 3).

3.1.3 Mechanical

i. *Drains:*

i(a) Main drains :

Normally natural drain lines already indicated in the land should be used except in cases where the distance between two natural drains becomes excessive, for example more than 60 m. On sloping land, the correct siting of these main drains is more important than the distance between them. The natural main drains can be improved by the construction of reverse slope pits, "spill platforms" and "splash cushions", with stone slabs. These will tend to reduce bank erosion while checking the rate of flow of water down the drain lines (Plate 1.1c).

i(b) Lateral drains :

All lateral drains should be on the contour with a slope of approximately 1 in 120. Construction of these drains should be completed before the heavy rains especially if a ground cover has not been established satisfactorily. This type of drains generally consists of a series of silt pits 3 m long, 60 cm wide and 45 cm deep, spaced at intervals of 90 cm and connected by shallow drains on a depressed bund of the same width. What is aimed at in these drains is that excess water is carried away from each deep section to

the next deep section over the shallow section while the transport of silt which gets deposited in the deeper section is prevented.

The tracing of the lateral drains can be done independently of the planting rows, commencing between two planting rows, which are approximately level contours; the spacing of lateral drains can bring the drain lines within 1.5-1.8 m (5-6 ft.) of the planting rows. The following spacings for lateral drains would be suitable for the satisfactory control of run-off water:

- (a) Spaced 14.5 m (48') apart for gradients between 1 in 25 and 1 in 5
- (b) Spaced 7 m (24') apart for gradients between 1 in 5 and 1 in 2.

The earth cut from the drain should be heaped up on the upper side of the drain, in a continuous ridge. The cutting of drains should be started at the top of the slope. Soil deposited in the lateral drains should be cleared regularly. This soil can be deposited uniformly in areas above the drain.

ii. *Stone terraces:*

On very rocky land, where it is impossible to cut continuous lateral drains, the soil conservation needs are partially satisfied by the construction of level contour stone terraces (Plate 1.1d). These terraces can check the rate and distance of movement of surface run-off water. The eroded soil will be deposited on the upper sides of the terraces and water will filter through the terraces. As in the case of lateral drains the distances between terraces should be adjusted according to the slope of the land.

In the construction of stone terraces, the following aspects need special attention.

- (a) The upper side of the terrace should be on a perfect contour.
- (b) For greater stability, the base of the terrace should be wider than the top.
- (c) The lower side of the terrace should have a slope towards the hill side.
- (d) The base of the terrace should be built with large even stones. The stones should be laid with a reverse slope to that of the land. To achieve this, beds should be cut into the hill side. Stone terraces can be built with 90 cm base converging to 30 cm at top level and 45 cm above ground level on the upper side.

Whatever the method that may be practiced, the objectives of this exercise should be to improve the structure of the soil so as to make it resistant to detachment and transportation and more absorptive of surface water; covering the surface to protect it from rainfall impact, slowing down run-off and providing safe ways for the disposal of excess run-off.



Plate 1.1. Soil conservation measures. **a.** Leguminous ground covers on sloping land; **b.** Vetiver hedges; **c.** Main drains; **d.** Stone terraces.

Chapter 2

Rubber growing soils and their characteristics

R.P. Hettiarachchi

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1. INTRODUCTION

Hevea can grow on a vast variety of soils where other tree crops might fail. It is grown widely in acidic soils of the humid tropics. However, its performance and economic viability can be restricted severely where there is a limitation of a particular soil. Soil is an important component influencing the establishment, growth and yield of rubber. An understanding of the numerous factors affecting soil fertility is a prerequisite to proper management of soils for

better performance of rubber. Suitable agro-management practices can be planned and implemented only upon knowing the physical, chemical and biological characteristics and limitations of a particular soil.

In essence, rubber can best be grown in areas where the soil is deep, well drained with no compacted or impermeable horizons close to the surface and with no toxic or extreme deficiency levels of nutrients. At the same time, the soil should be able to retain and supply sufficient nutrients and moisture for proper plant growth. However, the suitability of soils for better establishment of *Hevea* will vary on the prevailing physical, chemical and biological characteristics of the soil.

2. CLASSIFICATION OF RUBBER GROWING SOILS OF SRI LANKA

Many attempts have been made to classify rubber growing soils with parallel to the soil map developed by De Alwis and Panabokke (1972). Most of the rubber growing areas belongs to Great Soil Group of Red Yellow Podzolic Soils (in the wet zone), Reddish Brown Latosol soils and Immature Brown Loam soils (in the Wet and Intermediate Zone). The Great Soil Groups in the 1972 classification were refined as soils showing similar sequence of soil horizon immaterial of the depth. Subsequently, Silva (1972) went one step ahead and classified the rubber growing soils at Series level, where a series was defined as a soil having the same horizon sequence and developed from similar parent material. The series level classification was more useful for management aspects as the RRI could develop series based management practices as fertilizer recommendations.

With the advancement of Soil Science there was a need to classify soils of Sri Lanka using international methods and to be mapped in detail. Therefore Mapa *et al.* (1999, 2005, and 2007) classified the soils of Sri Lanka according to International methods as Soil Taxonomy (USDA) and WRB legend (FAO). The information such as soil moisture, temperature regimes and soil mineralogical data was lacking, classifying according to Soil Taxonomy was only done to sub-group level.

2.1 Great soil groups

All soils that belong to a particular great soil group will have a similar sequence and arrangement of master horizons and sub horizons within the soil profile. Growing of rubber in Sri Lanka was mostly confined to three groups: Red Yellow Podzolic (RYP), Reddish Brown Latosolic (RBL) and Immature Brown loams (IBL). These soil groups are found in the traditional rubber growing areas such as the low country and mid country of wet zone. At present rubber cultivation is being promoted into non-traditional drier areas in the intermediate and dry zones in order to increase the natural rubber production in Sri Lanka. Reddish Brown Earth (RBE) soils are the dominant soil group in these areas.

2.1.1 Red Yellow Podzolic (RYP) soils

The Red Yellow Podzolic soils are predominant in the rubber growing districts of Kalutara, Galle, Matara, Ratnapura, Avissawella and Monaragala. These soils are formed from colluvium or local alluvium derived from a wide variety of crystalline metamorphic rocks. The dominant rocks from which the soil parent materials have been derived are basic charnockites, garnet-biotite gneisses and quartzitic rocks. Red Yellow Podzolic soils are well to moderately well drained, deep to very deep, reddish to yellowish, moderately fine textured, highly leached and strongly acid soils.

2.1.2 Reddish Brown Latosolic (RBL) soils

The Reddish Brown Latosolic soils occur mainly in the Kegalle, Mawanella, Kurunegala and Matale regions. These soils are formed from slope colluvium and residuum on basic and intermediate type rocks of the highland series. In some locations, these soils are formed from acid rocks such as quartzite and acid charnockites.

2.1.3 Immature Brown Loams (IBL) soils

These soils mainly occur in Mawanella rubber growing areas. The soil profile is at intermediate level of development with genetic horizon sequence of A, Bw, C horizons. Even if these soils are shallow in the sense of depth to the parent material, it does not affect rubber root growth as the parent material is soft and roots could penetrate through. As these soils are developed from micaceous schists, the soil is rich in potassium than many other soils due to release of micas from rock weathering.

2.1.4 Reddish Brown Earth (RBE) soils

Well drained areas in most of the dry zone and some parts of the intermediate zone consist of RBE soils. They have been derived from quartzitic and metamorphic rocks. They are red in color and have neutral pH values. Since they are located in relatively dry areas, nutrients are not as leached as in rubber growing soils in the wet zone. Since their clay content is high, they tend to become very hard upon drying and slippery when wet.

2.2 Soil series

Soils that developed from the same parent material under similar conditions and have same sequence of master horizons and sub horizons with in the profile belong to the same soil series. The name of the soil series is usually derived from the place where the soil was first identified. In these rubber growing areas seven important soils series have been identified by the Rubber Research Institute (RRI) (Table 2.1 and Plate 2.1). Fertilizer recommendation for rubber is based on the characteristics of these soil series. A brief description of each soil series is given below.

Table 2.1. Different soil series of rubber growing areas.

Soils series	Great soil group	Soil taxonomy
<i>Ratnapura</i>	Red Yellow Podzolic	Ultisols
<i>Homagama</i>	Red Yellow Podzolic	Ultisols
<i>Agalawatta</i>	Red Yellow Podzolic	Ultisols
<i>Boralu</i>	Red Yellow Podzolic	Ultisols
<i>Matale</i>	Reddish Brown Latosolic	Ultisols
<i>Parambe</i>	Reddish Brown Latosolic	Ultisols
<i>Deniya</i>	Low humic gley	Alfisol

2.2.1 *Parambe series*

Parambe series soils are derived from micaceous parent materials, the most common such parent material being a biotite genesis. These soils are deep, sandy clay loam in texture and yellowish brown in colour. There are glistening specks of mica throughout the soil mass. These soils are high in potassium. The main areas where *Parambe* series soils occur are the Kegalle and Kandy districts (Plate 2.2a).

2.2.2 *Matale series*

Matale series soils are derived from residual materials and the erosion products of crystalline limestone deposits. These soils are deep, sandy clay loam in texture and dark brown to reddish brown in colour. The limited, sporadic occurrences of these fertile soils are found mainly in Matale district (Plate 2.2b).

2.2.3 *Homagama series*

Homagama series soils are derived from highly quartzitic rocks. They have a very scattered distribution and are easily identified by the presence of quartz gravel in the profile. These soils are moderately deep, sandy loam in texture and strong brown to reddish brown in colour. They have a low potassium status. *Homagama* series soils occur extensively around Yatiyantota, Dehiowita and Deraniyagala (Plate 2.2c).

2.2.4 *Agalawatta series*

Agalawatta series soils are derived from granite rocks, a large percentage of which is hypersthene granite. These soils are variable in depth, with boulders and outcrops of the granitic rocks. They are sandy clay loam in texture and strong brown to yellowish red in colour. They have a medium potassium status. These soils occur over a wide area of the steeply dissected hills which flank the Sinharaja forest (Plate 2.2d).

2.2.5 *Ratnapura series*

Ratnapura series are residual soils derived from garnetiferous parent materials and found mainly in the Ratnapura district. These soils are rather shallow, sandy clay loam in texture and yellowish brown in colour, overlying

more yellowish sub-soil, characteristically containing small amounts of garnetiferous gravels. They have a medium potassium status (Plate 2.3a).

2.2.6 Boralu series

Boralu series soils are derived from rocks of the Vijayan and Khondalite rock series. In soils of this series the parent material appears to reflect less on profile development and the processes of laterisation are predominant. The presence of laterite at different depths is a diagnostic character of this soil series. These soils are shallow, sandy clay loam in texture, brown to reddish yellow in colour and overlying cabook. They have a low potassium status. These soils are found in the gently undulating zones and low hills, on which the Southern rubber growing areas extend westward towards the coast (Plate 2.3b).

2.2.7 Deniya series

Deniya series soils are shallow, variable in texture, poorly drained, frequently waterlogged and often subject to flooding. These soils occur extensively in valley bottoms where they are used for rice cultivation; very little rubber growing is attempted on them (Plate 2.3c).

3. SOIL CHARACTERISTICS AND SOIL REQUIREMENTS

Soil is a highly heterogeneous system consists of four components. Organic matter and mineral matter comprises the solid phase of the soil while water and air occupies the void phase (or pore spaces). These four components are mixed in complex patterns and interact with each other in numerous ways at their interfaces to give rise to different properties of a soil.

An understanding on the numerous factors affecting soil fertility is a prerequisite to proper management of soils for better performance of rubber. Suitable management practices can be selected and implemented only upon knowing the physical, chemical and biological characteristics and their limitations of a particular soil.

3.1 Physical characteristics

Soil physical properties remain as the least amenable characteristics and these properties of a soil which determine growth of rubber plants are generally those which influence the extent of root proliferation, air and water movement and availability of water.

If the productivity of soil is to be maintained, the physical condition of the soil must be preserved satisfactorily. Soil degradation is usually described as a deterioration of soil physical properties. In the soil surface physical degradation implies a loss of porosity, often resulting from the formation of surface crust which leads to decreased water entry, increased runoff and increased erosion in rubber lands. In the subsoil, compaction will lead to hinder the development of rubber roots. A good soil physical condition is therefore, important in promoting growth and yield of rubber.

3.1.1 Soil colour

Generally soil colour is important to identify a soil, distinguish different horizons of a soil profile and also in soil classification. Most soil colours are derived from the colours of iron oxides and organic matter that coat the surfaces of soil particles. Organic coatings tends to darken the soil. This parameter depends on some inorganic ions like Fe and Mn. Hydrated Fe usually gives a yellow colour to the soil while dehydrated Fe gives a red colour. Soil colour also depends on the drainage conditions of the soil. The soil colour of different soil series is given in Table 2.2.

Table 2.2. Soil colour of different soil series.

Soil series	Soil colour
<i>Parambe</i>	Brown
<i>Matale</i>	Dark brown to reddish brown
<i>Homagama</i>	Brown to reddish brown
<i>Agalawatta</i>	Brown to yellowish red
<i>Ratnapura</i>	Yellowish brown
<i>Boralu</i>	Brown to reddish yellow

3.1.2 Bulk density

A second important measurable property of soil is bulk density, which is defined as the mass (weight) of a unit volume of dry soil. This volume includes both solid and pores. Soils with a high proportion of pore space to solids have lower bulk densities than those that are more compact and have less pore space. Consequently, any factor that influence soil pore space will affect bulk density. Moreover, the bulk density generally is higher in lower-profile layers. The land management practices in a given soil influences its bulk density. Increased bulk density often indicates reduced infiltration of rainwater and restricted root growth. The bulk density of different soil series is given in Table 2.3.

3.1.3 Porosity

Porosity indicates the proportion of soil volume not occupied by solids. The value of bulk density can be used to calculate the porosity of soil. For the growth of plant roots and the movement of water, air and solutes in soils, the volume and configuration of space between the solid particles are of critical importance. Porosity inversely related to the bulk density of the soil. Restricted soil aeration inhibits root development, impairs the process of respiration of the root system and inhibits beneficial microbial activities. The porosities of some common soil series under *Hevea* are shown in Table 2.3.

Rubber growing soils and their characteristics

Table 2.3. Bulk density and porosity of different soil series.

Soil series	Bulk density (g/cm ³)	Porosity (%)
Parambe	1.15	56.70
Matale	1.20	54.88
Homagama	1.38	48.12
Agalawatta	1.22	54.13
Ratnapura	1.28	51.87
Boralu	1.30	51.12

3.1.4 Soil texture

The relative proportion of different size mineral particles; sand, silt and clay in a soil refer to as soil texture. The texture of various horizons is often most important property and the grower can draw many conclusions from this information. Furthermore, the texture of a soil is not readily subject to change, so it is considered a basic property of a soil. Sand is defined as particles smaller than 2 mm but larger than 0.02 mm. Sand particles are generally visible to the naked eye and promote free drainage of water and the entry of air into the soil. Because of their large size, particles of sand have relatively little surface area for a given weight or volume. Therefore, sand particles can hold little water, and soils dominated by sand are promote low moisture availability to the plant. Particles smaller than 0.02 mm but larger than 0.002 mm in diameter are classified as silt. Silt is composed of particles similar in shape to sand, it feels smooth. The pores between silt particles are much smaller than those in sand. Therefore, it has a much higher water-holding capacity. Particles smaller than 0.002 mm are classified as clay and have a very large surface area and giving a remarkable capacity to absorb water and plant nutrients.

The various combinations of sand, silt and clay give rise to different textures. For example, a clayey soil has a dominant clay content (at least 40% of clay). Similarly, a sandy soil has a dominant sand content (at least 85-90% of sand). The particle size distribution and textural class of the different soil series are given in Table 2.4.

Table 2.4. The particle size distribution and soil textural class of different soil series.

Soil series	Particle distribution (%)			Soil textural class
	Sand	Silt	Clay	
Parambe	55-65	10-15	28-34	Sandy clay loam
Matale	60-70	7-10	20-30	Sandy clay loam
Homagama	65-75	8-12	10-20	Sandy loam
Agalawatta	60-70	9-12	20-30	Sandy clay loam
Ratnapura	55-65	7-12	20-30	Sandy clay loam
Boralu	65-75	5-10	20-30	Sandy clay loam

The texture of soils influences other physical properties and their behavior under cultivation. For example, a sandy loam soil like the *Homagama* series is

usually loose, well drained and retains little available water for growth of rubber plants. When water is limiting, the yield of rubber can also be lower on sandy soil compared to clayey soil. Better growth and establishment of rubber are obtained on clayey than sandy soils. This is expected since the inherent physical and chemical characteristics of clay give it the capacity to retain more nutrients and water. However, a correlation study on the effect of soil texture on root development showed that the root density was positively correlated with the sand content and negatively correlated with the clay content.

Soil texture with sufficient clay, preferably a minimum amount of 20% to retain adequate moisture and nutrients and about 70% sand to allow for expression of good physical soil properties like aeration and drainage can be considered as desirable for optimum rubber cultivation.

3.1.5 Soil structure

Soil structure relates to the grouping or arrangement of soil particles. It describes the gross, overall combination or arrangement of the primary soil particles into secondary groupings called aggregates or peds. Soil conditions and characteristics such as water movement, heat transfer, aeration and porosity are much influenced by structure. Many types of structural peds occur in soil. A particular soil profile may be dominated by a single type of structure. More often, however, several types are encountered in the different horizons. The structure of the surface horizon is generally subject to alteration by soil management practices.

Soil structural properties have a major influence on root growth. A soil with good structure and friable consistency is a good medium for root growth. This will allow the soil to be exploited fully. As such, the tree can have a good anchorage and be able to have a large source of water and nutrients. In fact, good soil structural properties have a good effect on the growth of rubber.

Soil is the medium where the rubber tree is anchored and will be critical for a tree crop like *Hevea*, which extends its roots far and deep. Basically, a well structured deep soil is found to sustain better wind resistance than a poorly structured shallow soil. Shallowness of a soil is mainly the result of the presence of a compact lateritic band, quartzite band or a laterized parent material layer in the profile or due to soil compaction. These less penetrable zones impede downward root penetration. The depth at which the compacted band occurs within a soil series can vary. Rubber plants tend to form stunted and knotty roots when grown on compacted soils.

3.1.6 Water holding capacity

The availability of water to the plants is determined not only by the intensity and distribution of rainfall, but also by the quantity of water that is actually retained in the soil. Thus, moisture characteristics are important physical properties of soils (Table 2.5). The maximum capacity of the soil to hold water is termed "water holding capacity". This is equivalent to the amount of water held at saturation. However, the water that is considered to be available to the plant is

limited to the field capacity as the upper limit and the permanent wilting percentage as the lower limit.

Table 2.5. Availability of moisture in different soil series.

Soil series	SMSC* (cm)	Volumetric moisture content (%)		
		-10kPa	-500kPa	-1500kPa
<i>Parambe</i>	22.9	37.5	34.7	32.8
<i>Matale</i>	22.4	36.3	33.4	32.5
<i>Homagama</i>	18.3	31.2	29.2	28.7
<i>Agalawatta</i>	19.7	33.4	31.1	29.3
<i>Ratnapura</i>	20.3	32.9	30.5	29.5
<i>Boralu</i>	19.3	32.7	30.1	29.6

*Soil Moisture Storage Capacity (SMSC) for 90 cm soil profile

3.2 Chemical characteristics

Owing to the humid tropical climate, the soils of Sri Lanka are highly weathered and leached. Most of the rubber growing soils are poor and low chemical fertility. Factors such as pH, organic matter content, cation exchange capacity, base saturation, sesquioxide content and physical characteristics of the soil also influence its chemical fertility. Important soil chemical properties influencing rubber cultivation have been identified as nutrient status, soil pH, soil organic matter content and cation exchange capacity.

3.2.1 Soil pH

Tropical climatic conditions prevailing in rubber growing areas of Sri Lanka with heavy rainfall and high temperature have left highly weathered laterite and lateritic type soils. These soils are frequently acidic in reaction and pH usually ranges from 4-6 and considered as optimum range for successful establishment of rubber in Sri Lanka. However, deviating conditions such as <3.5 or >6.5 are not favorable for rubber. Soil pH is a very important property correlated other soil parameters like base saturation, nutrient release and their availability (Table 2.6). The presence of aluminium (Al) and iron (Fe) increases phosphorus (P) fixation in acid soils.

3.2.2 Soil Electrical Conductivity (EC)

Soil electrical conductivity is an indirect measurement that correlates very well with several soil physical and chemical properties. It is the ability of a material to conduct (transmit) an electrical current and it is commonly expressed in units of milliSiemens per meter (mS/m) or deciSiemens per meter (dS/m). Electrical conductivity of a soil extract gives a satisfactorily accurate indication of the total concentration of ionized constituents in the soil solution.

3.2.3 Soil organic carbon

It is known that a rubber plantation is a very effective self-sustaining recycling system where the soil organic carbon content is maintained by the process of annual leaf foliation. In addition, leguminous cover crop increases organic carbon content in rubber growing soils (Table 2.6). Although the tropical soils of Sri Lanka in general contain relatively low amounts of organic carbon content and it is ranging from 1-2% in most of the rubber growing soils. Organic matter binds mineral particles into a granular structure and is probably responsible for the loose, easily managed condition of cultivated soils. This probably contributes to improve soil physical properties such as bulk density, porosity and water holding capacity of soils. Organic matter also increases the amount of water content in the soils and decomposition of organic matter are very effective in improving the fertility status of cultivated soils

3.2.4 Cation Exchange Capacity (CEC)

The total of the exchangeable cations that a soil can adsorb is termed as cation exchange capacity. This is expressed in terms of moles of positive charge adsorbed per unit mass and for the convenience of expressing CEC in whole number it, is presented as centimoles of positive charge per kilogram of soil (cmol₊/kg). Rubber is grown in soils with a wide range of CEC (Table 2.6). Due to low values of CEC in most rubber growing areas, added fertilizers can be frequently lost through leaching as well. Therefore, fertilizer split application is an accepted practice for rubber plantation and proper organic matter/crop residue management appears to hold promises to overcome this problem in a systematic way.

Table 2.6. Soil pH, organic Carbon (OC) and cation exchange capacity (CEC) of different soil series.

Soil series	pH	OC (%)	CEC (emol./kg)
Parambe	4.5-5.0	1.0-1.5	4.5-5.5
Matale	5.0-6.0	1.0-1.6	5.5-6.5
Homagama	4.2-5.2	0.8-1.2	2.2-2.7
Agalawatta	4.5-5.5	1.2-1.6	3.0-3.5
Ratnapura	5.0-5.5	1.1-1.5	3.0-3.7
Boralu	4.5-5.5	0.9-1.3	2.5-3.0

3.2.5 Nutrient status

Soils normally play a major role in determining the availability of nutrients to plants. The influence of this availability is primarily through the mineral reserves in the soil and the nutrients added to the soil. Soils contain different proportions of nutrients considered to be important for rubber trees, *viz.* nitrogen, phosphorus, potassium and magnesium (Table 2.7). Because of the extremely hot and wet tropical climate, the highly weathered soils of Sri Lanka, are unable to supply adequate amounts of all the nutrients which are required by

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rubber plants. The continuous cultivation of such monocultural cropping systems throughout the last several decades has reduced fertility and productivity of soils due to degradation of physical, chemical and biological properties encouraged by soil erosion, reduction of soil organic matter, alteration of pH and nutrient removal by crops, timber. The amount of nutrients removed by the crop is negligible, while large amounts of nutrients are locked up in the process of biomass accumulation and lost through timber during replanting. Therefore, gradual depletion of nutrient reserves in the soils through the cycles of replanting are being brought more marginal and depleted soils. Therefore, application of required amount of nutrients in the form of fertilizers is an accepted practice for rubber in order to sustain optimum growth and productivity.

Table 2.7. Categorization of nutrient contents in rubber growing soils of Sri Lanka.

Nutrient	Very low	Low	Medium	High	Very high
Total N (%)	<0.05	0.05-0.10	0.11-0.25	0.25-0.40	>0.40
Available P (ppm)	<5	5-12	12-30	>30	-
Exchangeable K (ppm)	<50	50-100	100-150	>150	-
Exchangeable Mg (ppm)	<18	18-30	30-50	>50	-

3.2.5.1 Soil nitrogen

Nitrogen is an important major nutrient required for all growth phases of the rubber plant. In all the soil series, total nitrogen levels are from 0.08% to 0.18% (Table 2.8).

3.2.5.2 Soil phosphorus

In all soil series, exchangeable phosphorus levels are medium and high, ranging from 20 ppm to 40 ppm (Table 2.8).

3.2.5.3 Soil potassium

The highest exchangeable potassium is in *Parambe* series, while relatively low levels are encountered in the *Homagama* series. In the other soil series, exchangeable potassium levels are low, ranging from 50 ppm to 90 ppm except the *Boralu* series (Table 2.8).

3.2.5.4 Soil magnesium

The exchangeable magnesium values are highest in the *Matale* series which has about 200 - 300 ppm. This of course is quite understandable because the *Matale* series soils are derived from dolomitic limestone which is rich in both calcium and magnesium (Table 2.8).

Table 2.8. Approximate major nutrient contents in different soil series.

Soil series	Total N (%)	Available P (ppm)	Available K (ppm)	Available Mg (ppm)
Parambe	0.12-0.18	22-40	90-150	45-65
Matale	0.12-0.17	25-35	70-90	200-300
Homagama	0.08-0.11	20-30	35-50	15-25
Agalawatta	0.09-0.14	25-40	55-65	22-30
Ratnapura	0.10-0.14	22-35	50-70	25-35
Boralu	0.09-0.13	20-35	40-60	20-30

3.2.5.5 Soil micronutrients

Micronutrients are required in small quantities and every element has certain specific role in the plant. Rubber trees are not yet reported of any deficiency symptoms of micronutrients. Although rubber cultivation in Sri Lanka is currently in the third or fourth cycle, regular removal of nutrients *via*. latex and timber in addition to leaching, erosion and other losses from *Hevea* ecosystem, demands replacement of these nutrients. While lack of micronutrients often limits rubber tree performance and high amounts of trace elements are toxic to rubber plants. For example, high amounts of manganese or boron may cause stunted plants. Furthermore, the difference between deficient and toxic levels may be very narrow.

3.3 Biological characteristics

A large number of organisms live in the soil. They perform a variety of functions for their growth and reproduction. Microorganisms play a significant role in maintaining the dynamic of soil fertility and plant growth. Primarily these bacteria employ beneficial effects on growth of plants *via*. direct and indirect mechanisms; fixation of atmospheric nitrogen, solubilization of minerals like phosphorus, secretion of stimulating hormones auxins, *etc.*

3.3.1 Soil microbial biomass

Microbial biomass is a measure of the weight of microorganisms in soil, which mostly consists of bacteria, fungi and other microbes called archaea. Microbial biomass usually measure either the weight of carbon or nitrogen in soil microorganisms.

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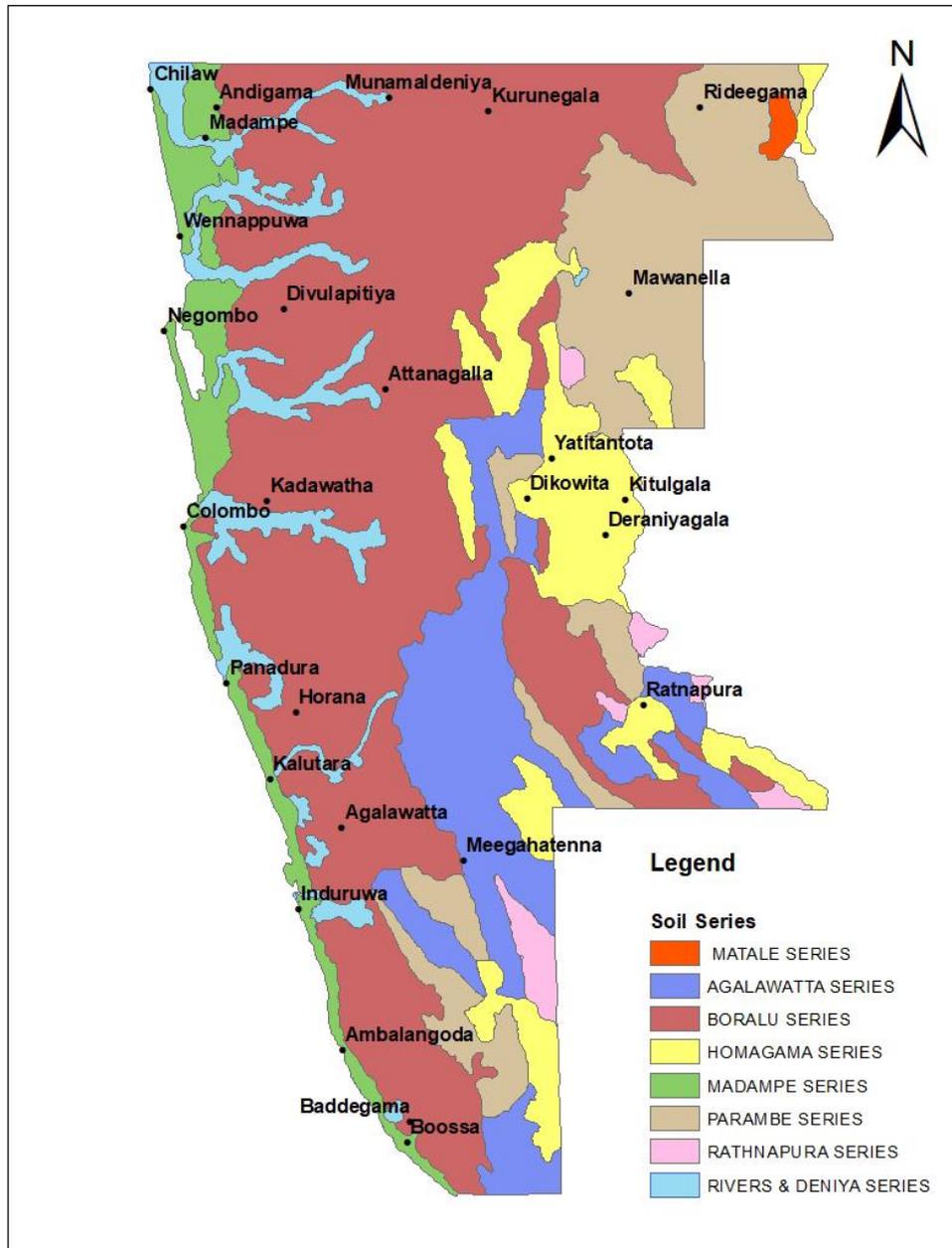


Plate 2.1. Rubber growing soils of Sri Lanka.



Plate 2.2. Profiles of different soil series. **a.** *Parambe* series; **b.** *Matale* series; **c.** *Homagama* series; **d.** *Agalawatta* series.

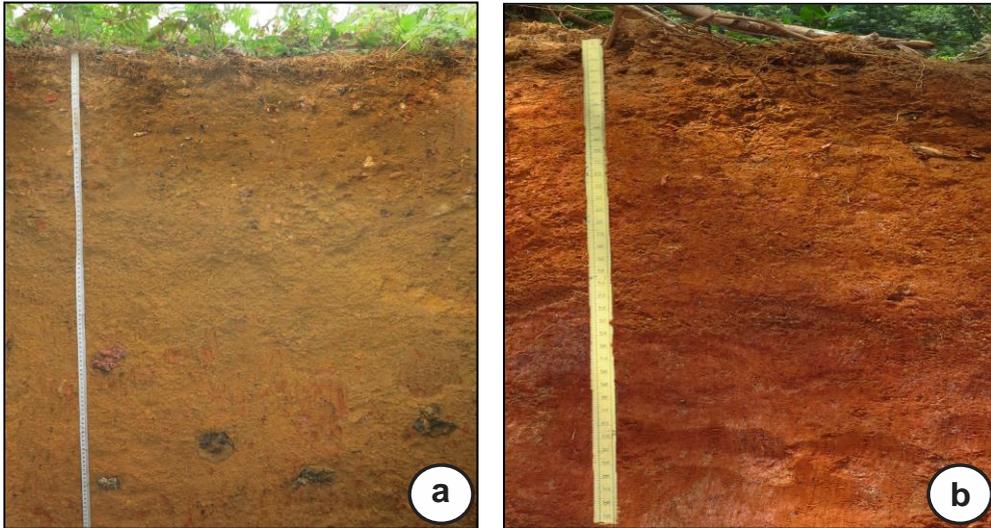


Plate 2.3. Profiles of different soil series. **a.** *Ratnapura* series; **b.** *Boralu* series.

Chapter 3

Ground cover management and weed management

R.P. Hettiarachchi

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1. GROUND COVERS AND COVER MANAGEMENT

1.1 Introduction

During the early years after planting, young rubber plants provide very little protection to the soil, mainly due to poor canopy cover. It is therefore, necessary to adopt suitable management practices that will provide sufficient ground cover to prevent soil erosion and enhance soil fertility status. Leguminous plants are the most useful ground covers, as besides other attributes which may also be possessed by other species, the legumes can fix atmospheric nitrogen when growing under the right conditions with the correct strains of bacteria. It may therefore be possible that the quantity of nitrogen fertilizer required under these conditions may be reduced.

1.2 Benefits of ground covers

1.2.1 Soil conservation

Cover crops help to conserve the soil in several ways,

1. Direct protection of soil surface by the leaves and stems, against washing by rain and blowing by wind.
2. Binding the soil together by the root system of the cover plant.
3. Formation of miniature bunds by the plants themselves which help to prevent surface wash.
4. The creeping habit of some species breaks up the movement of water over the soil.
5. The soil is opened and kept porous by the roots thus allowing better penetration of rain water and less run-off and wash.

1.2.2 Increases soil fertility

Cover crops ensure improvement and maintenance of soil fertility by,

1. Provision of surface mulch resulting from natural death of leaves and stems.
2. Addition of organic matter to the soil after the death and decay of leaves, stems and roots.
3. Provision of macro and micro nutrients to the soil through the decomposition of organic residues.
4. Addition of organic matter also help to increase water and nutrient holding capacities of the soil.
5. Aeration of the soil by root penetration and improvement of the soil structure with the addition of organic matter.

1.3 Qualities of cover crops

Any plant cannot be grown as a cover crop. To be a good cover crop, the plant selected should possess certain characters. They are;

1. Easily multiplied, preferably by seed.

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2. The root system should be such that it does not compete with the rubber yet have good soil binding properties and not require high quality soils.
3. The growth should be rapid and there should be abundant leaf both in full sunlight and shade.
4. Tolerate pruning or slashing.
5. Resistant to drought, pests and diseases.
6. A good competitor and be able to resist and suppress weeds.
7. Easily eradicated when required.
8. Suitable for land reclamation and afforestation.
9. Should not form products which are toxic to the main crop.

Leguminous plants contain a number of species which possess these attributes in a large measure as compared with other plant families.

1.4 Cover crop species

Plants that can be grown as cover crops under rubber are:

Mucuna bracteata (Plate 3.1a)

Pueraria phaseoloides (Plate 3.1b)

Desmodium ovalifolium (Plate 3.1c)

Calopogonium mucunoides (Plate 3.1d)

Centrosema pubescens (Plate 3.1e)

Many plants could be used as cover crops in rubber. In high rainfall areas any of the above legume species can be planted. A cover consisting of two or more species of legumes is often preferred because of the shortcomings of one could be remedied by the others. Probably use cover crops and their seed rates are given in Table 3.1.

Table 3.1. A list of cover crops and their seed rates.

Species	Seed rate
<i>Pueraria phaseoloides</i>	6 kg of seeds/ha (6 lb/acre)
<i>Desmodium ovalifolium</i>	4 kg of seeds/ha (4 lb/acre)
<i>Calopogonium mucunoides</i>	6 kg of seeds/ha (6 lb/acre)
<i>Centrosema pubescens</i>	8 kg of seeds/ha (8 lb/acre)

When established as a mixture of *Pueraria phaseoloides* and *Desmodium ovalifolium*, *Pueraria* grows rapidly at the early stages of a clearing but stands only light shade whereas *Desmodium* is weaker in initial growth, but tolerates shade much better and persists more satisfactorily under a fairly dense canopy of rubber. Some effects of legumes persist for about 4 years during the early mature phase. In areas under non legume covers application of extra nitrogen is important. Nowadays, the most widely used leguminous cover crop is *Mucuna bracteata* and has many advantages over the traditional cover crop *Pueraria phaseoloides*.

1.4.1 Advantages of *Mucuna bracteata*

1. Grow luxuriantly, produce 3 to 4 times more biomass than traditional leguminous cover crop and return large quantity of litter to the soil
2. Compete successfully against weed growth
3. Deep-rooted nature extract nutrients and moisture from more deeper layers of soil
4. Accumulate organic matter in the form of litter on the top of the soil due to continuous adding of decaying leaves, stems and roots
5. Minimize run-off and control erosion
6. Resistant to pest and diseases because of phenolic compounds in it
7. Less palatable to cattle

1.5 Establishment of covers

Cover crops are best established immediately after land clearing. Either seeds or cuttings should be planted according to the species being used. With creeping covers which root at the nodes, the cuttings or seeds may be spaced up to 2 meters apart as they rapidly cover the intervening spaces. Types such as *Desmodium*, however must be planted closely as they do not spread extensively.

For *Mucuna*, rooted cuttings should be first planted in polybags and at the stage it has 5/6 leaves should be transferred into the field.

In areas carrying heavy weeds, clean-weeded strips should be forked and the seeds or cuttings should be planted in these strips. When established, the intervening strips of weed growth should be gradually removed to allow the covers to spread, eventually covering the whole area. In such areas, however, only the creeping types which will spread and tend to smother the weeds should be used. Cover plants may be grown in nurseries and planted as basket or ball plants in areas where dry spells occur.

1.6 Seed treatment

Some species of leguminous cover plants have seeds which, unless specially treated, do not germinate quickly (*e.g. Pueraria* and *Desmodium* etc.). The seeds should either be placed in hot water (60°C - 80°C) and left in it for 24 hours to cool or treated with sulphuric acid. For acid treatment the seeds should be placed in a glass or other acid resistant container and sufficient concentrated sulphuric acid should be added to cover the seeds. After the required time (Table 3.2) during which period the mixture may be stirred occasionally, the acid should be drained off carefully and the seeds should be transferred into water. The seeds should be then washed thoroughly in several changes of water to remove the acid. The seeds may then be lightly dried to facilitate handling while planting.

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Table 3.2. Treatment procedure for different cover species.

Species	Quantity	Volume of acid (ml)	Soaking time (min)
<i>Pueraria</i>	1kg	50	30
<i>Desmodium</i>	1kg	200	15-30
<i>Calopogonium</i>	1kg	50	15-30
<i>Centrosema</i>	1kg	50	30

1.7 Manuring of covers

Phosphate is one of the important nutrients required by legumes for satisfactory growth. When establishing leguminous covers in beds or strips in a plantation, a dressing of 100g of rock phosphate per square meter would be beneficial. Subsequently, dusting of some rock phosphate on the cover crops needs to be done, at the rate of 100 to 200 kg per hectare during the first year, depending on the growth of covers. Residual effects of P applied to immature plantation would persist for about 8 years during the mature phase.

1.8 Weeding of covers

Since cover plants are cultivated for the purpose of benefiting the rubber plants, care should always be taken not to allow them to compete to any great extent with the rubber plants at any stage. For this reason, a strip of about 1 to 2 m (4-6 ft.) wide along the planting row or a circle of about 0.5 to 1 m (2-3 ft.) radius around each rubber plant should be clean weeded and kept clear of all under growth including cover plants. It is also a good practice that this clean weeded area is mulched with the slashed cover, if sufficient material for mulching is available. Selective weeding should be done once a month in order to maintain a good legume cover.

2. MULCHING

2.1 Introduction

The word mulch has a German derivation meaning soft and beginning to decay. In agricultural practice, mulching includes the application of any of a variety of materials to the surface on the soil.

The growing of leguminous cover crops may be beneficial, during the early years after planting. However, most of the legume covers take at least 6 to 12 months to provide sufficient protection to the soil and at the same time ground covers may compete with young rubber plants for moisture and nutrients. Therefore, a circle of about one meter radius around each rubber plant is clean weeded to avoid competition. This can lead to some degree of soil degradation around the base of the rubber plants due to the exposure of soil to adverse climatic conditions. Providing a protective layer of mulch on the exposed bare soil patches around the base of the rubber plants can therefore be considered as a very good agronomic practice. In addition, it provides nutrients and conserve moisture, dead mulch does not compete with rubber plant for nutrients and moisture. Moreover,

mulching had been found to be very effective in avoiding evapotranspiration losses, controlling soil erosion, improving organic carbon content, cation exchange capacity and soil microbial activities. Mulching could be done immediately after planting, as mulching materials can easily be found at the same time. By combination of all these beneficial effects of mulching resulted in better girdling and early opening of plants for tapping compared to naturals and creeping legumes.

2.2 Advantages of mulching

2.2.1 Addition of nutrients

Among the plant residues, paddy straw is particularly of importance as it contains about 0.6-0.7% nitrogen (N), 0.07-0.1% phosphorous (P), 1.4-1.9% potassium (K), 0.2-0.3% magnesium (Mg) and 30-40% carbon (C). Incorporation of 12 MT of rice straw per hectare during the 6 year immature period (2-5 kg/plant/application) will contribute approximately 75 kg of N, 190 kg of K and 10 kg of P.

2.2.2 Source of organic matter

The importance of mulching in enhancing the organic carbon content of the soil is known. Although decomposition of organic matter is rapid under tropical conditions, in most of the rubber growing soils.

2.2.3 Prevents soil erosion

By mulching with rice straw, a total accumulated soil loss of 60 MT/ha that takes place by erosion during the first 3 years after planting under the conventional method of planting, can be reduced to 3-5 MT/ha.

2.2.4 Retains moisture

There is an increase of 43% in the moisture storage capacity under mulching compared to the clean weeded circle around the rubber plants.

2.2.5 Controls weed growth

To avoid any competition from weeds, a strip of about 1-2 meters wide along the planting row or a circle of about 0.5-1.0 meter radius round each rubber plant is clean weeded and kept clear of all undergrowth including cover plants. Growth of legume creepers into the weed free circle can be controlled very effectively by mulching with rice straw.

2.3 Crop residues

Among the crop residues, rice straw is particularly of importance as it is rich in potassium and also contains a certain amount of other plant nutrients. Moreover, burning of large quantities of straw in the paddy fields every year, besides causing loss of valuable nutrients and organic matter, can also cause serious environmental pollution and health hazard problems. The main drawback

in mulching with paddy straw would be the lack of sufficient mulching material close to the field for the initial mulching operation and for replenishing the mulch layer at suitable intervals.

2.4 Bush/tree legumes

The practice of growing some acceptable plant species between the rows of rubber plants that would not compete for moisture and nutrients and at the same time would provide enough material for mulching. Use the loppings of these trees at suitable intervals for mulching the ground along the clean weeded strip or circles of the planting row would be undoubtedly be an acceptable agronomic practice. Growing of bush legumes may be considered useful in this regard.

2.4.1 Bush/tree legume species

Bush/tree legume species that can be grown successfully in rubber plantations are, *Crotalaria browni* (Plate 3.2a), *C. micans*, *C. anagyroides*, *Tephrosia vogelli* (Plate 3.2b), *Sesbenia* (Plate 3.2c), *Flemingia macrophylla*, (*F. congesta*), *Gliricidia* (Plate 3.2d).

2.4.2 Establishment

Bush legumes are best established immediately after land clearing. A clean weeded strip should be forked and the seeds should be planted in these strips. Care should always be taken not to allow them to compete with the rubber plants at any stage. For this reason a strip of about 120 cm should be left between the first row of bush legumes and the planting row of rubber. The spacing between two rows of bush legumes should be about 60 cm. *Gliricidia* sticks can be planted in the centres of each four rubber plants as a single row. Also, they can be planted in double rows and these double rows of *Gliricidia* should be established in a zigzag pattern to minimize the shade effect from one to another.

2.4.3 Manuring

When establishing bush legumes in strips, a dressing of 20 kg of rock phosphate per hectare would be beneficial. Depending on the growth of bush legumes in the first few years, 100 to 200 kg of rock phosphates per hectare could be applied by dusting.

2.4.4 Lopping and mulching

The first lopping may be done 4 months after planting depending on the weather conditions. The recovery after lopping will be restricted under drought conditions, therefore lopping should not be done during dry weather. It may be possible to do 3-4 loppings per year when climatic conditions are favourable. The loppings will provide adequate biomass for use as dead mulch along the clean - weeded strip or circles of the planting row. In situations where the loppings are insufficient, the use of any other acceptable materials such as paddy straw along with these loppings will undoubtedly be an acceptable agronomic practice.

2.5 Application of mulching materials

2.5.1 Method of application

- Mulching should be done around the base of the rubber plants
- Paddy straw should be loosely spread over the weed free circle around the rubber plants (Plate 3.2e)

2.5.2 Frequency and time of application

- The first application of mulching material should be done immediately after planting, around the base of the rubber plants
- Exposed soil patches of the newly replanted land (exposed soil) should also be mulched to prevent soil erosion
- Mulching could be done twice per year, when the mulching materials are freely available

2.5.3 Rate of application

The recommended rates of application of paddy straw/green manure compost (around the base of rubber plants) are given in Table 3.3.

Table 3.3. Rates of application of paddy straw/green manure/compost.

Year of planting	Quantity (kg/plant)
During the 1 st year after planting	2 kg/application
2 nd year	3 kg/application
3 rd and 4 th year	4 kg/application
5 th year until tapping	5 kg/application

3. WEEDS AND WEED MANAGEMENT

3.1 Introduction

Weeds are considered undesirable for various reasons, mostly connected with decreased economic return from the crop. Noxious weed species growing in the inter-row areas during the immature period can compete with rubber for soil moisture, light and nutrients thus affecting the growth and yield of rubber plants and also they hinder the routine estate practices such as tapping, spraying and fertilizing. Some weeds contain growth inhibitory substances which can suppress the growth of *Hevea*. Weeds may also act as hosts for many pests and diseases of rubber. Weed control is therefore considered important in rubber plantations.

The nature of the weed control or weed management problem in rubber plantations can be categorized as follows:

1. Weed control at the time of re-planting prior to establishment of leguminous cover crops
2. Elimination of weeds in areas where cover crops have been established

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3. Maintenance of the planting rows in a clean-weeded condition during the first few years from the time of replanting
4. Weed control in mature areas.

3.2 Common weeds

Common weeds that can be seen in rubber plantations are: *Mikania cordata* (Plate 3.3a), *Hedyotis auricularis* (Plate 3.3b), *Bracharia decumbens* (Plate 3.3c), *Wedelia* (Plate 3.3d), *Lantana camara* (Plate 3.3e), and *Eupatorium odoratum* (Plate 3.3f).

3.3 Weed management/control

It is very important to remember that the rubber lands in Sri Lanka are in general, very steep, very rocky and uneven and relatively difficult to traverse even on foot. The possible methods of weed control in rubber lands are as follows:

- Hand weeding (scraping, use of mammoty *etc.*)
- Mechanical methods
- Burning
- Ground cover management
- Mulching
- Intercropping
- Livestock grazing and
- Chemical method

The choice of a particular method for systematic management of weeds largely depends on the age of the rubber stand, climatic conditions, type of weed and its distribution and on the size of holding.

3.3.1 Hand weeding

This method is completely effective but is very often expensive; besides, it tends to cause severe erosion. Scraping with mammoties breaks down the structure of the soil and leaves on the ground a layer of loose top-soil which is easily washed away by rain. In addition, this will not only prepare a suitable bed for weeds to grow but also stimulate dormant seed to germinate. Hand weeding is very effective when establishing cover crops in areas carrying heavy weeds. This involves gradual removal of weeds around the cover beds to allow the covers to spread, eventually covering the entire area. Hand weeding is also done on strips of about 1.2 m to 1.8 m (4 - 6 ft.) wide along the planting rows or in circles of about 0.6 m to 0.9 m (2 - 3 ft.) radius around each rubber plant. Another situation where this method becomes useful is in the selective elimination of weeds in areas where cover crops have already been established.

3.3.2 Mechanical method

This method is virtually impossible owing to the type of land. In the few

areas where the land is sufficiently flat to permit mechanization, the amount of rock on the surface and immediately underneath makes it impossible.

3.3.3 Burning

The traditional practice of burning to control illuk in rubber plantations should not be continued, for illuk being fire resistant, this will only aggravate the problem by its rapid regeneration. Further, setting fire, particularly in the dry areas, could cause damage or even death of rubber plants. Except in opening new clearings burning is not advisable.

3.3.4 Ground cover management

Management of ground cover is very effective in suppressing weed growth in young rubber clearings and is essential for the preservation of fertility and soil conservation and for disease control.

3.3.5 Mulching

If sufficient material for mulching such as slashed cover, straw *etc.* are available, mulching the inter-row area could be a satisfactory method of weed control. Besides planting tree legumes like *Flemingia*, *Crotalaria*, *Tephrosia* and *Gliricidia*, formation of a mulch of leaf litter between planting rows by slashing and mulching is also a desirable method of weed control in immature rubber plantations.

3.3.6 Intercropping

It is another excellent method of weed management in rubber. Intercropping with banana, passion fruit and pineapple, if done systematically, will not cause any adverse effects on the growth and yield of rubber. This method of suppressing weeds in rubber is suitable for both estates and smallholder situations.

3.3.7 Livestock grazing

Controlled grazing by livestock like sheep, goats and even rearing of chickens under rubber can bring weeds under effective control.

3.3.8 Chemical control of weeds

The nature of herbicides to be used in chemical weed control programmes is dependent on a number of factors:

- The nature of the plants that are regarded as weeds
- The objective of weed control, and the degree of control necessary
- Cost of herbicides and their application.

Glyphosate is a water-soluble, translocated herbicide and therefore could kill underground parts of many perennial weeds when sprayed on the foliage. The herbicide however is inactivated when it comes in contact with the soil. Glyphosate has been found to effectively control weeds under rubber plantations. Therefore, it is

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recommended to use control weed growth around the base of the rubber plants from 3rd year onwards for immature rubber and the total period of mature rubber with minimum annual application.

However, their widespread use may creating possibilities of environmental pollution and degraded microbial diversity and activity.

Common weeds in rubber plantations of Sri Lanka and the recommended control measures are given in Table 3.4.

Table 3.4. Major weeds in rubber lands and their control methods

Local and botanical names of weed	Distribution in rubber growing areas	Propagation and dispersal	Method of control
Grasses			
01. <i>Axonopus affinis</i> (Carpet grass) Hinpotu Tana, Sappupul)	A dominant weed in rubber growing areas, Kalutara and Kurunegala.	Bushes grow to about 0.5 m high. Propagation by wind dispersal of seeds.	Slashing during tender stages. Uprooting and burning.
02. <i>Panicum repens</i> (Couch grass) Etora	Distributed in all rubber growing areas.	Has underground rhizomes. Propagation by seed and fragments.	Uprooting and burning of rhizomes. Repeated slashing and grazing.
03. <i>Paspalum conjugatum</i> (Sour grass)	A troublesome weed in all rubber growing areas.	Grows rapidly. Propagation by seeds and fragments.	Mammoty weeding. Uprooting and burning before flowering.
04. <i>Imperata cylindrica</i> (illuk)	A troublesome weed in all rubber growing areas, particularly in the drier districts.	Grows year round to 1-2 m high. Silvery white inflorescence 7 to 20 cm long. Dense root system. Propagation by wind dispersal of seeds and by rhizomes. Flowering starts in July.	Digging out of underground rhizomes, drying and burning.
05. <i>Lophatherum gracile</i> (Bata thanakola)	Distributed in all rubber growing areas.	Bushes grow to about 80 cm high. Propagation by seeds and rhizomes.	Slashing during tender stages.
06. <i>Digitaria longiflora</i>	A common grass in all rubber lands.	Annual grass, tufted. Clumps form and branch at nodes. 30 – 60 cm high. Propagation by seeds.	
07. <i>Pennisetum polystachyon</i> (Rilathana)	Distributed in all rubber growing areas.	Bushes grow 1-2 m high. Flowering in Nov-Dec. Propagation by seeds and fragments.	Slashing during tender stages. Uprooting and burning.
08. <i>Cynodon dactylon</i> (Kukul atawara)	A common grass in all rubber growing areas.	Grows year round. Propagation by seeds and rhizomes.	Manual weeding. Uprooting and burning of rhizomes. Repeated slashing.

Local and botanical names of weed	Distribution in rubber growing areas	Propagation and dispersal	Method of control
09. <i>Ottochloa nodosa</i>	A dominant weed in rubber growing areas; Kegalle, Kalutara and Kurunegala.	A tufted grass. Clumps form and branch at nodes. Propagation by fragments.	Manual weeding.
10. <i>Brachiaria decumbens</i>	Distributed in rubber growing areas; Kegalle and Kalutara.	Perennial grass. Spreading by creeping. Rooting at nodes. Propagation by runners and seeds.	Slashing during tender stages.
Sedges			
<i>Cyperus rotundus</i> (Kalanduru)	Grows vigorously in all rubber growing areas.	Perennial sedge. Bushes grow 30-60 cm high. Propagation by tubers.	Manual weeding.
Broad leaves			
01. <i>Mikania cordata</i> (Wathupalu)	A troublesome weed in all rubber growing areas.	Perennial climber. Grows twining round rubber plants. Grows vigorously with ground cover.	Mammoty weeding and slashing or by hand weeding.
02. <i>Exallage</i> (<i>Hedyotis auricularia</i>) (Getakola)	A dominant weed in Kalutara, Kurunegala and Kelani Valley areas.	Annual weed with numerous prostrate branches. Propagation by seeds.	Creepers dry up with Jan-March dry spells. Slashing.
03. <i>Drymaria cordata</i> (Kukulpala)	A common weed in rubber growing areas.	Annual weed. Propagation by seeds.	Slashing and mammoty weeding.
04. <i>Crassocephalum crepidioides</i>	Distributed in all rubber growing areas.	Annual weed. Propagation by seeds.	Mammoty or hand weeding.
05. <i>Ageratum conyzoides</i> (Hulanthala)	Distributed in all rubber growing areas.	Annual weed. Propagation by seeds.	Mammoty or hand weeding.
06. <i>Centella asiatica</i> (Gotukola)	Weed in all rubber growing areas.	Spreading by creeping. Rooting at nodes. Propagation by runners.	Hand weeding.
07. <i>Merremia umbellata</i> (Morning glory)	Distributed in all rubber growing areas.	Perennial weed. Propagated vegetatively and by seeds.	Mammoty and hand weeding.

Local and botanical names of weed	Distribution in rubber growing areas	Propagation and dispersal	Method of control
08. <i>Chromolaena odorata</i> (Podisinghomaran)	Dominant weed in Kalutara, Kurunegala and Kegalle areas.	Perennial shrub. Fast growing 2-3 m high. Flowering in Dec.-Jan. Seed dispersal by wind.	Mammoty weeding, uprooting and burning before flowering.
09. <i>Commelina indehiscens</i> (Girapala)	Distributed in all rubber growing areas.	Perennial herb. Blue flowers. Propagated by creeping stems and seeds.	Mammoty weeding.
10. <i>Spermacoce prostrata</i> (Getakola)	One of the commonest weeds in all rubber growing areas.	Annual shrub. Propagated by seeds.	Mammoty weeding.
11. <i>Emilia exserta</i> (Kadupahara)	Distributed in all rubber growing areas.	Annual shrub. Flowers small and purple in colour. Propagated by seeds.	Mammoty weeding.
12. <i>Mimosa pudica</i> (Nidikumba)	Distributed in all rubber growing areas.	Thorny herb. Pink flowers. Propagated by seeds.	Digging and burning. Slashing during tender stages.
13. <i>Tridax procumbens</i>	Distributed in all rubber growing areas.	Annual herb. Grows 30 cm high. Propagated by seeds.	Mammoty weeding.
14. <i>Clerodendrum infortunatum</i> (Pinna)	Distributed widely in Kalutara district.	Grows high. Produces red flowers. Propagated by seeds and root cuttings.	Mammoty weeding and slashing.
Ferns			
01. <i>Dicranopteris linearis</i> (Kekilla)	Abundant weed in Kelani valley and Kalutara rubber growing areas.	Zigzag fronds repeatedly branching. Spore capsules on the back of the frond, one at the end of a veinlet.	Repeated slashing or mammoty digging.
02. <i>Adiantum</i> spp	Grows vigorously in Kelani valley, Kegalle and Kalutara rubber growing areas.	Repeatedly branching at root nodes. Spore capsules on the back of the fronds. Propagation by underground rhizomes.	Repeated slashing or mammoty digging.
03. <i>Nephrolepis</i> spp.	Abundant in Kalutara and Kelani valley areas.	Propagated by underground rhizomes and runners.	Repeated slashing or mammoty digging.

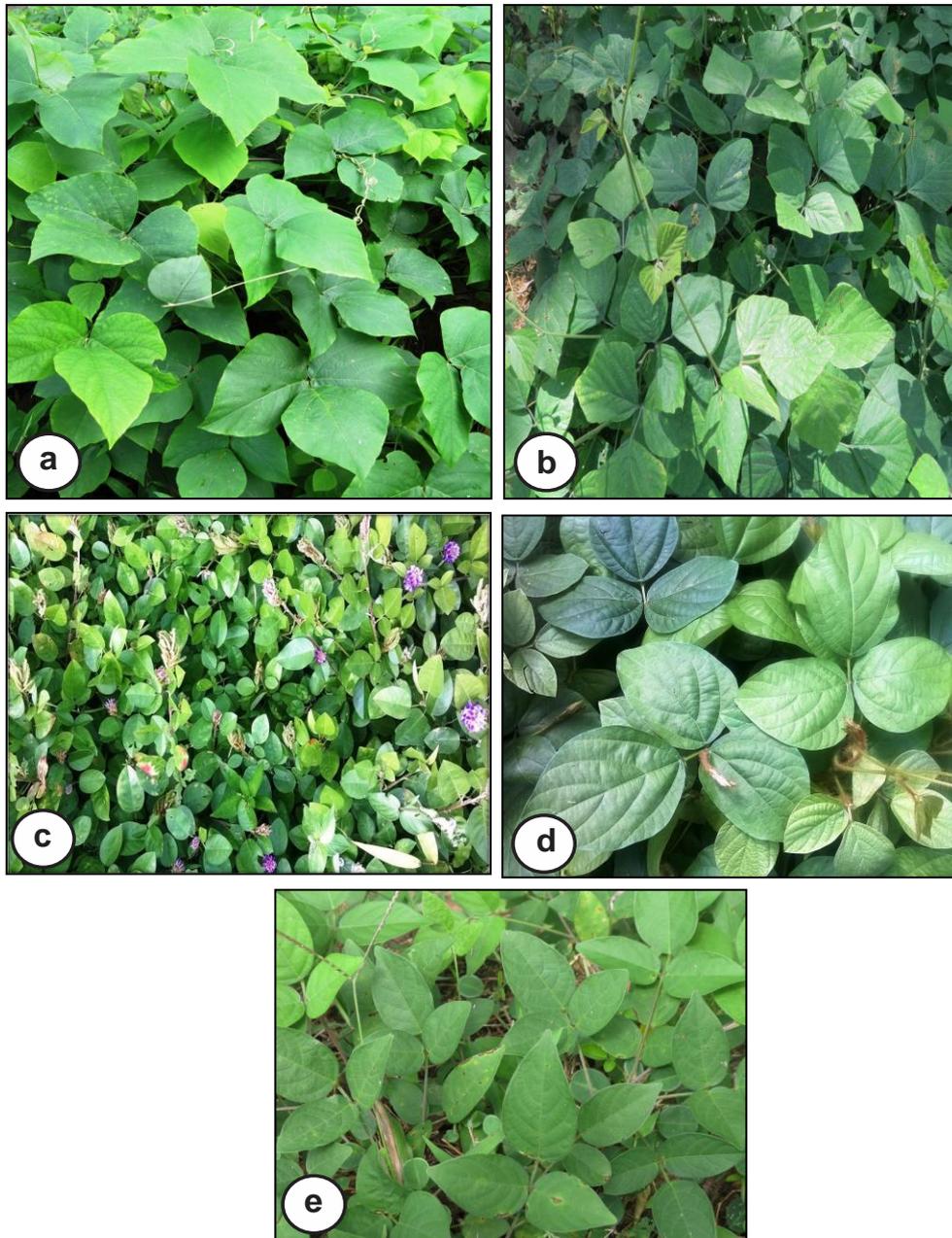


Plate 3.1. Cover crop species. **a.** *Mucuna bracteata*; **b.** *Pueraria phaseoloides*; **c.** *Desmodium ovalifolium*; **d.** *Calopogonium mucunoides*; **e.** *Centrosema pubescens*.

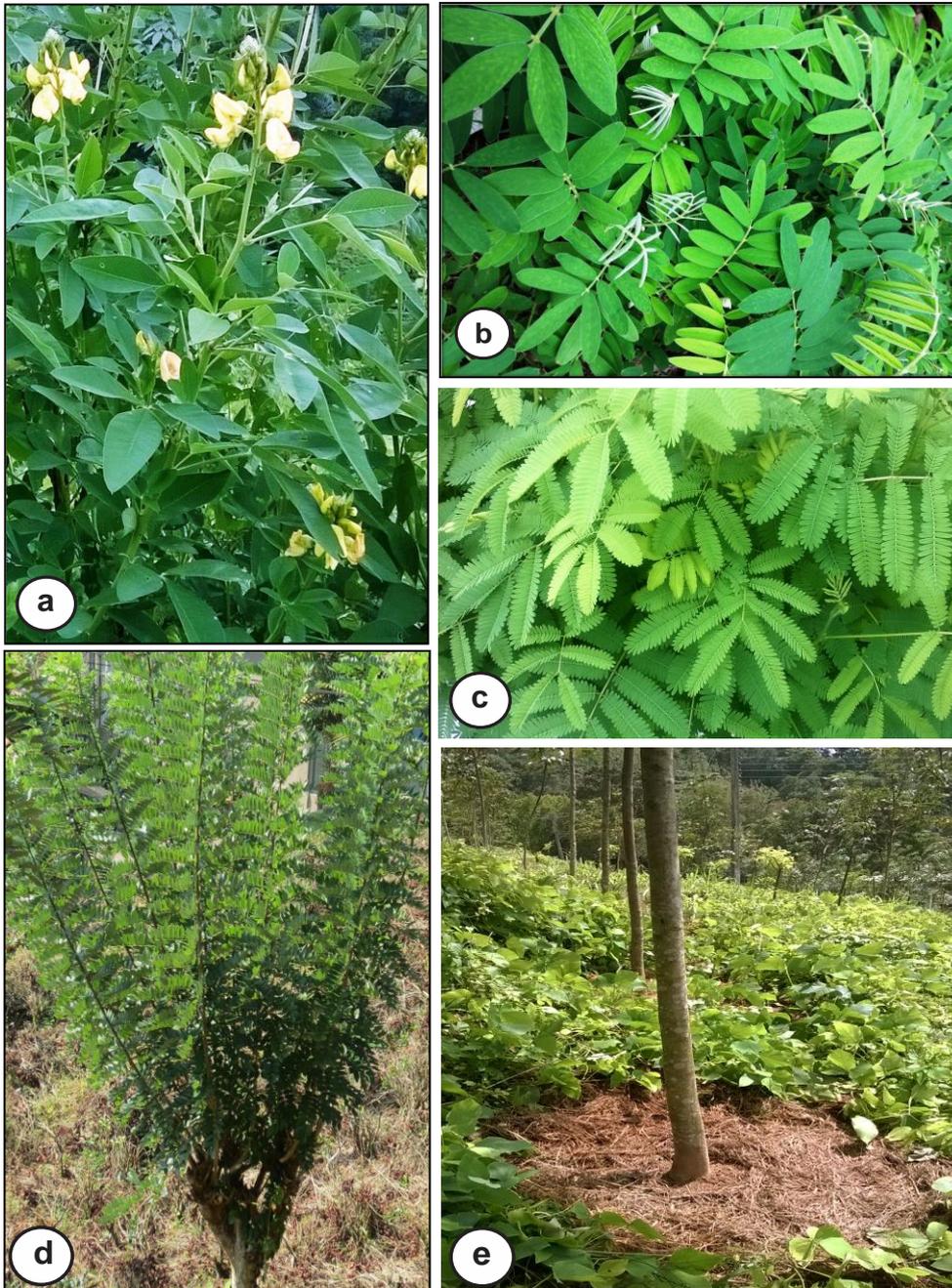


Plate 3.2. Bush/Tree legume species and mulching. **a.** *Crotalaria brownii* **b.** *Tephrosia vogelli*; **c.** *Sesbenia*; **d.** *Gliricidia*; **e.** Mulching around the weed free circle.



Plate 3.3. Common weed species. **a.** *Mikania cordata*; **b.** *Hedyotis auricularis*; **c.** *Bracharia decumbens*; **d.** *Wedelia*; **e.** *Lantana camara*; **f.** *Eupatorium odoratum*.

Chapter 4

Rainfall pattern in rubber growing areas of Sri Lanka

B.W. Wijesuriya and A.M.R.S.D. Rathnayaka

1. Introduction
2. Rainfall variability in rubber growing areas
 - 2.1 Monthly variation in rainfall
 - 2.2 Seasonal variation in rainfall
 - 2.3 Number of rainy days
 - 2.4 Occurrence of dry spells
3. Calendar for agronomic practices

1. INTRODUCTION

It is an accepted fact that rainfall is of primary importance for the establishment and growth of crops in the tropics. Hence, assessment of total annual rainfall and its distribution during the year is essential for perennial crops such as rubber. Based on analyses of rainfall data, the most reliable dates for the onset of rains in each rainy season can be predicted. Moreover, the duration for which there will be adequate soil moisture for crop growth can be determined. In Sri Lanka, dry spells are common in some months and prolonged drought periods also occur in some regions. These can lead to soil moisture stress of differential magnitude which adversely affects the growth and productivity of rubber. Therefore, information on rainfall behaviour provides a reliable basis for fixing a crop calendar and recommending an appropriate package of management practices for any location.

Any complete study of rainfall behaviour requires continuous and accurate records of rainfall collected over a considerable period of time. Usually, a series of about 30 years is required for a standard time series analysis to identify trends, seasonal variation and cycles in long-term records. This Chapter is based on analyses of long-term rainfall records in rubber growing areas of Sri Lanka and subsequently suggests an appropriate calendar for agronomic practices for the Wet and Intermediate Zones.

2. RAINFALL VARIABILITY IN RUBBER GROWING AREAS

Rubber growing areas in Sri Lanka mainly cover 12 administrative districts; namely; Kegalle, Kalutara, Ratnapura, Colombo, Gampaha, Galle, Matara, Kandy, Matale, Kurunegala, Moneragala and Badulla. In the recent past, rubber has been introduced to several other districts in the Intermediate and Dry Zone; *viz.* Puttalam, Hambantota, Nuwara Eliya and Ampara. In several other districts namely; Vavuniya, Mullaitivu, Anuradhapura, Polonnaruwa, and Kilinochchi have

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rubber plantations under the experimental stage. These districts belong to several agro-ecological regions; mainly Low Country Wet Zone (WL), Low Country Intermediate Zone (IL) and Mid Country Intermediate Zone (IM). Some annual average rainfall values reach 5000 mm in the wettest rubber growing areas (WL₁). The rubber growing areas and their agro-ecological regions together with 75% expected rainfall values (the value which can be exceeded 3 out of 4 years) are given in Table 4.1. Table 4.2 provides the same details of some non-traditional rubber growing areas, which have rubber plantations under the experimental stage.

Table 4.1. Major rubber growing areas, their agro-ecological regions and expected annual rainfall values with 75% probability.

Agro-ecological region	75% Expected rainfall (mm)	Rubber growing areas
Low Country Wet Zone		
WL _{1a}	>3200	Agalawatta, Awissawella, Ratnapura, Elpitiya
WL _{1b}	>2800	Pugoda, Horana
WL _{2a}	>2400	Akuressa, Kalutara, Galle, Bandaragama
WL _{2b}	>2200	Rambukkana, Kegalle
WL ₃	>1700	Gampaha, Divulapitiya, Pasyala
Mid Country Wet Zone		
WM _{3b}	>1400	Matale
Low Country Intermediate Zone		
IL _{1a}	>1400	Kurunegala
IL _{1b}	>1100	Panduwas Nuwara
IL _{1c}	>1300	Bibila, Moneragala, Wellawaya
IL ₂	>1600	Mahiyangana, Padiyathalawa
IL ₃	>1100	Maho, Galewela
Mid Country Intermediate Zone		
IM _{2b}	>1600	Badalkumbura, Lunugala
IM _{1a}	>2000	Badulla

Table 4.2. Newly established rubber growing areas, their agro-ecological regions and expected annual rainfall values with 75% probability.

Agro-ecological region	75% expected rainfall (mm)	Rubber growing areas
DL _{1b}	>900	Anuradhapura, Elaypattuwa, Medawachchiya, Pawatti Kulum, Vavuniya
DL _{2b}	>1100	Ampara
DL _{2a}	>1300	Uhana
DL _{1f}	>800	Akkarayan Kulum
DL ₃	>800	Iranamadu
DL _{1e}	>800	Muthuiyankaddu Kulam

2.1 Monthly variation in rainfall

Monthly rainfall distribution is widely presented in terms of expected probability at the 75% level, the value which can be expected in 3 times out of a 4 - year cycle. The usual bimodal pattern is observed in the Low Country Wet Zone (Fig. 4.1). The peak during the latter part of the year is more prominent in the Low Country Intermediate Zone (Fig. 4.2) and in the Mid Country Wet Zone (Fig. 4.3). In the Low Country Dry Zone areas, the usual bimodal pattern is not found. For instance, in Ampara (DL_{2b}), a long dry period is observed in the mid of the year as depicted in Figure 4.4.

2.2 Seasonal variations in rainfall

The usual bimodal pattern caused by the monsoonal influence exists in most rubber growing areas with peaks coinciding with May and October. North-East rains are usually experienced during the period from December to February. In general, the first inter-monsoon period (IM1) commences during March and April. South-West rains begin during May and extend to September followed by the second inter-monsoonal period (IM2) during October and November.

In wet areas, inter-monsoonal rains contribute nearly 40% to the total annual rainfall. The second inter-monsoon season (IM2) before the North-East rainy season carries more rain which usually lasts for 2 months when compared to the first inter-monsoon season before the commencement of South-West rains. Rains in the South-West season contribute nearly 45% to 50% to the total annual rainfall. A typical breakdown of the rainfall according to the rainfall seasons is given in Fig. 4.5 and Fig. 4.6.

Rainfall pattern in rubber growing areas of Sri Lanka

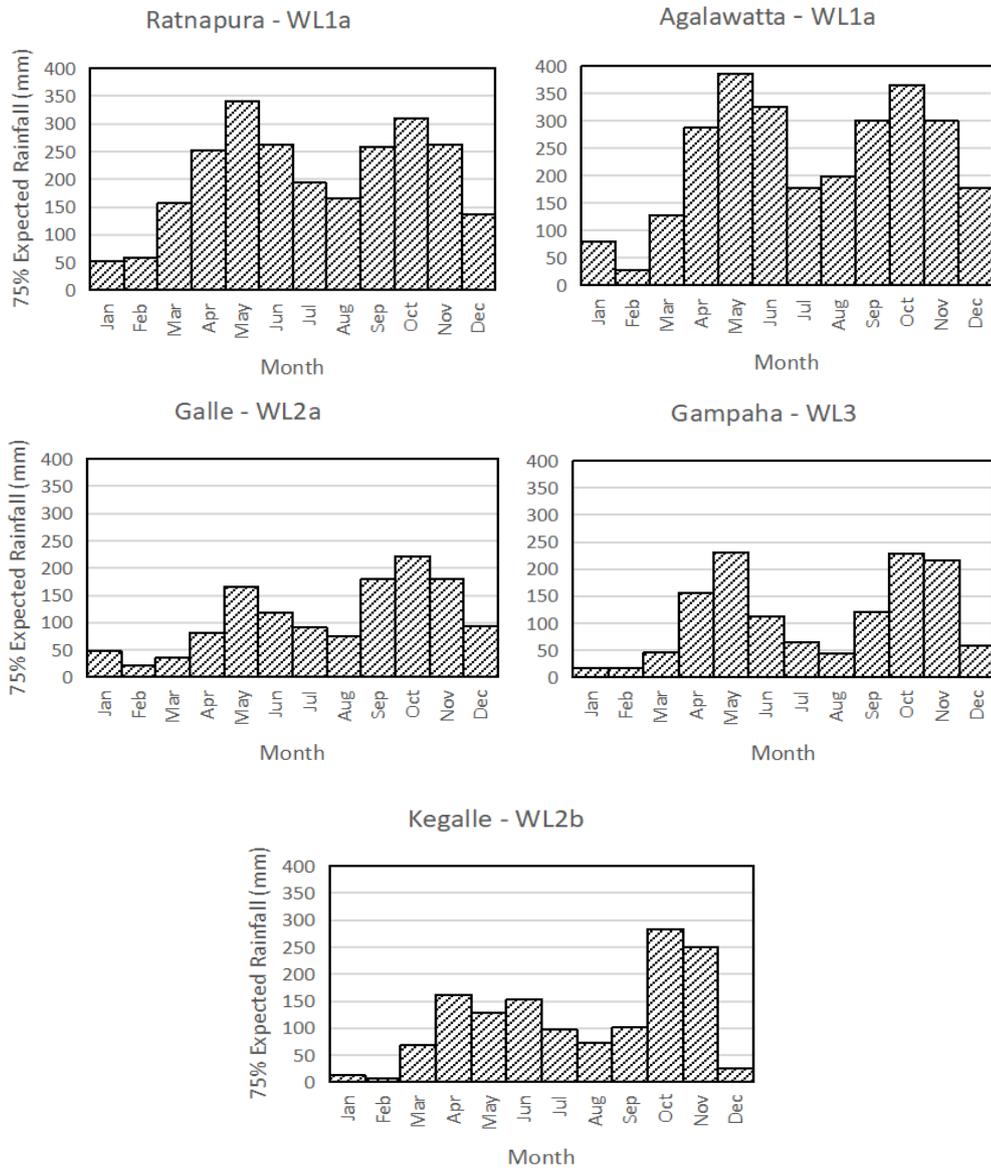


Fig. 4.1. Monthly 75% expected rainfall values in rubber growing areas of the Low Country Wet Zone of Sri Lanka.

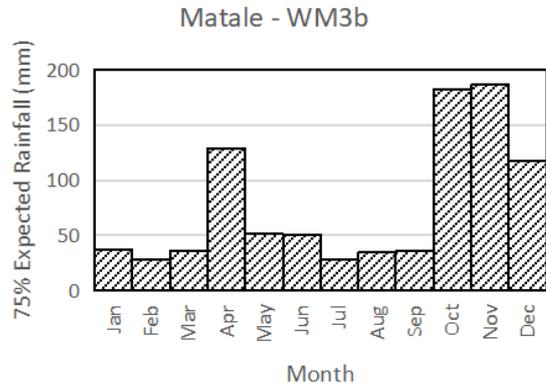


Fig. 4.2. Monthly 75% expected rainfall values in rubber growing areas of the Mid Country Wet Zone of Sri Lanka

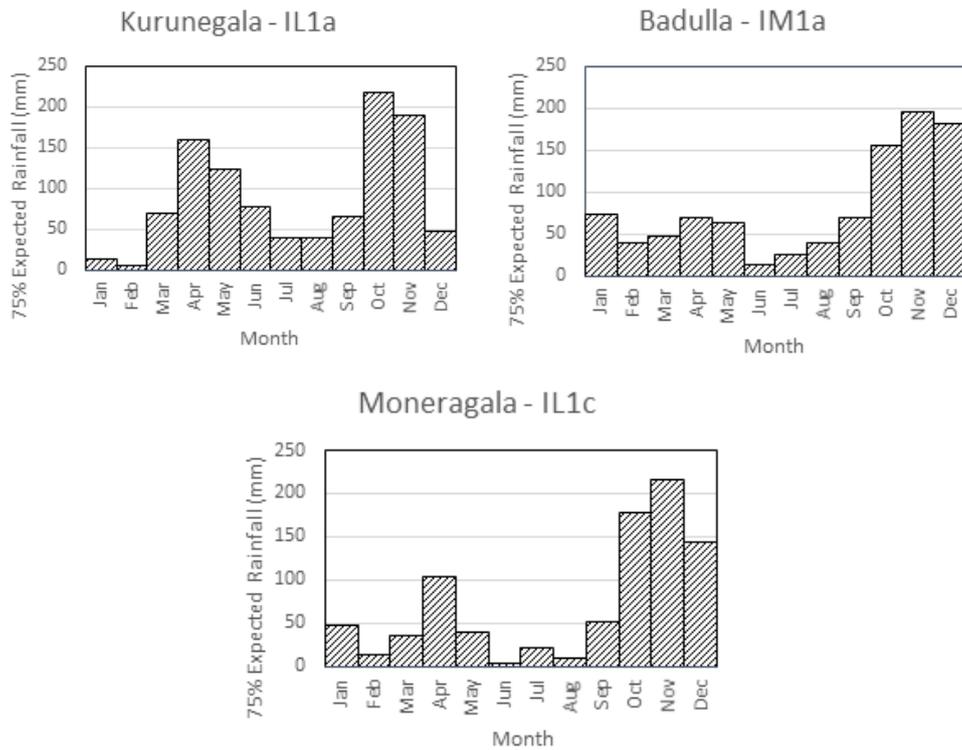


Fig. 4.3. Monthly 75% expected rainfall values in rubber growing areas of the Low Country and Mid Country Intermediate Zones of Sri Lanka.

Rainfall pattern in rubber growing areas of Sri Lanka

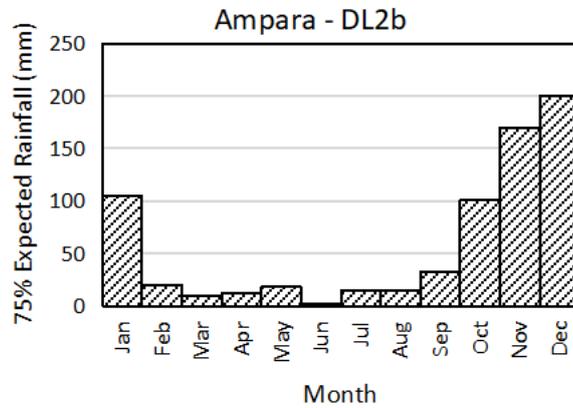


Fig. 4.4. Monthly 75% expected rainfall values in rubber growing areas of the Low Country Dry Zones of Sri Lanka.

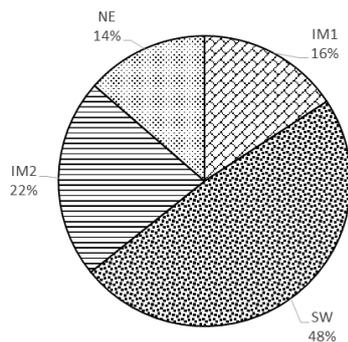


Fig. 4.5. Distribution of rainfall in different seasons in a Low Country Wet Zone areas (Eg. Agalawatta in WL_{1a}).

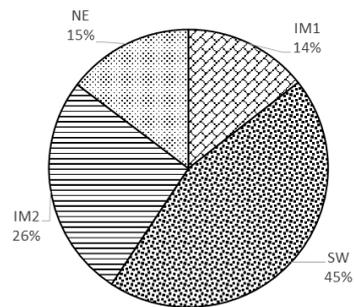


Fig. 4.6. Distribution of rainfall in different seasons in a Low Country Wet Zone areas (Eg. Galle in WL_{2a}).

The contribution from inter-monsoonal rains to the annual rainfall is greater, especially the IL_{1c} in the Moneragala area. The North-East rains are more prominent compared to the South-West rains, as depicted in Fig. 4.7. In the Low Country Dry Zone, the North-East monsoon brings a higher percentage of rains compared to the Intermediate Zone (Fig. 4.8). Yet, the contribution from the South-West rains is the same, and more or less similar contributions were observed for the inter-monsoonal rains.

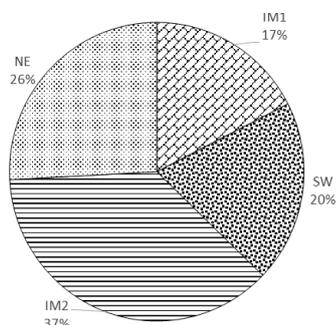


Fig. 4.7. Distribution of rainfall in different seasons in a Low Country Intermediate Zone areas (Eg. Moneragala - IL_{1c}).

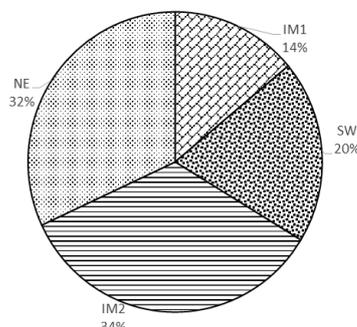


Fig. 4.8. Distribution of rainfall in different seasons in a Low Country Dry Zone areas (Eg. Vavuniya – DL_{1a}).

2.3 Number of rainy days

The number of rainy days is also a major determinant of rubber yield. In Low Country Wet Zone areas, a high number of rainy days is observed during April to November which coincides with the periods of inter-monsoonal and South-West monsoon influence. The average number of rainy days per year usually ranges from 180 to 240 days in the Wet Zone while it is less than 150 days in the Intermediate Zone.

In the Moneragala area, the number of rainy days is low except for the months October to December and April, which are mainly under the inter-monsoonal influence. More attention should be paid during these periods to control possible disease epidemics which can take place under wet weather conditions. The number of tapping days lost due to rains can be minimized by fixing rainguards or replacing the old ones during the dry periods before the commencement of rains.

2.4 Occurrence of dry spells

During the first 7 weeks of the year, there appears a fairly long dry spell that can adversely affect the growth of immature rubber plants, especially when planted with North-East rains. This observation is supported by the analysis of dry spells at Dartonfield, which is representative of the Wet Zone area, over the period 1964 to 2017 (Table 4.3). This dry spell during the early part of the year is common to the low country rubber growing areas covering the Agro-Ecological Zones WL₁, WL₂, WL₄, and IL₁. Hence, planting of rubber during the South-West season is advisable for the Low Country Wet Zone areas where there is less possibility of being affected by drought stress conditions. In the Intermediate Zone (Fig. 4.3, IM₃ and IL₁) there are two dry periods, which are more prominent in the Mid

Rainfall pattern in rubber growing areas of Sri Lanka

Country areas. The rubber growing areas in the Moneragala district which come under Intermediate Zone have sufficient rains during the early parts of the year. Therefore, in these areas, it may be appropriate to adhere to the North-East planting season with the onset of second inter-monsoonal rains. The use of poly-bagged plants instead of bare-root budded stumps will certainly enable the plants to tolerate deficit moisture conditions. Appropriate soil moisture conservation measures are also of great importance during the initial stages to overcome moisture stress during drought periods.

Prolonged dry spells also affect adversely the establishment of cover crops, which is an important activity during the initial stages. These cover crops may compete for moisture with rubber plants resulting in possible growth retardation during dry periods. In this respect, dead mulch material such as straw recommended by the Rubber Research Institute would be beneficial to crop growth as it effectively reduces the evapotranspiration demand while not competing with rubber plants for moisture.

Table 4.3. The frequency of dry spells during the period 1964 to 2017 - Dartonfield station (WL_{1a}).

Month	Dry period (days)				
	6-10	11-15	16-20	21-25	26-30
January	31	14	4	3	1
February	29	9	8	3	1
March	24	8	1	1	1
April	8	6	-	-	-
May	8	1	-	-	-
June	4	-	-	-	-
July	14	-	1	-	-
August	14	2	-	-	-
September	16	1	-	-	-
October	13	2	-	-	-
November	14	3	-	-	-
December	32	1	-	-	-

Table 4.4. The frequency of dry spells during the period 2003 to 2017- Moneragala (IL_{1c}).

Month	Dry period (days)				
	6-10	11-15	16-20	21-25	26-30
January	7	5	2	1	-
February	7	5	3		
March	5	3	4	1	1
April	8	1	-	-	-
May	7	1	6	1	-
June	4	2	-	5	4
July	3	6	5	1	-
August	10	4	1	-	-
September	5	5	1	1	-
October	7	1	-	-	-
November	2	-	-	-	-
December	7	2	1	-	-

4. Calendar for agronomic practices

Rubber being a perennial crop that is not usually irrigated except for some immature fields in Intermediate and Dry Zones, depends on the rainfall. Hence, all agronomic practices are connected with the rainfall pattern. The activity calendar for the Wet Zone is given in Fig. 4.9. The readers are requested to refer to Chapter 21, for the information on operations relevant to non-traditional rubber growing areas of Sri Lanka.

For land clearing, it is necessary to have a dry condition and this operation needs to be commenced during the August/September period and should be ready for burning during January/February period to get rid of root diseases of rubber.

Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Land clearing								■	■			
Burning	■	■										
Lining/Pegging/Holing			■	■								
Planting					■	■						
Filling gaps										■	■	
Fertilization (IM)	■		■	■			■	■		■	■	■
Fertilization (M)			■	■								

Fig. 4.9. The activity calendar for rubber in the Wet Zone.

Rainfall pattern in rubber growing areas of Sri Lanka

Lining, pegging and holing can be done during March and April. For holing a slightly moist soil is preferred and hence the latter half of April is suitable for this operation. Planting, which is the most important operation has to be done with the onset of South West rains, viz. May and June. Filling the gaps in plantations can be done during the second inter-monsoon season.

Fertilizer application for immature rubber fields can be done 4 times per year depending on the incidence of rainfall according to Fig. 4.9, avoiding dry spells and periods with heavy rainfall. For mature plantations, fertilizer application has to be done during the March/April period before the commencement of South West rains.

Once the trees attain the tappable girth, tapping panel marking can be done during February and tapping can be commenced in March. If interested, rainguard application is best to be carried out during February/March period and the fields have to be ready for tapping with rainguards in April.

Chapter 5

Genetic improvement of Hevea and Suitable Genotypes

Samanthi Withanage

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2. Genetic Improvement of planting material
3. Breeding and Selection procedure
 - 3.1 Selection
 - 3.2 Introduction
 - 3.3 Hybridization and Selection of good combiner clones for parents
 - 3.3.1 Selection criteria and preparation of mother trees
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1. INTRODUCTION: DEVELOPMENT OF PLANTING MATERIAL

The para rubber tree *Hevea brasiliensis* (A. Juss) mull. Arg was first introduced to Sri Lanka by Sir Henry Wickham. A collection of rubber seeds around 70,000 from the Tapajos valley of Amazon in Brazil was germinated in Kew garden in United Kingdom. In 1976, Thousand nine hundred and nineteen (1919) seedlings

from this collection was brought to Sri Lanka and were planted in Peradeniya and Henarathgoda Botanical Gardens. Later in 1883 seedlings derived from these trees were distributed to other South East Asian countries leading to establishment of a foundation stock for the rubber plantations in Asia which is generally referred to as Wickham genetic base. Since there is no positive evidence that the planting material from other sources such as the Cross or Ferris material survived in East Asian countries. Unselected seedlings were used as the planting material at the very beginning of the rubber industry. High yielding trees in the estates were identified and seedlings were raised from seeds of high yielding trees were then used as a planting material. With the introduction of successful bud grafting techniques in 1918 by Van Helton, clones became the main type of planting material. Until late 1930's, selected outstanding seedlings from estates were used to develop clones for commercial estates.

2. GENETIC IMPROVEMENT OF PLANTING MATERIAL

The next breakthrough in conventional breeding of *Hevea* was the perfection of artificial crossing or hybridization techniques which paved the way for crossing selected parents. Being a heterozygous out breeding species, it produces a wide range of genotypes facilitating superior selections. Seedling progenies derived from such crossing programs are subjected to a series of evaluation steps to produce a new clone (Fig. 5.1).

The main objective is to identify clones with high yield potential, to increase the intake per tapper so that it will reduce the tapping cost which is the highest component in the cost of production. Vigor or growth rate and tolerance to important foliar diseases were the other factors considered. Tapping at early stages and initial high yields are only possible with clones having vigorous growth. The growth vigor after the commencement of tapping (post tapping growth increment) is also an important indicator of high yield in the later years of exploitation.

Development of disease tolerant clones especially against *Corynespora*, *Oidium*, *Phytophthora* and *Gloeosporium* is in progress. Although SALB (South American Leaf Blight) is not yet experienced in Sri Lanka, due consideration has been given to develop and establish materials resistant to SALB. Development of clones suitable for sub optimal conditions such as, drought, high temperature, and high elevations has become important with the expansion of rubber in nontraditional areas. Therefore, incorporation of abiotic/biotic stress tolerant genes from Non-Wickham *Hevea* germplasm is carried to expand the genetic diversity of *Hevea* breeding pool.

In addition, clones which are resistant or tolerant to wind damage and TPD (Tapping Panel Dryness) have reduced the loss of tappable trees in the mature fields, thereby contributing to increased productivity.

Beside, above traits, interest in rubber wood by the timber industry has gained recognition of dual purpose trees which provide both latex and timber. Being

an industrial crop, the good technical properties of the latex produced by different clones also need to be improved or maintained at acceptable levels.

However, it is very difficult to identify high yielding and vigorous clones that possess all these secondary characters. But most of the clones possessing with high yield and vigorous growth may be susceptible to some disease and tolerant to others, or may be susceptible to wind damage. Therefore, the growers have been given a package as a clone recommendation with a wide variety of clones and a set of guidelines. Before choosing a clone for planting in a particular area, due consideration should be given to factors such as elevation, rainfall, susceptibility or tolerance of clones to diseases, wind damage and clones already planted in the area.

3. BREEDING AND SELECTION PROCEDURE

In conventional *Hevea* breeding; three main Procedures are practiced to develop a pool of new genotypes (bud wood/multiplication nursery level) (Fig. 5.1).

3.1 Selection

The selection of extremely performing trees from the existing plantation is the oldest method applied to rubber breeding; but it is still practiced in a minimum level. For example, if we can find out outstanding high yielding and disease free genotype in the population, it can be added to the new gene pool for further evaluation.

3.2 Introduction

This is the bringing of clones from the gene pool of foreign countries. Introduction or exchange of clones which are performing better in their environment is processed under bilateral or multilateral clone exchange program among natural rubber growing countries. Although these clones are already evaluated by that particular country, still it is considered as a new genotype and needs to be sent through the local evaluation process before taking a decision on recommendation.

3.3 Hybridization and selection of good combiner clones for parents

Hybridization is the most important technique used in *Hevea* breeding to combine a wide range of traits to genetic improvement of planting material. This is the process of production of new genotypes by the artificial crossing of selected parents. Parents are selected after evaluating their pedigree and performances on all aspects in yield, vigorous, disease resistance, adaptability *etc.*, considering the improvement of biodiversity among clones; Suitable genotypes which showed specific characters from the non-Wickham germplasm collection are often used as parents. Once decided the parents to be crossed, mother trees need to be prepared for pollination.

Hybridization

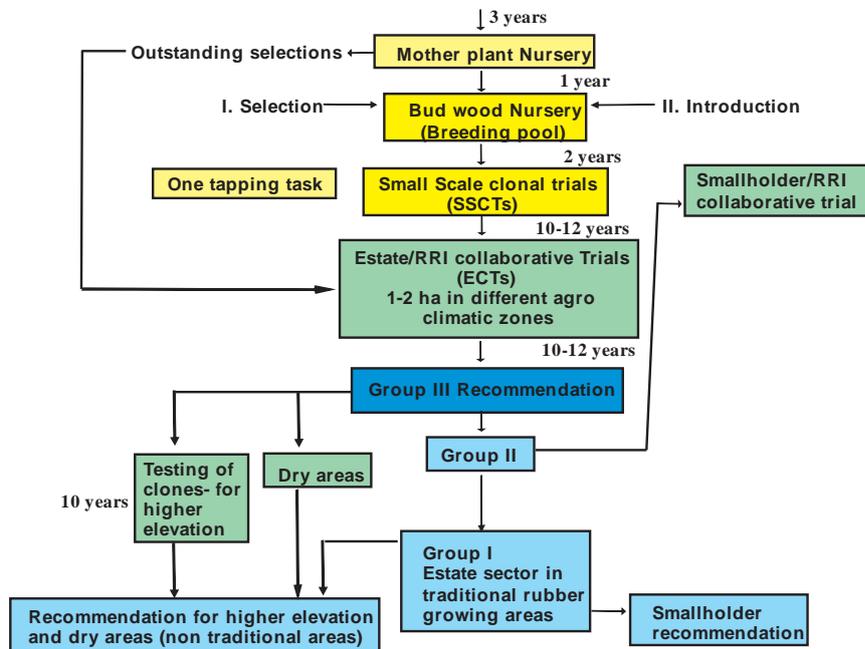


Fig. 1. *Hevea* breeding and selection procedure: The testing duration along with different evaluation steps in main conventional breeding procedure is given. SSCTs; small scale clonal trials, ECTs; estate/RRR collaborative trials, GP; group.

3.3.1 Selection criteria and preparation of mother trees

1. Healthy 8-12 years old trees are ideal
2. Trees which are having more branches exposed to sunlight are preferred.
3. If hybridization is carried in Estate trees, Land suitability is considered for the setting of bamboo scaff holds. When, hybridization is carried in breeding gardens, rubber trees are trained by bending branches towards the ground for easy and safe access to flower inflorescences.
4. Prior application of fertilizer is needed to get a healthy flush.
5. Regular application of fungicides for both selected male & female trees is needed during refoliation and flowering, especially for prevention of powdery mildew caused by *Oidium*. It will help to keep up as much as healthy inflorescence for successful hybridization.

After selection of mother tree in estates, bamboo scaffolds are set off prepare around the tree in order to reach as much as inflorescence which are born on tips of branches (Plate 5.1a). If mother tree are selected in breeding garden, trees are

trained by bending branches towards the ground for easy and safe access to flower inflorescences (Plate 5.1b).

3.3.2 Hybridization procedure

Artificial pollinations are carried out by trained pollinators under the close supervision of experienced officers. On each day of pollination, mature male flowers which are ready to open that particular day, are collected and brought to the female trees early in the morning. By keeping mature female flowers to be opened on the day of pollination: all other immature and already opened female flowers are cut off before the pollination. The staminal, column which contains ten anthers is completely excised from the male flower and carefully placed on the top of the stigma using forceps and then the perianth of pollinated female flower is blocked with a small cotton plug to prevent entering the other pollens naturally. Every pollination is tagged with details of the cross made, name of the pollinator and date, this whole process lasts until end of flowering. The initial fruit set can record over 6-8 weeks of the pollination. Being fruit set in *Hevea* is normally below five percent; all measures are needed to take care of success pollinations until mature fruits are collected within 5-6 months of period.

3.3.3 Field evaluation process

Long selection cycles are involved and generally 20-25 years are required for the final selection of clone reaching to the stage of RRISL recommendation. These new genotypes in the bud wood nurseries are subjected to three steps of evaluation under field level (Fig. 5.1).

3.3.3a Preliminary evaluation at mother plant nursery

Due to the inadequate facilities to carry out whole hybridization progeny for further field level evaluation, it is necessary to identify superior genotypes at the beginning by applying reliable early identification techniques. Annual girth increment, disease incidences and other growing performance are taken into record in juvenile trees individually. When trees reach the 3rd year, Morris Mann tapping is performed with S/2 d3 system (Plate 5.2a) during the cropping months (September – November) at the height of 45 cm. Latex of first three days is discarded and latex of next five tappings are collected continuously, into one cycle and the same procedure is repeated to get the records of 4 - 5 cycles of latex collections as cup coagulants.

Oven dried coagulated cup lumps are weighted. After evaluating all girth and yield records, a fair number of genotypes are selected and introduced to multiplication nurseries (Breeding pool). Foreign clones introduced from elsewhere are also tested initially in the same way.

Evaluation of genetic potential of new genotypes/Field level evaluation of selected genotypes under small scale clonal trials (SSCTs):

The new genotypes taken into the bud wood nursery are multiplied to evaluate under small scale level (SSCTs) field evaluation (Fig. 5.1). Evaluation of their genetic potential under experimental level is expected by this evaluation. These trails follow the basic experimental principles, as genotypes need to be replicated, randomized and they have to be evaluated by comparing control clones which are already performing well in the industry for particular objectives.

3.3.3b Evaluation in small scale trials (SSCTs):

- Growth rate: First year after planting, the plants are numbered and then girth is taken at the height of 120 cm from the bud union annually. When trees are opened for tapping, girth is taken at the height of 150 cm from the bud union.
- Yield records (Test Tappings): Yield is assessed by cup coagulation. Once a month latex in a cup of each individual tree is coagulated by mixing a few drops of 5% formic acid and labelled cup lumps are dried in the smoke house. Weight of dried cup lumps is recorded for at least A and B panels (Virgin Barks) in an individual basis (Plate 5.2b). It takes at least 10-12 years.
- Incidences of diseases and pests: Tolerance or susceptibility to critical foliar diseases at field conditions is done on the basis of visual symptoms with the assistance of the Plant Pathology Department. Assessment is carried yearly, throughout the whole experimental period.
- Tapping Panel Dryness (TPD): The percentage of dry trees in each genotype is recorded out yearly to monitor TPD susceptibility of that particular genotype.
- Wind damage: Number of trees damaged (branch or trunk snap or whole tree fallen) taken in to the census of wind damage in each genotype.
- With the above data, genotype comparison is performed using standard statistical methods, superior genotypes which are genetically capable of performing well are taken to large scale clonal trials for commercial level evaluation.

3.3.3c Evaluation in large scale level (ECTs)

Genotypes selected from SSCTs and if any outstanding genotype identified at mother plant nursery evaluation (which can skip the SSCTs evaluation step to reduce the evaluation period by 10-12 years) are taken into testing in large scale with the collaboration of the growers (ECTs) (Fig. 5.1).

Objectives of Estate/RRI collaborative clone trials:

- Monitor the performances of these selections further, at commercial scale.
- Study the Genetic environment (G x E) interactions of genotypes covering different agro - climatic regions (adaptation ability of genotypes in that particular environment can be evaluated).
- Make recommendations for estate sector, as these trials monitoring collaborate with estate sector (ECT/RRI).
- Make the recommendations for smallholders which are made from the collaborative trials with smallholders.

Planting materials raised by the RRISL are established at least one to two tapping task (250- 300 trees) in each grower site by covering all agro climatic regions. Trials are managed by growers under the supervision of RRISL. Annual girth and all other secondary observations such as incidences of diseases, tapping panel dryness and wind damages are recorded. Yield data are recorded in each genotype tested on all tapping days in terms of volume and metrolac reading of latex and percentage dry rubber content. Then dry rubber in kg per hectare per year is calculated. The performances of each genotype are assessed for 10-12 years to take a decision on release for cultivation. The genotypes which prove their performances up to satisfactory level are registered as a “clone” with the prefix “RRISL” then assigned numbers or names. However, the foreign introductions should be kept as their original designations given by own countries. Then these clones are introduced to group III of clone recommendation for the estate sector. The bet suited clones, at smallholder level are recommended to the particular sector under group “C”. Growers are allowed to choose this on their own preference. Apart of this main evaluation process, selected clones from group III are established to test their adaptability for higher elevations and drier areas, to make the clone recommendation for non-traditional areas (Fig. 5.1).

4. EXPANSION OF GENETIC DIVERSITY OF *HEVEA*

Most *Hevea* breeders believe that they have exploited the maximum genetic variability of Wickham’s original introduction and have now reached the threshold point with respect to economically important characters such as yield and vigour. *Hevea* breeders felt the need of exploration, collection and conservation of *Hevea* genetic material to widen the genetic base of present breeding populations. A necessity for such action becomes even more important as natural stands of *Hevea* in Amazon region are endangered by extensive felling of trees for agricultural purposes. In 1981 member countries of the International Rubber Research and Development Board (IRRDB) initiated and funded the project to collect new *Hevea*

germplasm. Maintenance and scientific evaluation of the IRRDB germplasm collection (Non-Wickham genetic base) and judicious use of promising genotypes will increase the efficiency of the present breeding programme by providing more genetic variability for the breeder to select upon (Plate 5.3).

Further, introduction of clones through multilateral clone exchange between IRRDB member countries is facilitated to expand the genetic diversity of breeding pool and promotion of international cooperation and capacity building for the betterment of the natural rubber Industry.

5. USE OF MOLECULAR STRATEGIES IN HEVEA BREEDING

In the conventional breeding procedure, the selection of genotypes is based on their visible or measurable traits. This process is time consuming, laborious, costly and also selections are less confident due to the influence of the environment for their expression. But molecular markers, which give genetic information, are efficient to identify or predict whether a plant will have desired characters (or genes) itself. *Hevea* breeders now use this marker-assisted selection to select precise genotypes for specific traits as stress tolerance, disease resistance, cold resistant, drought resistant, etc. Today many molecular techniques such as RAPD (random amplified polymorphic DNAs), RFLP (restriction fragment length polymorphisms), and microsatellites, AFLP (Amplified fragment length polymorphism), STS (sequence tagged sites) and ISA (Inter-simple sequence repeat amplification) are available.

Rubber Elongation Factor (*Ref*) protein mainly helps for the biosynthesis of natural rubber in *Hevea brasiliensis*. Rubber particles are tightly bound to this *Ref* protein. Previous studies found that the positive correlation between *Ref* gene expression pattern and latex yield. Therefore, quantitative gene expression of *Ref* gene is interest to identify and verify the yield performance of recommending clones.

6. CLONE RECOMMENDATION AND GUIDELINES TO GROWERS

Clone recommendation is the basic package given by the Rubber Research Institute to growers to maximize the productivity of rubber lands. It comprises of a wide variety of clones with the guidelines on their usage. Once a new clone is selected from ECTs, it is first registered and introduced into group III of the clone recommendation. The promising clones from group III gradually elevated to higher groups as group II and then finally to group I. Maintenance of the genetic diversity or a good clonal balance in estates is important because a good genetic buffering is needed to protect the industry against the possible disastrous conditions which might affect the rubber plantations in any time. Therefore, in the clone recommendation, the planters are encouraged to use as many clones as possible in a smaller extent according to the guidelines for planting.

- Group III- Newly registered clones. These clones have information from breeders' trials, but limited extent in growers' fields.

- Group II- Relatively new clones which are found promising in group III upgraded to group II
- Group I- consists of clones with proven track records for large scale planting.

6.1 Factors to be considered, when select the best clone/clones for their land:

It is a very difficult task to produce high yielding and vigorous clones with all other secondary characters upto satisfactory level. However, all recommended clones perform well in term of yield and girth, but may be susceptible to some diseases while tolerant to other diseases. Also, some clones perform differently in different agro climatic regions. Therefore, in a long term crop like rubber, it is important to select the best clone in order to reap the benefits of such clones over a long period. Because if a wrong selection is made, one has to bear the consequences for nearly 30 years before next replanting. The following factors should be considered when choose the best clone/s for the land.

- Elevation
- Rainfall of the area
- Clones already planted in the plantation
- Common rubber diseases in the area
- Performance of clone
- Availability of planting materials/bud wood nursery

6.1.2 Planting strategies

The clone recommendation tells the growers (planters) to use a wide variety of clones, but each in smaller extent, to widen the genetic diversity of rubber lands. It is advised to limit the planting of any single clone from group I, up to a maximum of 10% of the total extent. In group II, a single clone can be planted up to 3% of the total extent and whereas, in group III each clone can be planted in 2ha maximum. But when using many clones, growers have to be careful in maintaining the pure stands for each clone (see below “Maintenance and importance of pure stands of rubber”). The advisory circulars issued by RRISL time to time can be referred for updated information on usage of clones.

6.2 Current clone recommendation (Revised in November 2013)

Details are given at the Advisory Circular No. 2013/01

There are three basic recommendations

- Clone recommendation for the Plantation Sector
- Clone recommendation for the Smallholder Sector
- Clone recommendation for planting at high elevations

6.2a Clone recommendation for the Plantation Sector (below 300 m altitude)

Group I

Each clone to be planted up to a maximum of 10% of the total extent of the plantation to minimize the risk of sudden outbreak of diseases (e.g. *Corynespora* leaf fall)

RRIC 102, RRIC 121, RRIC 130*, RRISL 203, PB 260*

Group II

Each clone to be planted up to 3% of the total extent of the plantation.

RRIC 133	RRISL 201	RRISL 2001	BPM 24
	RRISL 205	RRISL 2003	PB 217*
	RRISL 206*		PB 235*
	RRISL 210		PB 28/59*
	RRISL 211*		
	RRISL 217*		
	RRISL 219		

Group III

Each clone, to be planted up to two hectares in a plantation. (Estate/RRI collaborative clone trials)

RRISL 208	RRISL Centennial 1	PB 255
RRISL 2000	RRISL Centennial 2	PR 255
RRISL 2002	RRISL Centennial 3	PR 305
RRISL 2004	RRISL Centennial 4	
RRISL 2005	RRISL Centennial 5	RRII 105
RRISL 2006		RRIM 712
RRISL 2100		

*Should be tapped 67% intensity *i.e.* S/2 d3

6.2b Clone recommendation for the Smallholder Sector

It has three groups,

Group (a) RRIC 102, RRIC 121, RRISL 203

Group (b) RRIC 100 - The clone is recommended only for non-traditional areas.

Group (c) RRISL 2001 - This clone is recommended for holdings more than 5 ha. in extent and the area planted should not exceed 10% of the total extent of the holding.

6.2c Clone recommendation for planting at high elevations

This recommendation is for the areas above 300m and up to 900m and this also has 2 groups,

- Group (a) - RRIC 100, RRIC 130
- Group (b) - RRIC 102, RRISL 206

6.2d Special notes on planting different clones

Note:

- **RRIC 100:** This clone is suitable for seed production - 1% of the total extent per year can be planted up to 10% of the total extent until the year 2020.
- **RRIC 121:** For the Plantation Sector - As in the case of RRIC 100, this clone has already been extensively planted during recent past. Therefore, it is better to refrain from planting the clone RRIC 121 until a reasonable clone balance is achieved.
- RRIC 121 and RRISL 203 should not be planted in humid pockets.
- RRIC 130 is prone to wind damage and should not be planted in areas prone to strong wind.
- Clones RRIC 130, RRISL 206, RRISL 211, RRISL 217, PB 217, PB 235, PB 28/59 and PB 260 should be tapped at 67% intensity *i.e.* S/2d3 until intensification.
- In the intermediate zone, planting may be extended to areas beyond 900m elevation on trial basis with the collaboration of RRISL.
- Clone RRIC 102, being very sensitive to magnesium deficiency, application of additional 25% of Mg fertilizer is recommended as an insurance dose.

7. MAIN CHARACTERISTICS OF SOME RECOMMENDED CLONES

7.1 RRIC 100 Series clones

RRIC 100

A vigorous clone, capable of yielding an average about 1700 kg/ha/yr during the first ten years of tapping. In year 2010, it claimed nearly 33% to the total rubber area in the country. Therefore, now it has been limited only for nontraditional areas. This clone is susceptible to Oidium leaf fall. Growth after tapping is average.

RRIC 102

A vigorous clone with the potential yield around 1800 – 2000 kg/ha/yr. claims during first ten years of tapping. Tolerant to Oidium leaf fall disease and free from Corynespora leaf fall disease. Latex is slightly yellow. Growth after tapping is slow.

RRIC 117

A vigorous clone; but its initial yields are low. RRIC 117 is capable of giving an average yield of 1,525 kg/ha/yr during the first 10 years. It tolerates some races of the SALB fungus. Latex is white.

RRIC 121

A very vigorous clone, RRIC 121 has given an average yield of 2,513 kg/ha/yr during the first seven years of tapping under experimental conditions. The level of tolerance to Oidium is below average. Girth increment after tapping is very good. It has below average tolerance level to Phytophthora leaf fall, but is resistant to the second phase, Phytophthora bark rot. Extensive leaf fall can reduce the yield. This clone is also susceptible to Colletotrichum leaf disease but is tolerant to certain races of the South American Leaf Blight (SALB) fungus. Sometimes RRIC 121 requires induction of lateral branching. Latex is slightly yellow. Maintains a very good growth after tapping.

RRIC 130

This too is a vigorous clone with very high initial yields of about 4,662 kg/ha/yr during first two years. It is prone to wind damage (trunk snapping) and should not be planted in areas prone to strong winds. The clone is highly susceptible to Phytophthora bark rot. It is tolerant to some races of the SALB fungus. Latex is white. It should be tapped at 67% intensity until intensification.

RRIC 131

A very vigorous clone with good post-tapping vigour. It is also a consistent yielder. In RRISL clone trials, it has yielded an average of 2,854 kg/ha/yr during the first nine years. This clone is slightly susceptible to Oidium. RRIC 131 shows above average susceptibility to Corynespora leaf disease. It has an average tolerance to other important foliar diseases.

RRIC 133

A very vigorous clone with a strong, straight trunk. Trunk characteristics are ideal for timber. In RRISL clone trials, it has yielded an average of 2,452 kg/ha/yr during the first 10 years. It exhibits below average tolerance to Phytophthora leaf disease.

7.2 RRISL 200 Series clones

RRISL 203

A vigorous clone, having good growth increment in both pre and post tapping. In small scale evaluation the yield potential was around 60 g/t and commercial average is around 3,000kg/ha/yr. in first four years of tapping. It is highly resistant to *Corynespora* leaf fall and *Oidium* leaf fall, but prone to *Phytophthora* leaf fall and *Gloeosporium* diseases.

RRISL 208

A vigorous clone that showed a good yield around 3,000 kg/ha/yr during the first ten years of tapping under commercial trials and the yield fluctuation throughout the year is very low. However, it shows moderate level infections of *Corynespora* leaf fall disease.

RRISL 211

A vigorous clone. A yield of around 3,000 kg/ha/yr was recorded in the first ten years of tapping. under commercial scale. But this clone is prone to brown bast at the level of above average under 100% tapping intensity. Hence, recommended low frequency tapping system (67%). Free from the *Corynespora* leaf fall disease.

7.3 Foreign clones

PB 28/59

A high-yielding clone. It is a slow starter with gradual increase in yield with age. Some commercial clearings have yielded an average of about 1,511 kg/ha/yr during the first ten years. It should be tapped at 67% intensity because of its high susceptibility to brown bast. PB 28/59 is susceptible to *Oidium* and *Gloeosporium* leaf diseases. Therefore, it should not be planted in very wet and humid locations where the micro-climate is favourable for the spread of these diseases. Latex is slightly yellow in colour.

PB 217

A good yielder. Commercial clearings in some estates have recorded a yield of more than 1,500 kg/ha/yr during the first ten years. PB 217 is highly susceptible to *Phytophthora* leaf fall and bark rot disease and also moderately susceptible to pink disease and *Oidium* leaf disease. It should not be planted in wet and humid localities where the micro-climate is favourable for the spread of these diseases. PB 217 is not recommended for areas with an average rainfall of more than 3750 mm and/ or at elevations above 300 m mean sea level. Latex is slightly yellow in colour. However, this clone is susceptible to tapping panel dryness. Therefore, tapping at 67% intensity until intensification is recommended.

PB 260

Field trials carried out by RRISL show that this clone is as vigorous as RRIC 121 and RRIC 110. It has good tolerance to Oidium and bark rot. Yield data from trials established in Sri Lanka are not available. But according RRIM it is capable of yielding an average of 2,192 kg/ha/year during first 12 years of tapping. Susceptible to tapping panel dryness and therefore should be tapped at 67% intensity. Latex colour is pale yellow.

PB 235

This is vigorous as RRIC 121 and RRIC 100. It has below average tolerance to Oidium and good tolerance to bark rot. Yield data are not available from trials in Sri Lanka. In Malaysia under experimental conditions PB 235 has yielded an average of 2,485 kg/ha/year during first 15 years of tapping. This too is prone to tapping panel dryness. Therefore, should be tapped at 67% intensity. Latex is pale yellow in colour.

7.4 RRISL 2000 series clones

All seven clones (RRISL 2000- RRISL 2006) of this series are more vigorous and reached the tappable girth at the age around 4½ years under small scale evaluation whereas, it was around 5½ years at commercial scale. Also, they showed good post tapping girth increment.

Under small scale evaluation, all these clones recorded an average yield potential in term of dry rubber weight (g) as g/tree/tapping (g/t) above 40 during the first 12 years of tapping. The clone RRISL 2000, 2001 and RRISL 2003 showed outstanding performance in yield under commercial scale evaluation. RRISL 2000, RRISL 2001 and RRISL 2005 are good for latex – timber production. All these clones are free from *Corynespora* leaf fall disease. But show below average susceptible to Oidium and *Phytophthora* leaf fall.

A general observation on the average yield potential of above RRISL clones, recently after experimental evaluation is the existence of a yield gap between genetic potential and experimental commercial output and growers output. However, it is possible to achieve this potential yield through proper stands, following recommended tapping system and agronomical practices.

7.5 RRISL Centennial clones

This series was raised after evaluation of 1987 – 1992 hand pollination progenies and released in the year 2009, with the celebration of hundred years of Rubber Research Institute of Sri Lanka. There are five clones (RRISL Centennial 1- RRISL Centennial 5). The average yield in terms of dry rubber weight (g) per tree per tapping (g/t) is ranged from 35 – 45 in S/2 d2 tapping system under small scale evaluation, during the first ten years of tapping. All clones showed vigorous growth before and after tapping.

8. RAW RUBBER PROPERTIES OF NEWLY INTRODUCED HEVEA CLONE

Latex obtained by tapping the bark of rubber tree contains not only rubber hydrocarbon but also a considerable number of non-rubber substances which include carbohydrates, lipids, proteins, amines, carotenoids, phenolic substances, and some inorganic constituents. Constitution of these substances is primarily a clonal factor and ultimately has an impact on raw rubber properties of natural rubber directly and indirectly. Nowadays breeding programs of *Hevea brasiliensis* are also concerned. About quality of raw rubber produced from latex of new clonal selections. This is to ensure quality of the rubber based products. Quality of the product depends on the quality of raw materials starting with latex. Adjustment of raw rubber properties is extremely difficult or costly hence attention has given to select *Hevea* clones with acceptable level of properties.

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

8.1. Raw rubber properties

Various technological advances made during recent past have led to drive the consumer interest to the quality and properties of raw rubber. Hence, different standards have been set based on quality parameters of end user requirements (Table 5.1).

Table 5.1. Specifications for raw rubber stipulated for Sri Lankan crepe rubber and Lankaprene.

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

8.1.1 Clonal difference of raw rubber properties

Recent studies have clearly shown the existence of clonal differences in almost all the properties against the specifications set for latex crepe and Lankaprene. The clonal selection in breeding programme is basically done on latex yielding capacity and other desirable agronomic characteristics. Whilst no individual grower, either planter or smallholder, pay any attention to plant rubber

with desirable raw rubber characteristics, raw rubber producers and manufacturers resolve the problem of variability in properties by adjusting the procedures in production lines resulting in additional costs. If clones having desirable raw rubber properties are used for cultivation, cost of production could be minimised and raw rubber could be produced even to niche markets. Focus on raw rubber properties in breeding programs is inadequate resulting in considerable variations among *Hevea* clones (Table 5.2). Therefore, paying special attention in this regard would be of great use to the producers as well as the consumer.

Table 5.2. Average raw rubber properties of different *Hevea* clones (coefficients of variation are in parentheses).

Clone	Initial plasticity number (Wallace units)	Plasticity retention index	Mooney viscosity (ML 1+4 @100°C)	Lovibond Colour	Ash % (w/w)	Nitrogen% (w/w)
RRIC 100	38 (7.89)	72 (9.72)	78 (5.13)	2.2(25.11)	0.19(21.05)	0.44(6.87)
RRIC 121	52(11.54)	63(28.57)	89(4.49)	1.6(27.67)	0.14(28.57)	0.45(15.56)
RRIC 130	52(9.62)	71(7.04)	96(3.13)	1.4(44.12)	0.11(36.36)	0.42(16.67)
RRIC 102	41(4.76)	69(17.39)	79(6.33)	2.1(25.84)	0.17(29.41)	0.48(22.92)
RRISL 201	42(9.67)	77(11.30)	78(7.91)	1.9(31.42)	0.12(44.97)	0.45(2.22)
RRISL 203	59(11.56)	68(5.28)	106(5.28)	2.1(13.75)	0.15(20.97)	0.41(36.66)
RRISL 205	43(10.78)	75(10.30)	81(8.08)	2.0(25.50)	0.14(17.59)	0.54(14.11)
RRISL 206	50(8.02)	72(12.67)	91(3.54)	4.7(24.52)	0.15(22.24)	0.41(4.88)
RRISL 208	46(9.51)	76(11.76)	83(6.15)	1.5(33.33)	0.15(13.37)	0.38(3.72)
RRISL 211	45(15.82)	76(13.49)	83(10.25)	1.4(13.11)	0.16(23.66)	0.41(12.67)
RRISL 217	40(14.12)	77(14.30)	74(12.58)	1.3(17.36)	0.14(23.05)	0.48(4.47)
RRISL 219	42(11.63)	74(13.88)	77(7.31)	1.6(28.58)	0.14(35.92)	0.43(6.15)
RRISL 2000	44(6.82)	69(4.89)	85(6.88)	1.6(30.16)	0.12(34.08)	0.38(14.89)
RRISL 2001	43(9.68)	72(7.37)	81(11.76)	1.7(40.07)	0.14(16.62)	0.41(8.68)

8.2. Lovibond colour

Colour is an essential property in the production of light-coloured goods such as infant teats, catheter tubing, blood tubing *etc.* Conventionally raw rubber is graded visually according to their colour and it doesn't represent the technical quality. In particular, higher amounts of poly-phenolic substances and carotenoids increase the colour of raw rubber. Carotenoids and phenolic substances are responsible for yellowish and greyish to blackish colour in crepe, respectively. Fractionation of latex and bleaching may improve the colour of crepe rubber. Colour of un-fractionated unbleached crepe process from latex varies among the clones (Table 5.3).

Table 5.3. Classification of *Hevea* clones based on Lovibond colour index.

Group	Range	<i>Hevea</i> clones
Low	<1.5	RRIC 130, RRISL 211, RRISL 217, RRISL 220,
Moderate	1.5-2.5	RRIC 100, RRIC 121, RRIC 102, RRISL 201, RRISL 203, RRISL 205, RRISL 208, RRISL 219, RRISL 2000, RRISL 2001
High	2.6-3.5	
Very high	>3.5	RRISL 206

(This work on **Raw rubber properties of newly introduced *Hevea* clone** was done by K V V S Kudaligama, Head, Biochemistry & Physiology Dept. and A P Attanayaka, Senior Research Officer, Raw Rubber & Chemical Analysis Dept.)

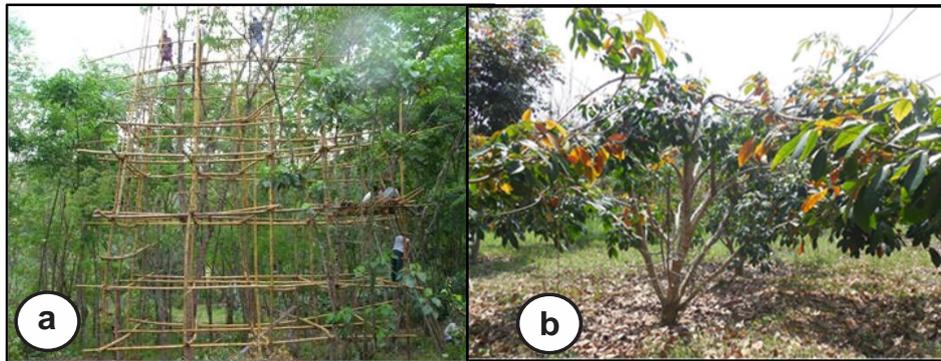


Plate 5.1. Hybridization. **a.** at estate fields, preparation of bamboo scaffolds to reach the inflorescences born on tips of branches; **b.** at breeding garden, mother trees are trained by bending branches towards the ground.

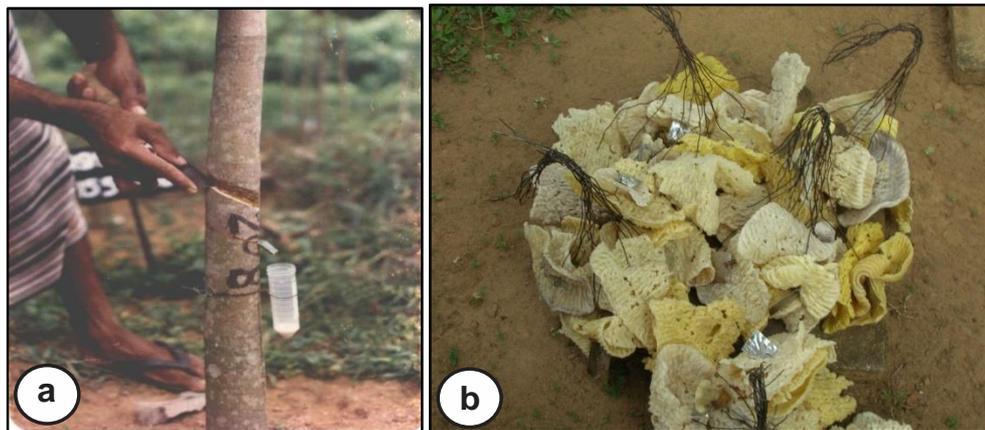


Plate 5.2. **a.** The Morris Mann tapping is applied in the mother plant nursery; **b.** Dried cup lumps collected from individual trees of a SSCT trial (test tapping samples).



Plate 5.3. Multiplication and evaluation of the genotypes collection of *Hevea* obtained from 1981 IRRDB expedition to the Amazon.

Chapter 6

Management of rootstock and budwood nurseries

Priyani Seneviratne and Sashika Nakandala

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1. INTRODUCTION

The successful dispatch of seeds from South America to England by Sir Henry A. Wickham in 1876 began the historical events of domestication of *Hevea brasiliensis* (A. Juss.) Muell. Arg., commonly known as the Brazilian rubber tree or the Para rubber tree. In the genus *Hevea* there are 12 species, some of which are *Hevea brasiliensis*, *H. nitida*, *H. guianensis*, *H. benthamiana*, *H. pauciflora*, *H. camporum*, *H. spruceana*, *H. rigidifolia* and *H. microphylla*. However, *H. brasiliensis* is the only economically important species.

The earliest method of commercial cultivation of *Hevea* was by unselected seeds. This was followed by planting seeds collected from superior individuals or

from seed gardens. However, the vegetative propagation method of budding on to seedlings developed by Van Helten, a Dutch Horticulturist in Java in 1917 was a real breakthrough towards improving the planting material with regard to yield. From the early 1920s bud-grafting was commercially adopted in establishing commercial rubber cultivations. In this method buds taken from high-yielding materials are grafted on to seedlings raised from unselected seeds.

2. NURSERIES

Vegetative propagation by bud-grafting demands management of nurseries. Two types of nurseries, *i.e.* seedling or rootstock nurseries to generate rootstocks and budwood or source bush nurseries to harvest budwood are involved in producing budded stumps.

Further, proper nursery management is needed to produce quality planting material. As it is well established that use of poor quality planting material leads to poor growth resulting in delayed maturity and reduced yield potential. Nursery management should always be a priority area in rubber plantations.

The earliest method of budded plant production was bare root budded stumps raised in ground root stock nurseries. The budded plants produced this way has no foliage on them and the root system also a pruned one. They carry many disadvantages such as not knowing the clone, usage of very old root stocks, lack of proper tap root development due to the initial damages occur at uprooting, uneven sprouting and growth in the field, higher casualties in field establishment, spreading root diseases due to disease infected ground nurseries.

In order to overcome some of the disadvantages associated with bare root budded stumps, they were planted in polythene bags and maintained as nurseries until the budded plants develop 2-3 leaf whorls and some roots. This method helped to identify the clone and even-sprouting and growth in the field by not using late sprouted plants. The casualty rate could also be reduced, but if the weather condition was not optimum, a high casualty rate was observed due to plants having leaves but not well developed root system. Though poly bag plants were better than bare root budded stumps, they also contained many disadvantages. Young budding plants on the other hand were superior to poly bag plants in all ways. Production of young buddings is discussed in this Chapter in detail. Furthermore, in order to produce advanced planting material especially to be used in infilling of 2-3 year old clearings, budded plants are maintained to be stumped after 1½-2 years of age, as per the new recommendation within the clearing itself, which will also be discussed later.

3. RUBBER SEEDS

Rubber seeds are the planting material for rootstock nurseries. Rootstock nurseries are established every year during the seed fall. The main seed fall in Sri Lanka is around August-September. In relatively drier areas *i.e.* Monaragala, Bibile *etc.* seed fall is in the dry months of February-March. Seeds of all the clones recommended for planting are suitable for raising rootstocks.

Since the late 1980s, rubber seed production in wet districts of Sri Lanka is very low, making it necessary to obtain seeds from where they are abundant *i.e.* relatively drier districts such as Kegalle, Kurunegala *etc.* Since rubber seeds remain viable only for a short period, fresh seeds should be collected and sown in germination beds with minimum delay, *i.e.* within 2-3 days. Seeds with glossy appearance are generally fresh. However, if the weather is dry the lustre may remain and seeds will look fresh. If it becomes necessary to store the seeds for a few days though not recommended, seeds should be spread on the ground in a cool and dry place, under 100% shade. Even during transporting they should not be packed in plastic sacks and transported under the sun in open cabs or trucks.

3.1 Selection of seeds

Depending on the prevailing weather conditions seed fall may last 2-4 weeks. Collecting seeds from the early seed fall is important, as they are more vigorous. This will also prevent collecting old seeds and it will also be an advantage. Further, within a clone heavier seeds produce more vigorous seedlings relative to lighter ones. But a large variation exists among the seeds of different clones with regard to shape and weight (Plate 6.1). As seeds are generally collected from mixed clonal areas, none of these parameters can be practically adopted for selecting quality seeds. Therefore, the only way to select vigorous seeds is to sow them in germination beds and selecting early germinated ones.

3.2 Germination bed

Germination beds are prepared by laying sand to a depth of 4-5 cm. The germination bed should be 1 m wide and any length as required (Fig. 6.1). Generally, pure sand is used in germination beds. This is important to prevent infection of germinating seedlings by soil-borne pathogens. Generally, a 1 m² size germination bed holds about 1,000 seeds, *i.e.* 4 kg of seeds. The number of seeds to be used in the germination bed should be at least twice as the number of rootstock plants or about four times as the number of budded plants required.

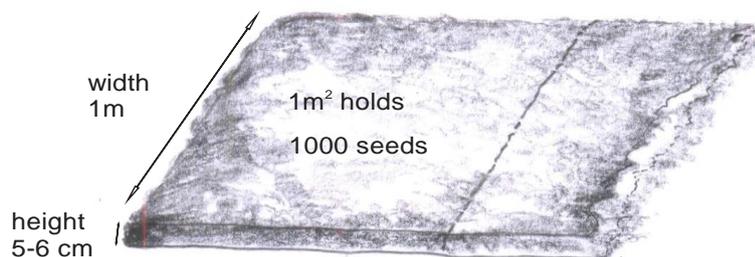


Fig. 6.1. Layout of the germination bed.

The seeds should be slightly covered with sand until the seeds are nearly in level with the surface of the sand (Plate 6.2). The old recommendation of placing seeds on the flat side facing the ground is no longer necessary but single

layer placing any side down is recommended. Germination beds should not be exposed to direct sunlight and where necessary a shade should be provided with cadjan or similar material. But not with black polythene sheets which results in heat buildup within. Germination beds can conveniently be laid out in the shade of mature rubber trees. The beds should be kept moist by watering at least once a day but should not be allowed to become water-logged. Beds may need to be suitably protected to prevent damage by animals.

Rodents such as squirrels may cause physical damages and on the other hand ants damage the seeds without any damage to the seed coat. Chemicals should be used in such events.

Germination will start after about 7 days of seed sowing, provided that the seeds are fresh and healthy. If the seeds are old the first sign of germination will be seen after about 12-14 days. In any case, seeds should be transferred to the rootstock nursery as soon as the tip of the radical has forced its way through the seed coat (Plate 6.3). Germinated seeds should be harvested every other day, and for a maximum of four rounds. Only about 50% of the seeds will germinate within this period and all the late germinates should be discarded as they will not grow into vigorous plants. Germinated seeds should be planted in holes about 2 cm deep and slightly covered with earth in polybags for young buddings for raising young buddings. Shading with bracken or any other suitable material may be necessary and under dry weather conditions, plants should be watered preferably in the late afternoon.

4. ROOTSTOCK NURSERIES

4.1 Ground rootstock nurseries

Ground rootstock nursery preparation is not discussed in this book as bare root budded plants are no longer recommended as planting material. However, site selection is more or less the same for both nurseries, ground or young budding.

4.1.1 Site selection

The ideal climatic conditions for rootstock nurseries are found in the traditional rubber growing districts of Sri Lanka. Availability of a continuous water supply is an important factor as watering becomes necessary in dry spells. Selecting a site away from mature clearings is beneficial, as far as diseases are concerned.

Having an adjoining mature clearing or a boundary consisting of large trees may shade the nursery and will result in unnecessary root growth from mature trees, even for a young budding nursery. A well-drained flat land is ideal for a rootstock nursery. Deniya, *i.e.* low lying, lands can also be used if water can be drained to a depth of about 1 m. If undulating lands are used soil conservation methods should be properly adopted.

4.1.2 Preparation of nursery beds

On average flat land, there is no difficulty in arranging of plant rows or

blocks containing rows. On sloppy land bags should be arranged on the contour. On steep land, it may be necessary to decrease the width of the nursery beds to arrange bags in rows. It is convenient to start leveling beds from the top of the slope and work downwards. A drain of 30 cm x 30 cm should be cut at the back of each bed. On flat land, the depth and distance between drains should be decided to prevent water-logging. Paths should be provided in a large nursery, enabling manuring, weeding, watering, bud-grafting and inspection and also to allow for free movement of air through the nursery plants.

4.1.3 Spacing and plant production capacity of the nursery

Once the beds are prepared, soil filled bags can be arranged in single rows, 45 cm between rows (Fig. 6.2a). Also, they can be planted in pairs of rows on spacing with 60 cm space between centres of adjacent pairs of rows (Fig. 6.2b).

With either way of spacing, one hectare of land, after allowing for inspection paths and drains, accommodates approximately 74,000 seedlings. On hilly terrain, this could be much less. The nursery should be inspected at monthly intervals and weak plants replaced with good plants. With 80% bud-grafting success, it should be possible to get about 35,000 plants from one hectare of young budding nursery.

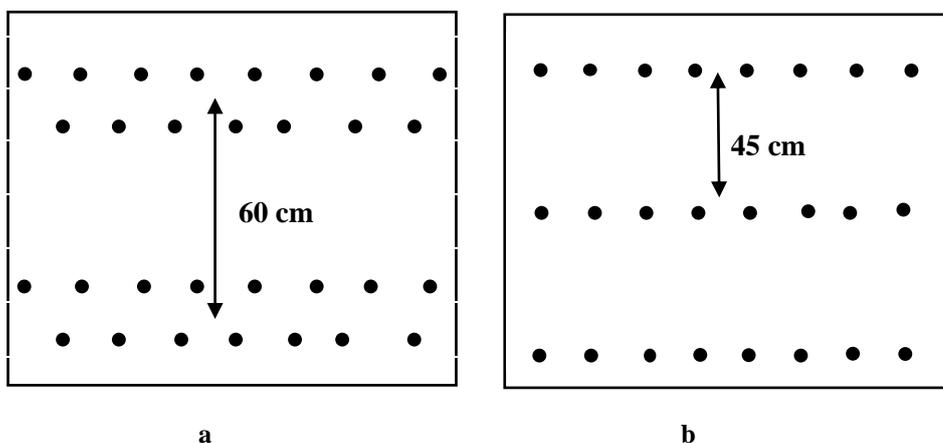


Fig. 6.2. Spacing systems for young budding nurseries. **a.** Single rows; **b.** Double rows.

4.2 Polybag rootstock nursery for raising young buddings

In young budding, as rootstock plants are raised in polybags, the ground rootstock nursery used for conventional green and brown buddings is replaced by a polybag nursery (Plate 6.4). Therefore, even a deniya, *i.e.* low lying land can be used in the absence of good land, but with proper draining of water upto about 2-3 feet.

Black virgin polythene of gauge 500 or 300 is used for preparation of bags. Both 15cm (6") or 17.5cm (7") width guzzetted polythene tubing made to 37cm (15") or 45 cm (18") length bags are suitable. However, standard size bags,

guzzetted and perforated, are readily available in the market and are supplied by many polythene manufactures. The price of polythene and hence the price per bag is on the increase and mixing of recycled polythene is a common problem. When the bags are made out of recycled polythene, durability is the major issue.

4.2.1 Soil for filling bags nursery maintenance

Top soil sieved with a 1 cm sieve, mixed with rock phosphate at a rate of 50 g/bag and compost at a rate of 100g per bag is used for filling bags. Soil-filled bags can be arranged in single or double rows as explained above. However, single rows seem better as there is humidity build up among interlocked leaves of plants arranged in double rows.

The success of a young budding nursery will mainly depend on some important factors. Selection of vigorous seedlings by using a germination bed is the most important. One reason for this is that faster growth required for young budding can be obtained only with vigorous seedlings. Further, at least 90% of plants grown in bags are expected to be bud-grafted. Manuring with liquid fertilizer mixture as recommended (Chapter 15) is equally important to achieve anticipated growth. Agro-management practices such as disease control in time are also essential. Young budding nursery should never be kept for more than one year.

5. BUDWOOD NURSERIES

Budwood nurseries of different clones recommended for planting should be maintained to harvest budwood in order to obtain buds for grafting. A clone is identified by a number proceeded by few letters to denote the place of origin of the clone *e.g.* RRIC 100, (RRIC for Rubber Research Institute of Ceylon, RRISL for Rubber Research Institute of Sri Lanka and PB for Prang Bersa).

5.1 Establishment of budwood nurseries

Budwood nurseries can be established preferably with young buddings. In order to maintain authenticity, it is recommended that planting material for establishment of budwood nurseries is obtained from the Rubber Research Institute of Sri Lanka. For expansion of the budwood nurseries planting material can be raised in the estate taking care to prevent mixing of clones.

5.2 Location and layout

Site selection is important for budwood nurseries. Areas away from mature clearings or large trees are recommended. Further, establishing them close to roads or estate bungalows will make supervision easy. Flat or sloping land may be used.

When establishing budwood nurseries, the current clonal composition of the estate, annual requirement of planting material for replanting *etc.* should be considered prior to deciding the clones and number of points per clone to be planted.

Budwood nurseries are normally established with the onset of either the Southwest (SW) or Northeast (NE) monsoon rains every year. However, as the number of plants planted will be small, the nursery can be established at any time and watered.

Budwood plants are planted in planting holes of 60 cm x 60 cm x 75 cm as for normal field planting. The recommended spacing for planting nurseries to harvest budwood is 90 cm x 120 cm (Fig. 6.3). This spacing is for budwood nurseries to be kept for about 10 years or *ca.* 7-8 harvests. A temporary nursery for a single or 2-3 harvests, plants can be spaced closer, according to the space available. Budwood nurseries can be established at a planting distance of 4' x 4' (1.2 m x 1.2 m) in order to make the plants grow as bushes and to harvest more green shoots. Branches should be cut when the bark is brown and just above a leaf whorl and fertilizer should be applied about 9-10 weeks before green budwood is required for young budding. The most vigorous shoots produced could be used as bud sticks. Also about 3-5 of the most vigorous shoots can be allowed to grow until a few centimeters of brown bark develop at the basal portion. They are then pruned to produce more shoots which can be removed to obtain green buds. By repeating this process, a bush with a number of branches can be obtained.

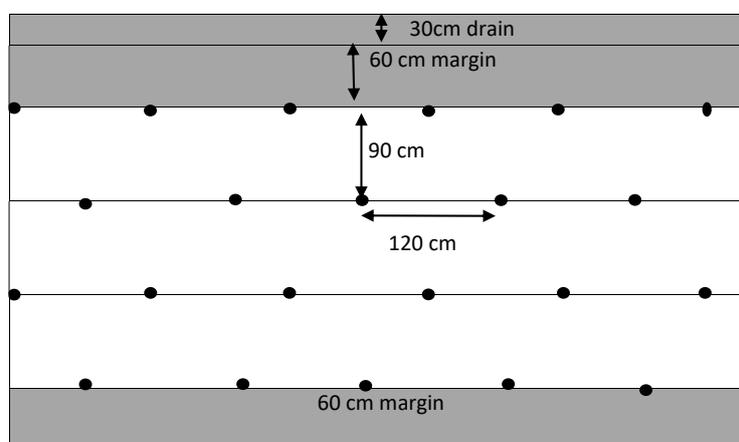


Fig. 6.3. Spacing of plants and layout in budwood nurseries.

5.3 Care of budwood nurseries

The agronomic practices recommended for young buddings grown in the field are also applicable for plants in the budwood nursery. All lateral shoots, as they appear, should be pruned, up to a height of about 2m. Such side shoots rarely appear in a closely planted nursery, if one ensures that the terminal bud is active through correct cultural operations. Every lateral bud which sprouts, is a bud lost and will also lower the quality of budwood.

Manuring of budwood nurseries is described elsewhere (Chapter 15). It was the practice that budwood nurseries not manured during the three-month period before harvesting of brown budwood. The aim should be to produce budwood with good peeling quality with the maximum quantity of food reserves in the budwood. A sudden flush of vigorous growth which depletes the food reserves is not desirable just before harvesting of brown budwood. Hence precautions should be taken not to stimulate such growth by fertilizer application close to the budwood-harvesting period. However, brown budwood is not used now as brown budding is not done.

For green budding, green shoots are obtained by pruning the budwood nursery plants about 10-12 weeks before they are required. Once the nursery is pollarded, plants should be fertilized in order to obtain a maximum number of vigorous shoots. To ensure quality budwood, not more than 5-6 shoots should be allowed to grow after pollarding.

5.4 Types of buds and approximate number of buds on budwood

5.4.1 Brown budwood

Though these are not used, in order to assure the knowledge on different types of buds, it is described here. Buds found in the axils of assimilatory leaves (“Leaf Scar buds”) as well as buds found in the axils of scale leaves (“Scale Leaf buds”) are generally suitable for bud grafting (Fig. 6.4).

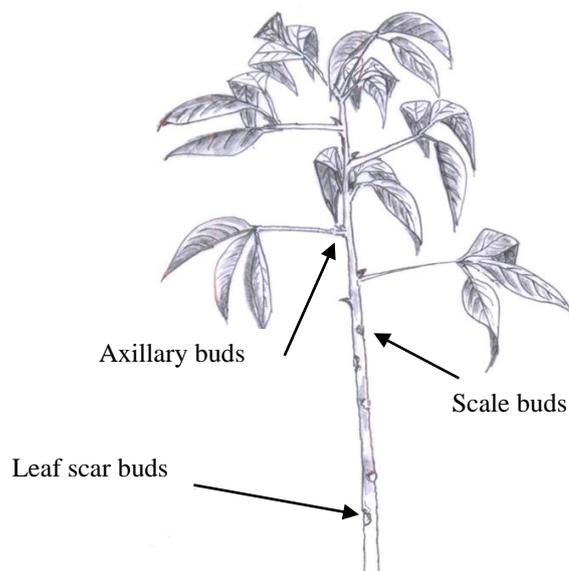


Fig. 6.4. Different types of buds on a budwood stick.

Axillary buds may be a little more difficult to peel than scale buds but the sprouting of buds is quicker than that of scale buds.

The number of buds that can be taken off from a metre of brown budwood varies with the clone and the condition of the plants. Generally, 15-20 buds are present in 1 m of brown budwood. It is possible for a skilled budder to obtain an average of 12 successful buds per metre of budwood. A more conservative estimate will be ten successful bud-grafts from one metre of budwood.

5.4.2 Green budwood

Green buds for young budding can be obtained from the base of the green budwood (base of the new flushes that grow after pruning). These are the buds which lie in the axils of scale leaves. Buds in the axils of assimilatory leaves, *i.e.* axillary buds, can also be used. If the axillary buds are to be used, the leaves should be removed by cutting the petiole about 3 weeks before they are required, (Plate 6.5) so that the leafstalks will fall off. About 50% of the axillary buds can be used in this manner. If all the leaves are removed the quality of the budwood will deteriorate.

However, the smaller number of buds available in green shoots will be compensated by the higher number of shoots produced each time the stem is pollarded (Plate 6.6).

5.5 Harvesting budwood and nomenclature

Brown budwood is not used commercially at present as the recommended planting material is young budding. But in order to transport budwood, brown budwood is used. Budwood sticks about 8-10 cm in circumference are ideal for removal of brown buds. This growth is achieved in 18-24 months. Normally, budwood should not be cut until there is brown bark developed up to a height of 2 m. Prior to harvesting budwood for the first time, colour bands of appropriate colour should be painted on every plant, 15 cm above the graft union. No shoots should be allowed to appear below this colour band. This ensures that no stock shoots are used at any time and the authenticity is preserved. The colour band recommended for each clone series is listed below.

Brown budwood is cut for the first time at 30 cm from the union, making sure that there are 2-3 buds within 10-12 cm of the cut. The cut is made at an angle of 45° and the cut end should be dressed with a fungicide and then sealed with a waterproof dressing (Fig. 6.5).

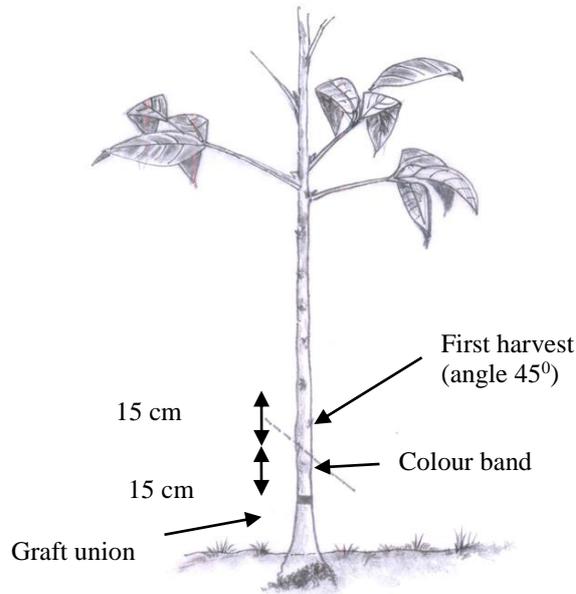


Fig. 6.5. Harvesting of a new budwood plant for the first time.

A hand pruning saw or a “Bushman’s” saw with fine teeth is suitable for cutting budwood without damaging the cut ends. Though brown budwood is not used commercially, the nursery can be maintained by maintaining the frame for future use.

After the first crop of budwood has been harvested in about 18-24 months from planting, two buds are allowed to develop, preferably on opposite sides of the cut shoot. When these two branches are removed for budwood, a sufficient length of stem, up to 15 cm from the point of last regeneration, should be kept for development of the next crop of budwood. These plants will provide about 12-15 m of budwood in another 15-18 months. After about the third harvest, plants in the budwood nursery will produce 6-7 branches of budwood and 25-30 m of budwood. This will continue until the nursery is uprooted after 10 years (Figs. 6.6 a,b & c). Budwood plants should be cut back for regeneration of more juvenile and fresh budwood annually. However, green budwood will not remain usable as long as brown budwood, and must be harvested within 3-4 weeks after it has become suitable for removal of buds.

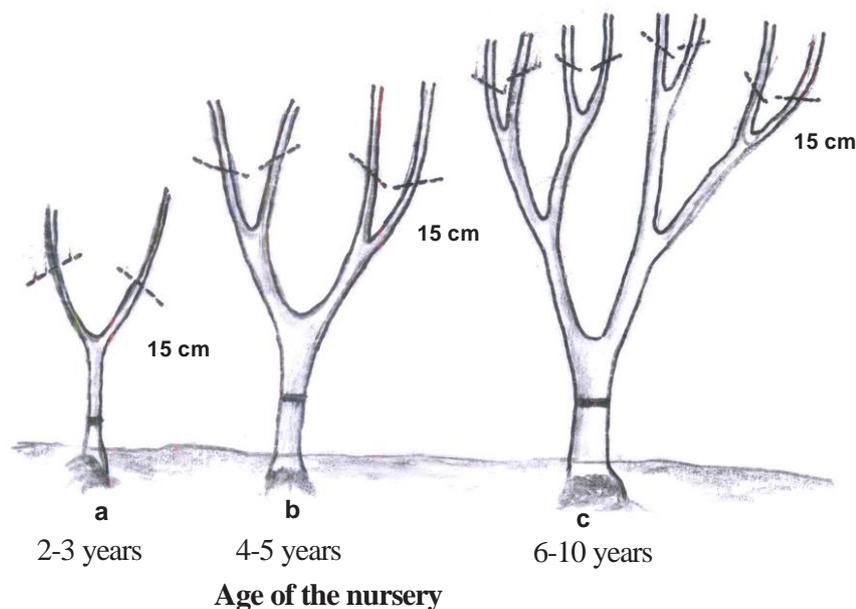


Fig. 6.6. Maintaining the frame of the budwood plant at harvesting **a.** 2-3 year old plants; **b.** 4-5 year old plants; **c.** More than 5 years old plants.

5.6 Labelling, packing and storage

The brown budwood should be labelled on the cut ends with the name of the clone immediately after harvesting from the plant. An indelible pencil or a permanent marker pen can be used for marking the name of the clone on cut ends that are moist. Soon after marking, cut ends are dipped in warm molten paraffin wax to preserve the budwood during transport and until it is used for grafting.

For transport, budwood can be covered with a banana sheath or moist coconut fibre. After enclosing in a banana sheath, 10 to 12 such sticks can be bundled for long-distance transport.

Good mature budwood can be preserved for several days. In order to do so, wax should be removed by cutting a thin slice from the base of the budwood stick and the cut end dipped up to a depth of 5 cm in a vessel of water placed in a shady place away from the direct sun.

It is preferable to cut green bud sticks early in the morning and if they are to be used on the same estate, they can be kept in polythene bags and left in a cool place. Green bud sticks can be stored in this way for 24-48 h without affecting grafting success. If they are to be transported some distance the bud sticks should be packed in moist sawdust or in banana sheaths to prevent desiccation and damaging the buds.

5.7 Management of budwood nurseries

An important aspect of the management of budwood nurseries is to preserve the authenticity of the materials. Hence, following precautions are recommended to any budwood nursery.

1. Attempts should be made to obtain authentic material from the RRISL in the establishment of budwood nurseries.
2. On no account should more than one clone be included in a block or section of the nursery.
3. Each block or section planted with a particular clone should be surrounded with two strands of galvanized wire or hardwood posts.
4. A separate access should be provided for each clonal block.
5. The correct nomenclature of the clone should be displayed in permanent letters on a board at each gate or stile. The board should also give the planting year and the number of budwood points (Plate 6.7).
6. Overbudding of existing clones with new clones should never be practised.
7. A plan of the nursery with the planting points of each clone correctly numbered should be made and maintained.
8. If possible the harvesting of budwood from various points should be recorded along with the dates and numbers. The name of the consignee of the budwood should also be recorded for future reference.

The management of the budwood nursery should ensure the supply of good quality juvenile budwood for budgrafting programmes. Pollarding, manuring of budwood nurseries and replanting when a nursery is 10 years old will help to achieve this.

5.8 Life span of budwood nurseries

Budwood should not be harvested from plants over 10 years of age. Such nurseries should be uprooted and replanted using new material. Budwood nurseries should never be overbudded with another clone. Though overbudding can be an economical way of introducing new clones to the nursery it could lead to mixing of clones and also may affect the quality of budwood.

6. IRRIGATION SYSTEMS FOR RUBBER NURSERIES

6.1 Introduction

Water plays an essential role in plant growth. Almost every plant processes from seed germination to bud grafting of rubber nursery plants are directly affected by the water availability to plants. Therefore, irrigation and water management are two major concerns in rubber nursery management, especially when rubber cultivation is moving towards non-traditional areas in the Intermediate and dry zones of the country. Decrease in water content in long dry spells is affected by resulting loss of turgor pressure and wilting, cessation of cell enlargement, closure of stomata, reduction in photosynthesis and interference with many basic metabolic processes of plants. Irrigation is generally defined as the

artificial application of water for supplying moisture for plant growth whenever the rainfall and soil moisture storage are insufficient. To improve the water use efficiency, it is very important to have proper water irrigation schedule with the selection of proper irrigation method.

Irrigation scheduling is the decision of “when” and “how much” water to apply to a field. In irrigation scheduling, “when to irrigate” refer as irrigation frequency or irrigation interval, which is mainly determined by the soil water depletion that is the level to be irrigated. “How much” to irrigate depends on the water requirement of the plant growth. The purpose of knowing above is to maximize irrigation efficiencies by applying the exact amount of water to fulfill the crop water requirement for sustaining of crop yield. Irrigation scheduling saves water and energy. Accurate water application prevents over or under irrigation. Over irrigation wastes water, energy and labour; leaches expensive nutrients below the roots zone, out of reach plants and reduces soil aeration and thus crop yield. Under irrigation stresses the plant and causes yield reduction. The availability of water resource, climatic condition, type of the soil and the topography of the land also determine the correct irrigation practice.

6.2 Types of irrigation systems

Irrigation technology has been developed rapidly from border to micro irrigation and from manual to automation, over the last two decades. Sprinkler and drip irrigation systems are two kinds of micro irrigation systems now widely used in many crops when compare the border irrigation system that consumes more water and labour. In the recent past, many nursery owners used rubber hose or water delivery pipes with a water pump to irrigate their nurseries which can be categorized as a type of boarder irrigation. However, there is no proper irrigation schedule for this type of irrigation system and it mainly depends on time and availability of labour. Irregularities in this type of manual irrigation have negative consequences on the efficiency and the productivity of nursery management.

Introduction of sprinkler irrigation system as a modern irrigation technology is very important for improving productivity in large scale rubber nurseries. Sprinklers are becoming more popular among nursery producers where labour shortage prevails and water scarcity occurs, especially in non-traditional areas. The advantage of moving towards sprinkler irrigation systems not only saves water but also increases the quality of planting materials and reduce the labor engagement in watering.

6.2.1 Sprinkler irrigation systems

Sprinkler irrigation is a convenient and efficient method of supplying water to crops for producing large and steady crop yield. In sprinkler irrigation system, water is sprayed in to air and allows falling on the ground resembling rainfall and it cools the leaves and reduces midday closure of stomata (Plate 6.8a).

The spray is developed by the flow of water under pressure through small orifices or nozzles. Sprinkler irrigation can be used for almost all crops (except

rice) and on most soils. It is however not usually suitable in very fine texture soils where the infiltration rate is low. Land leveling is not essential for sprinkler irrigation system. Soluble fertilizers, herbicides, and fungicides can also be applied via the irrigation water. Sprinkler irrigation can be used to protect crop against frost and high temperatures that reduce the quantity and quality of harvest.

The operational characteristics such as uniformity co-efficient, pattern efficiency and discharge rate would be directly attributed to the performance of the sprinkler irrigation systems.

6.2.1.1 Components of the sprinkler system

The parts of all sprinkler systems are similar in most respects. They consist of the water pump, filtration unit, main pipelines, laterals, risers and sprinkler heads. There are two types of sprinkler heads or nozzles *i.e.*; technical and non-technical sprinkler heads, varies according to the technical designs. Technical sprinkler usually operates with a revolving type sprinkler head with two nozzles (Plate 6.8b).

Non technical sprinkler contains only an orifice with a blade on top of the sprinkler head (Plate 6.8c). However, the prices of sprinkler heads are varying depending on technical designs, discharge rate, make and the market demand.

The cost should be considered when selecting a suitable type of sprinkler system for a nursery. A high initial investment is required to install a system with pumping and filtration units (Plate 6.8d). The cost of technical sprinkler system is high due to its design technology compared to non technical sprinkler. However, the design should be done considering many factors such as water availability, power source, area to be covered *etc.* in order to optimize its use. The operational cost for system varies with the size of the nursery, the crop stage and capacity of the water pumps, *etc.*

6.2.1.4 Irrigation schedule for sprinkler system

The process of irrigation scheduling of a sprinkler system, involves both identification of irrigation interval and the amount of water to be applied. Irrigation schedule is decided according to the crop water requirement which is influenced by a range of factors including crop growth stage, soil water availability, and evapo transpirational demand. Therefore, nursery owners can decide their irrigation plan and the operational hours of the sprinkler system accordingly.

6.2.2 Drip irrigation system

With growing scarcity and competition for water in dry and intermediate zones of Sri Lanka, finding water for rubber nurseries is now stands as a major threat. Therefore, alternative methods of irrigation other than sprinklers need to be introduced for the rubber nurseries consume less water than sprinkler systems. A Drip irrigation system has potentiality of using for rubber nurseries as a water saving method as well as by avoiding over and under irrigation.

Drip system comprises of emitters or drippers at selected spacing for supplying crop water requirement, while minimizing deep percolation, runoff and soil water evaporation. In drip irrigation system, 90 per cent application efficiency can be achieved than other systems. Substantial amount of water saving can be achieved from drip systems when compared to sprinkler or any other surface irrigation method. Drip irrigation permits the application of fertilizers through the system which is an advantage to address rubber nurseries for labor shortage.

Disadvantages of the drip system include high initial cost, individual emitter requirement per plant, need of filtering requirement, clogging of emitters and poor water distribution efficiency. Experiments are being carried out to see the suitability of installing drip irrigation systems for immature rubber fields with alternative power sources such as solar power in the dry and Intermediate zones of Sri Lanka.

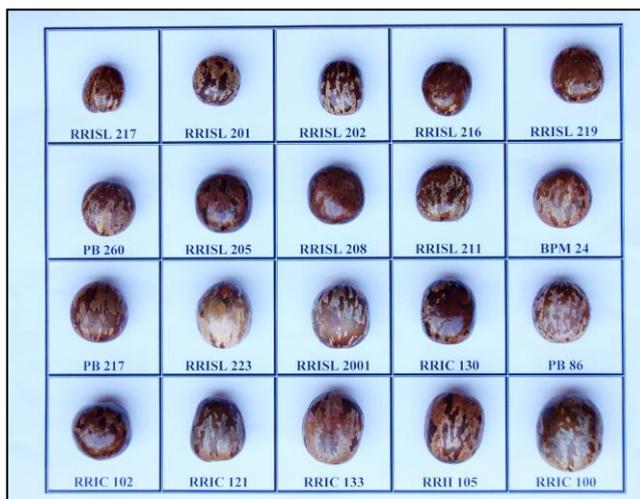


Plate 6.1. Morphological differences among seeds of different clones.



Plate 6.2. Seeds sown in the germination bed.



Plate 6.3. Germinated seed ready to be planted in the rootstock nursery.



Plate 6.4. Polybag rootstock nursery for raising young buddings.



Plate 6.5. Removing leaves from green budsticks to increase usable buds.



Plate 6.6. Cut end labelled with the clone and dipped in molten wax.



Plate 6.7. The board displaying the details of the budwood nursery.

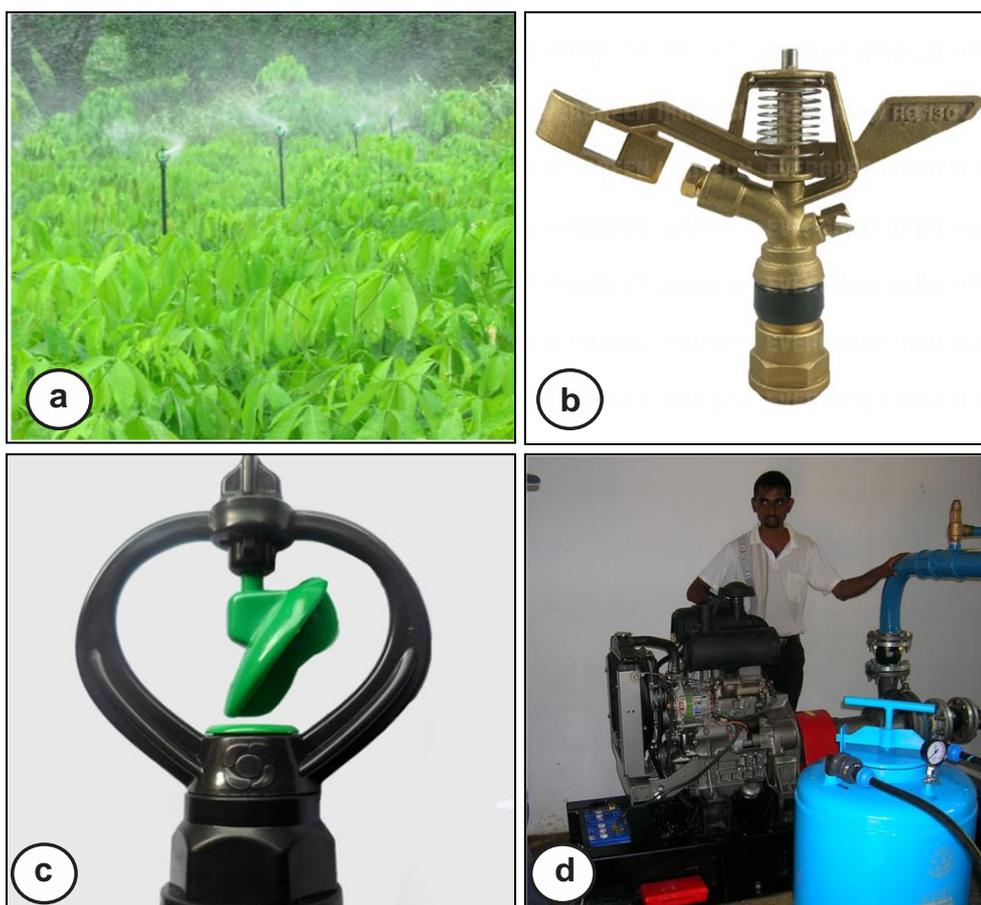


Plate 6.8 Sprinkler irrigation system for rubber nurseries **a.** for a rubber nursery **b.** a technical sprinkler **c.** a non technical sprinkler **d.** water pump.

Chapter 7

Bud-grafting techniques and types of planting material

Priyani Seneviratne

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 - 1.2 Green budding
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 - 1.3.1 Quality of stock plants and budwood
 - 1.3.2 Season
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1. BUD-GRAFTING

Bud-grafting is the technique available for vegetative propagation of selected high-yielding parent trees of *Hevea brasiliensis*. A population of such budded trees from a single tree is known as a “clone”. Unlimited propagation of such a clone can be done by bud-grafting using buds from budwood plants.

Bud-grafting involves removing a bud with a piece of bark and inserting it into an open panel at the base of the seedling stock plant. The bud thus inserted gets attached to the stock permanently and when the stock is cut and removed, above the grafting point, the grafted bud develops into a shoot. The new tree then formed is a two-part tree, comprising the root system of the stock plant and the above ground part or the scion developed from the grafted bud. Depending mainly on the age of the stock plant and bud patch used in grafting, two grafting methods are identified.

1.1 Brown budding

This method is not commercially used at present as we have moved away from ground root stock nurseries and producing bare root budded stumps since

Budgrafting techniques and types of planting material

2003. However, the technique of brown budding is explained here as they can be used for a particular purpose. Rootstock plants grown in bags can be grafted with brown buds if the plants are big enough.

In brown budding 1-1½ year old seedlings are used as stock plants and the buds for grafting are removed from brown budwood. The budwood should have grown for a period of 12-18 months and by then the diameter of the budwood will be about 3 cm and the bark is brown in colour.

The base of the stock plant is cleaned with a rag or waste cotton. From a point about 1 cm above ground level, two parallel cuts about 2-3 cm apart, are made through the bark in an upward direction for about 6 cm, and then curved inwards to meet as an arch (Plate 7.1). This demarcates the flap of bark which can be peeled from the top for insertion of the bud patch. This flap of bark can also be peeled upward, if the two parallel cuts are made to meet at the base. After the parallel cuts are made, about 10 minutes are usually allowed for the latex to dry before the flap is opened. Therefore, the flap can be marked in about 15-20 plants at a time.

Various methods have been adopted for removing the buds from budwood (Plate 7.2). One method is to remove an area of bark with a section of the wood (Plate 7.3). The two sides and the lower edge of the patch are then trimmed off and the bark is carefully peeled from the wood, taking care that the inner surface of the bark is touched only at the extreme top. It is important to bend only the slip of wood and avoid bending the bark when removing the wood (Plate 7.4). Keeping the inner side of the bark up, the top end of the patch which has been handled is then cut off leaving a neat rectangular patch, approximately 3 cm long and 1.5 cm width, with the bud in the centre or towards the bottom (Plate 7.5). The size of the bud patch and the panel will vary according to the size of the stock and budwood available. The size of the bud patch should be smaller in length and width so that the inner surface of the bud patch contacts well with the wood of the open panel of the stock plant, which is extremely important for the two tissues to get healed.

The core of the bud should be seen as a slight projection from the inner side of the bark (Plate 7.6). If this projection is not found it means that the core has been broken off or left behind in the piece of wood removed. With such bud patches, grafting can be successful but the scion will not grow to give rise to a scion shoot.

The panel on the stock plant is lifted from the tip with the spatula of the budding knife and peeled carefully. The bud patch is then inserted into the panel with the bottom edge resting in the angle between the wood and the flap (Plate 7.7). Care must be taken to place the bud the correct way up and ensure that the panel and the inner side of the bud patch are not touched by hand. Sliding the bud patch over the panel should also be avoided as this will injure the delicate cambium tissues.

The bark flap is then replaced and the bud patch is tied down in position with a 2 cm wide tape of gauge 300 transparent polythene (Plate 7.8).

After three weeks the polythene is removed and the bark flap covering the bud patch is cut off. The bud patch is scraped lightly below and above the bud, using the point of the knife. If green, it indicates that the patch is still alive. After a further 10 days the bud patch is again examined and if still green, the bud-grafting operation can be regarded as successful. The plants can be then uprooted, the stock cut back and planted as a budded stump, or they can be left in the nursery until required for planting. These are named as bare root budded stumps, as the root system is bare and there is no foliage on them.

1.2 Green budding

Grafting of young stock plants with green buds is called "Green budding". Green budding can be undertaken in 5-6 months old seedlings raised in ground root stock nurseries. When the seedlings are grown in polybags to raise young buddings they can be bud-grafted by the green budding technique at the age of 3-4 months. Plants above 6 mm diameter can be green budded with green bud sticks of the same diameter.

After cleaning the basal portion of the rootstock, two vertical incisions about 5-6 cm long and 1-1.5 cm apart are made starting from a point about 1 cm above the soil level. The upper ends of these cuts are joined by a horizontal cut. The flap of bark is then gently pulled downward using the tip of the bud-grafting knife exposing the budding panel. The flap is then cut off leaving about 1 cm at the bottom (Plate 7.9).

The bud patch is prepared in the same way as for brown budding. The lower end of the bud patch so prepared, is gently inserted under the flap (Plate 7.10) and then the bud patch is tied in position with a 2 cm wide strip of gauge 150 or 200 transparent polythene (Plate 7.11).

Bud patches are examined 3 weeks after bud-grafting. Retention of green colour indicates that the grafting is successful.

The first flush of the scion shoot in green buddings may be smaller compared to that of brown buddings, due to the lesser amount of food reserves in the stock.

1.3 Factors affecting grafting success

1.3.1 Quality of stock plants and budwood

Quality of both budwood and stock plants will influence bud-grafting success. Therefore, both budwood and stock plants should be healthy and vigorously growing. In order to achieve this status in both stock and budwood nurseries, proper agromanagement is very important. The age of both budwood and stock plants is another factor influencing rate of grafting success. Therefore, pollarding of budwood plants as and when required and discarding old stock nurseries have to be practised.

1.3.2 Season

Bud-grafting can be carried out throughout the year when the weather is

not too dry or too wet. Also, it can be undertaken at any time of the day provided that there is sufficient shade in stock nurseries. The best period will be from dawn to about 10.00 am and from about 3.00 pm until sunset. However, for young budding nurseries, the bud grafting season is rather definite as budded plants should be below one year with two leaf whorls at the time of planting.

1.3.3 Bud-grafting knives

Bud-grafting knives should be very sharp to do the grafting successfully. Folding knives with 7-8 cm long blades and a spatula at one end are used for brown budding (Plate 7.12). For green budding, the same knife can be used, but ordinary paper cutters or NT-cutters (Plate 7.13) having thin replaceable blades have been found to be ideal for this purpose, mainly owing to light weight and sharpness.

2. PLANTING MATERIAL

Planting material for rubber cultivation, until Van Hilton introduced bud grafting in 1917, was rubber seeds. Having well realized the uneconomical clearings resulted by seedlings, planting material for rubber was budded plants. Bud-grafted plants raised in nurseries can be introduced to the field in various forms, namely bare-root budded stumps, young buddings, polybag plants, stumped buddings and each type has its own advantages and disadvantages.

2.1 Bare-root budded stumps

Use of bare-root budded stumps is the easiest and cheapest method to establish a clearing. But 2004 onwards, young buddings are the recommended planting material for establishing rubber fields in Sri Lanka. However, in order to make the book complete, preparation of bare root budded stumps also is discussed. Brown budded stumps can be planted bare-root during both the South-West and North-East monsoons in traditional rubber growing areas. Nevertheless, green budded bare-root plants should be planted only during the South-West monsoon even in wet regions. As the field establishment of bare-roots depends on the weather conditions, the success rate may be low if monsoons fail. The same poor field establishment results when the planting is done at the tail end of the rainy period. Also, the growth of the plants will be very uneven owing to the differences in the time of sprouting of the grafted bud. However, if vacant points are supplied in time and also if weaker plants are replaced with vigorous plants, the stand and the growth of the clearing from bare-roots can be as good as that of a clearing established with polybag plants. Bare-root plants are not recommended for drier areas such as Moneragala and Bibile.

2.1.1 Preparation of bare-root budded stumps

When uprooting the successfully grafted plants from the nursery, the earth should be loosened with a fork or crow-bar so that the tap root and the lateral roots will not get damaged. Once the plant is uprooted from the nursery, the stock plant

should be cut leaving 10 cm and 15 cm long snags from the bud patch for brown and green buddings respectively. The cut end should be made to an angle of about 45° and sloping away from the bud patch. The cut end is then marked with the clone identity and then dipped in molten wax. The tap root should not be cut but the lateral roots can be pruned with a sharp knife leaving about 15 cm from the tap root (Plate 7.14). If the tap root cannot be accommodated in the planting hole even after making a central hole about 15 cm deep with a crow-bar the section of the tap root that cannot be accommodated should be cut using a sharp knife.

2.2 Polybag plants

Polybag plants are recommended for planting to overcome the weaknesses of bare root budded stumps. One hundred per cent success in field establishment and uniform growth of the plants could be obtained by using polybag plants correctly. This is possible as a further round of selection for vigor is possible. If planted correctly, the growth continues smoothly in the field with no set-back. By using polybag planting material correctly, the immature phase of a rubber clearing can be reduced. Both green and brown budded stumps can be grown in polybags.

Polythene bags made of gauge 500 black polythene are used to grow budded stumps. The sizes of the bags vary according to the type of budded stumps, *i.e.* whether green or brown budded and the period the plants will be kept in bags, *i.e.* up to 2-3 leaf whorl stage or 6-7 leaf whole stage. To raise plants up to 2-3 leaf whorl stage 15 x 45 cm and 23 x 45 cm sizes are recommended for green and brown budded stumps respectively. To raise plants up to 6-7 leaf whorl stage, the recommended size is 30 x 60 cm irrespective the type of bare root.

Polybags can be made by using guzatted polythene tubing of the correct diameter or ready-made bags of required size can be bought. The bottom half or two thirds of the bag should be perforated to allow excess water to drain out.

However, young budding plants are superior to polybag plants in every way. Therefore, usage of polybag plants got automatically diminished with the introduction of young buddings.

2.2.2 Soil for filling bags

Top soil of clay loamy texture is suitable for filling bags. Stones, pebbles and roots should be removed by sieving the soil with 1-1.5 cm sieve. A basal mixture of rubber fertilizer should be mixed with the soil as recommended prior to filling the bags. Adding compost is also recommended by Soils and Plant Nutrition Dept.

2.2.3 Planting budded stumps in bags

Though this is not practiced commercially, the main steps are mentioned here.

Fill the polybag halfway and then insert the budded stump prepared for planting into the bag spreading the laterals evenly around the tap root. Prior to planting in the bag, the tap root of the budded stump may have to be pruned to the

length of the polybag. The budded stump should be positioned in the centre of the bag, positioning the grafted bud to be level with the brim of the bag and the bag should be filled with soil up to 3-4 cm from the brim. Soil should be pressed carefully without damaging the laterals or the bag.

2.2.4 Polybag nurseries

After planting, bags can be positioned in shallow trenches dug 10-15 cm deep or supported with horizontal wooden bars. Bags can be arranged in single or double rows spacing 45 and 60 cm between single and double rows respectively. If the plants are to be grown up to 6-7 leaf whorl stage they should be spaced in such a way to prevent self-shading later. Even this is not required as the extra plants are recommended to plant within the field allowing them to grow with the rest of the plants in the field.

A temporary shade should be provided to the plants at the beginning and this should be removed gradually once the first whorl of leaves is hardened. As for ordinary budded stumps, any stock shoot should be removed at its first appearance, in order to encourage the sprouting of the grafted bud at the earliest.

Disease control, manuring, weeding, watering *etc.* are all important for the production of healthy and quality plants. Disease control and manuring of polybag nurseries are discussed in detail in Chapters 9 and 15 respectively.

Though large size bags are used for polybag plants, it is evident that only very little roots are formed within the bag and the shoot growth up to the 2nd whorl at planting affects adversely by this specially under unfavourable weather conditions after planting.

2.3 Young buddings

When seedlings grown in polybags are bud-grafted with green buds using the green budding technique the resulting plants are called young buddings. As the seedlings are grown in bags and they are fertilized with a soluble mixture, the growth is generally faster and the plants become buddable in 3-4 months. Then they are grafted using the green budding technique (Chapter 7.1.2).

Cutback of the snag can be done at 15 cm above the bud patch as for normal green buddings. However, if desirable and affordable a longer snag can be retained (Plate 7.15). Though a longer snag supports growth and reduces die back it delays sprouting and also growth among plants will be uneven in the nursery. With a 15 cm snag sprouting is faster and growth is even in the resulting plants. The snag should be cut with a sharp knife at a 45° angle sloping away from the bud patch. Applying a waterproof dressing on the cut will help to prevent die back. After cutback if necessary, the plants may be restacked separately and a temporary shade given until the first whorl hardens. The shade will significantly lower the incidence of leaf diseases and the casualty rate after cutback. However, in a young budding nursery 90% stock plants should be budgrafted and it is always recommended to remove the plants which have not been grafted or failed the graft. Moving to another location surely disturbs the root system. One of the

main advantages with young buddings is the shorter period involved in producing two whorl plants in bags. A nursery that is established during seed fall in August produces 2-3 whorl polybag plants for the main planting season in May-June of the following year. As far as the quality of the plants is concerned, they are superior to bare-root budded stumps and conventional polybag plants as they have a root system which is undisturbed right along and the age is only 10 months.

2.4 Stumped buddings

Stumped buddings are the most advanced type of planting material recommended. They are generally used in infilling casualties and replacing weak plants in 2-3 year old clearings and holdings. This helps in achieving correct stand and uniform growth in the plantations. One other important application of stumped buddings is in establishing rubber in areas that are frequently flooded during monsoon rains.

2.4.1 Preparation of stumped buddings

Stumped buddings can be raised in rootstock nurseries originally prepared for raising green or brown budded stumps though this is not commercially practiced now. After bud-grafting, successful plants should be extracted leaving the other plants for the preparation of stumped buddings with a distance of about 90 cm x 90 cm. However, ground rootstock are not practiced now.

If stock nurseries are specially established for this purpose, planting of germinated seeds, bare-root budded stumps or polybags should be done at 90 cm x 90 cm distance in holes of 60x60x75 cm. If seedlings are planted, green budding can be done in 5-6 months or brown budding in 10-12 months and successful grafts should be cut back 4 weeks later.

Whatever the planting material used for initial establishment the scion shoots are allowed to grow without branching for about 18 months until the brown bark is developed up to about 2.4 m (8 feet). At this growth stage the plant is ready for preparation of a stumped budding.

The method of preparation of a stumped budding is shown in Plate 7.16. Initially the tap root should be pruned leaving about 60 cm, *i.e.* tailing *ca.* 5-6 weeks before the plants are needed. This is done by exposing the tap root by cutting a trench on one side of the plant (Plate 7.16a). 3-4 weeks after tailing or about 2 weeks before field planting, the tree should be pollarded at a height of about 2.4 m (Plate 7.16b) just above a cluster of dormant buds. A waterproof dressing such as Candarson should be applied on the cut surface. Application of lime on the stump minimizes desiccation of the stem (Plate 7.16c). About 2 weeks after pollarding, the top dormant buds start sprouting (Plate 7.16d) and at this stage the stumps should be uprooted and planted in the field. Leaving the stumps longer than this in the nursery or in the original place will result in elongated tender shoots which may get damaged during transportation and transplanting. Further, such tender shoots will wilt after transplanting. The lateral roots should be pruned to a length of 15 cm from the tap root. Planting the stumped buddings in

the field is similar to planting bare-root budded stumps. Initially, a support is needed to keep the plant erect (Plate 7.16e). Mulching is beneficial and watering may be required during dry weather. If too many shoots develop, the rest should be pruned leaving about 2-5 vigorous shoots well spread around the stem.

2.5 Crown buddings

Crown budding is advocated to replace canopies with undesirable characters in clones having trunks with a high capacity to yield latex and timber. Susceptibility to diseases and wind damage are some of the undesirable canopy characters.

Depending on the age of the tree either green or brown budding technique can be used for crown budding. Green budding can be undertaken in 1 to 2 year old trees (Plate 7.17a and b) whilst brown budding is recommended for trees over 2 years old (Plate 7.17c and d). Crown budding should not be practised if trees are more than 3½ years old.

The tree produced by crown budding will give rise to a three-part-tree, consisting of a seedling rootstock, trunk clone and a crown of a different clone.

2.6 Rooted cuttings

Rooted cuttings on the other hand could be expected to provide a simple means of propagating clones on their own roots. Low success rates have always been reported with cuttings taken from mature trees.

Rooting of mature leafy cuttings has been reported using a mist chamber in the 1950s. As the cutting produces only a fibrous root system and the reliability of such a root system is uncertain, rooted cuttings are not yet a commercially accepted planting material (Plate 7.18 a,b &c).

2.7 Micropropagation

Tissue culture techniques involving micropropagation for mass-scale production of planting material from elite clones have been tested with various tissues of *Hevea*. However, the success rate, as far as the shoot proliferation rate is concerned, has not allowed commercial application of these techniques up to date. Though the first few plantlets from anther-derived callus tissues were obtained far back in the 1970s, the use of this technique is not yet commercialized. Plants can be produced with a fairly high shoot proliferation rate when nodal explants are taken from plants in the juvenile phase of growth. Rhizogenesis followed by acclimatization in propagator trays facilitates successful field transfer of the micropropagated plants (Plate 7.19 a,b,c & d). However, at present production of planting material needed for the rubber industry is done through bud-grafting of stock plants. However, genetic engineering will be a tool to improve the genetic composition of *Hevea* for various high tech usages in the future.



Plate 7.1. Marking the budgrafting panel on the rootstock plant.



Plate 7.2. Marking and removing the bud patch from budwood.



Plate 7.3. Bud patch removed from budwood with a piece of wood attached to it.



Plate 7.4. Removing the piece of wood attached to bud by breeding to wood.

Budgrafting techniques and types of planting material



Plate 7.5. The last cut to make a rectangular bud patch ready to be inserted.



Plate 7.6. The core of the bud seen as a projection from the inner side of the bud.



Plate 7.7. The bud patch inserted between the wood and the bark flap.



Plate 7.8. The flap replaced and tied with a strip of polythene.



Plate 7.9. The bark flap removed leaving a small portion to reset the bud.



Plate 7.10. The lower end of the bud inserted in to the remaining flap.

Budgrafting techniques and types of planting material



Plate 7.11. The bud patch tied in position with a strip of polythene.



Plate 7.12. Folding budding knife with a spatula at one end.



Plate 7.13. Paper cutter or NT cutter used for green budding.



Plate 7.14. The tap root and the lateral roots of a bare root budded stump.



Plate 7.15. Leaving a longer snag on young buddings.



Plate 7.16. Stumped buddings. **a.** Exposing and trimming the tap root; **b.** Pollarding the stem in two steps; **c.** application of lime; **d.** Bud bursting stage; **e.** A successfully transplanted stumped budding.

Budgrafting techniques and types of planting material



Plate 7.17. Crown budding. **a.** 1½ years old clearing being budded with green buds; **b.** Successful grafts cut at 15 cm; **c.** 3½ year old plants pollarded after checking grafting success; **d.** Growth of the crown buds.



Plate 7.18. Rooted cuttings. **a.** Mist propagator; **b.** A rooted seedling cutting; **c.** A rooted clonal cutting.

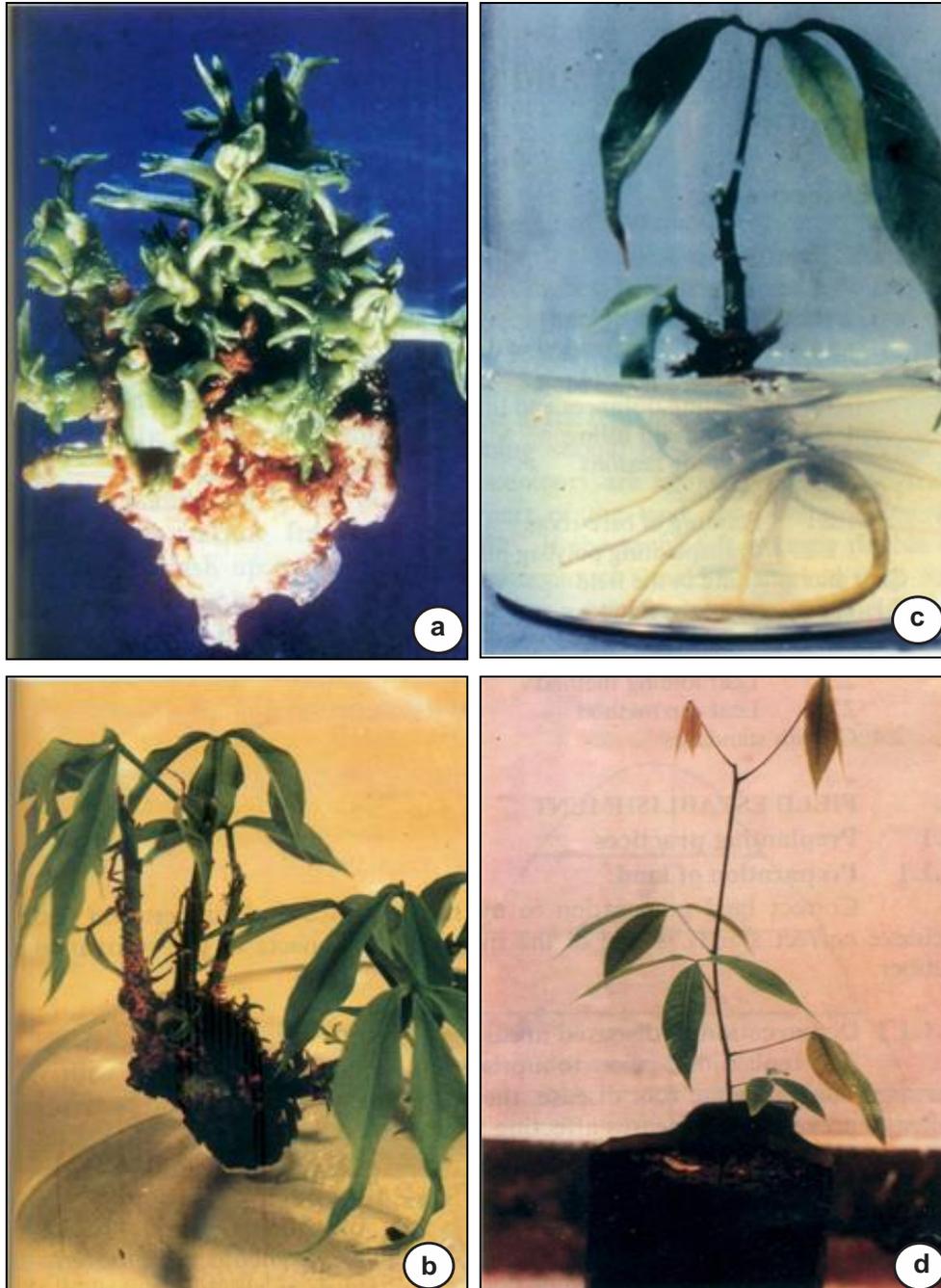


Plate 7.19. Micropropagation. **a.** Bud proliferation on a clonal node; **b.** Elongated axillary shoots of juvenile nodes; **c.** Rooted axillary shoots; **d.** Acclimatized plant.

Chapter 8

Field establishment and maintaining the stand of good quality plants

Priyani Seneviratne

1. Field establishment
 - 1.1 Preplanting practices
 - 1.1.1 Preparation of land
 - 1.1.1.1 Demarcation of diseased areas
 - 1.1.1.2 Uprooting
 - 1.1.2 Planting distances and lining
 - 1.1.3 Holing and filling
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 - 1.2 Planting practices
 - 1.2.1 Planting of bare-roots
 - 1.2.2 Transplanting polybag plants in the field
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 - 2.1 The growth of the scion
 - 2.2 Maintaining the stand
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 - 2.3.1 Leaf folding method
 - 2.3.2 Leaf cap method
 - 2.3.3 Chemical stimulation
 - 2.4 Growth standards

1. FIELD ESTABLISHMENT

1.1 Preplanting practices

Pre-planting practices cover the land preparation activities prior to planting. Most practices are common to both new planting and re-plantings but special attention is required for re-plantings when the old stand had been infected with deadly white root disease. Land survey to know the actual area to be planted is important and also a fence is a must at least up to the 4th year or so to prevent damage from animals such as cows and goats.

1.1.1 Preparation of land

Correct land preparation to avoid root diseases and soil erosion (Chapter 1) and to achieve correct stands is one of the most important aspects in the establishment of a cultivation of rubber.

1.1.1.1 Demarcation of diseased areas

In the process of replanting, prior to uprooting the old stand, areas infected with root diseases such as white root disease, should be demarcated and

Field establishment and maintaining the stand of good quality plants

precautions taken to prevent such diseases affecting the new stand. This is explained in detail in Chapter 9.

1.1.1.2 Uprooting

In the demarcated diseased patches the old rubber stand should be completely uprooted, *i.e.* all roots up to pencil thickness should be removed. In other areas too, uprooting should be done to remove roots as much as possible.

Uprooting is generally done using a monkey grubber. Any vegetative parts of the old stand not removed from the land should be burnt completely. It is a must that all infected roots are stacked and burnt *in situ*. Uprooting may be undertaken during Northeast (NE) monsoons in the Wet Zone when the soil is moist. This facilitates uprooting and also helps in the removal of the complete root system. If uprooting is completed by February then the remaining parts of the old stand, *i.e.* roots, small branches *etc.* could be burnt easily taking advantage of the dry weather during the period.

Use of backhoes to uproot the old trees is practiced now a days partly due to labour shortage and also to reduce the cost. Soil disturbance is very high and if carried out during the rainy season, there is a big chance to get fertile top soil washed away by this. Therefore, heavy rainy periods should be avoided, if backhoes are used for uprooting.

1.1.2 Planting density, distances and lining

Currently recommended planting density is to accommodate 516 trees per hectare in order to have a substantial tappable stand at harvesting time. Accordingly, three planting distances to give a stand of 516 trees per hectare are recommended for establishment of rubber plantations. One is square planting *i.e.*, 4.3 x 4.5 m to give the highest yield theoretically. Avenue type planting, 3.5 x 5.5 m and 2.75 x 7.75 m will save tappers time spent on walking from tree to tree. Also, this would be compulsory for some lands where planting has to be done on contours. A planting distance of 2.75 x 7.75 m is recommended if intercropping is to be undertaken. Changing the planting distances between replanting cycles has helped to reduce the incidence of white root disease in the replanting to a certain extent.

However, for sun loving perennial crops like cinnamon and tea, double rows of rubber having 2.7 - 3 m (8-9 ft) between plants in double rows and 18 m (60 ft) between double rows is recommended.

Marking of planting holes or lining should be done on the contour on steep or undulating land. If dead level contours are marked with a road tracer (Plate 8.1) starting from the steepest part of the land, the contour lines will diverge to finish up as unbroken contours. If the space left exceeds double the planting distance between rows, subsidiary contours should be marked (Fig. 8.1). If possible, it is best to avoid this by adopting a compromise between the straight lines.

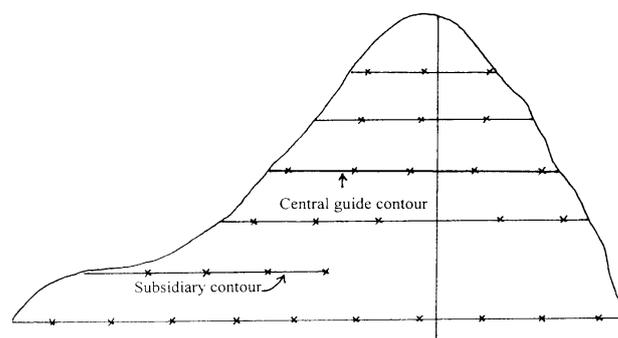


Fig. 8.1. Continuous and subsidiary contours marked on a hilly terrain.

1.1.3 Holing and filling

Planting holes can be cut either prior to uprooting or after uprooting and clearing the land is completed. It is important to ensure that the root debris is not allowed to fall in to the planting hole. The recommended size of the planting hole is 60 x 60 x 75 cm (2' x 2' x 2½'). The position of the hole may have to be changed if rocks are encountered. Holes must be refilled with top soil free of rocks, stones, roots or any other extraneous matter. Planting holes should be prepared at least one month in advance, refilled and allowed to settle naturally. The fertilizer application to the planting hole before planting, when bare root budded plants were used as planting material, is no longer recommended as planting bare root budded stumped was banned from 2004. Therefore, for planting of young buddings, refilling the hole with top soil prior to planting should be done but the application of basal fertilizer is not required. Holing is done with backhoes as a remedy to labour shortage but there is no control on the dimensions of the planting hole when backhoes are used. If carried out during the heavy rainy period, soil erosion, specially the top soil would be unavoidable. Anyhow, precautions should be taken to minimize the damage by refilling early.

1.1.4 Planting seasons

Field planting to establish rubber clearings/holdings should be done with the onset of the monsoon rains. The major rainy season in the Wet Zone is the South-West (SW) monsoon that falls in May-July each year and the minor season is the North-East (NE) that falls in October-November. As the duration and intensity of rainfall are relatively higher during the SW than in the NE in the wet zone, planting with the onset of the SW is ideal for traditional rubber growing districts such as Kalutara, Ratnapura, Kegalle, Colombo, Galle and Matara.

In areas where the major rainy season is the Northeast, *i.e.* in Monaragala, Bibile, Ampara *etc.*, planting should be undertaken during that period strictly as the rain starts in end October. Otherwise the plants are not established enough to undergo the dry spell that starts in January following year. Meteorology department issues weather forecasts which will be uploaded to RRISL website for the growers to know the exact period and the intensity of rain.

1.2 Planting practices

1.2.1 Planting of bare-roots

Planting bare roots is not recommended for new or replanting since 2004. Therefore, bare root budded stumps are not produced or used for replanting or new planting programmes. Therefore, only the main steps of planting a budded stump are discussed here.

Prior to planting the bare root part of the filled soil should be removed and a hole should be made with a crow-bar to accommodate the tap root in the planting hole (Fig. 8.2a). The tap root and the laterals should be arranged in the crow-bar hole so that the lateral roots are spread right round the tap root. The graft union should be placed about 5-6 cm below ground level. After planting, the earth should be forced towards the budded stump right round the plant using a crow bar (Fig. 8.2a). Soil around the plant should be packed by treading the earth while taking care not to tread on the laterals. A small drain should be made to prevent water collecting in the planting hole (Fig. 8.2b).

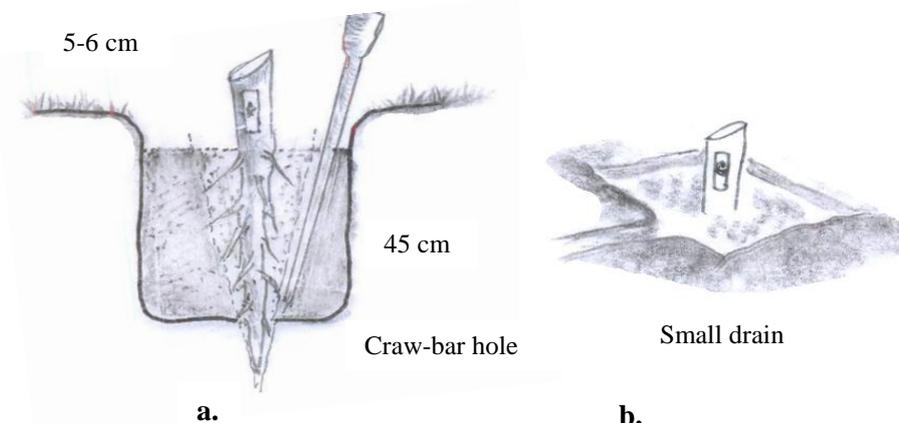


Fig. 8.2. Planting bare-root budded stumps. **a.** Positioning the bud patch 5-6 cm below the ground level; **b.** Small drain made to drive away the water collects in the unfilled area of the planting hole.

1.2.2 Transplanting young budding plants to the field

Only plants with a hardened top whorl should be transferred to the field (Plate 8.2). The number of plants with a hardened top whorl can be increased by stopping fertilizer applications about 4-6 weeks prior to field planting.

Plants at shoot elongating stage or with leaves at copper brown or apple green stages should never be transferred to the field, because it will result in shoot dieback, uneven growth and casualties.

Generally in a polybag nursery, when plants are ready for field planting, in almost all the plants the tap root has penetrated into the ground. Therefore, the roots that are growing out of the bag should be cut about 2 weeks before planting.

This can be done by tilting the plant to a side carefully and then cutting the roots, preferably with a pair of secateurs or a sharp knife (Plate 8.3). This should be done only in plants with a hardened top whorl. Once the roots are pruned plants should be well watered until they are transported or field planted. However, when plants are transported to the field, if the soil inside the bag is saturated, then there is a chance of the soil in the bag moving and thereby disturbing the root system. To prevent this, plants can be given only a limited amount of water during the last few days prior to field planting.

Transporting the plants to the field should be done with great care without damaging the aerial part of the plant or disturbing the root system within the bag. If plants are stacked tightly during transportation loosening of soil in the bags can be reduced to a great extent.

Prior to planting the young budding plant, the depth of the planting hole should be checked and be adjusted appropriately by removing or filling with soil. When planted, the graft union should be positioned a few centimeters below ground level (Plate 8.4). Young budding plants can be deep planted as well so that the graft union is buried about 15-20 cm below ground level (Plate 8.5a). This practice has the advantage of minimum rootstock effect on yield when the tapping panel is close to ground level. Basal fertilizer mixture should not be added to the planting hole, when adopting deep planting method, either. However, obviously, there will not be root formation on the buried portion of the stem. But, apart from the establishment of the root system well below the ground level, formation of "elephant foot" is totally avoided which is advantageous. Also the plants can tolerate adverse dry weather better, when deep planted (Plate 8.5b).

Once the depth of the planting hole is adjusted to suit the young budded plant, the base of the polybag should be removed by cutting it around with a sharp knife or a blade (Plate 8.6).

Then the plant should be lowered into the planting hole carefully and a slit should be made along the length of the bag stepwise starting from the base (Plate 8.7). Soil is put back into the hole up to the top of the slit prior to extending the slit. Likewise, while filling the hole with soil, the cut can be completed up to the brim of the bag. Once the hole is almost filled, the slit polythene can be pulled out carefully (Plate 8.8). The soil around the plant should not be pressed hard as it can disturb and damage the root system of the plant.

If planted with care, the root system remains virtually undisturbed, the survival rate will be one hundred per cent and growth will be uninterrupted and uniform.

It is also recommended to field plant the poly bag plants with the bags. In this method, only the base of the bag is removed carefully. No cuts should be made on the wall of the poly bag which leads to damage the lateral roots of the plant which are dense on the surface of the soil bowl.

2. CARE AFTER PLANTING IN THE FIELD

Maintaining the plants during the immature phase too vary according to

Field establishment and maintaining the stand of good quality plants

the type of planting material used. Bare root plants demand more attention but they are not recommended to use.

2.1 The growth of the scion

Though planting is normally done in the rainy season, if an unexpected dry spell occurs after planting the plants should be watered and a suitable mulch placed around it. After 3-4 weeks in the field, the apical bud would grow in to a new flush or a whorl of leaves. If the quality of the plant is good and other inputs provided, the new whorl is also normally larger.

The scion should be made to grow with a single unbranched stem up to a height of about 2-2.5 m by pruning of all side shoots as and when they appear (Plate 8.9).

Maintenance of young budding plants is easy when compared to bare root plants if transplanted satisfactorily. Though very rare, stock shoots can appear which should be removed as they grow out. Also, if the scion shoot is dead, naturally a bud on the stock plant can be grown in place of the clonal scion. Such plants should be replaced with a suitable young budding plant which are recommended to maintain within the field up to the 3rd year.

2.2 Maintaining the stand

Earlier recommendation of 10% of the total number of plants which were planted in polythene bags and as trenched plants should be used to replace weak and dead plants.

Transplanting using these plants can be done in the major planting seasons during the 2nd or 3rd year upkeep. Planting the 10% extra plants in the field is self up to the third year is recommended to allow the extra plants to grow with the rest of the plants in the clearing (Fig. 8.3).

Replacing weak plants is as important as infilling casualties. During the first year itself casualties or weak plants can be replaced with onset of the following monsoon rains without following the stumped budding procedure as the plants are small. But after that it should be done with stumped buddings *i.e.* during the second and the third years. The round of plant supply, season of the supply, age of the clearing at each supply, plant type and the form of the plant are given in Table 8.1. The method of preparation of stumped buddings should strictly be followed for successful transplanting (Chapter 7.2.4.1).

It is very important to highlight that, no extra plants planted in between permanent planting rows are allowed to remain in the field after the fifth consecutive supply or in other words after when the clearing is 2½ years old. By this time, the tree girth should be about 25 cm and they start competing with the permanent plants affecting the growth or the girth of the plants.

Maintaining the full stand with good quality plants by replacing weak plants or casualties with suitable advanced planting materials should be one of the priority areas during the early upkeep.

Table 8.1. Round of plant supply, season of the plant supply, age of the clearing at each supply and plant type or how they should be introduced to the new place of the field.

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

2.3 Branch induction

The budded plants of most of the clones recommended for planting in Sri Lanka branch naturally. However, a certain percentage of trees of some clones such as RRIC 121 seem to need artificial induction to produce side branches. If the trees do not start to branch even after about 2 years *i.e.* with about 2.5 m of unbranched brown stem, then artificial branch induction should be undertaken.

The most suitable methods of branch induction are by leaf folding or placing leaf caps over the terminal bud. Though there can be other methods to induce branching, the two methods suggested here have been found to be best for rubber.

It should also be remembered that the terminal bud of the main stem should be preserved throughout the life of the tree and it should not be damaged or removed in order to induce branches.

Further, within a clone, it has been observed that trees with more branches girth better suggesting that branch induction can be adopted to increase girthing of immature trees through enhanced light capture.

2.3.1 Leaf folding method

This method can be used when the terminal leaf whorl is sufficiently hardened (Plates 8.10a).

A few intact terminal leaves should be brought together and folded covering the apical bud (Plate 8.10b). The folded leaves should then be tied together, preferably with a rubber band, covering the apical bud (Plate 8.3c) until side branches develop.

2.3.2 Leaf cap method

This method can be adopted when the terminal bud is at bud break or when the young leaflets have just unfolded (Plate 8.11a). A leaf cap is made with 3-4 detached mature leaves (Plate 8.11b) and this cap is placed over the stem apex and fastened with a rubber band (Plate 8.11c) to keep it intact until side shoots start to grow.

In both methods, the cap should be removed after 3-4 weeks, if it does not come off spontaneously. Branches should normally emerge from the leaf axils of

Field establishment and maintaining the stand of good quality plants

the uppermost whorl of leaves (Plate 8.11d). If more than 5-6 branches develop the excess should be removed without delay, while making sure that the remaining branches are uniformly distributed around the main stem.

2.3.3 Chemical stimulation

Many chemical treatments are also reported to have induced branches. But the trials conducted at RRISL indicates that thiourea and urea solutions can be used for this.

2.4 Growth standards

Depending on the type of planting material used in replanting, there can be a variation in the initial growth. However, properly selected good quality young buddings grow more uniformly as well as faster. The potential growth rate of novel clones as measured by the girth of the plants is 10 cm per year minimum, making the trees tappable at the end of the fifth year with 50 cm girth measured at 120 cm height from the ground level. Agro management practices particularly the application of recommended dosage of fertilizer correctly as explained in Chapter 15 on fertilizer is extremely important for this.

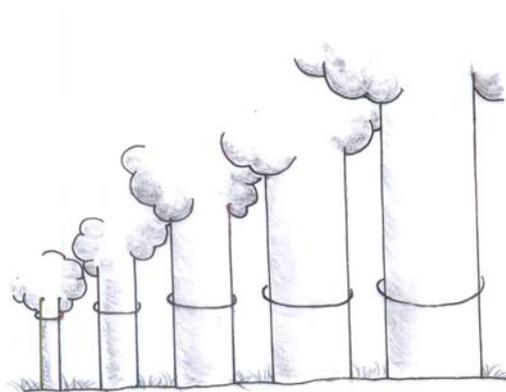


Fig. 8.3. Yearly growth standards of immature plants.



Plate 8.1. Using road tracer to mark contours.



Plate 8.2. Top whorl hardened, two whorled young budding plant.



Plate 8.3. Removing the tap root grown out of the base of the bag

Field establishment and maintaining the stand of good quality plants



Plate 8.4. Positioning the graft union a few centimeters below the ground level.



Plate 8.5a. Deep planting of young buddings placing the graft union 10-15 cm below the ground level.



Plate 8.5b. Deep planted young budding after 1½ years.



Plate 8.6. Removing the base of the bag prior to planting.



Plate 8.7. Making a slit along the length of the bag.



Plate 8.8. Pulling out the piece of polythene after planting.



Plate 8.9. Single unbranched stem up to about 2.5 m.

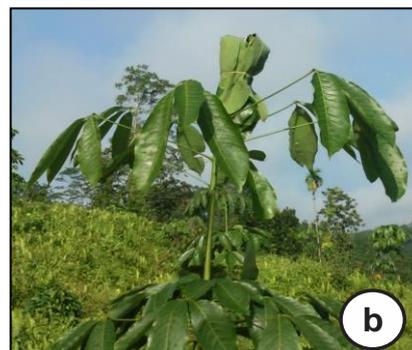


Plate 8.10. Leaf folding method. **a.** A tree suitable for leaf folding method; **b.** Terminal bud covered with mature leaves of the top most whorl.

Field establishment and maintaining the stand of good quality plants

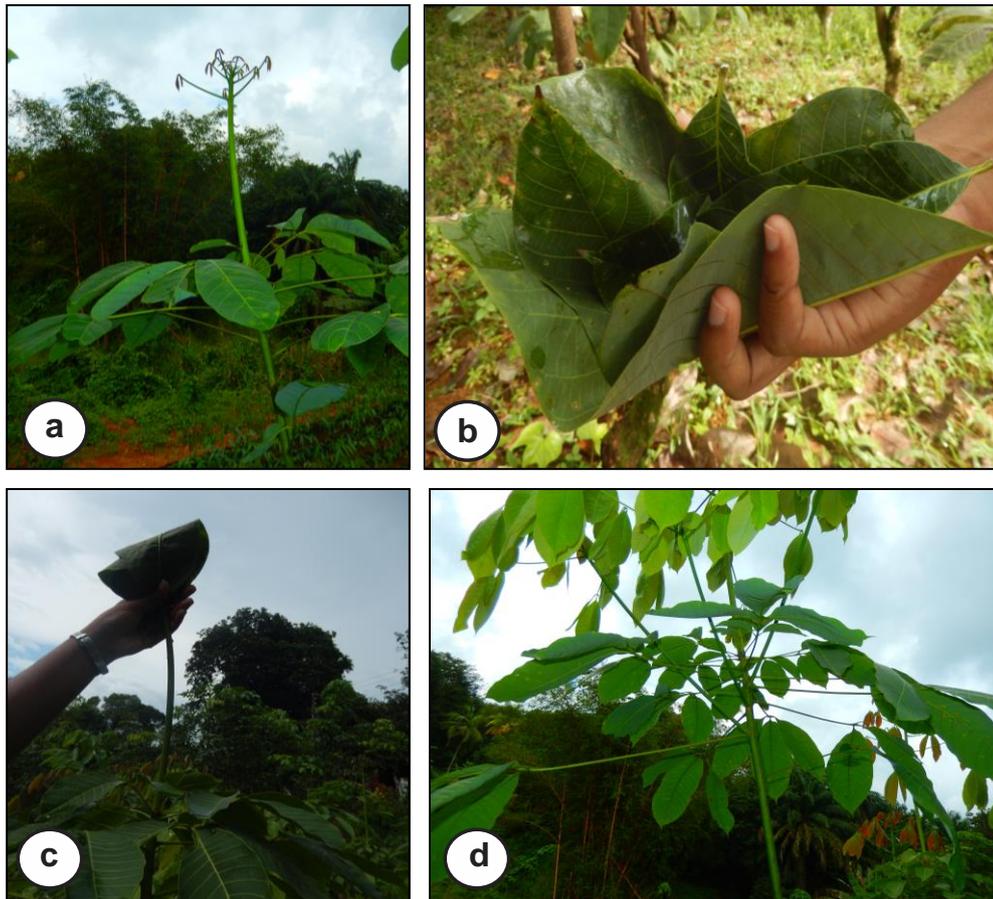


Plate 8.11. Leaf cap method. **a.** Terminal bud having small tender leaves; **b.** Detached mature leaves to make the cap; **c.** The leaf cap on the tender shoot; **d.** Well branched tree after branch induction.

Chapter 9

Economically important diseases of rubber plant

T.H.P.S. Fernando

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 - 4.4.2 Diagnosis

1. INTRODUCTION

The rubber tree (*Hevea brasiliensis*) is a jungle plant native to South American rain forests. Like any other agricultural crop, the incidence and the severity of the diseases has changed with the domestication. The first abnormality of the rubber tree, a canker of stem and branches was brought to the notice of a Mycologist, J.B. Carruthers. Later, in the year 1905, T. Petch, Mycologist of the government of Ceylon identified six fungal pathogens on leaves and roots. The disease conditions that had been identified as economically important at the beginning of the 20th century has changed with time. Powdery mildew (Oidium leaf disease), Colletotrichum leaf disease which was more commonly called as the Gloeosporium leaf disease, Phytophthora leaf fall disease, Phytophthora bark rot or the black stripe disease were present throughout the rubber growing areas and chemical controlling such as sulphur dusting and application of copper fungicides had been done as a routine basis in past, but now, has been recommended for restricted use. Chemical control methods were very popular among the growers and later, the concerns for the economic benefits and also the environmental hazards came up. As a result of the extensive research work carried out by the Plant Pathologists, today the use of chemicals has been reduced to a minimum.

The economic importance of each disease varies from one country to another, according to the microclimate within the country, cultural practices employed and type of the clone cultivated. In Sri Lanka, all economically significant diseases are caused by fungal parasites and can be divided into three main categories depending on the plant part affected: leaf, stem & colar and root (Table 9.1).

In addition to fungal attacks, a number of maladies of non-parasitic origin and injuries that are purely of a physical or mechanical nature can also affect the rubber plant. With the expansion of the rubber cultivation to non-traditional rubber growing areas, these abiotic stress conditions have increased considerably.

Although the damages by pests are minimal in the case of rubber, yet damage in nurseries and in young plantations has been reported.

Table 9.1. Economically important diseases of rubber plants.

Plant part affected	Disease	Causative agent
Leaf	Powdery Mildew	<i>Oidium heveae</i>
	Colletotrichum Leaf Disease	<i>Colletotrichum gloeosporioides</i> / <i>C. acutatum</i> / <i>C. simmondsii</i> / <i>C. laticipillum</i> / <i>C. nymphaeae</i> / <i>C. citri</i>
	Corynespora Leaf Fall Disease	<i>Corynespora cassiicola</i>
	Phytophthora Leaf Fall Disease	<i>Phytophthora</i> spp.
Stem & Colar	Bark Rot/Black Stripe	<i>Phytophthora</i> spp.
	Ustulina stem Rot	<i>Ustulina deusta</i>
	Pink Disease	<i>Corticium salmonicolor</i>
	Patch Canker Disease	<i>Pythium</i> spp. and secondary organisms
Root	White Root Disease	<i>Rigidoporus microporus</i>
	Brown Root Disease	<i>Phellinus noxius</i>
	Black Root Disease	<i>Xylaria thwatsii</i>

2. LEAF DISEASES

2.1 *Oidium* leaf disease (*Powdery mildew*)

One of the main causes for secondary leaf fall on rubber plantations in Sri Lanka. Repeated defoliation due to Powdery mildew results in poor canopies, loss of yield and poor girthing. The pathogen attacks tender leaflets and young inflorescence emerging after the annual wintering. The severity of the disease varies with the susceptibility of the clone, wintering pattern, elevation planted, microclimate of the clearing and weather conditions prevailing during the refoiliation period.

Causal Organism: *Oidium heveae*

The disease spreads by means of wind-borne conidia. The causative fungus is *Oidium heveae* Steinm, an obligate parasite. Produce oval shaped wind-borne conidia in chains (Fig. 9.1).

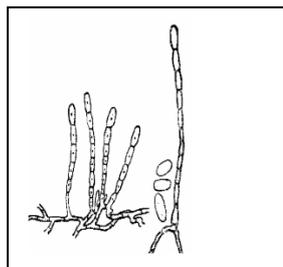


Fig. 9.1. The causative fungus of Powdery mildew, *Oidium heveae* produces oval shaped wind-borne conidia in chains

2.1.1 Symptoms

Copper brown and apple green leaves are the most susceptible stage for this disease. The growth of the fungus on the leaves appear as white powdery spots and they will be seen on both the surfaces. The lower leaf surface is generally heavily colonised, near the mid rib and veins. Severely infected copper brown leaflets shrivel (Plate 9.2a) and fall off leaving the petioles for some time on the plant (Plate 9.2b). When semi-mature leaves are infected, characteristic whitish to translucent spots are formed (Plate 9.2c & d). These whitish lesions later turn into brown in colour. These brownish necrotic patches (Plate 9.2e & f) will sometimes persist on the leaves throughout the year until they are shed during the next wintering season. Flowers are also attacked (Plate 9.2g) resulting less pod set.

The incidence of Powdery mildew helps to reduce the incidence of diseases caused by *Phytophthora* species. Severe and repeated attacks of *Oidium* could affect the growth, yield, bark renewal and even dieback of shoots could occur on highly susceptible clones, especially at higher elevations and disease prone areas.

2.1.2 Predisposing factors

Late wintering clones *e.g.* RRISL 2001, RRIC 121, PB 28/59, RRIM clones generally succumb to the disease. Early wintering clones *e.g.* RRIC 100, PB 86 usually escape the disease.

Cool nights with overhanging mist, dew on the leaves, intermittent light rains, low temperatures and high humidity favour the spread of the disease. Clones such as RRISL 203, RRISL 201, RRISL 205, RRIC 100, RRIC 117 and RRIC 130 are generally tolerant to the disease. The clone RRIC 102, tolerates the disease without shedding the leaves. However, necrotic lesions (old *Oidium* patches) remain on the leaf reducing the photosynthetic efficiency in this clone until the next wintering.

During an epidemic.....

At the time of refoliation, when the favourable weather conditions prevail, the disease reaches epidemic proportions. It results repeated defoliation and will result short term as well as long term disadvantages. Severe and repeated attacks of *Oidium* affect the growth, yield, bark renewal *etc.* especially at higher elevations and high humid pockets.

2.1.3 Prevention

Planting of clones highly susceptible to *Oidium* should be avoided at elevations above 90 m and in humid pockets. Application of the recommended fertilizer at right time will reduce the incidence and the severity of the disease to a certain extent.

2.1.4 Disease control

Application of soluble sulphur is not recommended as a routine practice below 90 m (300') elevation, except in some years when the infection is severe. At elevations above 90 m trees should be inspected during the refoliating season and control measures should be adopted depending on the severity of the disease. If repeated defoliation occurs in the same year, application of sulphur containing fungicides should be carried out immediately.

Chemical controlling routinely is recommended only for disease vulnerable sites. Chemical application should be commenced when 10% of the trees show signs of refoliation. Spot application is recommended when refoliation is uneven. Chemical application should be done using a power driven machine, between 4-7 a.m. to take advantage of still condition of the air. It is advantageous to allow a certain amount of *Oidium* infection to occur, as a protection against the disease could result in the production of an abundance of pods, which could increase the risk of *Phytophthora* leaf fall and bark rot conditions.

2.2 Colletotrichum leaf disease

This disease occurs throughout the year but it is severe during the Southwest and Northeast monsoon seasons. It is commonly seen in nurseries and in young plantations. It affects tender expanding leaflets on immature plants and immature leaves formed after wintering of mature trees. The fungus can infect green shoots causing them to die-back, flowers and developing fruits. The fungal spores are dispersed by rain splash and currents of damp air.

Causal Organism : *Colletotrichum acutatum*/ *C. gloeosporioides*/ *C. simmondsii*/
C. laticiphilum/ *C. nymphaeae*/ *C. citri*

2.2.1 Symptoms

Colletotrichum leaf disease occurs throughout the year in the presence of tender leaves but it is severe during the monsoon periods as the pathogen favours the wet weather. The tender expanding leaves formed after the wintering of mature plants are highly susceptible causing a secondary leaf fall condition. This pathogen can infect any green tissue such as green shoots causing them to die-back. The disease is favoured by the continuous overcast rainy weather and high humidity.

Immature copper brown and apple green leaves are highly susceptible to the disease. Copper brown leaves get discoloured, shrivel (Plate 9.3a) and fall off leaving the petioles on the plant for some time. Apple green leaves show tip die-back (Plate 9.3b) and sometimes the unaffected portion of the leaf blade is retained after the diseased tissue dries and drops away. Mature leaves are resistant to infection and the raised symptom 'blisters' are formed (Plate 9.3c). Under nursery conditions the characteristic anthracnose symptoms are formed (Plate 9.3d). These leaves are usually retained on the tree. Under continuous wet weather. These anthracnose symptoms are mostly prevalent on seedlings and pathogen attacks the green shoots causing die-back of branches in mature as well

as immature clearings. In budded stumps, infection spreads downward affecting bud patch and killing the new shoots.

2.2.2 Disease control

Excessive rain high humidity when tender leaves present are the main predisposing factor. Disease resistant clones such as RRIC 100, RRIC 102, and RRISL 203 can be used to prevent the disease. Fungicides such as copper oxychloride (3g in 1 litre), mancozeb 3g in 1litre, captan 3g in 1litre, propineb (3g in 1 litre) or cabendazim (2g in 1 litre) are recommended to chemically control the disease.

2.3 Corynespora Leaf Fall Disease (CLFD)

Corynespora Leaf fall Disease (CLFD) of rubber, a malady with relatively recent origin has become the most destructive leaf disease of rubber plantations in Sri Lanka. The first outbreak of CLFD was noticed in mid 1980's severely affecting several rubber clones. This was a global epidemic. The most severely affected clone was RRIC 103, an outstanding clone bred by Sri Lankan scientists and Sri Lanka lost approx. 4500 ha due to the spread of the disease. Consequently, the disease became more devastating over the years and by the year 1996, nearly a decade after the first epidemic, several clones considered as disease tolerant genetic materials during the first epidemic succumbed to the disease. RRIC 110 was among the affected clones.

C. cassiicola affects young as well as mature leaves of rubber. A unique feature of the pathogen is the capability in producing a wide variety of symptoms making identification of the disease complicated and affected leaves gradually take a characteristic yellow or orange colouration before shedding (Plate 9.4a). Repeated defoliation occurs and ultimately shoots of affected trees die resulting bare patches (Plate 9.4b, c & d). The protracted immaturity period in young rubber plants affected by the disease also result in potential loss of income from delayed opening for tapping and also the reduction in canopy. There are special characteristics of this disease is the invasion selected *Hevea* clones. At the time of the first epidemic, the clone RRIC 103 succumbed to the disease and at the second epidemic, the clone RRIC 110. Unlike the other foliar diseases (Oidium or Phytophthora), this pathogen will not be restricted to a short period of time during the year (seasonal) on susceptible clones. The disease is observed throughout the year. Hence chemical application is required throughout for susceptible clones. For any effective disease control programme, correct diagnosis of the disease is of very importance. Another very difficult character of this pathogen is that it produces a wide variety of symptoms. The Extension staff is facing problems in identifying the disease. Hence if there seems to be any unusual symptom, the assistance from the Plant Pathology & Microbiology Department of RRISL should be sought for proper diagnosis.

Causal organism

Corynespora cassiicola

Corynespora cassiicola (Berk. & Curt.) Wei. is the causative agent. The pathogen is recorded to be highly dynamic. The morphological characters of the pathogen are varying depending on the clone, location and many other environmental factors. The pathogen produces conidia and they too are showing variable shapes and sizes (Plate 9.5).

2.3.1 Symptoms

Immature copper brown and semi-mature apple green leaves are highly susceptible to the disease. Under favourable climatic conditions the disease spreads causing defoliation of leaflets. When semi-mature leaves are infected distinct, irregular leaf spots of varying sizes could be seen. Several of these spots could coalesce to form large lesions which eventually turn brown bearing a large number of spores. In some leaves, papery spots could also be seen. The damage caused to immature leaves could show up either as leaf spots or characteristic browning or blackening of the mid-rib and/or secondary and tertiary veins giving a railway-track like appearance on the mature leaves. Usually the leaf tissue around the infected area becomes yellow due to the destruction of chlorophyll in the leaves and eventually the leaves assume a reddish colour and fall off. Leaf fall may occur even when the lesions are quite small and few in numbers. Repeated defoliation could lead to dieback of the main stem and branches, sometimes killing the entire tree. During the recent past, different symptoms such as polyhedral and linear lesions have been noticed on different clones such as RRIC 110, RRISL 200, RRISL 201 and RRIC 133 respectively.

One of the unique characters of the pathogen is the production of diverse symptoms. The most characteristic symptom is the railway track lesion (Plate 9.6). The symptoms produced on the leaves of the clone RRIC 110 are somewhat different from the typical lesions showing circular to irregular lesions with prominent yellow halos. The lesions are either irregular or polyhedral and surrounded by extended yellow halos when the leaflet is viewed against light (Plate 9.6). In some other clones, symptoms very close to old Oidium patches are observed (Plate 9.6). Silvery white papery appearance develops in the centre and sometimes shot holes may also develop due to the disintegration of the centre tissue of the lesion. Another characteristic feature observed in this clone is the blackening of the portions of secondary veins associated with the polyhedral lesions (Plate 9.6). Appearance of the blackish linear lesions on midrib of leaflets is the common symptom on the clone RRIC 133 in bud wood nurseries. Lesions produced by *C. cassiicola* on the clone RRIC 132 is more or less similar to the lesions of Bird's eye spot disease caused by *Drechslera heveae*. On certain clones several types of symptoms are produced on the same leaf. The ideal example would be the RRII 105, the most widely accepted clone in India. During the juvenile stage of the plant, especially in poly-bag nurseries the most characteristic

symptom is the production of circular or irregular lesions of varying sizes delimited by a wavy border. Sometimes lesions coalesce to result in irregular papery lesions giving a scorched appearance. If wet weather persists, the leaves shrivel and fall off.

2.3.2 Predisposing factors

All plants in seedling nurseries are susceptible to the disease. In bud wood nurseries and in the field the following clones are highly susceptible to the disease: RRIC 110, RRISL 200, RRISL 202, RRIC 52, RRIC 103, RRIC 104, RRIC 106, RRIC 107, RRIM 600, RRIC 118, NAB 12, RRIM 725, RRISL 223 and RRISL 201. Clones such as RRISL 203, RRISL 2001, RRIC 121, RRIC 100, RRIC 102, PB 86, RRIC 130, RRIC 117 and PB 28/59 are reported to be free from the disease.

2.3.3 Prevention

- a) Only the clones resistant to the disease should be planted.
- b) The seedling nurseries and polybag nurseries should be sprayed regular intervals with dithane M 45 (3 g/litre), captan (3 g/litre), antracol (3 g/litre) or carbendazim (1.0 - 2.0 g/litre).
- c) All clearings of RRIC 103, RRIC 110 and other susceptible clones should be uprooted and all leaves should be completely burnt based on RRISL recommendations.

2.3.4 Control

Spraying of dithane M 45 (3 g/litre), captan (3 g/litre), antracol (3 g/litre) or carbendazim (1.0 - 2.0 g/litre) as a routine practice.

2.4 Phytophthora Leaf Fall Disease

Phytophthora disease occurs during the monsoon season in the presence of rubber pods. The pathogen attacks multiple parts of the tree: pod rot, stem die-back, bark rot or black stripe and cankers. Free water is required for propagation of the fungus. The disease is spread mainly by splash dispersal, currents of damp air and insects. Persistent rain and gloomy overcast conditions with low temperature and high air humidities favour the spread and dissemination of the fungus. The fungus has a wide host range. It survives on the rubber tree, from one season to the next, on mummified pods, stalks or shoots as chlamydospores or oospores.

Causal Organism: *Phytophthora* spp.

Phytophthora spp. is an oomycete fungus. The fungus produces abundant sporangia (Fig. 9.2) under favourable weather conditions and zoospores are mainly responsible in disseminating the disease. The fungus has a wide host range.

It survives on the rubber tree from one season to the next on mummified pods, stalks or shoots as chlamydospores or oospores.

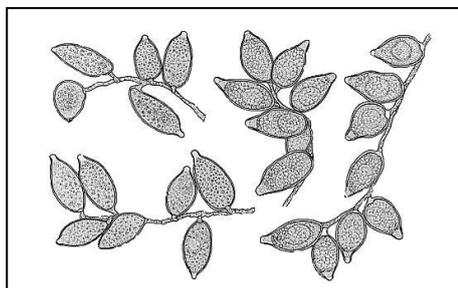


Fig. 9.2 Lemon shaped sporangia produced by the fungus, *Phytophthora* spp.

2.4.1 Symptoms

The disease starts on the pods, appearing as water-soaked lesions with black globules of latex (Plate 9.7a) symptoms usually appear on the bottom of the pods. Later they get encrusted with a white mat of the fungus. In mature leaves, petioles show chocolate-brown to dark brown lesions with drops of coagulated latex; lesions could be found anywhere on the petioles (Plate 9.7b). Leaf blades can also be infected. Infected leaves are shed and the leaflets can be easily shaken off (Plate 9.7c & d). Wind-damaged leaves have no lesions but will have a coagulated drop of latex at the damaged end of the petiole and leaflets cannot be shaken off easily. Severe infection leads to complete defoliation (Plate 9.7e & f). In such an event unlike in *Oidium* leaf disease, new leaves will not be formed until the next refoliation season. Growth and yield can be seriously affected.

2.4.2 Predisposing factors

Excessive rain and high humidity when tender leaves present are the main predisposing factors.

2.4.3 Prevention

Resistant or tolerant clones *e.g.* RRIC 100, RRIC 121 should be grown. During continuous rain and overcast conditions heavy shades in polybag nurseries should be removed.

2.4.4 Control

In Sri Lanka the incidence of the disease is mild and confined only to isolated pockets. Therefore, it is not economical to chemically control the disease in a routine basis. Clones RRIC 100, RRIC 102 and RRIC 121 show tolerance to *Phytophthora* leaf fall. The clones RRISL 203, RRIC 130, RRISL 201, RRISL 217, RRIC 133 and RRISL 202 are susceptible to the disease at various severity levels.

Prophylactic treatment with oil-based copper fungicides just before the rainy season in May is routinely practiced in India.

3. STEM AND BRANCH DISEASES

Several stem, branch and panel diseases are of economic importance where rubber plantations are concerned. Among them, bark rot caused by *Phytophthora* spp. is the most economically important disease. Ustilina stem rot is reported from main rubber growing districts and Pink disease is not very common in Sri Lankan rubber plantations. During the recent past incidences of stem rot conditions caused by Ustilina has increased. The collar rot condition caused by *Pythium* sp. is commonly called as the Patch canker disease and has become increasingly important during the recent past.

3.1 Bark rot (Black stripe, Black thread canker)

Phytophthora bark rot has been reported as the only economically important panel disease in Sri Lankan rubber plantations. It infects the inner bark and is severe during the monsoon seasons when infected pods are present on the trees (Plate 9.8a, b & c). Virgin bark is the most susceptible to the disease than the renewal bark and prophylactic measures have been recommended to prevent the incidence of this disease as bark is the most economically important part of the rubber plant. Clones that are highly susceptible to bark rot are RRIM 600, RRIM 623 and PB 86, RRIC 130 and RRIC 131.

Causal organism: *Phytophthora* spp.

Phytophthora spp. is the causative fungus and as shown in the Plate 9.8, the sporangia are lemon shaped. In temperature changes the cap of the sporangia are opened and zoospores with flagella which are mobile will ooze out. They can actively swim in free water and can enter into the panel easily if unprotected.

3.1.1 Symptoms

Dark grey sunken black vertical lines directly above the tapping cut are the characteristic symptom of the disease (Plate 9.8d). These lines sometimes comes together to form a continuous depressed patch on the tapping panel (Plate 9.8e). When infected bark is removed, these characteristic vertical black stripes can be observed on the wood and because of this disease is called the black stripe disease. During the rainy weather, the disease easily spreads into the bark and when untapped bark is infected, bark cracks are observed. As a consequence, latex exudation is observed and also latex pads are formed underneath the bark (Plate 9.8).

3.1.2 Control

Disease tolerant clones *viz.* RRIC 100, RRIC 102, RRIC 121, RRISL 2001.

3.1.2.1 Prophylactic treatment

The panel should be protected with a fungicide only during the wet

weather and the pod set. If the infected leaves or pods are noted regular application of fungicides is recommended to prevent any infection (Brunolinum planetarium 15% a.i., Ridomil 3g per liter of water).

Wet trees should not be tapped particularly when the leaf fall phase of the disease is evident. Fungicides Brunolinum planetarium 15% or Ridomil (5 g/litre) should be applied on every tapping day at latex collection, or if rain interferes, at the earliest available opportunity.

The trees should be groomed just before the rainy season. Heavy canopies should be pruned to increase free air circulation and penetration of sunlight to dry the panels. Thick weed growth and covers around the plant should be removed.

3.1.2.2 Curative treatment

All diseased tissues above the tapping cut should be removed well into the healthy tissue using a curved instrument. The infected area below the tapping panel can be removed by a few extra tappings. The resultant wounds should have smooth, even and sloping edges to facilitate proper drainage of water and encourage even callusing. Exposed wood should be treated with tar, taking care not to apply it on the bark as it could lead to scorch of bark. This prevents borer infestation. The wound should be treated with a fungicide and later sealed with a waterproof panel dressing. To avoid removal of large areas of the bark, disease symptoms must be recognized at very early stages. Treatment of infected bark should be done on a dry day. It may not be necessary to treat renewed panels unless the damage is extensive.

3.2 Pink disease

Pink disease is essentially a disease affecting young trees of 3 - 7 years of age. It is capable of causing extensive damage to the main stem and branches and could become a problem in wet areas. Symptoms are usually seen at the fork of the tree. The fungus is known to have several alternative hosts and produces two types of wind-borne spores (corticium stage and necator stage). Clones highly susceptible to the disease are RRIM 600, 701 and PB 28/59.

Causal organism: *Corticium salmonicolor*

3.2.1 Symptoms

A cobweb-like film of silky white mycelium appears on woody branches with exudation of latex, usually at the fork region (Plate 9.9a) and gives a pinkish appearance (Plate 9.9b) on the lower part of the affected tissue. It spreads causing damage to bark tissue resulting in almost 'ring barking', if it is not detected early. Shoots appear from dormant buds below the portion affected by the disease. This happens when the tree is ring barked due to the spread of the disease.

Salmon-pink encrustations are seen on the lower surface of the affected portion. Orange-red pustules often develop on the upper surface of branches killed by the disease.

3.2.2 Control

Early diagnosis is essential, when there is limited damage to the main stem and branches. Copper fungicide, Bordeaux mixture or Brunolinum 15% should be sprayed at weekly intervals during the wet season. And a single brush application in a paste form on the affected portion during a rainy season is recommended. Bordeaux mixture should not be used on trees in tapping because of the risk of contamination of latex with copper.

3.3 *Ustulina* stem rot (Collar and Root rot)

Ustulina usually affects the collar and root but it can affect any part of the stem, gaining entry through wounds and cracks in the fork region, deeply inserted spouts or cup - hangers and broken ends of branches. The disease is spread by means of wind-borne spores.

Causal organism: *Ustulina deusta*

3.3.1 Symptoms

Exudation of latex and formation of foul smelling latex pads beneath the bark (Plate 9.10a). The fungus penetrates right into the wood which shows a network of characteristic double black lines, (Plate 9.10b) causing stem or branch breakages, even before the tree is killed. Development of velvety-greyish black fructifications, which form a continuous sheet covering a large portion of the wounds, is another symptom (Plate 9.10c).

3.3.2 Control

All diseased tissues should be cut down to healthy wood and a fungicidal wound dressing should be applied. Trees severely attacked at the fork can be saved by pollarding below the diseased portion. When infected branches are removed they should be cleanly sawn with a sloping cut.

3.3.3 Prevention

Prompt attention should be paid by applying a wound dressing to wounds resulting from wind, fire or lightning and in the process of thinning and pruning. Spouts should not be inserted too deep into the wood.

3.4 Patch canker (Collar rot)

Highly susceptible clones under wet weather in humid locations are prone to this disease. Both mature and immature trees are liable to infection. Wounds caused at the collar region of the bark due to various reasons may predispose the plants to the disease. Sometimes the disease is seen in Phytophthora susceptible clones, grown under adverse conditions.

Casual organism: *Pythium* spp. is identified as the main cause and *Fusarium* spp. are also associated with the problem. Main cause, *Pythium* is a very weak parasite. The infection is followed by the fungus, *Fusarium* spp., one of the main soil inhabiting fungus.

3.4.1 Symptoms

Malady occurs more frequently anywhere on the bark close to the collar region. The first sign of the attack is the exudation of latex from the site of infection (Plate 9.11a). Latex coagulates as a pad underneath the bark giving a foul smell (Plate 9.11b). Subsequently, bark bulges and splits. If the bark of the infected area is removed at this stage, a black streak or patch is seen beneath the point of injury. If left untreated the wound enlarges causing the ring bark and death of the plant (Plate 9.11c & d).

3.4.2 Prevention

Predisposing factors such as planting rubber in rocky areas, sites showing flooding, water logging conditions are should be avoided. As the soil borne pathogens are weak parasites, any wound at the collar region may predispose the plants to infection.

3.4.3 Disease control

Affected portions of the plant should be carefully cleaned by removing the latex pads and rotten tissue. Then for mature rubber plants (after 3-4 years of age), 15g of mancozeb should be mixed in 3 liters of water and 1½ liters of the fungicidal solution should be applied on to the wound carefully and allow for about half an hour to get dried, and a wound dressing should be applied on top of it to prevent the fungicide getting washed off. Later the other 1½ liters of the fungicide solution should be drenched on to the soil around the root system to kill any fungus remaining in the surrounding soils. The treatment is very effective that about 3 months after the first application of fungicides, the regeneration of root can be observed (Plate 9.12).

4. ROOT DISEASES

Root diseases are very destructive and commonly accounts for the largest number of tree losses during the immature phase of the cultivations. Three common root diseases found in Sri Lankan rubber plantations are White root disease, Brown root disease and Black root disease. Among them white root disease is the most destructive while Brown root disease is reported to be destructive in non-traditional rubber growing areas.

4.1 White root disease

White root disease is the most destructive disease in rubber plantations of Sri Lanka. The disease has become an important economic factor in the rubber plantation industry during the recent past as this disease is the main cause for reducing tree stand in rubber plantations. Maintenance of the recommended stand per hectare plays a vital role in obtaining higher productivity levels to meet the expectations of the country. The rubber growing countries suffer a massive economic set back from the loss of potential revenue. Moreover, the use of labour in the land rehabilitation process increases the cost of production and later, the

cost of replanting and also use of pesticides to control the disease poses many environmental hazards.

Casual organism: *Rigidoporus microporus* (Fr.) Overeem (Syn: *Rigidoporus lignosus*)

4.1.1 Symptoms

The incapability of identifying the disease at early stages causes economic losses to the grower and the planters are continually confronted with this problem. The first visible symptom on the foliage is the change of colour of the leaves to off-green and yellowish (Plate 9.13a). Initially, this phenomenon is observed only on one or a few branches but eventually the whole canopy. The leaves become leathery and curves downwards giving typical buckling appearance (Plate 9.13b). Some of the trees flower and fruit prematurely during the off-season just before the death of the plant. The entire canopies of trees with advanced disease turn yellowish-brown and eventually abscise. To confirm the disease, growers should examine the collar region/root system during a wet weather. Then the firmly adhered mycelia aggregations called “rhizomorphs” could be noted (Plate 9.14a). Most of the growers do misidentify the rhizomorphs with the friendly decaying fungal growth (Plate 9.14b). Characteristic fructifications of the fungus appear only at the later stages of the infection concentrically zoned and grown at horizontally from the wood (Plate 9.15a). When fresh, the upper surface is yellowish orange with a lighter colour margin whilst the lower surface is orange brown (Plate 9.15b) with large number of minute pores.

4.1.2 Predisposing factors

Presence of infected roots in the old stand due to improper clearing of the old stand.

4.1.3 Prevention

Infected roots should be removed when clearing the old stand. Replantings or establishment of nurseries should never be established in patches affected by white root disease without rehabilitation.

4.1.3.1 Pre-planting practices

Inspection of mature clearings well before uprooting (at least 2-3 years) is a must and all the infected patches should be demarcated, encompassing 3-4 apparently healthy rows. Make use of natural features such as rocks to demarcate infected patches, and then paint the rocks with lime. Add a small quantity of common salt to prevent the lime being washed off easily. In areas where rocks are absent bury sufficiently large rocks round the patch so that the top surface of the rock is level with the soil. Do not use flagged poles as they get damaged and dislodged at uprooting. After demarcation of the disease patch, Field staff is capable to make the observation of the expansion of the diseased plants. Methods should be employed to stop further spread of the disease.

As foliar symptoms are not apparent in some plants the stumps of the uprooted trees should be examined at the time of land demarcation for white root disease. This process should be applicable to other alternative crops in the rubber lands like Cocoa, Albezia, Cinnamon, Tea, Manihot, Kanda, Alastonia & Jak as they have been identified as alternative hosts.

Now many plantation companies hand over the uprooting process to contractors. The job that is assigned to the contractor will be to remove all the root systems of the trees. The need to remove the root system is not being understood by many and hence the objective of the operation will be lost leaving lots of repercussions for the future planting.

It is vitally important to remove the White root disease infected root systems. Remove all the infected roots as practicable, including the trees at the edge of the patch. The direct supervision at this stage will prevent many future disease complications. Hence while operating the machines to remove plants, a supervisory officer should identify all the white root disease infected plants (Plate 9.16) and make steps to remove all the infected root pieces including the pencil thickness size. Collect all roots and stumps from within the patch and burn them *in situ*. Do not cut large laterals to facilitate uprooting of trees. Never roll infected stumps uprooted from infected patches to lower slopes as it can lead to introduction of inoculum to areas free of the disease (Plate 9.17). Number of White Root Disease affected plants has a direct relationship to the number of food bases left from the old stand (Plate 9.16). Collect all infected roots and stumps as much as possible and burn them *in situ* (Plate 9.18).

Change the planting points and the inter-row distances between replanting cycles. This helps to reduce the incidence of the disease, as it would take a longer time for roots of the new plants in the replanting to contact the old infected roots, if any.

Establish a dense creeping leguminous cover such as *Pueraria phaseoloides* as it helps in the rapid decay of roots, dissipates inoculum, encourages the growth of saprophytic organisms and exhausts the food reserves of potentially dangerous inoculum.

Bush legumes and *Mucuna bractiata* are less desirable as their woody roots are capable of sustaining the disease and helping to transmit it to adjoining rubber trees.

Commence clearing land shortly after the Southwest monsoon of the year before planting so that burning can be undertaken during the dry months just prior to planting. Fill in the planting holes about 4-6 weeks before planting; ensure that infected roots are not incorporated.

4.1.3.2 Planting practices

Sprinkle 125 g of sulphur on the surface of soil around the plant to cover an area of about one square meter leaving a ring about 15 cm wide round the base of the tree, after planting. Mix the sulphur into the soil with a fork. Take adequate precautions to prevent contact of roots with sulphur as it can scorch the roots, eventually resulting in death of plants. Although mixing sulphur with soil is as

effective as sprinkling, it should be done at the time of refilling the planting holes. The application of sulphur can be confined to planting points which fall within the demarcated patch or only for a white root disease threat area. This helps to economise the use of sulphur. Keeping the leguminous cover well away from the base of trees is also important to avoid enhanced disease spread through creepers.

Though it is very rare, the planting materials too may be infected with the disease (Plate 9.19). Hence make sure the plant is free of the disease at the time of planting.

4.1.3.3 Post-planting practices

The markings made on the rocks to identify the old infected patches should be transferred to rubber trees in the replanting. This could be done by painting the brown wood with a distinct band. Cover crops running over the rocks will sometimes hide the painted rocks.

For effective and early detection, inspect trees within demarcated patches for foliar symptoms. Commence this operation 6-9 months after planting. Uproot trees showing severe foliar symptoms as such trees are beyond treatment. Sometimes, if the infection can be detected very early, it may be possible to save such trees. All young rubber clearings should be inspected for the appearance of foliar symptoms (Plate 9.20) in every two months period.

When an infected tree is uprooted trace the food base and remove all root debris in the planting row. If the infection is detected early (within 1 year) the food base would be within the planting hole or just outside it. Infected roots should be burnt *in situ*.

4.1.4 Chemical controlling

Chemical controlling of the disease is the most popular method among the growers (Plate 9.21). White root disease can be managed by applying a systemic fungicide if detected early, as soon as the leaf symptoms are visible. By regular inspection of foliar symptoms followed by collar regions of plants in the risky area, the infections can be identified at very early stages enabling the chemical control. Infected trees having more than 25% healthy collars can be recovered by applying a systemic fungicide. Fungicides should be applied during early morning, on dry days. It is a very dry period make sure to apply a bucket of water to the plant at the roots before chemical is applied. The soil around the collar area should also be removed slightly to facilitate the absorption. Two systemic fungicides tebuconazole and hexaconazole are recommended to control the disease. Since most of the pesticides are toxic, it is always advisable to wear protective clothing. It is not advisable to consume any food while the application of the fungicides.

Prepare 0.25% a.i. solution from tebuconazole 250 EC

Age 0-1 yrs	- Dissolve 10ml of the fungicide in 1 liter of water
Age 1-2 yrs	- Dissolve 20ml of the fungicide in 2 liters of water
Age 2-3 yrs	- Dissolve 30ml of the fungicide in 3 liters of water

Ages above 3 yrs - Dissolve 40ml of the fungicide in 4 liters of water

Prepare 0.25% a.i. solution from hexaconazole 50g/liter

Age 0-1 yrs - Dissolve 50ml of the fungicide in 1 liter of water
Age 1-2 yrs - Dissolve 100ml of the fungicide in 2 liters of water
Age 2-3 yrs - Dissolve 150ml of the fungicide in 3 liters of water
Ages above 3 yrs - Dissolve 200ml of the fungicide in 4 liters of water

Drench the above fungicide solutions around the base of the infected trees. Care should be taken not to leave behind any infected roots. Identify treated trees with a distinctive paint band and also mark the date of treatment, so that these trees could be re-inspected regularly. Adjoining trees on either side of an infected tree should be treated similarly as a preventive measure though they can be healthy looking.

Inspect all treated plants quarterly or at least once a month in wet periods for re-infections. Repeat the fungicide application if necessary after 3 months. Any dead or severely infected plants including all infected root debris should be removed and supplied with new plants.

Establish sufficient number of plants based on the recommendations to supply vacancies created by removal of dead trees. Never select patches infected with *R. microporus* in the old stand to raise plants to be used as supplies.

4.1.4.1 Mature fields

The spread of white root disease in mature fields could be due to:

- failure to detect and treat the disease during the immature period.
- accidental introduction of infected material within the plantation.
- allowing stumps of wind-blown trees with freshly cut surfaces to stand in the clearing as they provide ideal substrates for spore germination, under certain conditions (not commonly experienced)

Treatment of individuals up to about 4-5 years would pay back the cost of treatment.

If a large number of mature trees have been killed, further spread of the disease should be curtailed by uprooting 2-3 rows of trees round each patch; uprooting should be done after exploiting the border trees fully to extract the maximum amount of latex. Uprooting trees in this manner will cause a crop loss in the short run, but will pay in the long run as it can help to prevent perpetuation of the disease in the replanting. These isolated patches should be fenced and a creeping leguminous cover crop like *Purearia* which will expedite the decay of the root debris should be established.

Cutting trenches serves little purpose as they are expensive to cut and maintain. Further, their proper maintenance is difficult. We have noted the neglected trenches in the fields and if not properly maintained they facilitate the disease spread much more. Hence, trenches can be useful only as an emergency

measure which can be temporarily used till the chemical controlling is undertaken. Trees blown over by wind should be uprooted and should not be cut at ground level leaving the exposed stumps.

4.1.4.2 Rehabilitation of white root disease patches

This operation is important in stopping further spread of the disease in rubber plantations. Removal of the dead plants and then rehabilitation of the diseased planting points will help to sustain the tree stand leading to high productivity levels in the rubber plantations. If the patch is large enough short term crops can be used to generate a additional income. When we have large patches in mature rubber plantations, again the rehabilitation is important as further spread of the disease result large unproductive bare patches which will exist for long periods. If not properly rehabilitated it will increase the cost of replanting.

- Mark the existing white root disease patches (demarcation should be done using natural land marks + lime)
- At least 2-3 plant rows (though they are healthy looking) should be included into the demarcated patch.
- Uproot all the dead plants, remove all the infected roots and burn *in situ*.
- Treat all the adjoining healthy looking plants too after marking them with a paint band.
- Then the patch – area should be ploughed mechanically or manually while removing all the infected roots. This step needs direct supervision.
- Sprinkle sulphur 200g/m² in the risky area.
- After two weeks time apply the bio-pesticide in the risky areas are approx. 50g/m². After three weeks of sulphur application plant *Gliricidia* poles or *Crotalaria* plants randomly to cover the area.
- After six months examine the poles for the presence of the pathogenic fungus, then adopt control measures again for rehabilitation.
- Later, any short term crop is suitable to be planted in this area. Will give an extra income.
- These plants will catch the disease and with the removal of the crop the disease detection will be easier
- When White root disease infected trees are found in the mature rubber plantations, eradication programmes should be undertaken in the given methods to stop further spread of the disease.
- Leguminous covers help in the rapid decay but they should be established only after making sure that the inocula base has been removed properly
- *Pueraria* roots dissipates the rhizomorphs and also encourage the microflora: saprophytic and antagonistic organisms in the soil
- However *Mucuna*, as they have comparatively larger roots with more moisture behaves differently by sustaining and transmitting the WRD to rubber trees (Plate 9.22)
- The Efficiency of the Process Depends on Correct Supervision

4.2 Black root disease

Black root disease is generally found in dry areas, mainly in the Kegalle and Kurunegala districts where the conditions are relatively dry. It spreads by root contact like white root disease. It affects both immature and mature plants.

Causal organism: *Xylaria thwaitesii*

4.2.1 Symptoms

Appearance of clusters of fructifications at the collar region or on dead lateral roots.

Fructifications (Plate 9.26) appear as clusters of finger-like protrusions, at the collar or on dead laterals. The mycelium is white at the advancing edge but rapidly becomes grey to black. The mycelium forms a closely knit network forming a continuous or patchy, thin, smooth black skin on the root surface (Plate 9.26). The leading edge of the lesion has white fan-shaped strands of mycelia. In the early stages of infection the wood of lateral roots shows a light brown discolouration immediately below the cortex and later it becomes dark brown. Infected roots remain hard until the final stages of decay, when a wet rot is evident. Discolouration of the foliage is not seen unlike in trees affected with white root disease. The activity of the fungus is entirely subterranean and advance on the root surface is inhibited on exposure to light.

4.2.2 Control

Same as that for white root disease. (Please refer 4.1.4)

4.3 *Fusarium* wilt

It is a rare root disease assuming some importance in Sri Lanka during the recent past. This fungus has been able to kill trees in the early stages of growth of the plants. A wound is essential for this fungus to gain entry into the host.

Causal organism: *Fusarium solani*.

4.3.1 Symptoms

Downward buckling of leaves. The change in colour of leaves is less marked than in white root disease. The collar region of trees showing wilt symptoms does not show an external mycelium. Roots of infected plants when longitudinally split show discolouration of the vascular tissue at points of entry of the fungus.

4.3.2 Control

Drenching the soil with systemic fungicides such as carbendazim is effective in controlling the disease. The fungicide concentration is 5g of carbendazim per litre of water and for a grown plant 4 liters of the above concentrated fungicide is sufficient.

4.3.3 Prevention

Any injuries to the root system or collar region should be avoided.

4.4 Brown Root Disease

The disease is becoming increasingly important in the non-traditional rubber growing areas where forestry plants are removed for rubber cultivation. The disease is less significant than the white root disease in the traditional rubber growing areas. The causative fungus spreads extremely slowly and infections usually occur on isolated trees rather than in extensive patches. The pathogen is a widely distributed tropical species and it affects a wide range of hosts (more than 50) including tea, coconut, cacao, coffee, rambutan, jack, bread fruit, avocado and mangosteen. The causative agent being a facultative parasite can live as a saprophyte for a long time on wood, old roots and other decaying matter. Spread of the disease is mainly through root contact.

Casual organism: *Phellinus noxius* (Corner) Cunn.

4.4.1 Disease spread

The method of spread is similar to white root diseases. According to some literature, brown root disease can also be disseminated by wind-borne spores. Spores lodge onto wounds on branches and trunks; roots can initiate infection and develop into a new source for disease spread.

4.4.2 Diagnosis

- The foliage symptoms are similar to those for white root disease. As in the case with red root disease, the surface of roots infected with brown root disease is coarse as it is covered with a layer of soils.
- On close examination, brown rusty spots are visible which can be used to distinguish between brown and red root disease. In addition, if the bark of roots infected with brown root disease is peeled off, the surface of the roots will be seen to be covered with honeycomb-like structures. These structures are also visible inside the infected roots.
- The fruiting bodies (Plate 9.27) are smaller than in the case with the other root diseases and are hard with dark brown upper surfaces.
- The diagnostic characteristic of the disease is the production of a dark brown gummy mycelium cemented to the roots of the affected plants. A heavy encrustation of sand and stones appear sticking to the brown mycelium cover. During the latter stages of the attack, fungus forms a blackish crust on the affected roots. The diseased bark disintegrates and the wood is penetrated by a net work of branching brownish black lines of the mycelium. This gives a honey-comb appearance (Plate 9.27) to the root when it splits. At this stage affected roots become friable, light and dry.

- As the infection progresses plants exhibit a general wilting of the foliage like in the other common root diseases. The wilting is followed later by a sudden drying out and death of the tree.
- The fungus has typical bracket fructifications (Plate 9.27) and they appear on the decaying stumps after the death of the tree. The upper surface of these thin hard brackets is brownish purple or black in colour with a yellow or brownish yellow margin. Concentric growth rings are seen on the brackets in the form of wrinkles. Lower surface is dark brown or black and sometimes grey and velvety. The size of the brackets may vary from 5-25 cm across. Brackets may grow singly or in layers.

4.4.3 Disease control

Some protocols should be adopted as given for white root disease management (Refer 4.1.4).



Plate 9.1. The most susceptible leaf stage, copper brown leaves appearing just after the refoliation.

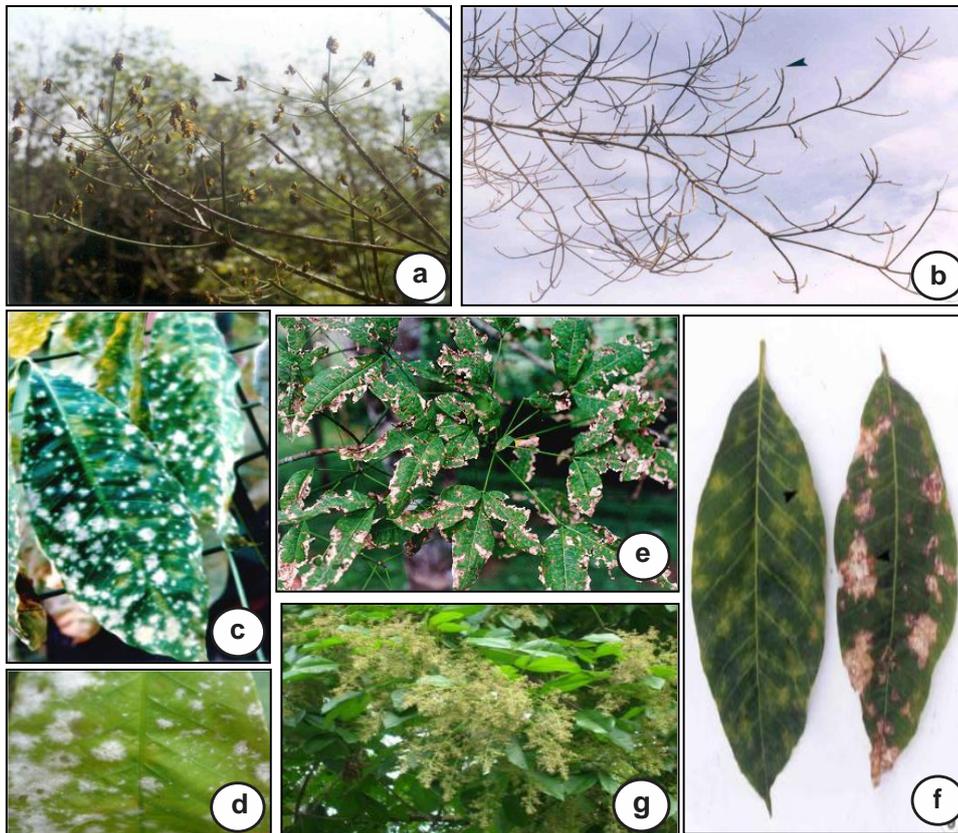


Plate 9.2. Symptoms of Powdery Mildew: **a.** Affected copper brown leaflets shrivel; **b.** characteristic whitish powdery spots; **c.** Whitish powder like conidia formed on the leaves, a close-up; **d.** Old Oidium patches; **e.** Brownish necrotic patches, a close up; **f.** Severely infected leaflets fall off leaving the petioles for some time on the plant; **g.** Flowers are affected.

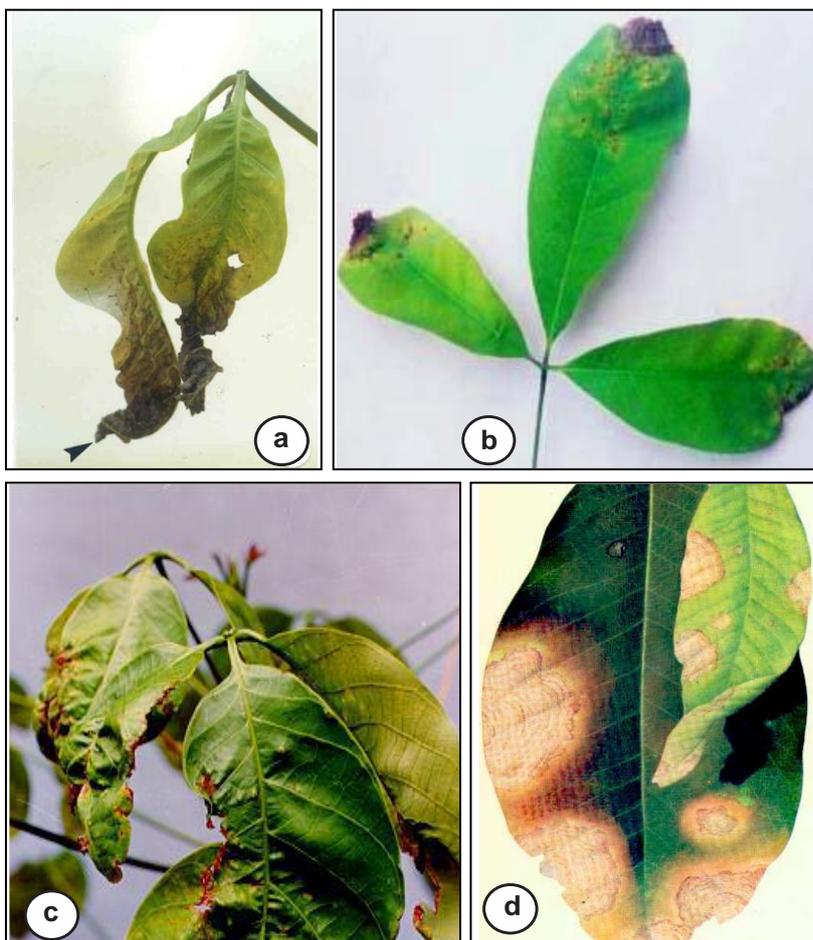


Plate 9.3. Symptoms of *Colletotrichum* leaf disease: **a.** apple green leaves shoe tip dieback; **b.** affected copper brown leaflets shrivel and get discoloured; **c.** mature leaves are resistant to some extent and show raised blisters; **d.** anthracnose symptom (showing the characteristic concentric rings) mostly seen under seedlings and in nurseries.

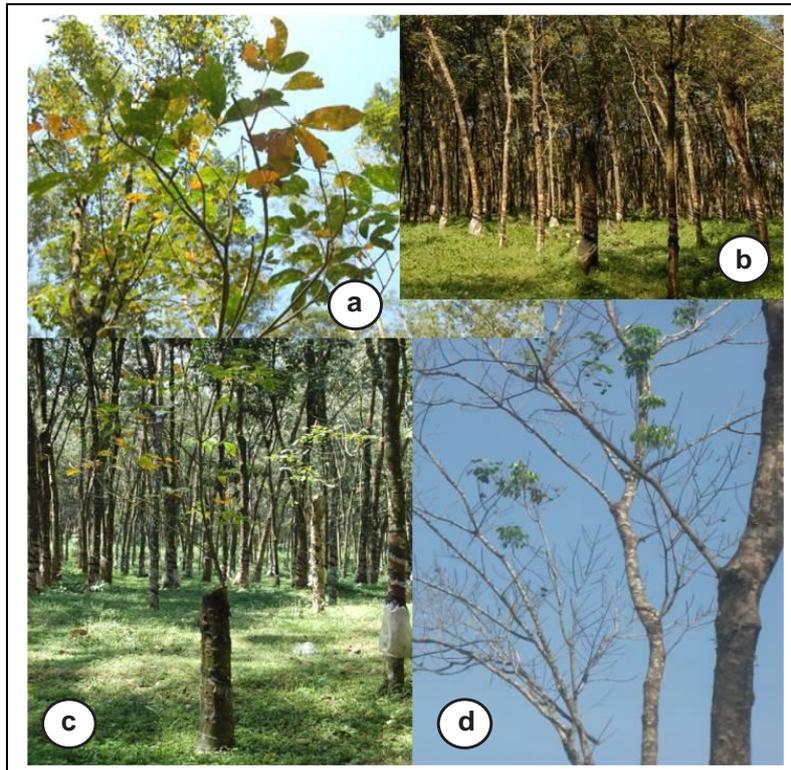


Plate 9.4. *Corynespora* leaf fall disease **a.** *Corynespora* infected branch showing numerous types of lesions with characteristic yellowing; **b.** affected mature plants showing defoliation resulting in low density plantations; **c.** *Corynespora* affected field showing the fallen off of the weak plants resulting bare unproductive patches; **d.** a defoliated tree showing refoliation in some branches (repeated defoliation).

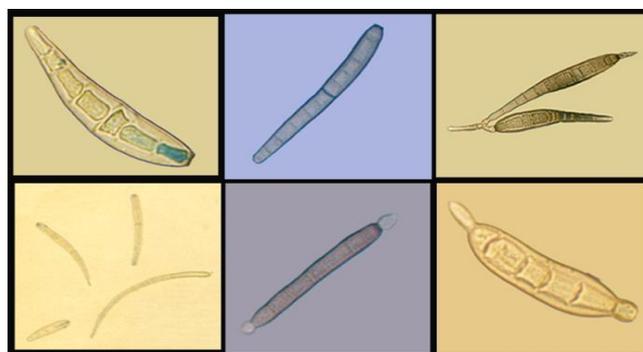


Plate 9.5. The conidia produced by *Corynespora cassiicola*. The conidia are highly variable in sizes and shapes.

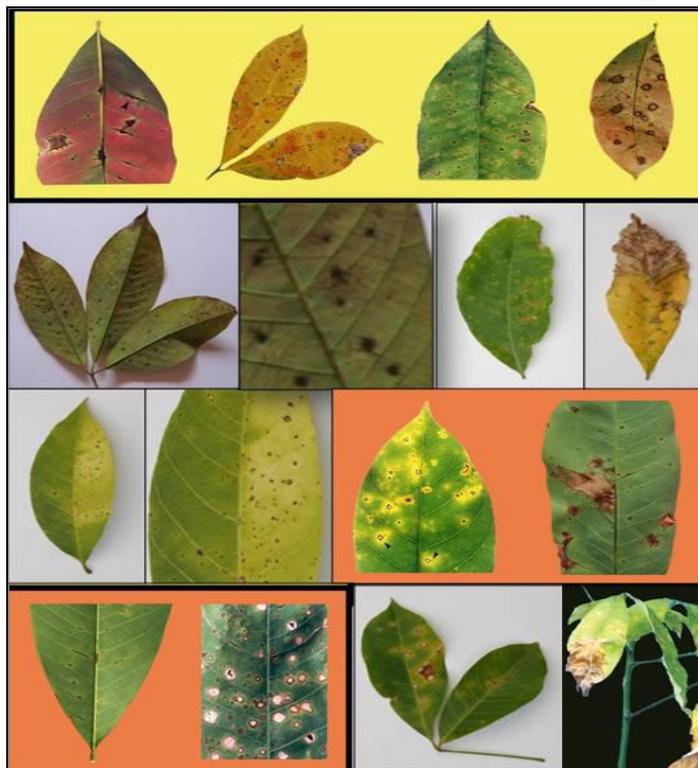


Plate 9.6. Diversity in symptoms produced by *C. cassiicola* on different clones of *Hevea brasiliensis*. Top left to right: typical herring bone pattern, characteristically blighted leaves, Bird's eye spot like lesions, lesions with concentric rings resembling anthracnose, second row: extremely localized lesions, a close up of the previous, blisters like symptoms, tip die-back condition. Third row: tiny dots with dark brown margins, a close up of the previous, irregular polyhedral lesions, irregular extended blotches, bottom: linear lesions on veins, old Oidium patches like lesions, lesions with numerous shapes, poly bag plant showing die-back symptoms.

Economically important diseases of rubber plant

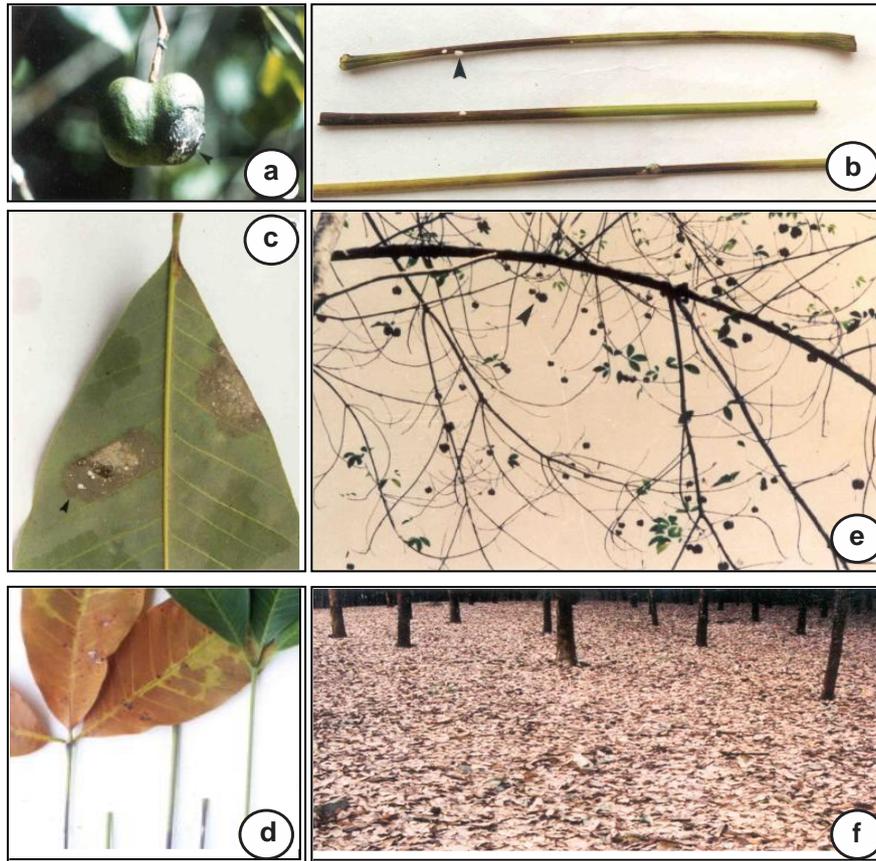


Plate 9.7. Symptoms of *Phytophthora* leaf fall disease; **a.** Infected pods showing water soaked lesions with black globules of latex; **b.** Infected petioles showing characteristic dark brown to black coloured lesion with a drop of coagulated latex; **c.** Infected leaf laminar; **d.** Infected leaves with the characteristic colouration; **e.** Infected plants shed leaves; **f.** Abnormal leaf fall occur under epidemic conditions.

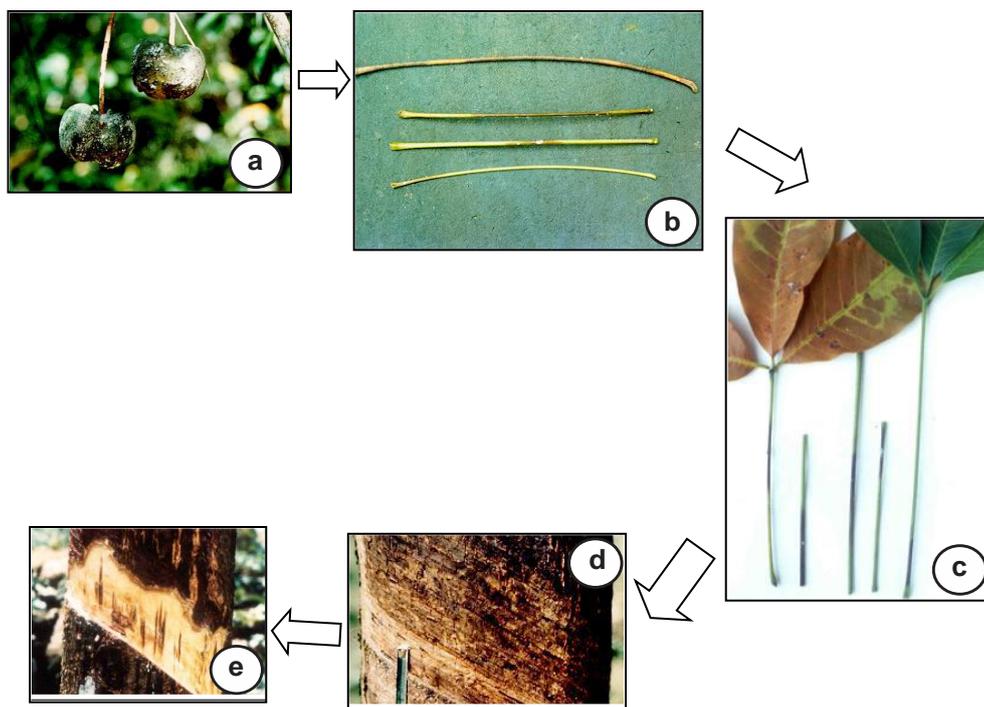


Plate 9.8. Symptoms of Phytophthora bark rot condition **a.** Infected pods showing water soaked lesions with black globules of latex; **b.** Infected petioles show characteristic dark brown to black coloured lesions with a drop of coagulated latex; **c.** Infected leaf laminae; **d.** Infected tapping panel with uneven black vertical edges; **e.** Infected bark is removed to expose the black vertical parallel lines, the characteristic symptom of Phytophthora bark rot on the bark.



Plate 9.9. Symptoms of Pink disease **a.** Initial symptoms, latex oozing out from the lesions and characteristic silky fungal growth on the branches; **b.** Pink encrustation on branches and the main stem.



Plate 9.10. Symptoms of *Ustulina* stem rot **a.** Mature trees are severely infected by *Ustulina*. Note the velvety-greyish black fruit bodies which forms a continuous sheet covering the wound; **b.** Net-work of well-defined wavy double black lines when the wood exposed as a longitudinal section; **c.** A close up photograph of the fruit bodies.



Plate 9.11. Symptoms of Patch Canker disease or collar rot. **a.** Initial symptoms of the disease: Latex exudation; **b.** Latex oozing causing bark cracks at the collar region; **c.** & **d.** If the bark of the infected area is removed at this stage, a black streak or patch is seen beneath the point of injury.



Plate 9.12. Root system of a rubber plant with Patch Canker. After treatments the regeneration of roots can be observed.

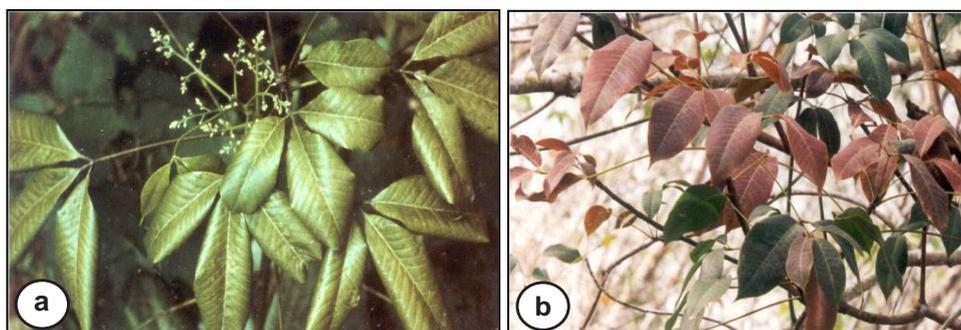


Plate 9.13. Foliar symptoms of white root disease of rubber **a.** Yellowing of the leaves, buckling and premature flowering during the off-season; **b.** Yellowing or turning to reddish brown depending on the type of the rubber clone.

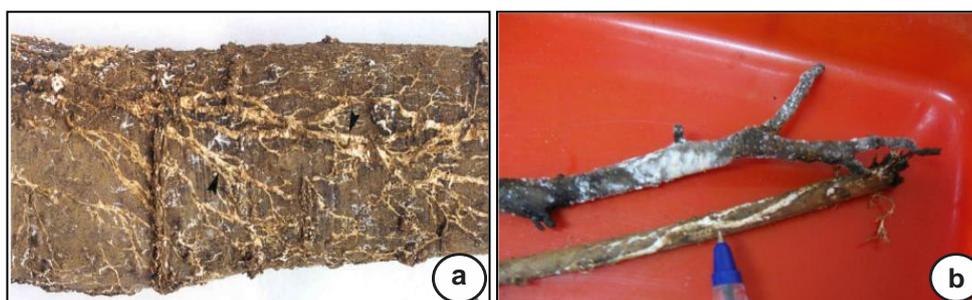


Plate 9.14. Identification of White root disease **a.** aggregation of the mycelia strands on rubber roots to form rhizomorphs; **b.** Distinguish the two fungal growth top root – the growth of the friendly fungal group showing puffy, more whitish growth, the bottom root – rhizomorphs formed by White root disease fungus *R. microporus* which are very firmly fixed on to the root and also yellowish white in colour.



Plate 9.15. Symptoms of White root disease **a.** at later stages of the disease fruit bodies appear at the collar region of the infected plants; **b.** bracket shaped, typically yellow to orange coloured fruit bodies of white root disease of rubber.



Plate 9.16. The lands to be uprooted needs to be well looked in to marking the White root disease patches. Identification of the diseased plants is very important by a supervisory officer. Detection of the of food bases left from the old stand is vitally important to prevent the disease in the new plantings.



Plate 9.17. Careful removal of all the root systems of the plants is important avoiding the introduction of inoculum to areas hitherto free of the disease.



Plate 9.18. Collect all white root disease infected roots and stumps as much as possible and burn them *in situ*.



Plate 9.19. Avoid white root diseased planting materials.

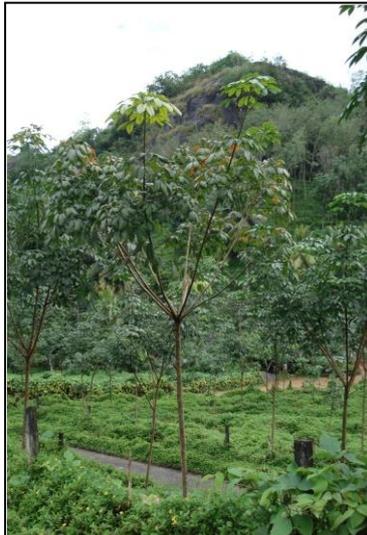


Plate 9.20. Inspect the rubber clearings for any foliar disease symptoms.



Plate 9.21. Application of systemic fungicides to chemically control white root disease of rubber trees.



Plate 9.22. Growth of *Mucuna bractiata* promotes the sustainability of the white root disease fungus. Note the well formed rhizomorphs on roots. And *Glicicidia* used as the indicator plants for white root disease.



Plate 9.23. Tree injection against rubber plants.



Plate 9.24. Biopesticide in compost base.



Plate 9.25. Symptoms of Black root disease **a.** affected rubber tree with the symptoms; **b.** The fungal mycelium initiates as whitish mat rapidly turns to black in colour; **c.** The fruit bodies are staghorn like and formed on the soil surface at the base of the affected trees.

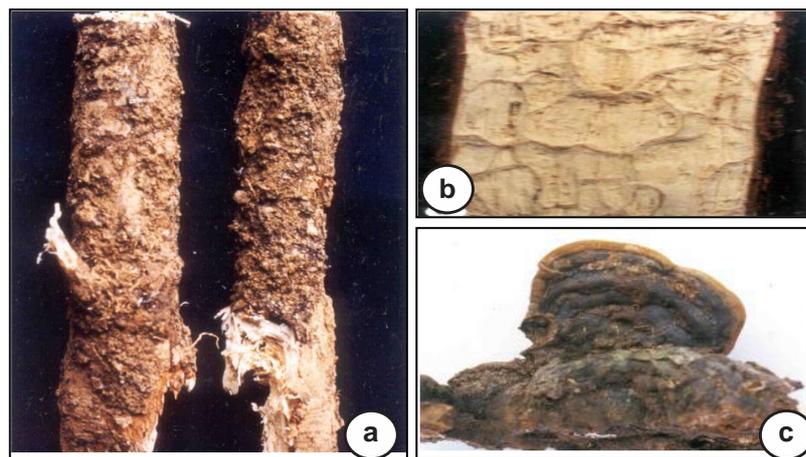


Plate 9.26. Symptoms of Brown root disease **a.** characteristic of the disease is the production of a dark brown gummy mycelium cemented to the roots of the affected plants. Note the heavy encrustation of sand and stones sticking to the brown mycelium; **b.** The diseased bark disintegrates by a net work of branching brownish black lines of the mycelium giving a honey-comb appearance; **c.** Typical bracket fructification appearing on the decaying stumps.



Plate 9.27. Some potential antagonistic plant species. **a.** *Curcuma domestica* L. (Turmeric); **b.** *Curcuma xanthorrhiza* L. (Wild ginger); **c.** *Zingiber officinale* L. (Ginger); **d.** *Alpinia galanga* L. (Galangale); **e.** *Elettaria cardamomum* L. (Cardamum); **f.** *Sansevieria trifasciata* L. (Snake plant); **g.** *Maranta arundinacea* L. (Arrowroot); **h.** *Pedilanthus tithymaloides* L. (Slipper flower); **i.** *Kalanchoe pinnata* L. (Cathedral bells).

Chapter 10

Pests of rubber

M.K.R. Silva

1. Introduction
2. Mammalian pests
 - 2.1 Nature of the damage
 - 2.2 Management strategies
3. Insect pests
 - 3.1 Cockchafer grubs
 - 3.1.1 Nature of the damage
 - 3.1.2 Management strategies
 - 3.2 Scale insects
 - 3.2.1 Nature of the damage
 - 3.2.2 Management strategies
 - 3.3 Mealybugs
 - 3.3.1 Nature of the damage
 - 3.3.2 Management strategies
4. Nematodes
 - 4.1 Nature of the damage
 - 4.2 Management strategies
5. Mites
 - 5.1 Nature of the damage
 - 5.2 Management strategies
6. Slugs
 - 6.1 Nature of the damage
 - 6.2 Management strategies

1. INTRODUCTION

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 destroyed while mature trees also could be led to death due to the ring bark condition caused by these pests. Porcupine, wild boar, sambar deer (“*gona*”), deer (“*olu muwa*”), rabbit, monkey and bandicoot are the main reported species causing damages on the rubber tree.

Generally, the rubber tree is free from serious damages caused by insect pests. This is due to the presence of latex which protects the tree by coagulating spontaneously in wounds made by insects. Pests, in their usual way of sucking plant sap from tissues, insert their mouth parts into rubber plant tissues. As a result of the injury, latex coming out from vessels coagulates and automatically traps the insect’s sucking organ in it. Insects which are adapted to feed between latex vessels or on tissues with little latex, or invade only the epidermal cells, can successfully colonize

and infest rubber trees causing considerable damage. However, not only insect pests, but also mollusks and nematodes are listed as pests of rubber in Sri Lanka.

2. MAMMALIAN PESTS

Most of the complaints are on damages due to porcupines and wild boars. Porcupines are responsible for a considerable percentage of casualties in certain immature rubber lands. They are rodents who basically attack the tree from the time of establishment up to tapping. The wild boars are one of the most widely distributed mammals in the world. They occupy an extremely wide range of habitat types, where they feed opportunistically on plant and animal species. In addition, wild boars have the highest reproductive rates among ungulates, and their local density can double in one year.

2.1 Nature of the damage

In the very early stages of the rubber plant, the porcupine uproots the plant and feeds on the immature underground parts. At latter stages, they feed on the bark of the rubber trees. The damage is characterized by the specific biting marks on the remaining wood surface (Plate 10.1a) and therefore it is easily distinguishable from the damage by other creatures on the bark.

Wild boar attacks the rubber tree from the time of establishment up to tapping. 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 behaviour. The damages resemble the cutting marks made by a sharp equipment (Plate 10.1b).

Bandicoots attack the roots and the collar region. Yellowing and wilting of leaves can be resulted from an attack and later the leaves turn brown and dry. Rats and squirrels can cause serious damage in seedling nurseries and in young plantations. They are attracted to cotyledons of germinating seedlings. They mainly feed on the pith in the stem of growing seedlings by splitting it open.

Consequences of the damage by mammalian pests will sometimes end up with the ring barked condition causing the death of the tree. Though the wound can recover, the growth retardation and the increasing proneness to wind damage from the point of recovered lesion may also be resulted. Moreover, the wounds may facilitate the growth of secondary invading microorganisms sometimes leading to the death of the plant/tree due to diseases.

2.2 Management strategies

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, legal, cultural and religious influences are the major problems encountered when adopting management strategies. There are conventional methods and recommended strategies used to protect plants from these pests.

Establishment of bamboo strips, plastic drink bottles, PVC tubes, gunny bags, old buckets, and old metallic roofing sheets are some of the methods conventionally adapted by the rubber growers to encircle the plants/trees. Hanging of white polythene (as bands or strips) surrounding the plants is another effective method against wild boar in most locations. However, it should be noted that this is not an effective practice against porcupine. Covering the animal paths with fish nets and employing sound-producing gadgets are also practiced in certain locations. However, some of these may have their own adverse features and therefore special attention is required while adopting.

The recommended methods of management include the use of the chemical repellent which is based on Tetramethyl Thiurum Disulphide (TMTD) and the use of a physical excluders. PVC mesh and Galvanized mesh have given proven results as physical excluders over these creatures. Though the initial cost incurred is comparatively high, the use of a mesh is economical in the long run as they can last throughout the immature phase.

A wound caused by a mammalian pest attack need to be treated by applying a suitable fungicide on the wound after scraping out the bark of the wound area with a sharp blade carefully. This application should be followed by the application of a wound dressing on top of the fungicide.

3. **INSECT PESTS**

Insects having mouth parts adapted for piercing and sucking and some insects with soil-inhabitant larval forms are capable of attacking young rubber plants in the field and in nurseries.

3.1 **Cockchafer grubs**

Cockchafer grubs are the larval stage of the beetles of the family Scarabaeidae (Plate 10.1c). The grubs of number of species under this family are known to feed on rubber roots. They consist of white or creamy fleshy grubs with incurved bodies of different sizes. The head is distinct and hard, chitinous, brown and they are equipped with a powerful pair of jaws and biting-type mouth parts.

3.1.1 **Nature of the damage**

Eggs are laid in soil and grubs hatch out in 2-3 weeks and feed on organic matter, and gradually begin to attack roots of the young plants. The lateral roots may be eaten off and similarly the cortex of the taproot may also be eaten away. With the root destruction, above-ground symptoms may appear as yellowing of leaves and dieback of shoots. In the case of severe attack, young trees may die.

3.1.2 **Management strategies**

Like in other pests, cockchafers also have many natural enemies who generally keep their population down. However, the plantation should be cleaned of decaying woody debris to eliminate breeding grounds for beetles. Application of the insecticide Imidocloprid to the surrounding soils of the infested plants gives a

satisfactory control. Each infested plant has to be treated with 2.5 ml of Imidocloprid diluted in 1.5 l of water. The insecticide has to be poured in to 4 holes dug 10 cm deep in a circle of a six inches to one foot-radius.

3.2 Scale insects

They belong to the class Coccidae of the order Hemiptera. The females are flattened, elongated-oval shaped, purple black, convex and sedentary, covered with a protective hard smooth exoskeleton, hence referred to as scale insects (Plate 10.1d). The adult males are delicate and possess mouth parts and are harmless to the plants.

3.2.1 Nature of the damage

Their feeding mechanism is to insert specialized tube-like mouth parts into plant tissues and suck the sap. The adult females and the pupal stages of both sexes are well adapted for this type of feeding. As a result of their feeding on the green shoots, petioles and underside of the leaves along the mid-rib and veins, plants get weakened. Similarly, the apical bud may also be destroyed in a heavy attack. Young seedling plants in nurseries are highly susceptible to the scale insects. Under favourable weather conditions, the seedlings may be completely killed. In addition to the direct damage, it results in reduction of the photosynthesis due to sooty moulds development on their sugary excreta.

3.2.2 Management strategies

Normally, scale insects are biologically controlled by natural enemies such as predatory insects and parasitic fungi in the field conditions. However, the natural balance could be destroyed in situations such as in large-scale nurseries which are a favourable habitat for them. In a heavy infestation, it is recommended to contact the rubber research institute of Sri Lanka for the management instructions.

3.3 Mealybugs

They belong to the class Pseudococcidae of the order Hemiptera. They have sap-sucking mouth parts and their feeding habit is similar to that of the scale insects. However, unlike in the scales, the body of the female mealy bug is covered with a protective white waxy material. The males are tiny, fly-like active insects with two wings and are incapable of feeding at the adult stage. Young stages of the both sexes are flattened, oval, light yellow, six-legged.

3.3.1 Nature of the damage

Mealybugs are mainly found feeding at the axils of branching stems and leaves and on the upper and lower surfaces of leaves. When heavily infested, stunting of the plants, defoliation and die back of the infected parts will occur (Plate 10.1e).

3.3.2 Management strategies

Mealybugs are not economically important under the field conditions as they are biologically controlled by natural enemies. If the infestation is heavy and alarming, it is recommended to contact the rubber research institute of Sri Lanka for the management instructions.

4. NEMATODES

The root-knot nematode *Meloidogyne incognita* has been identified as the causative agent. However, at present, the incidence is not serious on rubber and is limited only to nurseries.

4.1 Nature of the damage

Affected seedlings become stunted and show symptoms similar to those of nutrient deficiency. Conspicuous swellings (Plate 10.1f) on the lateral roots or rootlets are characteristic to the plants infested with root-knot nematodes. At this stage, pear-shaped females can be dissected out from the galled tissue of the roots.

4.2 Management strategies

Affected seedlings should be removed during the thinning process of seedling nurseries. Only at the heavy infestations, chemical management is needed and it is recommended to contact the rubber research institute of Sri Lanka for the management instructions.

5. MITES

Mites belong to the order Acarina of the class Arachnida. Mites in rubber plantations include yellow tea mite, red spider mite and scarlet mite. They are minute creatures hardly visible to the naked eye. However, their presence on the leaves could be easily detected by the characteristic symptoms: irregular twisting and distortion of leaves (Plate 10.1g). The damage could be more serious in young plants and seedlings under crowded and heavily-shaded conditions.

5.1 Nature of the damage

Yellow tea mites damage young actively growing shoots and leaflets by feeding on the underside of the leaflets. The damage causes irregular symmetry of the leaflet, which ultimately becomes twisted and shrivelled. Heavy infestation may lead to leaf fall.

Red spider mites feed on plants in seedling nurseries by piercing the leaf with sharp slender lances attached to the mouth, causing a brownish or rusty discoloration of the leaves. Under favourable conditions defoliation could occur. Affected areas are covered with fine silk webbing in which eggs are laid.

5.2 Management strategies

Mites are naturally controlled by predators such as lady bird beetles, small spiders and other predatory mites. However, in an outbreak, it is recommended to contact the rubber research institute of Sri Lanka for the management instructions.

6. SLUGS

Slugs belong to the order Acarina of the class Arachnida of the Phylum Mollusca and bear characteristic soft shiny, legless bodies pointed at both ends and a head with two pairs of tentacles. They are easily distinguishable from snails as they have a greatly reduced shell, which lies beneath the body surface. They lay eggs in masses in damp places or in soil. Normally they are held together by a sticky secretion. These eggs hatch to produce small young slugs identical to adults.

6.1 Nature of the damage

Slugs feed at night and usually hide during the day. They climb young plants to eat the terminal bud and the side shoots (Plate 10.1h). This process is continual resulting in a cluster of short arrested shoots at the apex of the plant. This appearance is characteristic of a slug attack and repeated attacks can cause death of the plant. In addition, slugs sometimes ascend trees in tapping and feed on the latex. Though their consumption of latex is negligible, they can cause considerable spillage from the cut over the trunk.

6.2 Management strategies

As slugs have a number of natural enemies, the infestation is not frequently encountered. However, in a sudden outbreak in rubber plantations, slugs should be controlled by distributing poisoned bait and therefore it is recommended to contact the rubber research institute of Sri Lanka for the management instructions.

Pests of rubber

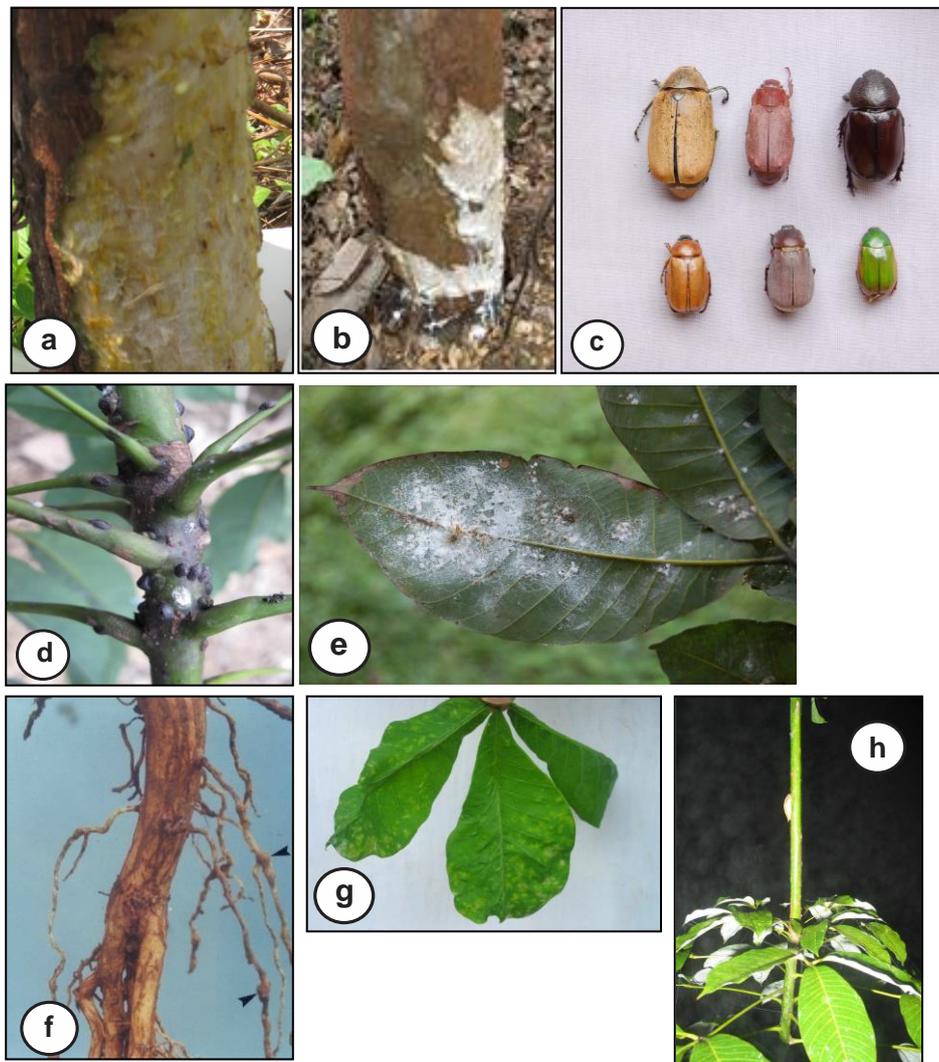


Plate 10.1. Pests on rubber. **a.** Porcupine damage on rubber bark; **b.** Wild boar damage on rubber bark; **c.** adult forms of several cockchafer; **d.** infestation of scale insects on an immature stem; **e.** a leaf damaged by mealy bugs; **f.** nematode infestation on lateral roots: arrows indicate nodules; **g.** a leaf damaged by Mites; **h.** Slug attack on a shoot.

Chapter 11

Conditions caused by physical injuries

T.H.P.S. Fernando

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 - 2.3 Prevention
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1. INTRODUCTION

In rubber plants there could be occasions when injuries due to either natural forces of the environment or accidents could occur. Presently more complains are received by the RRI on physical injuries especially from the non-traditional rubber growing areas. Due to the adverse weather conditions there is always a possibility for physical injuries. They produce effects which are easily mistaken for disease symptoms. However, the affected plant parts may be later invaded by parasitic or saprophytic fungi, some of which may enhance the injury. If proper treatments are not given, they sometimes cause serious damages resulting in death of trees.

2. FIRE DAMAGE

2.1 Introduction

They are common in rubber plantations, especially during the wintering season. During these periods, a thick carpet of dry leaves can be observed on the ground. During the dry weather these conditions are more prevalent. Fires in rubber plantations start accidentally, mostly by carelessly throwing away cigarette butts or because of inadequate precautions taken in organized burning of unwanted adjoining materials.

2.2 Symptoms

When young trees are damaged by fire, they may cause sudden death of the plants. Scorched leaves become brown and brittle either partly or entirely and later, the dead tissues are invaded by saprophytic fungi. In mature trees the lower portion of the trunk is most vulnerable. The affected portion cracks with profuse exudation of latex (Plate 11.1a). Sometimes there may be no external indication until the stem starts to ooze out latex. The dead tissue may be invaded by borer-beetles and saprophytic fungi such as *Botryodiplodia* spp. or *Fusarium* spp. The bark of the burnt portions of the trunk becomes loose and peels off easily. The full extent of damage in mature trees does not become evident until several days later.

2.3 Prevention

Precautions should be taken when building a fire for any other purpose surrounding the cultivations. It should be kept well away from the boundary of any field of rubber. Special care should be taken during the wintering period. Fire breaks should be maintained by clearing the ground of dried leaf litter. The risk is more if the public has access to roads going through the cultivations.

2.4 Treatment

The damaged trees should be treated as soon as possible before they are attacked by secondary invaders or borers. The recovery of trees affected by fire depends on the extent of damage. Most of the trees which are not extensively burnt could be treated. If the tree is burnt all round, such trees are impossible to save. Severely affected trees should be tapped on any remaining bark by opening upward cuts on them and they could be eventually uprooted following maximum

exploitation. If the damage is limited to only one panel, the scorched tissue of that panel could be removed and the unaffected panel may be tapped as usual.

Trees scorched by fire should be treated as given below. All the affected bark should be removed leaving a smooth edge to the resulting wound. The wound should then be treated with an application of a fungicide such as Brunolinum plantarium (15 parts in 85 parts of water), mancozeb (5 g in a litre of water), captan (5 g in a litre of water) or carbendazim (2 g in a litre of water). Once this is dry, the entire wound must be painted with a wound dressing such as candarsan to avoid the wash off of the fungicide. If the wound is large it is advisable to protect the wood with an application of tar (candarsan) to prevent borers attack. When carrying out this operation, care should be taken not to apply tar/candarsan on the exposed bark as tar is known to scorch the bark resulting the death of the plant.

The affected plants of the cultivation should be inspected daily for about two weeks to confirm that no damaged trees have been missed. It is often difficult to determine whether trees have been injured or not, as the damaged bark in some cases is not blackened until late. Such trees may be easily overlooked, until the borers find them out. Generally, the borers attacking trees which are slightly scorched more readily than those which are severely scorched.

3. LIGHTNING STRIKE

3.1 General

Lightening injuries can be observed both in mature and immature rubber plantations. In non-traditional areas lightening damages are more frequently reported. Sometimes it takes about a month to show the symptoms.

3.2 Symptoms

Lightning strike could affect trees in the field in different ways,

- Single trees, or groups of trees, may be killed. In some instances, a tree is killed, while the branches of the trees nearest to it are withered. In some other cases, one or more trees are killed and the top level branches of the neighbouring trees wither, as seen in pathogenic die-back conditions.
- Trees which have been struck by lightning, but not killed, may sometimes bear short vertical wounds on the stem, sometimes arranged spirally. They may be accompanied by a wound at the collar region.
- Exudation of latex is seen from the upper branches due to the injury caused by lightning (Plate 11.1b).

These symptoms appear suddenly and often show up first in trees at the center of the group. Withered leaves on the tree show a characteristic yellowing followed by browning. The first symptom on the trunk would be a discolouration of the bark, which later turns in to chocolate brown in colour, rapidly turning to black colour. Subsequently the bark dies, cracks and comes off. The bark and the wood of affected trees by lightning are highly susceptible to invasion by boring insects and saprophytic fungi. The development of new shoots at various points on the trunk is another characteristic feature of lightning damage. Dieback of

branches and main stem could occur to varying degrees, a few weeks after a lightning strike.

3.3 Treatment

The affected parts should be removed by cutting just below the point of dieback. The resulting wound should be treated with a fungicide (Brunolinum plantarium - 15 parts in 85 parts of water, mancozeb - 5 g in a litre of water, captan - 5 g in a litre of water or carbendazim - 2 g in a litre of water) and painted using a waterproof panel dressing such as candarsan. When carrying out this operation, care should be taken not to apply tar/candarsan on the exposed bark as tar is known to scorch the bark resulting the death of the plant. It is advisable to give an additional dose of fertilizer to the affected plants in order to allow the shoots to regenerate and develop in to normal trees.

4. SUN SCORCH

4.1 General

Sunlight is a major requirement for plant growth. Nevertheless, plants are sensitive to injury by excessive radiation and heat from the sun, especially in areas where quartzite soils are present. Frequent sun scorching conditions are reported from nontraditional rubber growing areas as well.

Sun scorching of leaves and stems mostly occur in localities which are well exposed to sunlight for a long period during the day. Young plants are more susceptible to this condition. Sun scorch is also common when polybag plants are removed from shaded nurseries without prior hardening by progressive thinning of the shade and also when closely planted seedlings are thinned in a nursery. Drops of water retained at the tips of leaflets as a result of dew or a shower can promote scorching of the leaflets, if a period of bright sunshine follows. Reflection from light coloured and granitic soils can also cause stem scorch of young plants.

4.2 Symptoms

The symptoms of leaf scorch occur on the leaves as bleached and papery areas. Young leaves in addition are severely puckered and deformed. The bleached area corresponds to a droplet of water and this is a characteristic symptom (Plate 11.1c). Sun - scorched leaves generally drop off except those that are only slightly affected. The dead tissues of leaves are generally invaded by secondary saprophytic fungi.

The bark at the base of stems of young plants can also die due to sun scorching. This condition is commonly evident in clearings where a good cover growth is absent and more prevalent in rocky lands. The heat generated from rocks on the soil surface can also affect the base of the stem, killing it. The renewing bark on the tapping panel of mature trees may be scorched and wounded during the wintering period as it gets exposed to intense sunlight due to the loss of the leaf canopy. Saprophytic fungi growing on such wounds may suggest that the panel is infected by bark rot (Plate 11.1c).

4.3 Prevention

Stem scorch in clean weeded plantations during intense sunlight could be avoided by mulching around the base of the plant, but without the mulch touching the trunk. In the case of polybag plants shade should be removed gradually to harden the plants before planting them out in the field. Stumped buddings and the stems of other advanced planting materials should be lime washed before planting in the field, to minimize the scorching and desiccating effects of the sun. It is recommended to apply lime for the basal stem of plants grown in non-traditional areas to avoid severe sunscorching.

In nurseries, the routine fungicide application equipment should be well calibrated or sometimes larger droplets of colourful fungicide solutions may lead to scorching conditions.

4.4 Treatment

Plants affected by leaf scorch generally recover by producing a new flush unless the plants are severely affected. Most of the trees which are not extensively scorched will recover if the following methods of treatment are adopted. In young plants the dead shoot should be cut back to promote a new flush. In mature plants remove the scorched bark by scraping, so as to give a smooth edge to the resultant wood. This facilitates easy drainage of water and encourages even callusing. Apply a fungicide such as Brunolinum plantarium (15%), mancozeb (5 g in a litre of water), captan (5 g in a litre of water) or carbendazim (2 g in a litre of water) and seal off the wound with a waterproof panel dressing, such as candarsan.

5. WIND DAMAGE

5.1 General

Small plants or trees when exposed to strong winds can get damaged easily. Under extreme conditions this can lead to either uprooting of trees or trunk or branch snap. This could occur during the monsoon months, especially if the canopies are heavy. Clones such as RRIC 130 are prone to wind damages due to the specific branching pattern. When the planting practices are not properly practiced (bud-grafting union is exposed) the plants are prone to wind damages.

5.2 Symptoms

In immature trees the stems or branches could either bend or twist forming cracks. Such trees are characterized by the presence of black streaks of latex along the length of the trunk or branch. Cracks that occur as a result of wind damage are prone to infections caused by secondary fungi such as *Ustilina deusta*, *Botryodiplodia theobromae* and *Fusarium* spp..

5.3 Prevention

Wind damage is commonly seen in areas which are open and exposed to strong winds especially in valleys. When using such areas for planting, the plant should be placed deep enough to allow for proper anchorage. Establishment of

wind belts with a fast growing tree species where possible will alleviate the problem. Rubber planted in areas prone to wind damage should not be allowed to develop a heavy canopy. Pollarding of branches in mature trees also helps to reduce wind damage, if the canopies are too heavy. The cut end of branches and stems should be protected with a wound dressing. Clones prone to wind damage such as RRIC 130 should not be planted in wind-swept areas.

5.4 Treatment

When wind-blown trees are removed, it is advisable to protect the cut ends of stumps from colonization by the spores of the white root disease. It is best to uproot such stumps. When stems and branches are damaged they should be pruned in such a manner as to leave a smooth sloping surface. Further, the cut end should be protected with a fungicide followed by a wound dressing.

6. DROUGHT AND WILTING

6.1 General

Drought affects the growth of the plant, as an adequate supply of water is a primary requisite for good growth. This condition generally occurs in plants during prolonged dry weather and it is more likely to arise in sandy soils having poor water-retaining capacities. The condition has become very frequent under non-traditional rubber growing areas.

6.2 Symptoms

Wilting of leaves is the first symptom. Tender leaves wilt first. If the drought persists, the temporary wilting becomes a permanent causing shriveling of a part or the entire canopy. At this stage, saprophytic fungi may invade the dead leaf tissues giving the impression of a disease. Sometimes small bluish green blisters are seen on newly shriveled young leaves. Die-back of green stems also occur.

Older trees can also get affected by prolonged drought causing discoloration and early senescence of mature leaves. Lack of moisture can also lead to suppression of new growth, die-back of twigs and a reduction in the yield.

6.3 Prevention

To prevent young plants coming into this condition it is essential to avoid planting during or just before the dry season. It is recommended to begin planting when the soil is adequately moist during planting season. Young plants which are not properly established should be watered during a dry spell. If wilting is partial, plants may recover with prompt watering. In the case of advanced wilting, with the shoot affected as well, the plant should be pruned up to the healthy stem and preferably a protective dressing such as candarson should be applied at the cut end.

6.4 Treatment

Dead plants should be uprooted and vacancies filled. Moisture retention of the field should be improved. Mulching or composting will also be helpful to improve water retention capacity. Special irrigation systems should be used especially for the establishment of the plants.

7. FLOODING AND WATERLOGGING

7.1 General

Flooding and waterlogging are common during the monsoon period due to heavy and prolonged rains especially in poorly drained areas. This is likely to occur more frequently in low-lying areas close to rivers and in areas with clay soils. This condition affects the growth of plants as excess water around the roots impairs their respiration by replacing the air between soil particles. In well drained clay soils, sometimes localized pockets of ill-drained areas may be found. In soils with good structure this condition arises when there is impeded drainage, through unattended drains and bunds, soil erosion and silting of rivers. The condition has become very frequent under non-traditional rubber growing areas too.

7.2 Symptoms

These plants are generally slow in growth and appear to be weak and unthrifty. The leaves gradually turn yellowish and the bark is often dull silvery white. A distinguishing feature in young plants is the enlargement of lenticels at the base of the stem and the presence of blackened dead roots.

Plants which are about one year old can die due to prolonged flooding or waterlogging. However, older plants suffer less and the extent of damage depends on the duration and the level of flood waters. Usually the plants are affected to varying degrees of leaf, bark and root damage. The bark may crack all over the stem accompanied by exudation of latex.

7.3 Prevention

As a precautionary measure a good drainage system should be maintained by regularly attending to the bunds and desilting of the drains. Localized water logging should be prevented by diverting the water courses.

7.4 Treatment

Drainage should be improved by various cultural practices. If soil around the base of the plant is hardened it should be broken up with a fork. Cut drains at proper places and repair or deepen already existing ones to minimize soil erosion.

8. POISONING

8.1 General

A concentrated dose of a fungicide or a herbicide could cause varying degrees of injury to rubber plants if adequate precautions are not taken while using

them. Use of large doses of fertilizer could also cause similar damage. Sometimes, accidental poisoning can occur by direct contact with the spray drift or by uptake of any poisonous substance spilt on the ground. The failure to calibrate the spray equipment, use of non-recommended chemicals and also contamination of spray tanks can also lead to similar toxicity conditions.

8.2 Symptoms

When herbicides come into contact with leaves large white patches appear on them, which later become invaded by secondary fungi. When hormone type herbicides are used the leaves are severely distorted and crinkled. Sometimes dieback of stems also occur. Severely damaged leaves fall. If the stem comes into contact with these chemicals the bark will split open in patches with exudation of latex. When the bark is dead, borer infestations are evident.

8.3 Prevention

Spraying should be carried out when atmospheric conditions are still. Spray nozzles must be held close to the ground to prevent spray drift, especially in young rubber fields. Spray equipment should also be calibrated.

8.4 Treatment

Pruning of affected shoots well into healthy areas followed by the application of a wound dressing to the cut end is the only treatment that could be carried out.

9. EXPOSURE OF BUD UNION (ELEPHANT FOOT CONDITION)

9.1 General

This condition is commonly seen when the bud union is exposed due to incorrect planting. In hilly areas where strong winds are experienced cracks appear at the exposed union. Through these cracks saprophytic and weak parasitic fungi such as *Pythium* spp., *Ustilina deusta* and *Botryodiplodia theobromae* enter causing decay of the bark tissue (Plate 11.1d).

9.2 Symptoms

Affected portions of the tree become greyish or blackish in colour with exudation of latex.

9.3 Prevention

Care should be taken to ensure that the bud union is below ground level during planting. Do not remove soil at the base of the tree during weeding rounds.

9.4 Treatment

Scrape off the affected bark and the resultant wound should be treated with a suitable fungicide (carbendazim or mancozeb 5 g per litre), let it dry and apply a wound dressing on top of the fungicide to avoid the wash off.

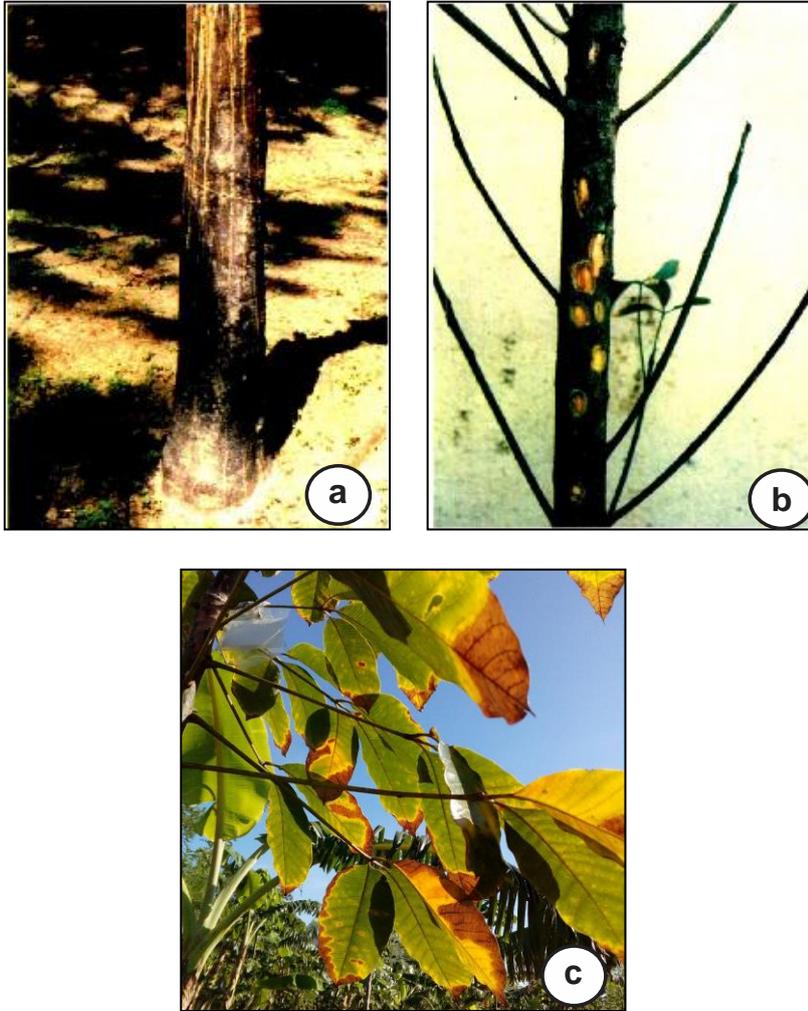


Plate 11.1. Physical injuries. **a.** fire damage; **b.** lightning strike; **c.** sun scorch.

Chapter 12

Important diseases of Hevea brasiliensis uncommon or absent in Sri Lanka

T.H.P.S. Fernando

1. Introduction
2. South American leaf blight
 - 2.1 Symptoms
3. Target leaf spot
 - 3.1 Symptoms
4. *Fusicoccum* leaf blight
 - 4.1 Symptoms
 - 4.2 Susceptible clones
5. *Phytophthora* leaf wither
 - 5.1 Symptoms
6. Tar spot disease
 - 6.1 Symptoms
7. Public vigilance

1. INTRODUCTION

Disease scenario of rubber plantations has changed with time in many countries. For instance, *Corynespora* leaf fall disease which was considered as a minor leaf disease in seedling nurseries in 1958 has assumed epidemic proportions in several rubber growing countries such as Sri Lanka, Malaysia, Thailand and Indonesia during the latter part of 1980. Two other leaf diseases, *Phytophthora* leaf wither and Target leaf spots caused by *Thanatephorus cucumeris*, which were of little concern a decade ago in Brazil, now require regular spraying to prevent extensive leaf fall and die-back. White root disease has become the most destructive root disease in many rubber growing countries. Currently a new leaf fall disease is emerging in many rubber growing countries. This disease has devastated many popular clones in many rubber growing countries causing concerns among the rubber growers.

2. SOUTH AMERICAN LEAF BLIGHT

South American Leaf Blight of *Hevea* rubber is identified as one of the world's five most threatening plant diseases and it is still endemic to the Central and South American regions. The disease extends from Southern Mexico (18° latitude North) to the state of Sao Paulo in Brazil (24° latitude South) covering Brazil, Bolivia, Colombia, Peru, Venezuela, Guyana, Surinam, Trinidad and Tobago, French Guiana, Haiti, Panama, Costa Rica, Nicaragua, Salvador, Honduras, Guatemala, Belize and Mexico.

The causative agent *Microcyclus ulei* (P. Henn.) Von Arx. is an obligatory parasitic fungus which affects only the genus *Hevea*. The fungus produces sexual

and asexual stages both on the same rubber leaf. Three types of spores namely conidia, pycnidiospores (Plate 12.1a) and ascospores are produced and conidia and ascospores are responsible for disease dissemination. Conidia are produced in large numbers (Plate 12.1b) and they are the most important propagules responsible for the spread of the disease. With regard to survival, ascospores (Plate 12.1c) play a significant role as they are protected from desiccation by a thick wall of the spore-producing organ (ascocarp).

2.1 Symptoms

Immature leaves are the most susceptible to SALB and the leaves become more resistant and finally immune as they mature. The type of symptom produced on the leaves is greatly influenced by the age of the leaves at the time of infection, the susceptibility of the clone and the prevailing weather conditions.

Severe infection on copper brown leaves during wet weather will cause the leaves to shrivel, turn black and fall, leaving the petiole intact (Plate 12.1d).

When infection is mild or infection occurs on relatively mature leaves or less susceptible clones, the leaflets will not drop immediately. On these leaflets characteristic dull velvety lesions which are olive to grayish green in colour are developed mostly on the lower surface (Plate 12.1e). The lesions are covered with masses of conidia. If leaves remain intact, after several weeks, small spherical black structures (pycnidia) are formed on the upper leaf surface of the disease lesions (Plate 12.1f). Subsequently, (about a month later) more prominent raised bodies called perithecia are formed. The perithecia produce ascospores. Finally, the leaf tissues at the centre of the lesions turn papery white as they die and eventually tear off leaving holes surrounded by black spherical perithecia (Plate 12.1g). *M. ulei* also infects other tissues of the rubber plants such as the petioles, shoots, stems, flowers and young fruits. When shoot tips are infected, eventually they will cause shoot die-back.

3. TARGET LEAF SPOT

Target leaf spot is considered as the leaf disease next in importance to South American Leaf Blight in rubber growing areas in the Amazon region. Though the occurrence of the disease has been reported from several Asian and African countries like Thailand, Sri Lanka, Papua New Guinea and Ivory Coast the disease is still confined to nursery plants.

Cause: Thanatephorus cucumeris

3.1 Symptoms

Young leaves are the most susceptible. The first visible symptom is small translucent circular spots of about 2-10 mm diameter on the abaxial leaf surface normally with drops of latex. Later, mycelia appear on the leaf surface giving a purplish appearance. The most conspicuous symptom in nursery plants is the appearance of a network of silvery mycelium on the affected leaves, petioles and stems.

Important diseases of H. brasiliensis uncommon or absent in Sri Lanka

4. FUSICOCCUM LEAF BLIGHT

This disease was first detected on *Hevea* in 1987, in Malaysia. During the year 2020, this disease was reported from Sri Lanka for the first time. The disease was reported from Padiyathalawa, Ampara district in a bud wood nursery. Research projects are in progress to establish the pathogenicity of the fungal isolate.

Cause: Fusicoccum sp.

4.1 Symptoms

The lesions resemble those of rubber anthracnose disease, but the affected portions are more extensive with target - like concentric zones. Lesions are prominent on upper surfaces of fully expanded leaves. Affected leaves gradually turn bronze prior to abscission.

5. PHYTOPHTHORA LEAF WITHER

Unknown to Sri Lanka but causes a significant yield loss in Brazil.

Cause: Phytophthora capsici

5.1 Symptoms

Green shoots are the most susceptible parts rather than the leaves. Young leaves wither and remain attached to the dead or dying shoot tip, although the leaves themselves are not attacked. Both young and mature plants are affected and dried leaves could be seen hanging downward on mature trees during epidemics.

6. TAR SPOT DISEASE

Not reported in Sri Lanka. Presently it is restricted to South American countries such as Brazil, Bolivia, Peru and Guiana.

Cause: Phyllachora huberi

6.1 Symptoms

Though the young leaves are susceptible, symptoms appear only in mature leaflets. The first symptom is the development of chlorotic lesions on the abaxial surface. Later brilliant brown masses of stromata could be seen forming a circle around green leaf tissue with a single fungal stroma or black spot at the centre. Defoliation of the affected leaves occurs during wet weather.

7. PUBLIC VIGILANCE

Anyone suspecting the presence of a new disease on *Hevea* should inform the Rubber Research Institute immediately as it is hard to predict the extent of the damage which a new disease can cause.

A few samples showing the suspected symptoms should be sent wrapped in newspaper together with a description of the symptoms and a route map to the affected area other details such as clone, age, cropping system and the details of the person to be contacted (Specially the telephone number).

Due to the serious nature of South American Leaf Blight, no suspected material should be sent to the RRI under any circumstances. It would be more appropriate first to report the photographs of the suspected disease samples. Contact the RRISL for advice and then with our directions only the samples should be sent to RRI as given below.

Thoroughly moisten a newspaper strip with a disinfecting solution (*e.g.* 10% solution of formalin) and then roll the leaves up in it carefully. Place the roll in a bottle/tin and press the lid on tightly.

The disinfection and packing should be carried out on the site of the suspected infection, so as to avoid spreading the disease to other areas. Parcel the container and dispatch it to the RRI, marked "Suspected SALB".

Important diseases of H. brasiliensis uncommon or absent in Sri Lanka

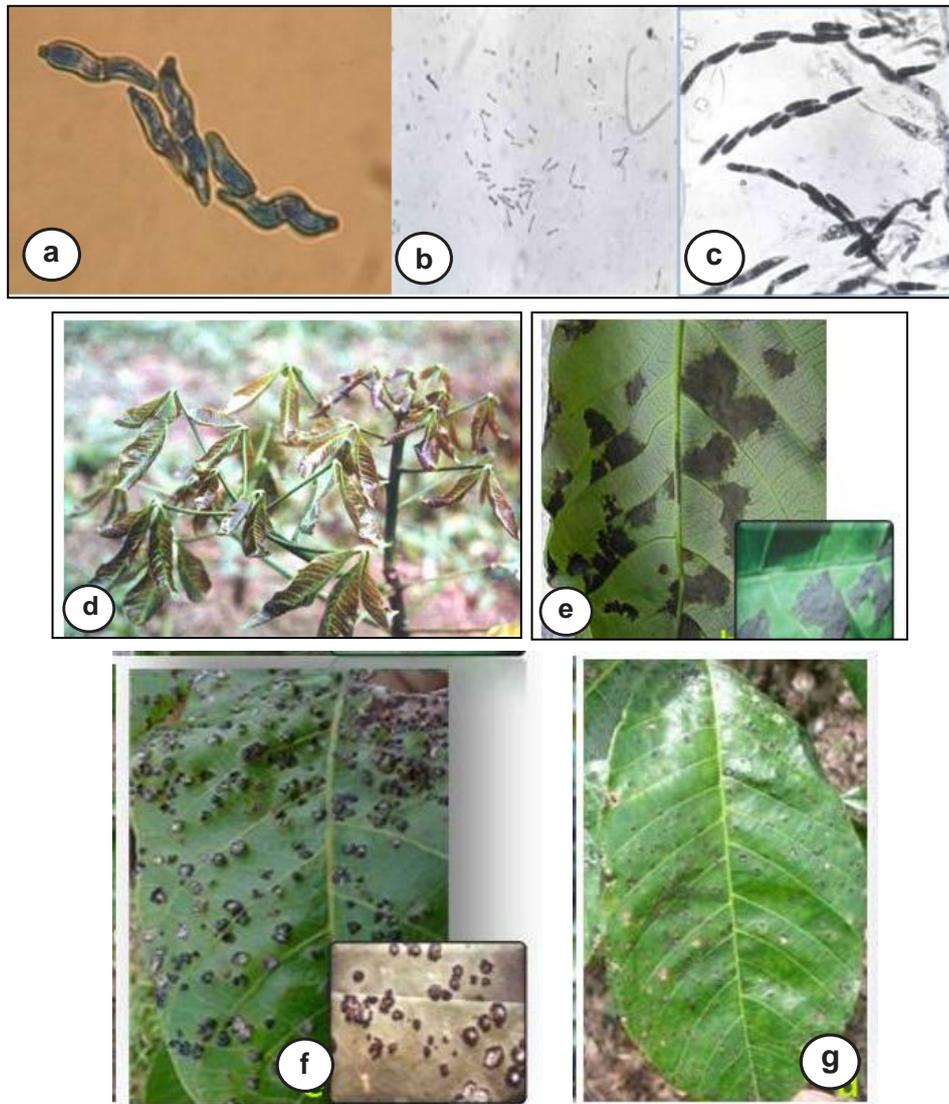


Plate 12.1. Three types of spores namely conidia; **a.** pycnidiospores and ascospores are produced and conidia and ascospores are responsible for disease dissemination; **b.** Conidia are produced in large numbers and they are the most important propagules responsible for the spread of the disease. **c.** With regard to survival, ascospores; **d.** Severe infection on copper brown leaves during wet weather will cause the leaves to shrivel, turn black and fall, leaving the petiole intact; **e.** olive to grayish green in colour are developed mostly on the lower surface; **f.** black structures (pycnidia) are formed on the upper leaf surface at the fringes of the disease lesions; **g.** the leaf tissues at the centre of the lesions turn papery white as they die and eventually tear off leaving holes surrounded by black spherical perithecia.

Chapter 13

Disorders of non-parasitic origin

T.H.P.S. Fernando

1. Introduction
2. Fasciation
 - 2.1 Treatment
3. Kinked stem
 - 3.1 Treatment
4. Elongated leaves
5. Nodules and galls
6. Panel burrs and fissures
 - 6.1 Treatment
7. Physiologic yellows
 - 7.1 Treatment
8. Genetic yellow
9. Tapping panel dryness (Brown bast)

1. INTRODUCTION

Various malformations occur in the actively growing parts of rubber plants.

2. FASCIATION

The terminal bud becomes distorted by uneven growth into a ribbon-like striated flattened band which may be curved or divided into many abnormal forms (Plate 13.1a). These show several growing points with aborted leaves and shoots. If left alone, a fasciated shoot becomes woody and normal branches overtake its growth. Any occurrence of fasciation has several possible causes, including hormonal, genetic, bacterial, fungal, viral and environmental causes.

These fasciated shoots are frequently inhabited by mealybugs and sometimes by mites. The physical damage they cause by sucking the juice from the tissues in the actively growing terminal buds is suspected to stimulate rapid proliferation of the tissues. Further, it has been observed that the mechanical damage caused to the apical bud by the feeding habit of slugs and some beetles also can stimulate the rapid proliferation of tissues resulting in various forms of fasciation.

2.1 Treatment

Fasciated shoots should be pruned at least 30 cm below the fasciated portion. If an insect infestation is observed controlling of it should be carried out.

3. KINKED STEM

Kinking of stem is a condition mainly found in nursery plants. The kinking of stems can range from bends to a complete loop at about 80 to 100 cm from the ground in young buddings (Plate 13.1b). The plants remain healthy, but with a

concentration of leaf bases in the distorted portion. This usually happens when seeds are planted vertically with the micropyle uppermost instead of placing the seed horizontally with the flat side downwards.

3.1 Treatment

Plants with more than a single kink should be removed from the nurseries.

4. ELONGATED LEAVES

Abnormally elongated leaflets have wavy margins, somewhat resembling those that have been attacked by mites. Sometimes these symptoms are formed with the exposure of the plant leaves to a weedicide drift. However, the leaflets are symmetrical, healthy and green, free of any other disease (Plate 13.1c).

5. NODULES AND GALLS

Nodules are small swellings or protuberances developing in the cortex of untapped bark. Galls are unusually large protuberances or large uniform swellings on one side of the tree.

Nodules and galls arise from abnormal meristematic activity resulting in formation of excessive amounts of wood. There has been no evidence of involvement of any pathogens like bacteria or viruses. Sometimes the bark over the nodules and galls develops cracks or fissures which are prone to secondary infections caused by fungi. This abnormal meristematic activity of the stem leading to galls is probably triggered by enhanced production of growth substances due to some unknown physiological stress or due to some external injury to the cambium, such as in deep tapping. Nodules generally develop around leaf scars and dormant buds, and result from irritation caused by their suppression. The production of nodules after the occurrence of tapping panel dryness (brown bast) is also common and should be regarded as a secondary effect of this condition.

The nodules and galls should be cut away neatly with a pen knife in their early stages of development and the resulting wound should be treated with a protective fungicide and covered with a waterproof panel dressing.

6. PANEL BURRS AND FISSURES

Burrs and protuberances of varying sizes and shapes occur on the tapping panel. The commonest causes are deep tapping and inserting the spouts too deep. Some clones are highly sensitive to wounding. If infection caused by bark rot is neglected, fissures develop in the cortex of the renewed bark. In some *Hevea* clones like RRIC 133 characteristically shows the stem knots. During the wet periods these knots are sometimes get infected by pathogenic micro-organisms. Both conditions make tapping difficult or impossible on the renewed bark. Panel fissures are also seen in the upper portion of the stem, running longitudinally along its length. These may arise from wounds caused by the action of strong winds and sometimes give a fluted appearance to the stem.

6.1 Treatment

Panel burrs can be prevented by careful tapping and avoiding damage to the cambium. Prompt attention to panel diseases will also reduce the development of panel burrs. Large burrs should be removed so as to leave a smooth cut followed by treatment with a fungicidal wound dressing.

7. PHYSIOLOGIC YELLOWS

Yellowing of leaves on lower branches followed by leaf fall is a feature of common occurrence in clearings with heavy canopies. Physiological yellowing is generally confined to the leaves on the lower branches. The affected leaves initially show a uniform yellow colour, which changes to brown, before leaf fall. Lack of sunlight as a result of the heavy canopy is the chief cause of this condition.

7.1 Treatment

Control measures are not warranted. The loss of a few leaves which are unproductive due to lack of sunlight is of no consequence and in fact it may be beneficial for the trees.

8. GENETIC YELLOW

A certain proportion of seedlings in a nursery usually exhibit yellowing of leaves, which is a genetic character. Sometimes, a mottling of leaves also can be seen. These plants should be destroyed in the seedling stage (Plate 13.1d).

9. TAPPING PANEL DRYNESS (BROWN BAST)

This is a serious condition of the tapping panel, affecting several high-yielding clones. The cause of this condition is not fully understood yet, but it is believed to be a physiological response of the tree to over-exploitation. For details please refer to Chapter 16.



Plate 13.1. Disorders of non – parasitic origin. **a.** Fasciation; **b.** Kinked stem; **c.** Elongated leaves; **d.** Genetic yellow.

Chapter 14

Rubber-based intercropping systems

T.U.K. Silva

1. Introduction
2. Importance of rubber-based intercrops for greener economy
3. Present status and possibilities of rubber-based intercropping in Sri Lanka
4. Factors to be considered in intercropping
5. Crops suitable for intercropping at the immature phase of rubber
 - 5.1 Banana
 - 5.2 Pineapple
 - 5.3 Passion fruit
 - 5.4 Sugarcane
 - 5.5 Annual and seasonal crops
 - 5.6 Some other suitable crops
6. Crops suitable for intercropping only at the mature phase of rubber
 - 6.1 Cardamom
 - 6.2 Vanilla
 - 6.3 Rattan
7. Intercropping throughout the life-cycle of rubber
 - 7.1 Crops to be grown without compromising on the rubber density
 - 7.1.1 Coffee
 - 7.1.2 Cocoa
 - 7.2 Crops that can be grown if the planting density of rubber is reduced
 - 7.2.1 Tea
 - 7.2.2 Cinnamon
 - 7.2.3 Pepper
 - 7.2.4 Other suitable crops
8. Other intercropping systems
 - 8.1 Crops to be grown along the boundary of rubber
 - 8.1.1 Timber species
 - 8.1.2 Cinnamon
 - 8.1.3 Messengiana
 - 8.2 Crops that can be grown as alternatives for rubber in specific places
9. Incorporation of animal husbandry with the rubber crop

1. INTRODUCTION

Growing two or more crops simultaneously without distinct row arrangement is called “mixed farming.” Contrary to this, cultivation of two or more crops simultaneously in the same field with distinct row arrangement is known as “intercropping.” Crop intensification by means of intercropping has advantages in both time and space dimensions during all or part of crop growth. Intercropping is a historical way of increasing total yield per unit area and time even for rubber, especially for smallholding farmers. With proper intercropping systems, component crops use resources effectively and efficiently than mono-cropping systems

preventing exhaust of natural resources. However, the competition for resources is a main factor which could result in a significant impact on yield of crop mixtures compared to pure stands. Therefore, in intercropping the overall impact should be taken in to the consideration.

At the beginning of rubber plantations in Sri Lanka, rubber was interplanted with tea and cocoa on large estates. By 1905, there were 7,256 acres of rubber/tea intercrop. In the areas where agro climatic conditions were conducive to good growth and latex yields, rubber was continued as a sole crop. Intercropping of rubber once more became popular in the 1940s when the Second World War resulted in food shortages and plantations were interplanted with crops such as maize and cowpea. The rubber subsidy scheme introduced to Sri Lanka in 1953 actively discouraged the interplanting of rubber with crops other than cover crops for soil conservation. Whilst a few experimental trials on rubber/cocoa intercropping were established in the 1960s, it was not until the 1970s that interest in rubber intercropping research resurfaced. A few tentative recommendations for intercropping with crops such as banana, pineapple, passion fruit, coffee and cocoa were made in 1979 and demonstration/observation plots were established during the 1980s. However, it was not until the last decade of the 20th century that intercropping research was fully revitalized at the Rubber Research Institute of Sri Lanka (RRISL) with the overall aim of improving productivity and income generation of smallholder rubber lands. As a result, possible combinations of different spatial arrangements of rubber with suitable component crops were introduced to the industry.

The drastic socio-economical changes have been attributed to the implementation levels of intercropping. Due to the increasing demand for the raw materials locally, government has decided to expand the rubber cultivation to the (non-traditional areas) Intermediate Zone of the country. The growth rate and canopy architecture of rubber grown in nontraditional areas are different from those grown in other areas. Therefore, the light availability and competition to the intercrops subsequently differ from those in traditional areas. Hence, the screening of possible crops with modified spatial arrangements of rubber under suboptimal conditions will be the future goals in rubber intercropping.

2. BENIFITS OF INTERCROPPING

The long lag period between planting and beginning of tapping (*ca.* 6 yr) poses a significant problem to most growers. Whilst large-scale planters are able to cope with the problem by adopting an annual replanting cycle, this option is not available to smallholders due to the limited land available. In addition to the lack of income, land tends to be underutilized in immature rubber plantations because wide plant spacings are used in order to meet the growth requirements of the mature tree. Intercropping offers a practical means of raising not only land use efficiency but also income during the immature phase of the rubber plantation, which is particularly important in the case of resource-poor smallholders.

When crops are grown together then competition may occur for available resources with the result that productivity of the intercrop components may be

affected compared with the respective sole crop. Research and on-farm trials in Sri Lanka and elsewhere have shown that intercropping has no detrimental effect on growth of rubber, in fact it often improved relative to the sole crop. Evidence suggests two possible reasons for this increase in growth, firstly partial shading is beneficial to the growth of young rubber trees by reducing radiation stress and secondly, the early returns from intercropping encourages farmers to adopt agronomic practices more often. The comparative increase in growth of rubber when intercropped presents several advantages to rubber growers; (i) it reduces the immature, unproductive period of the rubber plantation, (ii) increases yield return due to improved growth of rubber, (iii) associated increase in timber volume and (iv) in the smallholder sector resource-poor farmers may secure subsidy payments as a result of improved rubber growth.

Even in mature rubber, harvesting/tapping is not continuous due to interference by rain. Whilst rainguards offer one solution to this problem, intercropping with other crops whose harvest is not so greatly affected by rains (for example, tea) offers another by compensating for the loss of income from rubber on wet days.

Combinations of crops which differ in canopy and root architecture enable more efficient capture and use of growth resources. For instance, deep-rooted crops may act as a nutrient pump by capturing nutrients deep in the soil profile and making them available to more shallow-rooted crops through litter fall. Furthermore, the dense canopy cover typical of most intercropping systems acts as a boundary layer for evaporation reducing water loss at the soil surface and radiation stress on understorey crops.

Land availability in traditional rubber growing areas is diminishing with population pressure and hence new areas are being targeted for planting of rubber. In order to make this effort successful, intercropping with local crops is essential; otherwise farmers will not be willing to accept the long income gap from planting to harvest of rubber and the unknown risks involved. Also, where land is marginal or unproductive for other crops, intercropping with rubber offers a means of raising productivity and hence income.

3. PRACTICALITY IN ADOPTING RUBBER-BASED INTERCROPPING IN SRI LANKA

The fluctuation of natural rubber prices and the increasing trend of cost of production highlight the importance of intercropping to balance the cash flow of the rubber estates. In general, the decision making and implementation on crop diversification will be taken by the same person in the smallholdings whilst different approach can be seen in the Regional Plantation Companies. Due to some procedural barriers, security problems and lack of knowledge more planters reluctant to adopt intercropping. Security, pest and disease problems and lack of knowledge are perceived by smallholders as the major problems associated with intercropping. Also, shade imposed by rubber as it matures limits the potential for intercropping.

At the subsistence level, farmers tend to intercrop on their lands using locally available inputs. For instance, the use of family labour for farm activities is very common, but to use good quality planting materials or apply fertilizer to their crops. However, under commercial cultivation, cultivators try to maximize the profit with more inputs such as fertilizer, pesticides and irrigation. Although landowners do their own cultivation with or without hired labour, some lease out their immature rubber lands for *ca.* 5 years for intercropping (*i.e.* contract farming). The levier is responsible for upkeep of the rubber and any labour inputs. In return, they obtain the income from other crops such as banana, pineapple and brinjal which are intercropped on the young rubber land. In general, these contract farmers are well-organized and affluent are looking for extra land for commercial cultivation, but in the case of rubber/banana intercropping landless or land-poor contract farmers can also be found due to the low demand for inputs in this cropping system.

The estate sector labour force is generally under-utilized with poor wages and working hours which are in practice are often limited to morning only. The relatively low profit made on large rubber plantations does not allow for increased wages; however, if immature rubber clearings are given to estate workers on a lease basis for intercropping as done on smallholdings with contract farming as explained before or on an income-sharing basis, it will provide extra income for these underprivileged workers while reducing the cost of upkeep of the immature plantations and/or increasing profit to the estate management.

In non-traditional areas for rubber intercropping under plays significant role in generating income during gestation period of the rubber. It improves land use efficiency, maximizes the utilization of resources and develops micro-climatic conditions with enhanced bio diversity. The additionality in fixing CO₂ leads to mitigate the climate change effects.

4. FACTORS TO BE CONSIDERED IN INTERCROPPING

Crops should be selected mainly based on the recommendation made by the RRISL. The recommendations are basically introduced for the growers after considering of both biophysical factors and socioeconomic conditions. The biophysical factors relate to the agronomic feasibility of growing a certain crop given the soil and climatic conditions of a particular location (*i.e.* soil depth, structure and texture, soil pH, nutrient availability, rainfall, erosion, relative humidity, wind and elevation/temperature) and crop-related factors (*i.e.* root and canopy architecture, susceptibility/tolerance to pests and diseases, demand for nutrients, light requirement, allelopathy and life cycle). Important socioeconomic factors comprise demand for produce, marketing/price, capital and maintenance cost, availability of subsidies and loan schemes, security, labour availability and its requirement, availability of planting materials and other inputs such as local knowledge and skill.

The general tendency is to select a marketable or subsistence crop for intercropping with rubber; however, care must be taken to check whether both crops are susceptible to the same diseases since it may increase the possibility of spread of such diseases. It is very important to take the control or prophylactic for white

root disease prior to implement rubber intercropping as mixed cropping system will aggravate the situation further. Also, crops that are highly demanding in terms of labour inputs are not suitable as labour availability in most rubber growing areas is becoming increasingly limited.

Wider alleys between the rubber rows are always preferred if a second crop is to be grown as they allow for sufficient transmission of solar radiation in the long run. Planting of rubber can be done in an East - West direction, only if the land is more or less flat so that sufficient light is available to the understory crop throughout the course of the day. However, most rubber is grown on sloping land and in order to minimize soil erosion, contour planting must be practiced. In addition, some crops such as timber species, cinnamon, areca and rattan etc. can be grown along the fencing area (boundary) as they are obviously exposed to additional resources such as light due to extended gap to next crop without compromising the stand per hectare of rubber. Some timber species and areca can be used for the infilling purposes in the vacant places creating after initial 3 years of the immature period instead of rubber.

5. CROPS SUITABLE FOR INTERCROPPING AT THE IMMATURE PHASE OF RUBBER

Most sun-loving crops are considered as suitable, if they can produce a yield before the canopy closure of rubber, *i.e.* within the first 4 years. Rubber is spaced at 2.4 x 7.75 m (*i.e.* 8' x 26') leaving a minimum gap of *ca.* 2-2.5 m for rubber in biannual and perennial intercropping. However, for seasonal and annual crops, a shorter gap can be used depending on the growth stage of the rubber trees. The most common crops grown during the immature phase of rubber are banana, pineapple, passion fruit, sugarcane and different kinds of vegetables.

5.1 Banana

Banana appears to be the most popular rubber-based intercrop in most parts of Sri Lanka due to the ready local market, less inputs and familiarity of farmers with the growth requirements. This is a crop for poor smallholder farmers and market studies show that expansion of the rubber/banana intercrop would not affect the price of banana in the market. It can be grown successfully during the first 3-4 years of the rubber crop and requires well-drained soils with a pH *ca.* 7 and this crop cannot withstand strong winds. Banana appears to be less competitive with rubber and evidence suggests that the microclimate of the rubber/ banana intercrop promotes better growth of rubber and less disease spread (*e.g.* Panama) in the banana crop.

Varieties:

- ◆ Embul - commonly grown variety, but local market prices are not attractive.
- ◆ Kolikuttu - superior quality but highly susceptible to diseases such as Bunchytop and Panama. Although this is not recommended for the wet zone

of the country, prevailing high market prices for the produce attracts farmers to this variety.

- ◆ Anamalu - more suitable for wetter areas
- ◆ Ambun - prefers wet climates
- ◆ Alukehel - prefers drier climates

In addition, some dwarf/tissue cultured varieties recommended by the Department of Agriculture can also be used.

Cultural practices:

Recent studies have shown that immature rubber plantations can tolerate high planting densities of banana with no detrimental effect on growth of either crop. It is possible to incorporate up to three banana rows between the rubber rows, particularly when using varieties with narrow canopies such as Kolikuttu (Plate 14.1a & b). Within the row, spacing varies from 2.4 m to 3.6 m, again depending on the variety of banana. This spacing is based on that used in sole crops, as recommended by the Department of Agriculture. For instance, the variety Kolikuttu requires only 2.4 m, whilst Anamalu and Ambun are planted at a wider spacing of 3.6 m. In general, all other varieties including Embul are planted at 3 m. An intensive method, *i.e.*, 3.0m distance in between two adjacent banana plants, was recently introduced with single tree (without bush) system by the same department. It is also possible to incorporate more plants/ha. In order to get maximum yield from banana before the shade given by the rubber canopy. Planting holes of dimensions 60 x 60 x 60 cm and filled with organic manure and topsoil are used for banana. For acidic soils, it may be necessary to apply 600 g of Dolomite.

It is important to ensure that good quality planting material is obtained in order to minimize the risk of banana diseases since the most common banana diseases (*e.g.* Bunchy top, Panama wilt) cannot be treated once infected. Clumps are to be maintained with three plants, *i.e.* mother plant with two suckers of different sizes. Fertilizer application and other management practices should be done as per the recommendations of the Department of Agriculture.

5.2 Pineapple

Pineapple is considered to be highly profitable, but it requires high labour and capital inputs. It has a ready local and international market. The crop requires clean weeding and so is only grown on flat or gently undulating land. Sandy loam and lateritic soils with pH 5.5-6 are ideal for the growth of pineapple.

Varieties:

- ◆ Mauritius - very popular as a fresh fruit
- ◆ Kew - specially used for canning

Cultural practices:

Three paired rows of pineapple with a gap of 1.25 m in between, can be planted between the rubber rows (Plate 14.1c). Within the paired rows, suckers are

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spaced 30-45 cm within and 60 cm between rows. For initial land preparation, ploughing can be done on flat and slightly undulating land but 20 cm deep and 20 cm wide ditches must be prepared sloped lands for planting of the pineapple rows.

After the first harvest, additional suckers are to be removed leaving two per plant at the base. All other agro management activities are to be done as per the recommendations of the Department of Agriculture.

5.3 Passion fruit

Passion fruit grows well across a range of climatic conditions, but if grown in the intermediate/dry zone it requires irrigation during the dry spells. Soil should be well drained with a pH of 6.0-7.5. The market price of passion fruit fluctuates drastically in Sri Lanka; hence it is advisable to establish a forward selling contract with canning factories, if planning to go for large-scale cultivation.

Varieties:

Two types are recommended by the Department of Agriculture for the low country where rubber is grown. The traditional yellow fruit type is suitable for both wet and dry areas, whilst variety 'Maani', another yellow type, is only for wet areas.

Cultural practices:

Planting holes of dimensions 60 x 60 x 60 cm should be used and filled with organic manure *ca.* 2 weeks before planting. One to two rows of passion fruit can be planted in between the rubber rows (Plate 14.1c). Within the row, planting is done 4.5 m apart and in the case of two rows a 2 m gap should be left between rows.

Strong support with post and string (galvanized wires) should be provided at *ca.* 2 m height for the growth of the vine. Only two branches are trained on either side of the plant along the string up to *ca.* 2 m and then, secondary branches which produce fruits, should be promoted to grow down by removing tendrils.

5.4 Sugarcane

This is a crop for drier areas, and particularly the Monaragala district where a good market exists. It is evident that sugarcane alleviates radiation and heat stress on the rubber plant at a very early stage resulting in improved rate of establishment. All clones recommended by the Sugarcane Research Institute are compatible with rubber.

Four to five rows of sugarcane with a 1.2 m inter-row distance can be planted between rubber rows (Plate 14.1d).

5.5 Annual and seasonal crops

In general, all crop types are compatible with rubber during the early stages of the immature phase. Therefore, crops should be identified considering the suitability of soil and other climatic factors and the market. In most cases, irrigation is required to obtain improved yields. Otherwise, proper planning in accordance

with the weather pattern is essential. Even with limited space, cultivation of some of these crops is viable and they can be grown with other rubber-based intercrops. For instance, in the Intermediate Zone of the country seasonal crops such as cowpea, millet, maize (Plate 14.1 e & f), brinjals and upland paddy are grown in combination with rubber/banana intercrops. Rubber/banana/brinjal intercrops are also popular in the wet areas of the country. Interchanging crops between wet and drier areas is not always possible due to the reasons associated with specific climatic needs. For example, pulses such as cowpea are not successful in wet areas due to fungal attacks on the fruit.

During the first year of the rubber crop, a gap of 1.2 m between rubber and these crops is sufficient and then in subsequent years, this gap should be increased by *ca.* 0.6 m to cope with canopy and root development of the rubber crop.

5.6 Some other suitable crops

Citronella is a commercial crop grown widely in the southern region of Sri Lanka and has been grown successfully with rubber during the immature phase. However, in practice, citronella has been grown in this area as a sole crop for a long time and productivity has declined drastically mainly due to poor application of fertilizer. As a consequence, rubber is interplanted with the objective of diversifying income away from a sole dependence on citronella. Cultivation of economically important medicinal plants is also in the interest of farmers. As explained before, in all sorts of these cropping systems, as a rule of thumb, it is advisable to leave a gap of *ca.* 1.2 m for rubber.

6. CROPS SUITABLE FOR INTERCROPPING ONLY AT THE MATURE PHASE OF RUBBER

The mature rubber crop produces a very dense shade as well as an extensive root network in the inter-row space. This means that two important factors must be taken into consideration when selecting crops suitable for intercropping during the mature phase of rubber: firstly, the crop should be shade-tolerant and secondly, should be able to withstand competition with the dense root network of rubber for below-ground resources. Examples of suitable crops are cardamom, rattan and vanilla.

6.1 Cardamom

This is a unique spice, known as the 'Queen of Spices' in Sri Lanka. Although its cultivation was initially confined to the high altitudes with low temperature, some suitable varieties for low altitudes have been selected after screening, particularly under mature rubber. Varieties identified so far for rubber growing areas are EC1/100, EC1/101, EC1/102 and EC2/400MT, available at the Department of Export Agriculture. Soils should be rich in organic matter and well drained, but not sufficiently to promote water stress.

If rubber is spaced at 2.4 x 7.75 m, two or three rows of cardamom can be planted between the rubber rows. Spacing for cardamom is 2.4 m within and 1.8 m

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between rows in the case of 3 rows and *vice versa* for two rows. Even for rubber planted at a narrow spacing (*i.e.* 3.6 x 5.4 m), a single row of cardamom can be established 2 m apart. Planting holes of dimensions 40 x 40 x 40 cm should be used and filled with organic manure and topsoil. Manuring and general maintenance are as per the recommendations of the Department of Export Agriculture.

6.2 Vanilla

This appears to be a suitable crop under mature rubber, if the soil is well drained, loamy and rich in organic matter. Although experimental evidence is lacking, a few small-scale observation plots made by the RRISL and elsewhere support this view. Flowering may commence after three years of planting and it takes *ca.* 7-8 years to obtain the maximum yields.

Plants are vegetatively propagated through cuttings (usually *ca.* 1 m in length) which should be obtained from selected mother plants with desired characters, such as regular and consistent annual bearing, fast growth, free from pests and diseases and sturdy stem with thick large fleshy leaves. Supporting materials such as wooden posts should be established at a distance of 1.5 m as a single row or in two rows 1.5 x 3 m, if possible. Planting pits (60 cm diameter and 20 cm deep) should be prepared close to the supports and filled with 2-3 buckets of organic manure thoroughly mixed with soil.

Full guidance on vanilla cultivation is available at the Department of Export Agriculture.

6.3 Rattan

Although the effect of rattan on the growth and yield of rubber has not yet been fully evaluated, observations here in Sri Lanka and elsewhere suggest that it is a suitable crop to be grown during the mature phase of rubber. All rattan species belong to the genus *Calamus* and for intercropping with rubber, species producing thicker cane (locally referred as Maveval), would be suitable (Plate 14.2a). As a matter of convenience, it would be better to harvest the rattan at the time of uprooting rubber trees and so leaving *ca.* 15 years for growth, planting of rattan can be done at 10-15 years after planting of rubber. Preliminary observations suggest that sufficient light is available and that other micro-climatic factors under the rubber canopy would not adversely affect the growth of rattan. Whilst the thorny canopy of rattan might cause problems when undertaking inter-cultivation activities of rubber. However, this is not the case with the thicker cane varieties as they do not climb up the trunk, but tend to intertwine with the branches of rubber higher up. Planting of a single row of rattan between rubber rows at a distance of *ca.* 3-4 m apart is found practically effective. In addition, rattan requires a minimal amount of inter-cultivation and so appears to be suitable for the reservations on rubber estates (*i.e.* areas subjected to very high erosion which are not planted with rubber).

6.4 Cut foliage and anthurium

Varying climatic regions within the island have good potential to produce

different floriculture products by fetching both local and international market. Mature rubber provides natural shade as well as better micro-climate for some potential varieties of cut foliage and anthurium. Performance of cane palm, dracaena and chinese grass have been identified to grow under mature stage of rubber (Plate 14.2b, c, d and e). With special supervision, anthurium can also be grown in the pots under the mature rubber plantation (Plate 14.2f). However, it is advisable to establish a forward selling contract if planning to grow such crops with rubber.

7. INTERCROPPING THROUGHOUT THE LIFE-CYCLE OF RUBBER

Long-term perennial crops can be planted together with the rubber crop. However, since light penetration through the mature rubber canopy is very poor, selection must be based on shade tolerance. Should one wish to plant economically attractive sun-loving crops, then the planting density of rubber needs to be compromised in order to provide adequate solar radiation for the second crop (*e.g.* tea, cinnamon). For some shade-tolerant crops, such a reduction in shading may result in improved yields (*e.g.* cocoa, pepper). However, for good establishment, temporary shading will need to be provided at planting for these shade crops. The option of delaying planting until sufficient shade is available from the rubber canopy is not practicable as the second crop is unlikely to be able to withstand root competition from the more mature rubber crop during its establishment phase.

7.1 Crops to be grown without compromising on the rubber density

Where rubber is planted at a spacing of 2.4 x 7.75 m (8' x 26').

7.1.1 Coffee

Three economically important species are available and suited to different climatic regimes. In general, coffee thrives well in soils of pH 6.5, therefore suits for rubber growing soils.

Coffea arabica (Arabica coffee): Well suited to cooler climates and hence higher altitudes. However, it is commonly grown under widely varying conditions of elevations where rubber is cultivated. This species fetches a premium price due to its superior quality.

Coffea canephora (Robusta coffee): Thrives well at low altitudes with warm and humid conditions. Extensively used in instant coffee.

Coffea liberica: Tolerates warm and wet conditions and thrives in different soil types such as clay and peat. Fruits are large and hard, hence processing costs are high. Since the produce has a bitter taste, it is preferred in certain countries like Malaysia and Middle East.

Cultural practices:

Although propagation can be done by seeds, cuttings or bud grafting, use

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of seeds appears to be cheapest. One or two rows of coffee can be planted between the rubber rows and spaced 2.5 m between and within rows, with a single stem pruning. Improved yields can be obtained with the two stems training system for which planting needs to be done with a spacing of 3 x 3 m (10' x 10'), according to the Department of Export Agriculture, Sri Lanka (DEA). The initial shade required by the coffee during the immature phase of rubber could be provided economically by combining this system with a rubber/banana intercrop.

7.1.2 Cocoa

Cocoa is suitable for comparatively drier areas of rubber due to disease problems, although high humidity is required during flowering in order to enhance pollination. The best soils are well drained clay loams rich in organic matter with a pH ranging from 6.0 to 6.5. Cocoa grows well below 600 m altitude with evenly distributed annual rainfall of *ca.* 1650-2750 mm and temperatures of 24-27 °C. Based on the agro-economical sustainability for both crops, Moneragala, Matale, Kurunegala, Kegalle and Badulla districts are the possible districts for large scale cultivation of cocoa under rubber. Cocoa can be processed easily under small holder condition without involving high cost. Therefore, this system is more compatible and sustainable farming model for the rural community in this area (Plate 14.3a & b).

Varieties:

Criollo - Creamy white beans with a very good flavour; but low productivity and susceptible to pests and diseases.

Forastero - Dark purple bean; highly productive and resistant to pests and diseases.

Trinitario - A hybrid of the above two varieties and so has moderate characteristics.

Cultural practices:

This can be established as a single row spaced at 3 m (within the row) between rubber rows. Poly-bagged plants raised either by seedlings or cuttings (NB. the former is more practicable) are used for propagation. The size of a planting hole is *ca.* 45 x 45 x 45 cm.

Plants should be maintained with one set of fan branches and additional water shoots must be removed. It has been noticed that heavy shade causes an increase in wilted fruits, a physiological disorder related to low photosynthetic productivity.

7.2 Crops that can be grown if the planting density of rubber is reduced

The ultimate objective of reducing the planting density of rubber when intercropping is to provide wider alleys between the rubber rows and so improved light transmission. Because of the greater heterogeneity of intercrop canopies, higher total crop densities and total productivity can be supported compared with monocrops. Moreover, all sorts of intercropping advantages, as explained earlier, can be achieved throughout the lifecycle of the rubber crop and with most

economically important crops, including those mentioned in the earlier section on 'Crops to be grown without compromising the rubber density'. Two systems, namely single and paired row systems of planting rubber have been proposed by the RRISL.

In the single row system, rubber is planted at a spacing of 2.4 m along rows as usual, but between row spacing is increased to 12 m, reducing the overall planting density by *ca.* 30%. In the case of paired row systems, rubber is planted either at 2.7 x 2.7 m or 3 x 3 m within the paired row and between paired-row spacing is adjusted to 18 m. The former system of paired rows provides a similar density of rubber as in the single row system, whilst the latter gives only 63% of the sole crop density. The paired row system with an 18 m alley is more advantageous over the single row system as far as light availability is concerned; however, intra-specific competition of rubber within the paired row may be greater, particularly at maturity.

Although yet to be tested, most of the economically important crops can be interplanted successfully with rubber using the paired row system. However, practical limitations exist when introducing this arrangement on small land areas typical of smallholdings, as the gap across the slope is not sufficient to establish contour paired rows.

7.2.1 Tea

The rubber/tea intercrop is well suited to the wetter regions where rubber is grown and it fits in well with the social aspects of the smallholder farming community. Under normal circumstances, rubber cannot be tapped very often during the rainy season and farmers can still obtain an income through tea harvests. Also for large estates, this intercrop secures more job opportunities for estate workers. Moreover, rubber/tea intercropping has proved to be economically sustainable under conditions where the market price of one of the component crops falls. The rubber crop also provides a shelter for tea during drought resulting in significantly less casualties when compared with sole tea.

When grown with the single row planting system of rubber (Plate 14.3c), *i.e.* 2.4 x 12 m, seven rows of tea may be interplanted between rubber rows at a spacing of 0.6 m within and 1.2 m between rows. However in the paired row system (Plate 14.3d), at the same spacing 12 rows can be incorporated leaving 2.4 m on each side for inter cultivation activities of rubber. In the former system, the stand of tea is *ca.* 70% of the sole crop density, whilst that of the paired row system is almost same (*i.e.* 69.5% and 68.5% for 2.7 x 2.7 m and 3 x 3 m paired spacing systems, respectively). Nevertheless, productivity of the tea crop begins to decline in the former single row planting system after *ca.* 6 years in growth; therefore the paired row system may be more advantageous.

Planting of tea requires preliminary soil reconditioning which takes *ca.* 1.5-2 years in marginal tea areas where the soil organic matter content is low. No clonal selection for either rubber or tea has so far been done and so clones can be selected on the basis of suitability for local agro climatic conditions. Planting holes are dug of the size 0.6 x 0.6 x 0.75 m and all other management practices for individual

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crops are done as per the recommendations of the RRISL and the Tea Research Institute of Sri Lanka (TRISL). The cover crop should be restricted to the area reserved for rubber. Moreover, medium level shade trees such as gliricidia should be raised and maintained until the rubber trees are mature enough to provide sufficient shade.

7.2.2 Cinnamon

This is another economically important crop (Plate 14.3e & f) that can be planted with rubber and can also be extended to drier regions and most soil types. No drastic price decline has been experienced in the recent past, which has helped to build up confidence amongst farmers. Nevertheless, a major problem encountered is the limited skilled labour available to peel the cinnamon. Evidence indicates that the bark becomes thin under the shade of mature rubber but elongated stems compensate for this weakness to some extent.

Intra- and inter-row spacing of cinnamon are 1.2 m and 0.9 m respectively, number of rows between the rubber, are virtually identical to that used for rubber/tea intercrops (see above). Planting and other cultural practices required for cinnamon are as recommended by the Department Export Agriculture.

7.2.3 Pepper

This is also a commercially important crop and the area under this crop is presently expanding. According to observations of intercropping with rubber at traditional spacings of 2.4 x 7.75 m, pepper does not produce well under the heavy shade of the mature rubber canopy in the traditional wet zone. Consequently, success of pepper/rubber intercrops will require a reduction in the planting density of rubber in those areas in order to allow sufficient light penetration to the understorey pepper crop. Considering the sole crop spacing, three and five rows of pepper spaced at 2.5 x 2.5 m may be planted successfully towards the centre of the alley of the single and paired row systems of rubber, respectively. However, the traditional spacing of rubber can probably be used in the intermediate zone like Moneragala District due to the slow canopy growth of rubber and high light availability for intercrop in those areas. If dead rather than live stems are used to support vines, then yield may be improved due to reduced crop competition and perhaps the density of pepper under rubber could also be increased by planting another row with 2 x 2 m spacing. As is the case for many other crops, temporary shades are essential for better establishment of pepper plants and all management conditions should be based on the recommendations of the Department of Export Agriculture.

7.2.4 Other suitable crops

As mentioned before, crops such as coffee and cocoa (*'Crops to be grown without compromising the rubber density'*), can also be grown to improve yields provided rubber is grown at a reduced density *i.e.* with either single or paired row systems. These crops may be planted in several rows within the alleys of rubber at

the spacings recommended for sole cropping leaving a sufficient gap for rubber. In the case of coffee, *ca.* 3 m gap is sufficient for rubber, whilst a minimum of 4 m is required for cocoa.

8. OTHER CROPPING SYSTEMS

Most intercropping systems mentioned, where the planting density of rubber is unchanged, are designed to improve the capture of resources (mainly light), which would otherwise not be fully utilized by the rubber crop. However, resource availability is not consistent throughout the rubber crop; for instance, a dead rubber plant may lead to underutilization of resources. Also, at the boundary of the rubber crop there may be more resources available if there is no other crop grown. Growing economically important other tree crops along the boundary and in place of dead rubber plants seems to offer a practical solution to utilize the otherwise “wasted” resource.

8.1. Crops to be grown along the boundary of rubber

On the boundaries, most timber crops could be raised at the time of planting of rubber and, in the case of tree crops grown along boundaries, other economically important vines, such as pepper, could be trained on them.

8.1.1 Timber species

Growing timber species such as alstonia, mahogany, jak are more popular among the growers (Plate 14.4a).

8.1.2 Cinnamon

Recent study reported that, cinnamon can successfully be grown along the boundary of rubber fields. Considering the long-term financial benefits of growing cinnamon and the land size of the smallholdings, this system is more adoptable even for them without compromising the stand per hectare of rubber. A single or paired row systems of cinnamon keeping 0.6m – 0.9m gap in between two cinnamon bushes can be planted along the boundary of rubber. Reasonable gap, *i.e.* 1.2m in between the cinnamon row and the adjacent rubber tree should be maintained at the establishment. The best way to do that is lining for rubber should be done first as usual and planting points for cinnamon should be marked secondly (Plate 14.4b).

8.1.3 Dracaena (Messengiana)

Messengiana is one of the popular foliage plants in Sri Lanka. There is high demand as a cut foliage and has the ability to grow well in most of the rubber growing areas.

8.2. Crops that can be grown as alternatives for rubber in specific places

In the case of replacing dead rubber plants, planting of timber crops which requires shade conditions for better establishment is advantageous (*e.g.* Mahogany – damage due to stem borer attack is reduced under shade). Arecanut which survives

well under high crop densities, is another potential tree crop for these purposes. Such highly intensified intercropping systems leading to greater efficiency of land utilization is common in the smallholder sector especially where the landowner is fully dependent on his/her limited land area. Under such conditions, some farmers have been capable of utilizing big rocks, which are generally a waste, by training pepper vines on to them and also, growing pineapple with a thin layer of soil and mulch. Most importantly, we have no evidence to support the idea that such intensified intercropping systems have a negative effect on the growth of rubber; instead, rubber growth is usually improved. Although it cannot be commonly seen in Sri Lanka, the wider alley available between rubber rows has been utilized for raising rubber nurseries and the cut flower industry elsewhere. Beekeeping is also another option available with rubber-based intercrops since different crops may provide a rather continuous food source for bees, otherwise they have to be fed with sugar solutions during off seasons of the rubber crop.

9. INCORPORATION OF ANIMAL HUSBANDRY WITH THE RUBBER CROP

If properly adopted, animal husbandry on rubber lands is another potential source for income generation. Only a few cases of this have so far been recorded in Sri Lanka, unlike in some other countries. Possible damage to rubber plants, abundance of leeches in most of rubber growing areas and other socio-cultural effects limit animal husbandry on traditional rubber lands in Sri Lanka. Nevertheless, the situation may differ from nontraditional areas in the country. Fencing on either side of rubber rows is practiced in some other countries in cattle/sheep farming to avoid any damage to the rubber. Stall feeding in cattle/goat/sheep farming is another option to overcome these. Though not specifically done with rubber, free-range poultry farming is widely practiced by rubber smallholder farmers. Raring poultry and ducks are more popular among the smallholders in Vietnam.

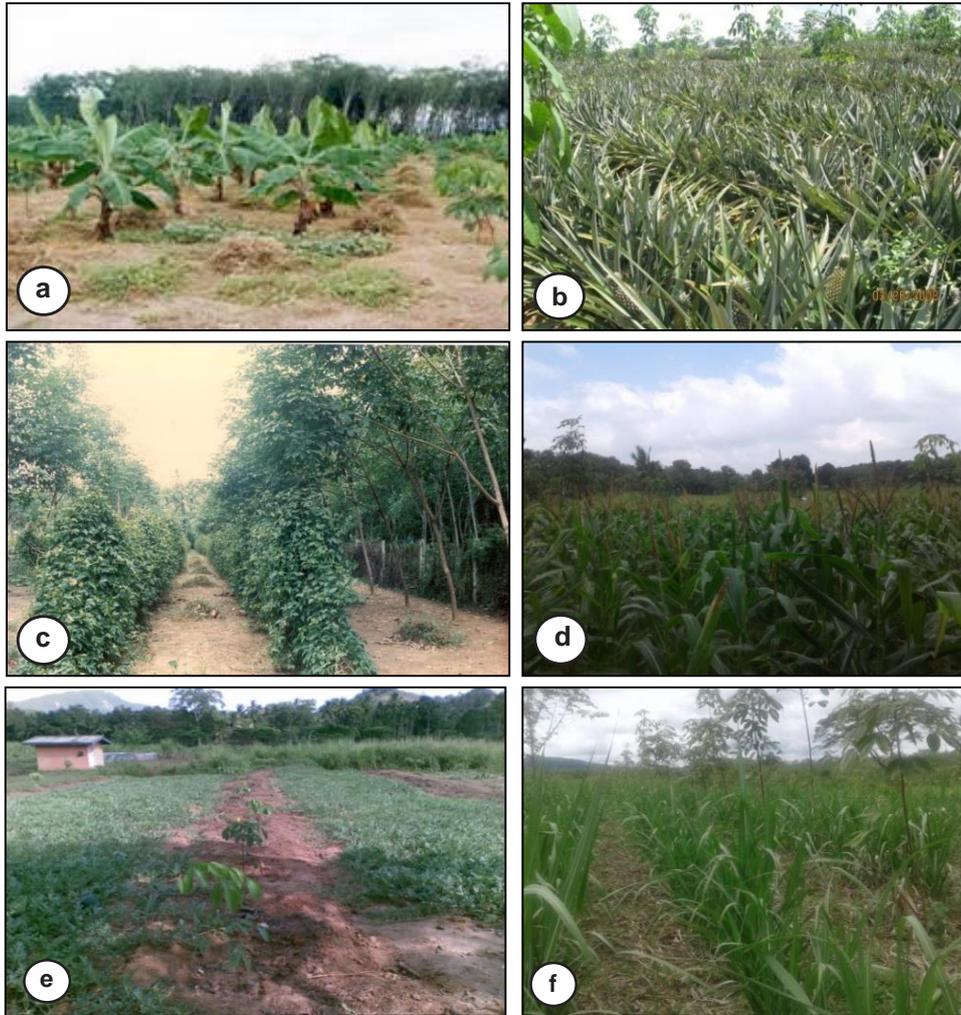


Plate 14.1. Intercropping during immature phase of rubber. **a.** Banana; **b.** Pineapple; **c.** Passion fruit; **d.** Maize; **e.** Water melon; **f.** Sugarcane.



Plate 14.2. Intercropping long term crops with rubber. **a.** and **b.** cocoa; **c.** and **d.** tea; **e.** and **f.** cinnamon.



Plate 14.3. Intercropping during mature phase of rubber. **a.** Rattan; **b.** Cane palm; **c.** Dracaena/messengiana; **d.** Chinese grass; **e.** Foliage mixed; and **f.** Anthurium



Plate 14.4. Two suitable boundary crops with rubber. **a.** Cinnamon; **b.** Alstonia.

Chapter 15

Nutrient management in rubber growing soils

R.P. Hettiarachchi

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1. INTRODUCTION

Hevea plantations are no longer raised in virgin forests and most of the rubber growing soils are either in the third or the fourth cycle of replanting. Even though nutrients removed through the crop are negligible, large amounts of mineral elements are locked up in the process of biomass accumulation and are lost through timber during replanting. Gradual depletion of nutrient reserves in the soils through the cycles of replanting have resulted in deterioration of soil fertility. Low soil fertility is considered as one of the vast constraint on improved agricultural production. Therefore, proper soil and nutrient management is essential to sustain productivity up to their economic levels.

Further, the introduction of high yielding clones of *Hevea* has no doubt provided a mechanism for obtaining high production, given a set of specific conditions. It is also a known fact that the implementation of a proper package of agro-management practices in accordance with soil and climate is a prerequisite to the realization of the crop's potential yield capacity. In this package, proper fertilizer use is a vital aspect.

2. NUTRIENTS REQUIRED BY RUBBER

The response of a perennial crop like rubber to nutrition is influenced by the nutrient-supplying capacity of the soil on one hand and factors like clonal variation, stage of growth, intensity of exploitation and ground cover management on the other. Like any other plant, *Hevea* is expected to require 18 essential plant nutrients for growth and development.

2.1 Macronutrients

The conditions in Sri Lanka necessitate the application of nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg) which are required in relatively large amounts, and are known as macronutrients. Marked responses to N, K and Mg have been observed in most replanted soils in Sri Lanka. Often responses to P are also evident.

2.2 Micronutrients

Some mineral plant nutrients are required by the rubber tree in relatively

small amounts or in traces. These are called micronutrients. It appears that rubber growing soils in Sri Lanka have adequate supplies of micronutrients for satisfactory performance of rubber trees. While no serious problems are encountered in dealing with macronutrients, correction of micronutrient imbalance or deficiency is not a simple task since very small amounts are involved. A small excess of micronutrients may prove to be fatal to the rubber plant. However, it may be possible to alleviate micronutrient deficiency or toxicity problems by adopting appropriate agronomic practices.

2.3 Role of different nutrients

Essential plant nutrients are the elements necessary for the plant to complete its life cycle. In general, each has at least one function which other elements cannot perform.

2.3.1 Nitrogen

- for cell production and function
- an important constituent of all proteins and enzymes
- for increased growth of plant tissues
- essential constituent of chlorophyll

2.3.2 Phosphorus

- essential for cell division and development
- important for cell respiration; leads to growth
- affects latex stability
- essential for maintenance and productivity

2.3.3 Potassium

- involved in various processes of plant metabolism
- essential for water balance in the plant
- essential to balance excess magnesium
- influences latex stability and flow

2.3.4 Magnesium

- constituent of chlorophyll
- plays a role in photosynthesis and growth
- influences stability and pre-coagulation of latex

3. RUBBER GROWING SOILS

Soils normally play a major role in determining the availability of nutrients to plants, primarily through the mineral reserves in the soil and the nutrients added to the soil. Factors such as pH, organic matter content, cation exchange capacity, base saturation, sesquioxide content and physical characteristics of the soil influence the availability of the reserves as well as of the nutrients added. It is

evident that in general soils under rubber are acidic in nature and most of them are low in nutrient status. These characters are therefore often used to separate soils into different soil series. Considering the productivity and nutrient management, all soil series in the country are divided into two groups.

3.1 Group I - *Parambe* series

Parambe series soils are deep, silty in texture and brown in colour. There are glistening specks of mica throughout the soil mass. These soils are high in potassium. The main areas where *Parambe* series soils occur are Kegalle and Kandy districts.

3.2 Group II - All other soil series in traditional rubber growing areas

3.2.1 *Matale* series

Matale series soils are deep, silty clay in texture and dark brown to reddish brown in colour, occurring in localities where soil formation has been influenced by the drainage of lime-rich solutions from adjacent outcrops of crystalline limestone. The limited, sporadic occurrences of these fertile soils are confined to the Matale district.

3.2.2 *Homagama* series

Homagama series soils are moderately deep, gravelly loam in texture and deep brown to reddish brown in colour. They are characterized by the abundance of quartz gravel in them. They have a low potassium status. *Homagama* series soils occur extensively around Yatiyantota, Dehiowita and Deraniyagala.

3.2.3 *Agalawatta* series

Agalawatta series soils are of variable depth, with boulders and outcrops of the granitic rocks from which they are derived. They are silty clay loam in texture and deep brown to yellowish red in colour. They have a medium potassium status. These soils occur over a wide area of the steeply dissected hills which flank the Sinharaja forest.

3.2.4 *Ratnapura* series

Ratnapura series soils are rather shallow, sandy clay loam in texture and yellowish brown in colour, overlying more yellowish sub-soil, characteristically containing small amounts of garnetiferous gravels. They have a medium potassium status. These soils occur only in the Meegahatenne and Ratnapura areas.

3.2.5 *Boralu* series

Boralu soils are shallow, gravelly loam in texture, brown to reddish yellow in colour and overlying *cabook* (laterite). They are characterized by the presence of iron concretions, which occur throughout the soil mass. They have a low potassium status. They mantle the gently undulating mounds and low hills, on which the southern rubber producing areas extend westward towards the coast.

3.3 Group III – Ares in Dry and Intermediate Zones

Different soil series are having with different chemical and physical properties.

4. FERTILIZERS FOR RUBBER

Optimum growth and yields of plants can be achieved only by properly balancing the nutrients according to the needs of the tree. The optimum nutrient level can be maintained within the plant by implementation of a well-planned manuring programme.

4.1 Sources of fertilizers

The promise of equivalent nutritional contents, low purchasing costs, easy availability and applicability greatly popularized chemical fertilizers. Cost of fertilizer can be minimized and fertilizer use efficiency can be improved by proper selection of fertilizer sources. The different fertilizer sources used and their nutrient contents are in Table 15.1.

Table 15.1. Chemical fertilizers recommended for rubber plantations and their nutrient contents.

Fertilizer	Abbreviation	N %	P₂O₅ %	K₂O %	MgO %
Urea	U	46	-	-	-
Sulfate of Ammonia	SA	21	-	-	-
Di ammonium Phosphate	DAP	18	46	-	-
Eppawala Rock Phosphate	ERP	-	30	-	-
High grade Eppawala Rock Phosphate	HERP	-	38.5	-	-
Muriate of Potash	MOP	-	-	60	-
Sulfate of Potash	SOP	-	-	48	-
Dolomite	DOL	-	-	-	20
Kieserite	KIES	-	-	-	24
Commercial Epsom Salt	CES	-	-	-	16

4.2 Fertilizer mixtures

The currently recommended fertilizer mixtures that should be used in different soils and their composition are given in Table 15.2 and Table 15.3, respectively. The significance of the rubber fertilizer mixtures recommended lies in the differences in their nutrient contents. The recommendation to apply 100 g of the mixture R/U 12:14:14 indicates that this would give the plant 12 g of N (nitrogen), 14 g of P₂O₅ (phosphorus) and 14 g of K₂O (potassium).

Table 15.2. Fertilizer mixtures recommended for different rubber growing soils.

Soil series	District/Region	Fertilizer mixture	
		Sulphate of Ammonia-based fertilizers (R/SA)	Urea-based fertilizers (R/U)
Group I			
Parambe	Parambe series in Kandy, Kegalle and Kurunegala	-	R/U 15:15:7 R/U 23:8:15 R/U 31:0:20
Group II			
Matale	Matale	-	R/U 12:14:14
Homagama, Boralu, Agalawatta, Ratnapura	Kalutara, Ratnapura, Galle, Matara Colombo		R/U 18:6:24 R/U 23:0:30
Group III			
	Areas in Dry and Intermediate Zones	R/SA 7:9:9:3, R/SA 13:4:16 R/SA 15:0:18	-

Table 15.3. The compositions of the rubber fertilizer mixtures.

Formulation	Sulphate of Ammonia	Urea	Rock Phosphate	Muriate of Potash	Kieserite	Total
R/U 12:14:14	-	26	50	24	-	100
R/U 15:15:7	-	33	55	12	-	100
R/U 18:6:24	-	40	20	40	-	100
R/U 23:8:15	-	50	25	25	-	100
R/U 23:0:30	-	50	-	50	-	100
R/U 31:0:20	-	67	-	33	-	100
R/SA 7:9:9:3	36	-	33	15	16	100
R/SA 13:4:16	60	-	13	27	-	100
R/SA 15:0:18	70	-	-	30	-	100

4.3 Organic manures

The mono-cultural cropping system adopted in rubber cultivation over the last several decades using same agro-management practices and continuous use of inorganic fertilizers have resulted in deterioration of soil fertility. Unfertile soil cannot sustain economic yields even with high doses of inorganic fertilizers. Therefore, the combined use of organic manure with inorganic fertilizer is one such way of management soil fertility in an environmentally friendly manner. Proper soil management is dependent on adequate organic matter that would stabilize soil structure, decrease susceptibility to erosion, encourage soil microbial activity,

provide a favourable medium for the development of the root system and increase the water holding capacity and cation exchange capacity of the soil, which are essential during immature stage of rubber plants. Another advantage in using organic manures is the ability to cut down upto some extent of chemical fertilizer application. Addition of litter through annual leaf fall in rubber plantations helps to buildup organic matter content in the soil automatically. However, litter accumulation has found to be low under rubber which could be due to the fast rate of decomposition associated with high temperature and moisture. Growers are encouraged to apply following organic manures in one or two applications during anytime of the year with desired climatic conditions depending on their availability (Table 15.4).

Table 15.4. Recommendation for organic manure applications in rubber plantations.

Age Years	Quantity (kg/plant/application)		
	Paddy straw/ Green manure	Compost/Cowdung/ Poultry litter	Poultry manure
Planting hole ^a	-	3	2
1 st	2	2	1
2 nd	3	3	2
3 rd	4	4	3
4 th	4	4	3
5 th onwards	5	5	4

^a Planting hole applications of poultry manure should be done at least 3-4 weeks prior to planting. Other materials could be applied at the time of planting. From first year onwards recommended dosage of organic manure should be incorporated into the top soil layer around the base of the rubber plant.

4.4 Biofertilizers

Biofertilizers is a broad term used for the products including living or dormant microorganisms. They stimulate plant growth by several mechanisms such as decomposing organic materials and release of inorganic nutrients, increasing the availability of nutrients in the soil by solubilization, chelation, oxidation and reduction processes, increasing root surface area by inducing root growth promotion and enhancing other beneficial symbiosis associated with plant. They are in the front of organic agriculture and enhance fertilizer use efficiency for efficient supply of plant nutrients. Recently, there is an increasing interest in this type of environmental friendly, sustainable agricultural practices to alleviate deterioration of nature and environmental pollution.

Bio fertilizer should be sprayed around the base of the rubber plants at a rate of three months interval, 300 ml volume per plant per application.

5. FERTILIZATION OF NURSERIES

The objective of fertilization of nurseries is to facilitate to provide quality plants meet production targets. The following practices are recommended for achieving this objective:

5.1 Budwood nurseries

These nursery plants should be manured in the same manner of immature field plants during 1st year. From 2nd year onwards, the recommended quantity for the 2nd year should be split into two and each portion should be applied soon after pollarding.

5.2 Young budding nurseries

The recommended soluble fertilizer mixtures for young budding plants, composition, and manuring schedule for young budding plants are presented in Tables 15.5, 15.6 and 15.7, respectively.

Table 15.5. Recommended fertilizer mixtures for young budding plants for different soil series.

Mixture	Soil series	District/Region
R/YB 13:17:6:3	<i>Parambe</i>	Parambe series in Kegalle and Kurunegala
R/YB 13:16:16	Matale	Matale
R/YB 9:11:11:4	All other soils	Kalutara, Ratnapura, Galle, Avissawella, Badulla and other areas of Dry and Intermediate Zone

Table 15.6. Composition of recommended fertilizer mixtures for young budding plants.

Mixture	Sulphate of ammonia	Diammonium phosphate	Sulphate of potash	Epsom salt	Total
R/YB 13:17:6:3	31	38	13	18	100
R/YB 13:16:16	32	35	33	-	100
R/YB 9:11:11:4	23	25	23	29	100

5.2.1 Method of application

As a basal application 50 g of HERP and 50 g of compost per bag should be thoroughly mixed with the soil at the bag filling stage and should leave for 2 weeks prior to planting. The required quantities of fertilizer should be dissolved in 4.5 litres of water and 100 ml of this solution should be applied per bag at 4 weeks intervals (or 50 ml per bag at 2 week intervals) (Plate 15.1a) (Table 15.7). Constant stirring is essential to make sure that every bag receives the required amounts of nutrients.

Table 15.7. Manuring schedule for young budding plants.

Time of application	Dosage
Basal application	
2 weeks before planting	50 g HERP + 100 g compost/bag mix with the soil
After planting	
Formulation I	
2 weeks after planting until Cut-back	112 g of relevant R/YB mixture dissolved in 4.5 litres of water and apply 100 ml/bag at 4 weeks interval (or 50 ml/bag at 2 weeks interval)
After cut back	
Formulation II	
After cut-back until 2 weeks before planting	168 g of relevant R/YB mixture dissolved in 4.5 litres of water and apply 100 ml/bag at 4 weeks interval (or 50 ml/bag at 2 weeks interval)

6. FERTILIZATION OF IMMAURE FIELD PLANTS

Rubber trees immobilize substantial quantities of nutrients in the trunks, branches and roots of which about half get immobilized during the pre-tapping phase. During the immature phase, the nitrogen requirement is estimated to be much greater than the fertilizer input. The deficit nitrogen content has to be met from nutrients gradually released by the leguminous cover crop. The response to fertilizers is highest in the pre-tapping stage and the trees attain tapping girth at the end of 5th year with proper fertilizer application. Moreover, systematic application of fertilizers throughout the immature phase leads to build-up of plant nutrient reserves in the soil.

6.1 Rates of application

The total quantities of fertilizer that should be applied per tree will depend on the age of the tree and the soil in the locality. The recommended rates of application of the urea based mixtures for Group I and II soils are given in Table 15.8. The recommended rates of sulphate of ammonia based mixtures for dry and intermediate zone are given in Table 15.9.

6.2 Frequency of application

It is recommended that the annual requirements of fertilizers be split and applied in as many number of applications as possible (Table 15.8 & 15.9). Further, recommended quantity of fertilizers may be reduced by increasing number of applications.

6.3 Fertilizers for areas previously planted with tea

In addition to the fertilizers recommended in Table 15.8, an extra dose of

kieserite at the rate of 25 g per tree should be applied during the 1st year, 2 months after planting. Another application of dolomite at the rate of 50 g per tree is also recommended during the 2nd year, 14 months after planting.

6.4 Time of application

Uptake of nutrients by the rubber plant is restricted by drought conditions, so fertilizers should not be applied at the height of dry weather. Periods of prolonged dry and heavy rains also should be avoided, for then the fertilizer may be washed out of the soil and lost before its nutrients can be absorbed by the plant.

Dolomite lime is recommended (except in the *Matale* series) as it will serve as a reservoir of the plant nutrient, magnesium. Dolomite should be given in a single application each year, separated by at least one month from the nearest application of urea-based fertilizer. Otherwise, dolomite and urea-based fertilizer could be applied at once in two different places around the tree. Since urea readily gives off ammonia in the presence of lime consisting dolomite and there is a risk of loss of nitrogen as ammonia when urea and dolomite are mixed.

Table 15.8. Manuring schedule for immature rubber on group I and group II soils.

Year of planting	Frequency & Time of application	Quantity/tree	
		Urea based	
		R/U 12:14:14	R/U 15:15:7
1 st year	4 applications/year	275g NPK mix.+75g dol.	275g NPK mix.+50g dol.
	2 months after planting	50g NPK mix.+25g dol.	50g NPK mix.+25g dol.
	5 months	50g NPK mix.	50g NPK mix.
	7 months	75g NPK mix.+50g dol.	75g NPK mix.+25g dol.
	10 months	100g NPK mix.	100g NPK mix
2 nd year	4 applications/year	550g NPK mix.+150g dol	550g NPK mix.+ 75g dol
	13 months after planting	100g NPK mix.	100g NPK mix.
	14 months after planting	150g dol.	75g dol.
	16 months after planting	150g NPK mix.	150g NPK mix.
	19 months after planting	150g NPK mix.	150g NPK mix.
	22 months after planting	150g NPK mix.	150g NPK mix

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Year of planting	Frequency & Time of application	Quantity/tree	
		Urea based	
		R/U 12:14:14	R/U 15:15:7
3rd year	3 applications/year	800g NPK mix.+200g dol	
	26 months after planting	265g NPK mix.	800g NPK mix.+100g dol 265g NPK mix.
	27 months after planting	200g dol.	100g dol.
	30 months after planting	265g NPK mix.	265g NPK mix.
	34 months after planting	265g NPK mix.	265g NPK mix.
4th year	3 applications/year	800g NPK mix.+200g dol	800g NPK mix.+100g dol
	38 months after planting	265g NPK mix.	265g NPK mix.
	39 months after planting	200g dol.	100g dol.
	42 months after planting	265g NPK mix.	265g NPK mix.
	46 months after planting	265g NPK mix.	265g NPK mix.
5th year until tapping	3 applications/year	1100g NPK mix.+250g dol.	1100g NPK mix.+150g dol
	50 months after planting	365g NPK mix.	365g NPK mix.
	51 months after planting	250g dol.	150g dol.
	54 months after planting	365g NPK mix.	365g NPK mix.
	58 months after planting	365g NPK mix.	365g NPK mix.

Dol. – Dolomite

6.5 Method of application

Under conditions of rainfall prevailing in most of the rubber growing districts, the aim should be to incorporate the fertilizers into the soil, in order to prevent loss by surface wash. This may be achieved by pocketing or forking. It is however desirable that as wide a spread of roots as possible comes in contact with the fertilizer and the best way of achieving this would be forking. Nitrogen loss as ammonia, from the ammonium carbonate to which urea is converted in the soil, is reduced to a minimum under all conditions of soil and moisture where fertilizer is applied, by forking. Broadcasting without forking is likely to lead to nitrogen loss and should not be practiced.

During the first year after planting, the fertilizer should be applied in a circle, free of weeds, 25-30 cm from the base of the plant with light forking (Plate,

15.1b). The radius of this circle should be increased with age, up to about 100-120 cm at the end of the 5th year. After the 5th year the fertilizer should be applied at 2 to 4 points in areas cleared of weeds around the tree within a radius of 100-120 cm. Where mulching is carried out, fertilizers should be applied into the soil before spreading the mulch.

Table 15.9. Manuring schedule for immature rubber in Dry and Intermediate Zone.

Year of planting	Frequency & Time of application	Quantity of sulphate of ammonia based/tree
1st year	3 applications/year	450 g NPKMg mix.
	End of December	100 g NPK mix.
	End of March	150 g NPK mix.
2nd year	3 applications/year	900 g NPKMg mix.
	End of December	250 g NPK mix.
	End of March	300 g NPK mix.
3rd year	3 applications/year	1350 g NPKMg mix.
	End of December	400 g NPK mix.
	End of March	450 g NPK mix.
4th year	3 applications/year	1350 g NPKMg mix.
	End of December	400 g NPK mix.
	End of March	450 g NPK mix.
5th year until tapping	3 applications/year	1800 g NPKMg mix.
	End of December	600 g NPK mix.
	End of March	600 g NPK mix.
	End of September	600 g NPK mix.

7. FERTILIZATION OF MATURE TREES

It is evident that major nutrients N, P, K and Mg have a positive effect on rubber yield. This could be a direct effect or mediated through their effect on growth of bark, bark renewal, *etc.* Under proper initial management, especially with respect to optimum nutrition during the immature phase, the fertilizer use during the mature stage could definitely be minimized.

7.1 Site-specific fertilizer recommendation

The concept of discriminatory fertilizer recommendation target to supply of an adequate quantity of nutrients to the plants taking into consideration of nutrient reserves and the available nutrient content in the soil, plant nutrient status, site characteristics and other specific parameters. This practice has been widely

Nutrient management in rubber soils

accepted and extensively used for formulating fertilizer recommendations for mature rubber.

This scheme of fertilizer recommendation is based on the contention that when a tree has access to sufficient nutrients for maximum productivity and growth, its leaves will contain defined amounts of the essential nutrients. For the interpretation of leaf nutrient data to determine the deficiency and sufficiency of nutrients, a range of values has been suggested (Table 15.10).

Table 15.10. Nutrient assessment of low shade leaves of *Hevea* in all clones.

Nutrient	Very low	Low	Medium	High	Very high
N (%)	<2.90	2.90-3.40	3.40-3.50	3.51-3.70	>3.70
P (%)	<0.17	0.17-0.19	0.20-0.25	0.26-0.27	>0.28
K (%)	<1.21	1.21-1.40	1.40-1.69	1.70-1.85	>1.85
Mg (%)	<0.18	0.18-0.21	0.21-0.26	0.26-0.28	>0.29

Very low - levels are well below sub-optimal tending to visible deficiencies

Low - levels are sub-optimal

Medium - levels are optimal

High - levels are above optimal and responses are unlikely

A service based on this technique was started for the first time in Sri Lanka by the RRISL in 1973, and is currently catering to mature rubber only. The site specific fertilizer recommendations are intended to cover 3 years of manuring, after which a resurvey is due and new recommendations for the next 3 years are formulated. In areas where fertilizers are not recommended on the basis of site specific fertilizer recommendation program, the conventional fertilizer recommendations could be used (Table 15.11).

Table 15.11. Manuring schedule for mature rubber on group I and II soils*.

Stage of Maturity	Quantity/tree/year		
	Urea based fertilizer		Sulphate of ammonia based fertilizer
	Group I	Group II	Group III
While tapped on virgin bark	R/U 23:8:15 400 g	R/U 18:6:24 500 g	R/SA 13:4:16 750 g
While tapped on renewed bark	R/U 31:0:20 225 g	R/U 23:0:30 300 g	R/SA 15:0:18 500 g

* For areas where fertilizers are not recommended under site specific fertilizer recommendation program.

7.2 Time of fertilizer application

From an economic as well as agronomic point of view, all fertilizers for mature rubber should be applied within one month after refoliation, at the stage of

appearing apple green colour leaves (depending on weather conditions at the time). It is important that all fertilizer for mature rubber in wet zone should be applied before June.

7.3 Methods of fertilizer application

The fertilizer should be applied at 2 to 4 points, in areas cleared of weeds around the tree within a radius of 100-120 cm. All fertilizers should be forked into the top 10-20 cm of soil. Where mulching is carried out fertilizers should be applied into the soil before spreading the mulch (Plate, 15.1c).

8. FERTILIZATION OF GROUND-COVER CROPS

Phosphate is one of the important plant nutrients required by legumes for satisfactory growth. When establishing leguminous covers in beds or strips in the plantation, a dressing of 100 g of rock phosphate per square meter would be beneficial. Further, this phosphate fertilizer could be applied at the rate of 100 to 200 kg per hectare per year in the first two years, depending on the growth of covers.

9. NUTRIENT DEFICIENCIES

Rubber plants require a number of elements for normal, healthy growth and development. The presence of each of these elements in correct proportions and amounts is equally important and when there is an inadequacy in supply, the performance of the plant is affected. No symptoms are seen when there is a mild deficiency. But physiologically the plant may not be functioning properly. However, when a plant is subjected to a deficiency for a long period of time it begins to exhibit hunger signs in various tissues, particularly in the leaves, indicating that there is a nutritional deficiency in the plant. When the supply of a single nutrient is lacking it can be easily identified by a trained eye because each nutrient has its characteristic deficiency symptoms. The most important thing to remember is that by the time the deficiency symptoms are observed the growth of the plant may have been severely retarded and a certain amount of crop may have already been lost.

9.1 Symptoms and diagnosis

In Sri Lanka deficiency symptoms of K and Mg are often observed in immature rubber plants but in general N and P deficiencies have not been observed except in nurseries. Micronutrient deficiency symptoms are very rare in occurrence. A brief description of the deficiency symptoms seen in rubber plants is given here.

9.1.1 Nitrogen deficiency

Nitrogen (N) deficiency symptoms in rubber are seldom reported in Sri Lanka. This could be probably due to the widespread use of N fertilizers, and also to the use of leguminous cover crop when replanting rubber. In poorly maintained plantations where fertilizer usage has been restricted and in cases of severe competition, N deficiency is likely to occur.

9.1.1.1 Symptoms

The usual symptom is restricted growth of the entire tree: this is reflected in reduced leaf size and number, and reduced girth. The tree becomes very stunted. The main indication of N deficiency is a yellowish green colour of the leaves in the early stages (Plate, 15.2a) and a yellow colour in the later stages. The deficiency symptoms will first appear on the older leaves in the lower stories and are likely to be more pronounced on leaves exposed to full sunlight than on leaves in the shade of the canopy.

9.1.2 Phosphorus deficiency

Symptoms of phosphorus (P) deficiency have not been identified on mature rubber and are only very rarely found on immature and nursery plants.

9.1.2.1 Symptoms

The distinguishing symptom of P deficiency is a bronzing of part of the under surface of the leaf (Plate, 15.2b). This is not clearly evident on inspection of the upper surface of the leaf. The bronzing is often largely restricted to one half of the leaf, and is usually first seen at the end of the lamina and the leaf tip frequently dies back. The symptoms are usually first found on leaves in the middle and upper stories of the plant.

9.1.3 Potassium deficiency

Potassium (K) deficiency in rubber is commonly found, particularly on sandy soils.

9.1.3.1 Symptoms

The characteristic symptom of K deficiency is the development of a marginal and tip chlorosis, which is followed by necrosis. The marginal chlorosis usually appears first as a yellow mottling and later the mottled areas combine to form a fairly distinct marginal band of chlorotic tissue. This band quickly becomes necrotic, the necrosis first appearing at or near the leaf tip (Plate, 15.2c). The observation of such necrosis, and also the lack of any definite herring-bone pattern of yellowing, allows potassium deficiency symptoms to be distinguished from those of magnesium deficiency. The symptoms usually appear on the leaves in the lower or older whorls on young plants. When the deficiency becomes more severe the symptoms will also appear on mid stem whorls. In mature trees potassium deficiency symptoms are found on leaves exposed to full sunlight. Seen from a distance, the crowns of affected trees appear predominantly yellow.

9.1.4 Magnesium deficiency

Magnesium (Mg) deficiency symptoms on rubber are very common in Sri Lanka.

9.1.4.1 Symptoms

The characteristic symptom of magnesium deficiency is the development of a chlorosis in the interveinal areas on the leaf. Generally, the chlorosis appears to spread inward from the leaf margin, giving a herring-bone pattern (Plate 15.2d). In severe deficiency, the chlorosis which is generally a deep yellow colour, is often followed by interveinal necrosis and sometimes by marginal necrosis. The symptoms first appear on the leaves in the lower or older stories on the young plant, whereas in mature trees they are found on leaves exposed to full sunlight.

9.2 Correction of deficiencies

The corrective measures recommended for each nutrient deficiency (Table 15.12) should be carried out and if the plants do not recover within four months, the problem should be referred to the Soils and Plant Nutrition Department of the RRISL.

9.2.1 Nitrogen deficiency

N deficiency could be corrected by applying 50-100 g of urea with 100-200 g of the appropriate urea-based NPK fertilizer mixture per plant depending on the age. Where sulphate of ammonia based fertilizer mixture is used, the deficiency could be corrected by applying 100-200 g of sulphate of ammonia with 200-400 g of sulphate of ammonia-based NPKMg fertilizer mixture depending on the age.

9.2.2 Phosphorus deficiency

A generalized corrective measure is not recommended. It should therefore, be made based on a foliar analysis.

9.2.3 Potassium deficiency

Common symptom of the deficiency could be corrected by applying 50 -100 g of MOP and 25-50 g of kieserite with 100-200 g of the appropriate urea-based NPK fertilizer mixture depending on the age. Where sulphate of ammonia based fertilizer mixture is used the deficiency could be corrected by applying 50-100 g of MOP with 200-400 g of sulphate of ammonia –based NPKMg fertilizer mixture depending on the age.

9.2.4 Magnesium deficiency

This disorder could be corrected by applying 50-100 g of kieserite with 100-200 g of appropriate urea-based NPK fertilizer mixture depending on the age. Where sulphate of ammonia based fertilizer mixture is used the deficiency could be corrected by applying 25-50 g of kieserite with 200-400 g of sulphate of ammonia –based NPKMg fertilizer mixture depending on the age.

As Mg deficiency could occur either due to poor Mg status or due to high K status of the soil, studying the history of manuring is important before recommendations are made. If high K fertilizer application has been done earlier, to correct Mg deficiency in such cases, high doses of Mg fertilizer should be applied.

Table 15.12. Corrective measures for nutrient deficiencies of *Hevea*.

Deficiency	Age	Dosage	Remarks
Nitrogen (N)	During 1 st and 2 nd years of planting	50g of urea	100 g of urea based NPK fertilizer mixture should be applied
		100g of sulphate of ammonia	200g of Sulphate of ammonia based NPKMg fertilizer mixture should be applied
	2 nd year – until tapping	100g of urea	200 g of urea based NPK fertilizer mixture should be applied
		200g of sulphate of ammonia	400g of Sulphate of ammonia based NPKMg fertilizer mixture should be applied
Mature stage	100g of urea 200g of sulphate of ammonia	200 g of urea based NPK fertilizer mixture should be applied	
		400g of Sulphate of ammonia based NPKMg fertilizer mixture should be applied	
Phosphorus (P)	Visual symptoms are not common. Recommendation should therefore, be made based on a foliar analysis		
Potassium (K)	During 1 st and 2 nd years of planting	50 g of MOP + 25g of Kieserite	100 g of urea based NPK fertilizer mixture should be applied
		50 g of MOP	200g of Sulphate of ammonia based NPKMg fertilizer mixture should be applied
	2 nd year – until tapping	100 g of MOP + 50g of Kieserite	200 g of urea based NPK fertilizer mixture should be applied
		100 g of MOP	400g of Sulphate of ammonia based NPKMg fertilizer mixture should be applied
Mature	100 g of MOP + 50g of Kieserite 100 g of MOP	200 g of urea based NPK fertilizer mixture should be applied	
		400g of Sulphate of ammonia based NPKMg fertilizer mixture should be applied	
Magnesium (Mg)	During 1 st and 2 nd years of planting	50g of Kieserite	100 g of urea based NPK fertilizer mixture should be applied
		25g of Kieserite	200g of Sulphate of ammonia based NPKMg fertilizer mixture should be applied
	2 nd year – until tapping	100g of Kieserite	200 g of urea based NPK fertilizer mixture should be applied
		50g of Kieserite	400g of Sulphate of ammonia based NPKMg fertilizer mixture should be applied
Mature	100g of Kieserite 50g of Kieserite	200 g of urea based NPK fertilizer mixture should be applied	
		400g of Sulphate of ammonia based NPKMg fertilizer mixture should be applied	



Plate 15.1. a. Application of liquid formulation for nursery plants; b. Application of fertilizer for immature plants; c. Application of fertilizer by forking into the soil for mature plants.

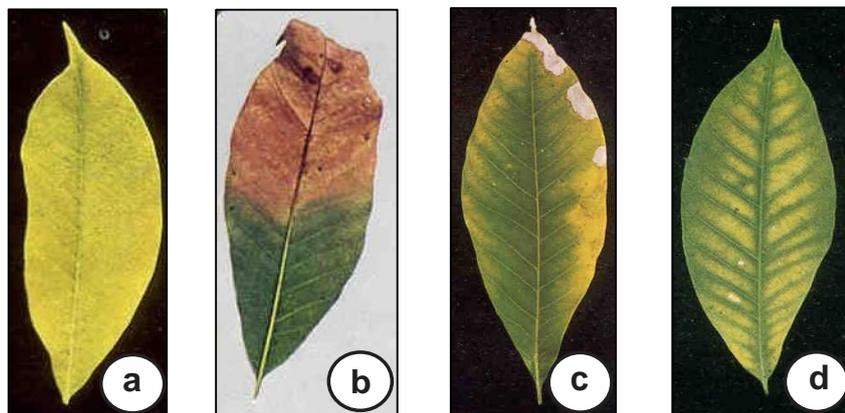


Plate 15.2. a. Nitrogen deficiency; b. Phosphorus deficiency; c. Potassium deficiency; d. Magnesium deficiency.

Chapter 16

Latex harvesting of rubber

Chamil Nayanakantha

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1. INTRODUCTION

Latex is the economically important component of the rubber tree. Tapping is a process of systematic wounding of the bark of the rubber tree to harvest crop of latex. Therefore, rubber tree is exploited by periodic excision of a thin shaving of the bark along a sloping groove placed spirally on the bark of the tree trunk (Plate 16.1 a). The best tapping system is one which gives the highest latex yield at lowest tapping cost and bark consumption with satisfactory tree growth, bark renewal and lowest incidence of brown bast or tapping panel dryness.

The methods employed to tap the rubber tree for latex are determined by the anatomical features, *i.e.* arrangement of various tissue layers, of the bark and therefore a knowledge of the anatomy of rubber tree bark with special reference to the distribution of latex vessels is essential to understand and develop appropriate tapping systems.

2. ANATOMY OF THE BARK

2.1 The bark

The depth, angle and other attributes of tapping cut depend on the arrangement of the various tissue layers of the trunk. In the trunk of a mature rubber tree, a central cylinder of wood (xylem) is surrounded by bark (phloem). The phloem and xylem are separated by a thin layer of vascular cambium which generates xylem tissue on the inside and phloem tissue on the outside.

In the virgin bark of the rubber tree, three concentric layers can be identified. The closest to the cambium is the soft bark which mainly comprises concentric cylinders of sieve tubes and phloem parenchyma altering with thinner cylinders of laticifers which contain latex. The second layer, the hard bark, also contains sieve tubes and laticifers, but both become progressively disorganized and non-functional with increasing distance from the cambium. The hardness of the bark is attributed to the presence of the stone cells which are sclerified parenchymatous cells. The outermost layer is the cork (phellem) which is derived towards the outside from an inner cork cambium (phellegon). There then occurs a layer of cortical parenchyma (phelloderm) also generated by the cork cambium.

The vascular cambium cuts off cells towards the exterior which then differentiate to form phloem elements (bark) and cells towards the interior to form xylem elements (wood). Latex vessels (laticifers) which contain latex are found in the phloem tissue of the rubber plant. They initiate from the cambium in a rhythmic manner and latex vessel initiation diminishes during the wintering period. When considering the spatial organization of laticiferous tissue in the bark of *Hevea* two zones can be distinguished, *viz.* the inner soft zone (soft bark) and outer hard zone (hard bark). The laticifers are found mostly in the inner soft zone (soft bark) (Fig. 16.1).

2.2 Latex vessels (laticiferous tissue)

The laticiferous tissue mainly consists of latex vessels which are modified phloem sieve tube cells. Unlike sieve tubes, latex vessels do not have porous end walls (sieve plates) and tonoplast and hence true vacuole. Nuclei and ribosome line the longitudinal walls of these elongated tube like cells, whilst the central portion is occupied by rubber and other constituents of the protoplast.

In a cross section of the bark, latex vessels are circular or somewhat irregular in shape with close opposition to the neighboring parenchyma. They are arranged in regular rows, almost parallel to the cambium, as concentric rings or mantels (Fig. 16.2). These mantels are separated by zones of sieve elements and phloem parenchyma cells.

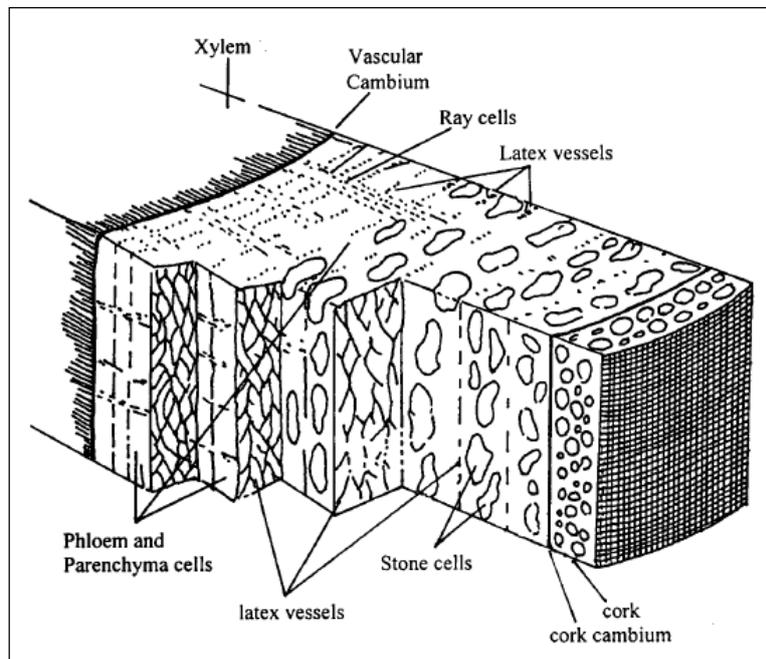


Fig. 16.1. A three dimensional view of the bark of *Hevea brasiliensis* showing the arrangement of latex vessels and other tissues [Source: “A Handbook on Rubber Culture and Processing, 1983].

The latex vessels are articulated (being joined longitudinally at the point of fusion between cells) and anastomosing (interconnected laterally between adjacent cells). The vessels of the soft bark appear continuous in each row but in the outer bark, they appear as discontinuous tubes. As the mantels are required to increase their circumference due to increase in girth of the tree, they do so by accommodation in the tissue by lateral dilation than by growth. This obviously brings disruption to the external latex vessels.

The latex vessels are aligned at an angle to the vertical axis of the trunk in an anticlockwise direction, *i.e.* incline from lower left to upper right as one faces the tree. Depending on the clone, the angle of deviation varies in the range between 2.1° – 7.1° . Because of this alignment, tapping cuts are normally made to slope from high left to low right at an angle of about 30° as this cuts more vessels and gives a higher yield.

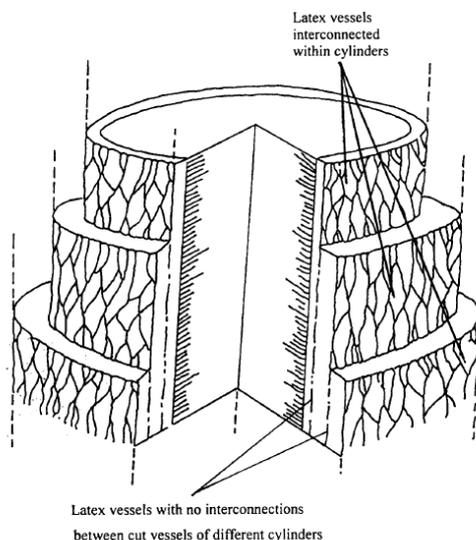


Fig. 16.2. Concentric rings of latex vessels. The vessels are inclined at 2.1-7.1° to the vertical. Vessels making up a ring are interconnected, but there is no connection between rings. [Source: “A Handbook on Rubber Culture and Processing, 1983].

Quantitative consideration on laticiferous tissue

The number of latex vessel rings is influenced by clone, age, thickness of the bark, planting density and nutrient status. The more rapid the growth the greater the frequency with which latex vessel rings are initiated and hence the larger their number. About 8½ year old tree of a modern clone of *Hevea* would have about 26 latex vessel rings at a height of 150 cm from the union on virgin bark. Here a mean of 40% of the rings lay within 1mm of the cambium, but depending on the clone, the proportion in this zone varies from 20-55% (Fig. 16.3). In most occasions, tapping is not done closer to 1mm to the cambium due to fear of injury to the cambium. Further, damage to the cambium would prevent proper bark renewal for further tapping. In a 25 year old rubber tree, about 75% of the rings is uniformly distributed through the inner most 5 mm of the bark.

Bark regeneration and cork formation

Tapping induces injury to the bark and hence creates a wound tissue consisting of cork on the outside and cork parenchyma or phelloderm on the inside. The vascular cambium is also activated and produces new phloem tissue including rings of latex vessels. The renewed bark does not regenerate at the same rate as virgin bark and therefore, requires about 8 years to be tapped again. Nevertheless, a rapid bark regeneration rate can be observed during the first six months after tapping. Renewed bark is thinner than the virgin bark due to a reduction in the corky layer and the absence of stone cells. Under normal growth conditions, the number of latex vessel rings in the renewed bark is greater than that found in the virgin bark.

This is responsible for the higher yield which may be obtained sometimes from renewed bark.

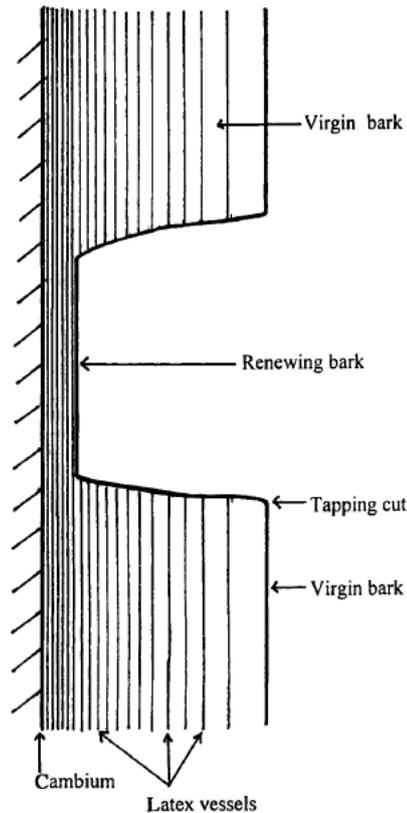


Fig. 16.3. A diagrammatic representation of latex vessel rings in the bark. Vessels found 1 mm adjacent to vascular cambium cannot be tapped for fear of injury to cambium. [Source: "A Handbook on Rubber Culture and Processing, 1983].

3. PHYSIOLOGY OF LATEX PRODUCTION

Photosynthesis takes place in leaves of rubber trees which synthesizes carbohydrates. In mature trees, genetic makeup determines the partitioning of synthesized carbohydrates to dry matter production, metabolic activities and latex production. The latex production takes place within the latex vessels from sucrose, the end product of photosynthesis. Tapping affects the growth of the tree due to the additional demand for photosynthetic assimilates required for the extra needs created by loss of latex and tissues during tapping. The first tapping yields only a small quantity of latex with a high dry rubber content (DRC), *ca.* 60%. The subsequent tapping yields increasing volumes of latex with a low DRC, *i.e.* 30 - 35%.

3.1 Physiology of latex flow

Latex found in the latex vessels is a colloidal suspension which contains most of the subcellular elements. Besides rubber particles which accounts for about 25-40%, latex contain non-rubber constituents of mineral salts, proteins, sugars, resins, glucosides, tannins and alkaloids. The surrounding phloem and parenchyma also have cell contents with various components such as mineral salts, proteins and sugar in an aqueous solution. When two such aqueous solutions with differing solute concentrations are separated from each other by a semi-permeable membrane which allows water but not other solute molecule to pass through it, water flow along an osmotic pressure gradient from the lower solute concentration to the higher solute concentration. Since the solute concentration is high in latex vessels, water flows from the surrounding phloem and parenchyma into latex vessels.

When the latex vessels become filled to capacity and the solute concentrations are not yet equalized between the two solutions, water would continue to flow into latex vessels from neighboring phloem and parenchyma. Under such circumstances, cell walls of latex vessels exert opposing pressure (a hydrostatic/turgor pressure) which resists further expansion of latex vessels. This turgor pressure causes latex to be exuded from the latex vessels upon tapping.

The turgor pressure in the latex vessels is in the range of 10 - 15 atmospheres. The turgor pressure is high in the early morning but falls during the day as a result of withdrawal of water under transpirational stress. Immediately after tapping the pressure in the vessels is reduced to atmospheric pressure and hence latex flows out. Therefore, with latex flowing out after tapping the turgor pressure exerted by the latex vessels on the neighboring cells is also reduced. As a result the cell walls of the neighboring cells will arch into the latex vessels and a pressure is exerted and this would result in further release of latex from the latex vessels. Water will enter the latex vessels to compensate for the losses and the latex thus gets diluted. Latex is expelled by the contraction of the vessels under the pressure of the still turgid surrounding cells and by the gradient of pressure from the more remote parts of the vessel to the cut ends

3.2 Latex vessel plugging

Upon tapping, the high turgor pressure in the latex vessels expels latex from the vessels and the flow of latex is gradually impeded and finally halted by a barrier which develops in the latex vessels at or near the cut surface. The formation of this has been recognized as the plugging reaction of the latex vessels. The lutoids (vacuole-like organelles) found in the bottom fraction of the centrifuged latex is considered to be responsible for latex vessel plugging. Changes in the osmotic concentration of the latex during latex flow damage the lutoids which form aggregates with rubber particles which are found in larger number at the bottom of the tapping cut. The most commonly used measure of latex vessel plugging rate is the "plugging index (PI) which estimates the average plugging rate over the entire flow." Plugging index is a clonal characteristic that varies with season, the tapping system and stimulation schedule adopted.

Plugging index can be calculated using the formula given below:

$$\text{Plugging Index (PI)} = \frac{100 \times \text{mean flow rate (ml/min) during first 5 mts. after tapping}}{\text{Total volume (ml)}}$$

The higher the PI, the lower will be the latex yield. Here, plug formation is relatively quick and hence latex flow ends early. Such clones respond well to yield stimulation. Generally, in trees treated with yield stimulants the plugging reaction is delayed. Once the latex flow ceases after the plugging of vessels, the turgor pressure in the vessels is gradually restored and the latex is reconcentrated through biosynthesis of latex within the vessels. The total solids content depends very much on tapping intensity and is related in the dry rubber content (DRC). A low DRC (< 34%) indicates that the tree is over exploited.

3.3 The drainage area

A knowledge of the extent of the drainage area is required for rational development of tapping systems, especially those involving multiple cuts. The main flow of latex during tapping is from the vessel rings immediately below the cut. It is believed that the drainage area extends 70 - 120 cm below the cut and that there is some flow from above the cut as well (Fig. 16.4).

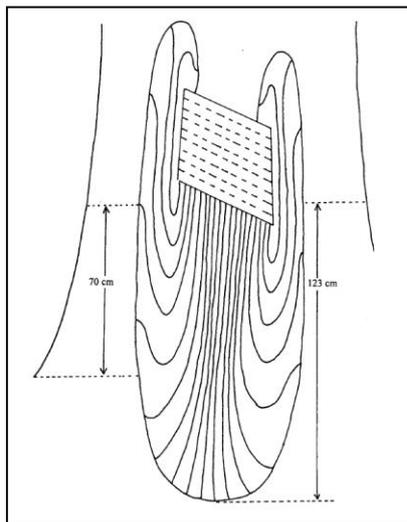


Fig. 16.4. Main flow of latex to the tapping cut is from below the cut, from a distance of 70-120 cm. There is some flow from above the cut as well. [Source: "A Handbook on Rubber Culture and Processing, 1983].

4. TAPPING

4.1 History of tapping

The earliest method for harvesting latex from wild rubber trees involved random wounding of trees using sharp tools. As no attempts were made to regulate depth and direction, such tapping resulted in injury to the cambium, irregular secondary growth, wastage of latex, poor yields and hence early abandonment of trees.

The credit of discovery of a systematic way of exploiting rubber trees to allow sustained yields goes to H.N. Ridley at the Singapore Royal Botanical Gardens. He invented what is to-day the most widely used method of continuous excision tapping and a detailed description of this method was first published in 1897 in the Annual Report of the Singapore Royal Botanical Gardens. By employing this method, trees could be continuously exploited by removing a thin shaving of bark along a sloping groove at regular intervals. With this method, the depth, length and direction of the cut are controlled. This system allows free flow of latex along the sloping cut and also bark regeneration above the cut facilitating the exploitation of renewed bark as well.

4.2 Current methods

Presently, the continuous excision method of tapping developed by Ridley is used to exploit rubber trees for latex. During tapping the original cut is systematically reopened by the removal (excision) of a thin shaving of bark from the sloping cut (Plate 16.1a). The special knife used cuts a shallow channel along which the latex flows to a collecting vessel.

4.3 Procedures

4.3.1 Tappable tree

Tapping should be commenced only after rubber trees attain a standard girth. Since the tapping reduces the growth of rubber trees, it is necessary to maintain a satisfactory rate of growth of trees under tapping to obtain sustained yield during the entire tapping cycle. Rubber trees can be regarded as tappable with the continuous excision method once they attain a girth of at least 50 cm, measured at a height of 120 cm from the highest point of the stock-scion union (Plate 16.1b). Tapping of under-girth trees may seriously retard further growth of the tree and will lead to uneconomic yields. Moreover, tapping of under-girth trees will result in damage to cambium and subsequent poor bark renewal.

4.3.2 Tappable clearing

When 70% of the trees in a clearing/smallholding reach the tappable girth, tapping can be commenced. In such a clearing trees having a girth of 45 cm may also be marked for tapping. Generally, it takes five to six years to reach this stage.

In trees not originally tapped due to insufficient girth but attain tappable girth later, tapping should commence at the initial height of opening adopted (see para 4.3.4) for the other trees in the clearing, not at the height of the existing cuts.

4.3.3 Commencement of tapping

Rubber trees of all clones are vulnerable to bark rot caused by *Phytophthora* during initial months of tapping. Therefore, tapping of a new clearing should not be undertaken during the *Phytophthora* season, *i.e.* May to September each year. November/December is an ideal period for commencement of tapping in a new clearing.

4.3.4 Height of opening cut

The trunk of the budded rubber tree is cylindrical and hence equal amount of laticiferous vessels are found along the trunk. Therefore, there is no significant difference in yield due to opening of cuts at different heights. However, by considering the stature of tappers and their convenience, tapping cuts should be made at a height of 120 cm from the highest point of the union to the lower end of the tapping cut. Nevertheless, the height of opening will have to be lowered if the tapper cannot reach 120 cm due to his/her low stature. Generally, on the base panels tapping is done from high left to low right using a modified Michi-Golledge tapping knife (Plate 16.1d). The initial cuts are made at a height that will provide adequate time for bark renewal when tapped with the recommended tapping systems and bark consumption rates.

4.3.5 Slope and direction of cut

As the latex vessels in the bark are oriented at an angle of $2.1 - 7.1^{\circ}$ to the vertical in an anti - clockwise manner, a greater number of latex vessels is cut making continuous latex flow and thereby a greater yield is obtained when cuts are made at 30° to the horizontal sloping from high left to low right. For upward tapping of higher panels a 45° angle to the horizontal is advocated to prevent wastage of latex. Deviations from correct angles result in yield losses.

4.3.6 Marking of trees

The tapping panel should be marked using a stencil made out of an aluminium sheet for tappers to achieve correct angle and length of cut and also to achieve correct bark consumption (Plate 16.1c). The side of the tree to be cut should be determined considering the convenience of the tapper. If the terrain is steep, tappers prefer the cut to be on the contour. On flat terrain consideration may be given to the cut to face East - West for quick drying of wet panels.

Once the height of opening and side of the tapping cut are decided marking of guide lines on the trees should be made. Firstly a vertical line (Neththi Kanu) is drawn on the tree commencing at a height slightly above the height of opening to reach the graft union (Plate 16.2a). On this line the opening height is marked (Plate 16.2b). Subsequently, half circumference of the tree is determined using a measuring tape or a string at two points and marked on the tree (Plate 16.2c). Another vertical line called 'Poi Kanu' is drawn through these two points from a point above the opening height to the graft union (Plate 16.2d). With the aid of the appropriate stencil placed on the tree at the opening height with its handles parallel

to both Neththi and Poi Kanu (Plate 16.3a), lines are drawn for the tapping cut and guidelines with a high left to low right orientation (Plate 16.3b). The lowest point of the tapping cut (on the vertical line, on the right) is at 120 cm above the graft union.

The lines should be marked superficially using a pointed object such as a mounted needle. These marks should not be more than 1 mm deep as they are only required temporarily as guidelines for tapping. After the marking of guidelines, the spout and the cup hanger are fixed. Subsequent guide lines are marked every year before commencement of tapping (Plate 16.3c).

4.3.7 Depth of tapping

Tapping is a highly skilled operation and the best yields can be obtained by tapping as close as possible to the cambium but without injuring these delicate cells. Up to forty per cent (40%) of the productive latex vessels are found in the 1 mm adjacent to the cambium (Fig. 16.3). A skilled tapper will tap to the optimum depth of within 0.5mm of the cambium to obtain optimum yield without wounding the cambium. Nevertheless, tapping to a depth of up to 1 mm from the vascular cambium is considered satisfactory.

The absence of injuries on the tapped panel is not always a sign of good tapping as this may be due to shallow tapping which gives reduced yield. Therefore, high yields coupled with smooth, even and uninjured to very little injured renewed panels are good indications of correct depth of tapping.

4.3.8 Bark consumption

In order to remove the plugs of coagulated latex at the cut ends of latex vessels, it is enough to cut off only a thin layer of bark at each tapping. The thickness of the bark shaving removed at each tapping depends on the skill of the tapper and the degree to which the bark has dried out. There is no increase in yield with increasing thickness of bark shaving. Excessive bark consumption shortens the economic life of the tree. Nevertheless, low frequency tapping systems caused more drying of the bark tissue between tappings and hence a thicker bark shaving per tapping is required. In calculating the tapping life of rubber trees, a bark consumption of 0.125 cm (1/20") per tapping excision has been used. In general, the maximum number of tapping days that could be achieved in Sri Lanka is *ca.* 320 per annum, therefore, 160 days per tree on a S/2 d2 system. Hence, for the S/2 d2 tapping system, the annual bark consumption will be approximately 20 cm (0.125 cm x 160). Similarly for the S/2 d3 tapping system the annual bark consumption will be *ca.* 14 cm (0.125 cm x 107). Bark regeneration (formation of the renewed panel) is brought about by the activity of the cambium. The rate and the extent of renewal are dependent on the inherent genetic characters of the planting material, fertility of the soil, climatic conditions, tapping system, intensity and quality of tapping, planting density, disease incidence, *etc.*

4.3.9 Time of tapping

The yield of latex from tapping depends mainly on the initial flow rate of the latex which in turn depends on the turgor pressure in the latex vessels. The turgor pressure normally falls as a result of withdrawal of water under transpirational stress during day time. The lowest turgor pressure is recorded at 1300-1400 hours and started recovering slowly during night. The highest yield of latex is obtained by tapping in the early hours of the morning and late tapping will reduce latex yield due to lower turgor pressure in the latex vessels. Such yield reductions will be significant on cloudless, bright and sunny days. In practice, the beginning and end points of the task are changed periodically to allow comparable latex yield from all the trees in a block. Tapping of wet trees is not recommended. In such cases, delay in tapping until the trees get dry is acceptable due to the fact that much latex is often lost by dripping off the tapping cut and there is also a risk of infection.

4.3.10 Tapping task

The number of trees assigned to a tapper to be tapped in a day is referred to as the tapping task. The stand/ha, topography of land, number of tapping cuts and distance between the block and the weighing point should be considered when fixing the task size. The normal tapping task varies from 275 - 325 trees.

4.3.11. Factors affecting tapping efficiency

Tapping is a skilled operation and hence the efficiency of tapping varies from person to person and is influenced by a number of factors. In general, young trees are given to experienced tappers with the objective of minimizing wounding. Proper supervision is necessary to ensure that the tappers complete their tasks and do not leave trees untapped. They must also ensure that tapping is carried out to proper slope and depth and latex flows along the cut into the cup and never spills over the panel. As mentioned earlier, tapping at dawn is most preferred since hydrostatic pressure of the tree is high (1.0-1.5Mpa) and diurnal variation in latex flow follows the vapour pressure deficit of the air.

Tapping efficiency is influenced by the condition of the field. If weeds and other obstacles are not cleared from the inter-row, tappers will find it difficult to tap their trees efficiently. Sharpness of tapping knife is very much essential as blunt tapping knives cause wounds on bark. Age of trees also affects tapping efficiency. Normally, it requires less time for tapping on BO-1 panel than on BO-2 panel because of lower girth. When tapping on renewed panel, the time taken may still be higher due to increased length of tapping cut and condition of the bark.

4.4 Current tapping systems

Tapping systems depend on clones and are devised to harvest the highest possible yields, *i.e.* economic yields, during the entire tapping cycle. In general, the modern clones are capable of yielding *ca.* 6 - 8 kgs of dry rubber/tree/annum during peak yielding periods. Also, certain clones are capable of giving a relatively higher

yield/tree/tapping (g/t/t) than the other recommended clones. From such clones the potential yield can be obtained by tapping a tree once in three days, *i.e.* d3 frequency, whilst the other clones will need a higher frequency of tapping, *i.e.* d2 frequency. If high g/t/t clones are tapped at d2 frequency such clones are unable to sustain high yields and are prone to tapping panel dryness. Therefore, the clones recommended for planting are broadly classified as d2 and d3 tapping clones. Anyhow, the length of the tapping cut is the same for both d2 and d3 clones, *i.e.* half spiral (S/2) (Table 16.1).

Table 16.1. Recommended clones and their tapping systems.

Tapping System	Clones
S/2 d/2	: RRIC 100, RRIC 102, RRIC 121, RRIC 133, RRISL 201, RRISL 203, RRISL 205, RRISL 208, RRISL 210, RRISL 219, All RRISL 2000 series clones, BPM 24, RRIM 712, PB 255, PR 255, PR 305, RRII 105
S/2 d/3	: RRIC 130, RRISL 206, RRISL 211, RRISL 217, PB 28/59, PB 217, PB 235, PB 260

The above tapping systems can be used for tapping of panels BO-1, BO-2 and BI-1, *i.e. ca.* 18 and 21 years of tapping using S/2 d/2 and S/2 d/3 systems respectively.

4.4.1 Intensification in tapping

In order to arrest the yield decline evident in Panel BI -2 and to harvest the maximum crop prior to uprooting of the rubber tree, intensified tapping is recommended after the tapping of panel BI – 1, *i.e.* during last six years (Table 16.2).

Table 16.2. The scheme of intensification for last six years of tapping.

Year of intensification	Tapping system	
1 st 2 nd & 3 rd years	S/2 d2 + S/4U d2	150%
4 th & 5 th year	2 x S/2DU d2	200%
6 th year (final)	2 x S/2 d2 + 2 x S/2 U d2	400%

During first three years of intensification (19th to 21st years of tapping), in addition to panel D (BI-2), an upward quarter cut is made on the opposite higher panel (HO-1). Each upward cut should be tapped only for 1½ years under d2 system. During the 4th and 5th years (22nd & 23rd years of tapping) upward and downward half spiral cuts are also made on opposite panels along with what has been tapped during the first three years. During the last year (24th year of tapping), a total of 4 half spiral cuts, two tapped upwards and two tapped downwards on opposite panels, are made.

The upward cuts should be at an angle of 45⁰ to the horizontal. Further, when two cuts are introduced they should be at least 50 cm apart to prevent overlap of the drainage area. For d2 frequency of tapping bark allocation is 25cm in the first year. Bark allocation could be increased in subsequent years.

4.4.2 Panel position

The position of the tapping panel during each year of the 24 years tapping cycle is described in Fig. 16.5.

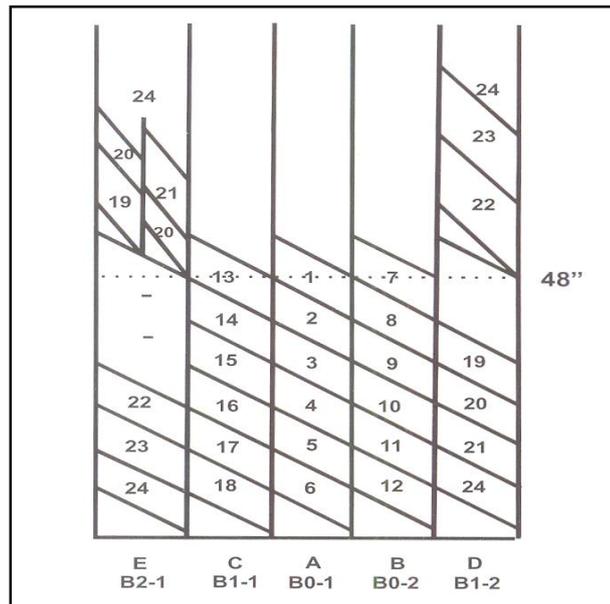


Fig. 16.5. Panel position and tapping system for each year of tapping.

4.5 Controlled upward tapping (CUT)

Controlled upward tapping can be practiced when virgin panels have been consumed earlier than recommended. This will allow more time for BI-2 (D) panel to renew. CUT is useful to utilize high panels effectively and to obtain high yield. It will also extend the replanting cycle by delaying intensified tapping (additional 4 years can be tapped using this method).

Quarter spiral upward cuts are introduced above the renewed bark (BI-2) during first two years. The first quarter panel should be attached to Poikanu. In the 3rd and 4th years, virgin bark above the BII-1 panel is tapped. However, the panels should be changed every 3 months. Being an upward cut, tapping angle should be maintained at 45⁰ to ensure better control, minimum injury of cambium, lower bark consumption and minimum spillage of latex along the panel. In order to avoid any waste of bark, all upward cuts should be commenced at the same height where lower cuts had been introduced. 5% Ethephon should be applied at monthly intervals and

tapping frequency should be d3. Rainguards have to be used to get an optimum yield for a longer period. Stimulants can be applied just below the tapping cut without removing the lace.

4.6 Tapping panel dryness

Tapping panel dryness (TPD), commonly known as brown bast, is a major syndrome encountered in tapping trees in rubber plantations. It can be defined as “a tappable rubber tree which is unable to give economic yields through any recommended tapping technique due to non production or obstruction in latex flow in the drainage area of the tapping cut”. In today’s context, TPD is of great concern because of the high yield loss, which can exceed even 50% in some mature rubber plantations. The incidence of TPD depends on the age, clone, level of agro-management practices and quality and frequency of exploitation.

The term TPD is related to two types of physiological symptoms. Firstly, a temporary halt in latex flow is reversible after a resting period for the trees (Plate 16.4a & b). This form of TPD is related to an overproduction of reactive oxygen species (ROS) in laticifers, and can lead to a situation called ROS-TPD. In aggravated conditions, an irreversible-type of TPD occurs that is called brown bast TPD (BB-TPD) (Plate 16.4d). The latter involves histological deformation of bark due to thylousoid formation, lignified gum, and abnormal division of parenchyma cells, and may be related to a cyanogenesis process. During the development of TPD, many physiological and biochemical changes occur, including decrease of sucrose and dry matter and increase of inorganic phosphorus in the latex, increase of activities of RNase and proteinase and decrease of the content of protein, nucleic acid, thiols, ascorbic acid, the levels of variable peroxidase and superoxide dismutase isozyme (SOD), and the impaired rubber synthesis. Uncompensated oxidative stress within the latex cells might be associated with membrane destabilization that ultimately results in bursting of the lutoids and consecutive *in situ* latex coagulation.

Normal yielding rubber trees will yield very little or no latex with the onset of tapping panel dryness. This change in the yielding potential of the tree can be gradual or sudden. Generally, high g/t/t clones are more susceptible to this syndrome. Over exploitation of trees, use of excessive yield stimulants, curtailing of fertilizer use whilst harvesting and tapping of wet panels favour incidence of dryness. TPD susceptibility depends also on the planting material (genetic susceptibility and rootstock-scion interaction) and the environment (harvesting system, abiotic and biotic stress, soil compaction, *etc.*). So the choice of clones and harvesting systems (management of tapping panel, tapping frequency, ethephon stimulation) must be carefully adapted to the eco-climatic conditions and intrinsic latex metabolism of the rubber clone. Tapping can be reconsidered after a resting period up to bark regeneration. In some instances, dryness is temporary. Such trees will yield when the tree is rested for a period of *ca.* 6 months. If trees do not recover after the period of rest a S/4 cut can be introduced on the higher panel opposite to the dry panel. When exploiting previously dry trees, *i.e.* recovered or S/4U cuts on unrecovered trees, recovery tapping should not be done on them.



Plate 16.1. Exploitation of rubber. Pretapping procedures. **a.** Tapping through systematic removal of a thin shaving of bark; **b.** A rubber tree is tappable only when a girth of 50 cm, measured at 120 cm from the highest point of tree union, is reached; **c.** d/2 and d/3 stencils made out of aluminium sheets; **d.** Modified Michi-Golledge tapping knife used in Sri Lanka.



Plate 16.2. Exploitation of rubber. Pre-tapping procedures. **a.** Drawing of neththi kanu commencing at a height slightly above the height of opening; **b.** Marking of opening height on the neththi kanu; **c.** Half circumference is determined at two points and marked on the tree; **d.** Drawing of poi kanu to divide tree into two equal halves.



Plate 16.3. Exploitation of rubber. **a.** Drawing of guidelines using appropriate stencil; **b.** Guidelines drawn on a tree with a high left to low right orientation. After the marking of guidelines spout, cup hanger and cup should be placed correctly; **c.** Guidelines should be marked each year to guide the tapper for correct tapping.

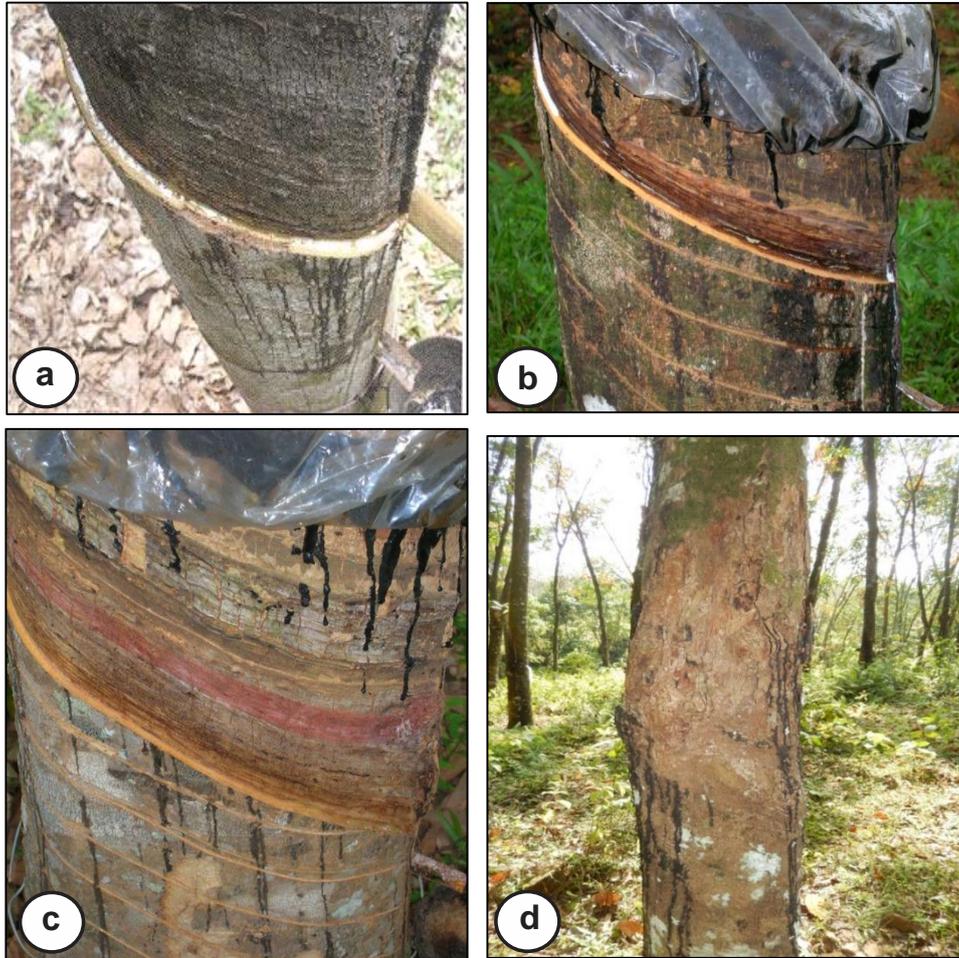


Plate 16.4. Tapping panel dryness in rubber trees. **a.** and **b.** partially dried tree with TPD symptoms, **c.** a fully dried tree, **d.** a fully dried tree with brown bast symptoms.

Chapter 17

Use of yield stimulants and tapping notation

Chamil Nayanakantha

1. Yield stimulation
 - 1.1 Mode of action of stimulants
 - 1.2 Renewed bark stimulation
 - 1.3 Virgin bark stimulation
2. Tapping notation
 - 2.1 Tapping method
 - 2.2 Panel position and type
 - 2.3 Stimulation
 - 2.3.1 Method of application
 - 2.4 Complete notation for exploitation system
3. Tapping intensity
 - 3.1 Relative tapping intensity
 - 3.2 Actual tapping intensity

1. YIELD STIMULATION

In the past, the sole objective of stimulating a rubber tree was to enhance income levels from rubber cultivations through increased latex dry rubber yields. However, indiscriminate use of stimulants during this period had resulted in negative impacts. In this context it is imperative to realize the fact that the dry rubber yield that could be obtained from a tree will ultimately be determined by the capacity of the tree to produce it. If deliberate attempts are being made to harvest yields higher than what the tree could give, *i.e.* the potential yield, the tree will not be able to sustain such high yield levels. This could lead to reduction of the economic life span of the tree resulting in poor returns for the investments. Therefore, stimulants need to be used at correct concentration, quantity and frequency for the grower to benefit from this technology in a sustainable manner.

In the current scenario, stimulants are used to obtain only the potential yield with lowest tapping costs. This is achieved through low frequency tapping (LFT) coupled with yield stimulation. Various chemicals have been tried in the past as effective yield stimulants, but 2-chloroethyl phosphonic acid (Fig. 17.1) has been found to be the best for this purpose.

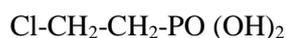


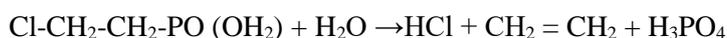
Fig. 17.1. The chemical formula of 2 - Chloroethyl phosphonic acid

This stimulant is now available in the market under various brand names such as Ethrel, Ethepon, Ethepon Plus, Mortex and Levotex. Anyhow the active ingredient in all of these yield stimulants is 2-chloroethyl phosphonic acid. The above yield stimulants are currently marketed in gel form. This helps to apply the

stimulant effectively on the tree. If the stimulant is watery wastage could occur due to dripping. Currently above stimulants are recommended to obtain high yields from the renewed bark. Moreover, it is recommended even on virgin bark when tapped at lower frequency to reduce the tapper requirement. As virgin bark stimulation is recommended only with LFT, it has other advantages such as low tapping costs, higher tapper income, use of skilled tappers only with the low tapper requirement and enhancing the economic life span of the tree.

1.1 Mode of action of stimulants

2-Chloroethyl phosphonic acid in its liquid state and at low pH levels is a stable compound. However, when it gets into the rubber tree due to the relatively high level of pH in the plant tissues, it reacts with water and yields ethylene. This chemical reaction which takes place within the tree is shown below;



Cl-CH ₂ -CH ₂ -PO (OH) ₂	= 2-Chloroethyl phosphonic acid
H ₂ O	= Water
HCl	= Hydrochloric acid
CH ₂ = CH ₂	= Ethylene
H ₃ PO ₄	= Phosphoric acid

Ethylene released in this manner within the plant, is the chemical actually responsible for increasing yields from rubber trees. Stimulation delays latex vessel plugging and prolongs duration of latex flow. Further, the increase in latex pH consequent to stimulation increases rate of latex regeneration through enhanced enzyme activity. Therefore, enhanced yields through use of Ethephon are due to delaying of plugging and increased rate of latex biosynthesis.

Generally low g/t/t clones respond better to yield stimulation when compared to high g/t/t clones. Therefore, both renewed and virgin bark stimulation is not advocated for clones recommended for d/3 frequency tapping. Clearings with high yields under d/2 frequency tapping would bring the greatest return from stimulation. Thus, stimulation should be done only in clearings whose agro-management and yields are good. Clearings with poor yields as a consequence of poor management and hence poor growth or due to over exploitation should not be stimulated. If stimulated the response will be poor, short-term and uneconomical.

To achieve the full benefit of stimulation split task application is recommended. In this method trees in one half of the tapping task are stimulated first. These trees should be tapped first and collection of latex done only at the end. The other half of the trees should be stimulated 2 weeks later. Then, the tapping of these trees should be done first and collection done last. To achieve a sustainable response from stimulation the nutrient status of the trees has to be maintained by application of a complete fertilizer based on foliar analysis. Stimulation has to be undertaken during dry periods and also in the cropping months to achieve highest

returns. Interruption of tapping after stimulation and washing away of stimulants result in a poor yield response during wet months. Stimulation should be carried out on a non-tapping day.

Stimulants are applied either on the bark, panel or the groove of the tree. What is important here is one to ensure that the stimulant applied will get in to the tree. Therefore, if bark application is under taken, the bark should be lightly scraped to remove dead cork cells, enabling the stimulant to move into the tree.

Light scraping is not necessary for panel application. If wood is exposed in more than 25% of the area of the panel where the stimulant is to be applied due to deep tapping the stimulant applied will not get absorbed to the tree. This is because the wood does not have the capacity to absorb the chemical. A rainfall prior to this resulting in water seeping along the tree trunk could lead to the stimulants getting washed off fully or partly, depending on the timing and intensity of rainfall.

1.2 Renewed bark stimulation

Trees can be stimulated by 2.5% Ethephon. Commercially available 5% Ethrel could be mixed with an equal volume of warm water (*ca.* 50°C) to obtain 2.5% Ethrel. With 2.5% Ethrel, 4-5 rounds of stimulation per tree can be undertaken per year for d3 frequency and 10 rounds per year for d4 frequency. Nevertheless, 4-5 rounds of stimulation per year may not be possible without rainguards due to the interference of rain. Also, stimulation has to be done in cropping months. The best months to undertake stimulation are given in Table 17.1.

Table 17.1. Months suitable for stimulation

Stimulation round	Months for stimulation
1	January
2	June
3	August
4	November

On the renewed bark, panel application (P_a) of the stimulant is recommended. For P_a apply Ethrel on a 2.5 cm band 1 cm above the cut on the tapping panel. The quantity to be applied is 1.6 g of 2.5% Ethrel per tree per application.

1.3 Virgin bark stimulation

Rubber trees should be tapped at $\frac{1}{2}S$ d/3 or at a lower frequency to undertake virgin bark stimulation. Nevertheless, clones recommended for d/3 frequency tapping, *i.e.* high g/t/t clones, should not be stimulated. Virgin bark stimulation can be undertaken from the first year of tapping. Four to five rounds of stimulation per annum is recommended using 2.5% Ethrel. For virgin bark the method of stimulation advocated is bark application (B_a). A 2.5 cm band just below

the tapping cut is scraped and 1.6 g of 2.5% Ethrel is applied per tree per application (Plate 17. 1).

2. TAPPING NOTATION

Tapping is the action of opening the latex vessels of a rubber tree. Many tapping practices have evolved over the years which included complicated systems such as the herringbone system. Local names were given to each system and this led to confusion and difficulties. Thus, an internationally acceptable tapping notation was needed and on the initiative of the International Rubber Research and Development Board (IRRDB) a tapping notation for *Hevea* was developed and revised time to time. The latest version was published by Vijayakumar *et al.* (2009).

The tapping notation is a series of letters, numbers, symbols and punctuations describing the length and type of tapping cut, the direction of tapping, the sequence and the frequency of tapping in a certain period of time. It also includes notation for stimulation *viz.*, the type of stimulant, the concentration and the volume of the stimulant used, the method of application, the frequency of applications, the number of applications in a year, *etc.* The advent of gaseous stimulation technology, increased popularity of rain guarding and others make it necessary to give abbreviations to these also. The tapping notation denotes

- tapping method
- panel position and type
- stimulation method.

2.1 Tapping method

Symbols for tapping method describes the number and nature of the cuts.

- a). Symbol of cut - Cut tapping is the operation in which a thin shaving of bark is excised for the extraction of latex. The symbol of type of cut is denoted by a capital letter or a capital letter followed by a small letter. Four symbols are used to represent four types of cuts;

Examples:

S	= Spiral cut
C	= Circumference (unspecified).
Sc	= Small cut (<S/4 and > 5 cm cut)
Mc	= Mini cut (cut length of 5 cm and less).

- b). Length of cut - This is expressed as a relative proportion of the trunk circumference that is embraced by the tapping cut and hence it does not refer to actual length. However, the length of small cut and mini cut are expressed directly in centimeters. A fraction preceding the symbol of cut denotes the relative length of cut. For the minicut, the actual length is denoted in centimeters.

Use of yield stimulants and tapping notation

Examples:

S/1	= one full spiral cut
S/2	= one half spiral cut
S/4	= one quarter spiral cut
S/3	= one third spiral cut
3S/4	= three fourth spiral cut
Sc 8	= small cut of 8 cm
Mc2	= mini cut, the length of cut is 2 cm

- c). Number of cuts - A tapping system with more than one cut of the same type may be applied on a rubber tree, either they are tapped on the same tapping day or on alternate tapping days or season. The number of cuts is represented by a figure before the length of cut notation and a multiplication sign is inserted in between.

Examples:

2 x S/2	= two half spiral cuts.
4 x Mc 2	= four mini cuts of 2 cm length.

When tapping cuts are of different types these are indicated by '+' sign or punctuations ';' or ',' depending on the sequence of tapping.

- d) Direction of tapping - Direction of tapping is normally downward. When tapping is downward only, no symbol of direction is used. For upward tapping, the symbol is English alphabet U (capital letter) immediately after the cut notation (without space). When two directions of tapping are being applied on the same tree in both downward and upward directions the symbols D and U are shown together as DU after the cut notation concerned. In combination tapping, the downward direction need not be indicated. When tapping is downward only, no symbol of direction is used. However, when upward tapping is practiced an upward arrow (↑) is used within brackets immediately after the cut notation. If two cuts are tapped, one in each direction, use upward and downward arrows, *e.g.* (↑↓).

Examples:

S/2	= one half spiral cut tapped downward.
S/4U	= one quarter spiral cut tapped upward.
2 x S/4DU	= two quarter spiral cuts one quarter cut tapped downward and the other quarter cut tapped upward.
S/2 + S/4U	= one half spiral cut tapped downward and one quarter spiral cut tapped upward

- e) Frequency of tapping
Notation for frequency of tapping describes the interval between tapping expressed as number of days. The other notations of the tapping frequency which may possibly follow this are for practical frequency, periodicity and

change over. One letter space is to be left in between notations of the frequency of tapping.

(a) *Actual frequency:*

The notation for actual frequency is denoted as the interval between tappings in days expressed by the letter d followed by an Arabic numeral.

Examples:

d2 = alternate daily tapping (once in two days)

d3 = third daily tapping (once in three days)

d4 = fourth daily tapping (once in four days)

(b) *Practical frequency*

Where continuous tapping is broken by a regular day (or days) of rest, a fraction is written after the actual frequency. The fraction showing the 'practical frequency' has a numerator, the number of days tapped in a period, the period being denoted by the denominator.

Example;

d2 6d/7 = alternate daily tapping, six days in tapping followed by one day of tapping rest in one week.

d3 6d/7 = tapping once in three days with one day of tapping rest in one week.

If there is no tapping rest in a week, the practical frequency will not be mentioned or can be written as 7d/7.

f) *Periodicity*

Periodicity consists of details of weeks (w), months (m) and years (y). The numerator of each fraction denotes the tapping period while the denominator denotes the length of the cycle (tapping period + tapping rest). Each succeeding fraction in the periodicity notation modifies the period of operation of the previous fraction.

Examples:

2w/4 = two weeks in four (two weeks in tapping followed by two weeks of tapping rest).

3m/4 = three month in four (three months in tapping followed by one month of tapping rest).

When the period of tapping is less than 12 months, the full cycle of tapping in a year can be shown in parenthesis after number of months by writing the starting and closing months separated by a hyphen. Months will be written in three capital letters.

Use of yield stimulants and tapping notation

Examples:

9m (JUN-FEB)/12 = Annual tapping period for 9 months from June to February with three months of tapping rest during March to May.

9m (MAR-NOV)/12 = Annual tapping period for 9 months from March to November with three months of tapping rest from December to February

- (g) Number of tapping days realized
After expressing periodicity, actual number of tapping days can be mentioned as a fraction of the total number of tapping days that would have been possible as per schedule

95/104 = 95 tapping days realized against 104 scheduled tapping days.

d3 6d/7 95/104 = third daily tapping, six days in tapping followed by one day of tapping rest, 95 tapping days realized out of 104 possible tapping days in a year.

- (h) Rainguarding
Rainguarding is essential for the success of low frequency tapping. Rainguarding can be included in the tapping notation with 'RG' as its notation. RG can be written in parenthesis after the notation of the cut without any space in between.

Examples:

S/2(RG) d3 = a half spiral cut with rainguarding tapped on third daily frequency.

2 x S/2(RG) d3 = two half spiral cuts, both the cuts with rainguarding, both the cuts tapped on the same day at third daily frequency.

S/2(RG), S/2 d2 = Two half spiral cuts, one with rainguarding and the other without rainguarding, tapped at alternate daily frequency.

2.2 Panel notation

Panel is the area of bark of the rubber tree in which the tapping cut is located. Panel notation is the symbol or series of symbols, which describe the panel location and the panel renewal succession of the tapping panels. With the introduction of short cuts, panel notations A and B to denote original bark and C and D to denote first renewed bark were changed.

Normal panels where cuts are opened at a height of 120 cm above the union and tapped downward are termed 'Base' panels and are denoted by the letter 'B'. Panels above these are denoted by the letter 'H'. The base panel virgin bark, the first renewed and second renewed bark are designated as the base panels by the symbols BO, BI and BII respectively and the sequence of panels are indicated by a

number. For the high panel, the letter 'H' is used. The sequence of panel is denoted by a number (Arabic).

The panels located above the height of the first opening for cut tapping of clones are called the 'high panels' and denoted by the letter 'H' (high). The panels formed below this opening are considered the base panels and for them the letter 'B' is used.

Examples:

- BO - 1 = base panel 1
- BO - 2 = base panel 2
- HO - 1 = high panel 1
- HO - 3 = high panel 3
- BI - 3 = the third panel on first renewed bark of the base panel.
- BII - 2 = the second panel on the second renewed bark of the base panels.
- HO - 4 = the fourth panel on virgin bark of the high panels.

2.3 Stimulation notations

Stimulation notation consists of three parts. The first part denotes type of stimulant and its concentration. The place of application, quantity of stimulant and method of application are described in the second part. Thirdly, the number of applications and periodicity are indicated. Space must be given between these units to differentiate them clearly.

The stimulation notations are not separated from the tapping notations. The two should be presented together as complete notation with a full stop inserted between them. The notations of stimulation are grouped into three units in the order – stimulant, application and periodicity. Concentration of the active ingredient of the stimulant in the formulation used should be noted immediately after the code of the stimulant.

Examples:

- ET = Ethephon
- ETG = Ethylene gas
- CaC₂ = Calcium carbide
- ST = Stimulant unspecified
- ET 2.5% = Stimulated with 2.5% of ethephon
- ETG 99% = Stimulated with 99% ethylene gas.

2.3.1 Method of application

The symbol consists of two letters, a capital letter followed by small letter.

Examples:

- Pa = Panel application (on the renewing bark close to the tapping cut)
- Ba = Bark application (on scraped bark to be tapped)

Use of yield stimulants and tapping notation

La = Lace application (on the tapping cut over tree lace)

Ga = Groove application (on the tapping cut after removal of tree lace)

2.4 Complete stimulation notations

Examples:

ET5.0% Pa2(2) 8/y(m) = stimulated with 5% ethephon, panel application, 2 g of stimulant per application on 2 cm band, eight applications per year applied at monthly interval.

S/2 d3 6d/7 ET2.5% Pa2(2) 8/y(m) = half spiral cut without rainguard tapped downward at third daily frequency, six days in tapping followed by one day of tapping rest, stimulated with ethephon of 2.5% active ingredient with 2 g of stimulant applied on panel on 2 cm band, eight applications per year at monthly intervals (scheduled tapping system with scheduled ethephon stimulation).

S/2(RG) d3 6d/7 95/104. ET2.5% Pa2(2) 8/y(m)6/8 = Half spiral rain guarded cut tapped downward at third daily frequency, six days in tapping followed by one day rest, with 95 tapping achieved against 104 scheduled tapping days per year. Stimulated with 2.5% ethephon with 2g of the stimulant applied on panel on 2 cm band, eight scheduled applications per year at monthly intervals. Six stimulations could be done against the scheduled eight per year.

3. TAPPING INTENSITY

Tapping intensity can be calculated from various components of the tapping notation to provide a parameter for comparison and evaluation. Relative tapping intensity (RI) is no longer considered valid as an estimate of the physiological intensity of exploitation, for comparison and evaluation of tapping systems. Actual intensity (AI), which is more suitable for this purpose may be calculated from the total number of days tapped (including recovery tapping). The methods of calculating relative and actual tapping intensity are described below.

3.1 Relative tapping intensity:

The relative intensity is expressed in percentage of the standard systems.

Example:

S/2 d2 or S/4 d1 = 100%

To calculate the relative intensity, multiply four times the ratio of the length of tapping cut (expressed in fraction) and the tapping interval with 100.

S/2 d2 = $4 \times \frac{1}{2} \times \frac{1}{2} \times 100 = 100\%$

S/2 d3 = $4 \times \frac{1}{2} \times \frac{1}{3} \times 100 = 66.6\%$

3.2 Actual intensity:

The actual intensity is the amount of tapping actually realized and expressed in percentage. To calculate the actual intensity, multiply four times the length of tapping cut in the formula by the average number of tappings (tapping days per year) and divide by the total number of days in the given period (year).

Examples

$$S/2 \text{ d}2 = 4 \times \frac{1}{2} \times \frac{167}{365} \times 100 = 92\%$$

$$S/2 \text{ d}6 = 4 \times \frac{1}{2} \times \frac{50}{365} \times 100 = 27\%$$

Reference

Vijayakumar, K R, Gohet, E, Thomas, K U, Xiaodi, W, Sumarmadji, Rodrigo, L, Kimthanh, D, Sopchoke, P, Karunaichamy, K and Said, M A M D (2009). Special Communication: Revised international notation for latex harvest technology. *Journal of Rubber Research* **12**(2), 103-115.

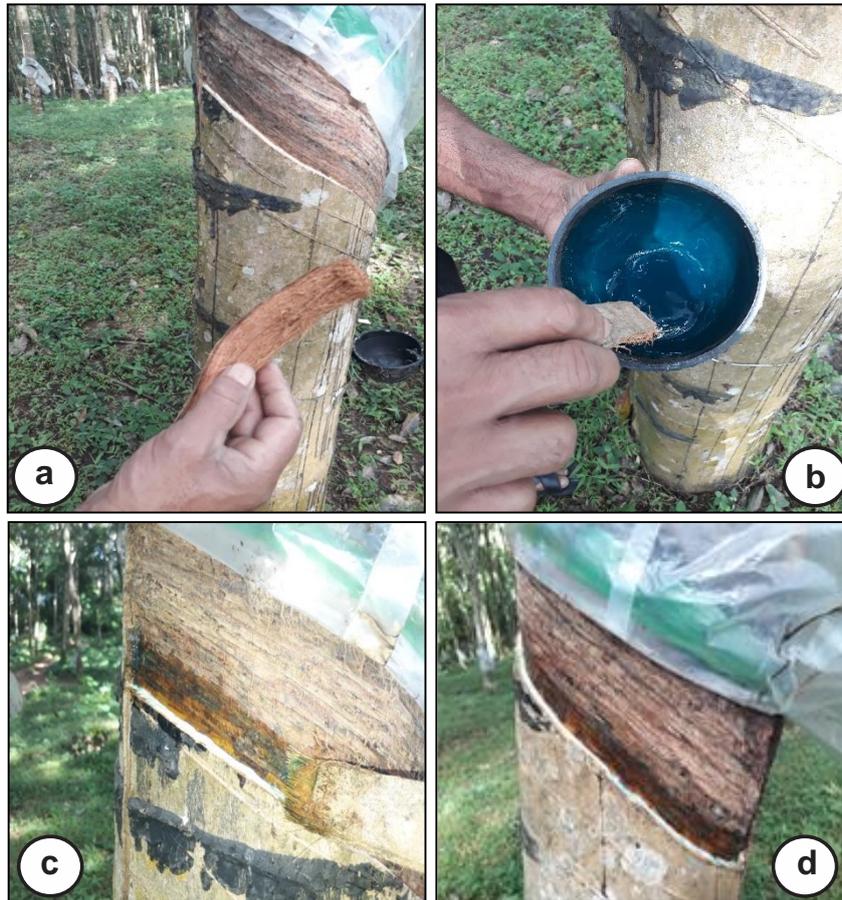


Plate 17. 1. Stimulation of virgin barks. **a.** A brush made out of coconut husk for application of stimulant; **b.** Dip half an inch of the brush in the stimulant; **c.** Application of stimulant on the tapping panel; **d.** A tapping panel after application of stimulant.

Chapter 18

Minimizing of crop losses due to interference of rain on tapping

Chamil Nayanakantha

1. Introduction
2. Grooming
3. Recovery tapping
4. Rainguards
 - 4.1 Types of rainguards
 - 4.2 Sealant
 - 4.2.1 Ingredients needed
 - 4.3 Economics of using rainguards

1. INTRODUCTION

Rain interferes directly with the harvesting of latex from rubber trees and therefore, tapping on rainy days is not practiced. Tapping of wet panels is not recommended as it leads to panel diseases caused by *Phytophthora meadii/P. palmivora*. Also it interrupts flow of latex leading to wastage. Each year around 100 days of tapping are lost due to wet panels. Further, commencement of tapping of about 50 days of the year is delayed due to rain sometimes up to 10 am to 12 noon, after the panels dry up, *i.e.* late tapping. Also sudden showers occurring between tapping and latex collection result in latex getting washed away prior to collection. In a year *ca* 10 - 15 of such washouts are reported. No tapping, late tapping and washouts lead to about 30 - 35% loss in the potential crop each year. This situation affects the income levels of land owners, tappers and factory workers. Hence, various methods are adopted to minimise the crop loss caused by interference of rain on tapping.

2. GROOMING

During rains, the water is seeping along the trunk and the mosses found on the trunk of the rubber tree absorb part of this water and retain. The water absorbed by mosses in this manner is released only gradually. Thus the tapping panel of the tree remains wet for a considerable period of time even after the rain has ceased. This situation could be avoided by grooming, *i.e.* the removal of the mosses by scraping the trunk on upper (about 60 cm), lower (30 cm) and lateral sides (30cm) of the tapping cut. This quickens the drying up process of the wet panels. Grooming should be undertaken annually, before the onset of monsoons on trees where mosses are found. This will help to increase the number of tapping days and convert late tapping days into normal tapping days. In some clones, *e.g.* RRIC 121, mosses do not grow on the trunk of the tree.

3. RECOVERY TAPPING

Current recommendation is to tap a rubber tree every other day or once in three/four days (low frequency tapping) depending on the clone. This will make it possible to sustain the potential tapper and land productivity levels throughout the tapping cycle. However, to recover the tapping days lost due to interference by rain, recovery tapping, *i.e.* an additional tapping in between two recommended tappings, is recommended. Nevertheless, no recovery tapping should be done during the first three years of tapping and after that, maximum of two per week and 6 per month can be allowed. More importantly, dry and wintering periods should be avoided and a minimum of two normal tappings should be placed in between two recovery tappings.

Nevertheless, a popular approach is to tap the rubber trees continuously when weather conditions permit to do so. As a result, a tapping task is tapped continuously during dry months. With this method the desired objective of the land owner, *i.e.* recovering the crop loss due to not tapping in wet days, cannot be achieved. Daily tapping negatively affects the growth and yield of trees. This is because once the crop is harvested from a tree a certain period of time should be given for it to re-synthesize the latex prior to harvesting it again. Therefore, daily tapping results in severe stress to the rubber plants, lowering of the dry rubber content of latex and tapping panel dryness (TPD) incidence. If uninterrupted tapping is possible for a period in excess of a month, recovery tapping during such periods will not enhance yields.

4. RAINGUARDS

Loss of many tapping days due to rain can be minimized by way of using rainguards, *i.e.* an appliance to protect the tapping panel from rain. When rainguards are used, tapping is always done on dry panels minimizing the incidence of panel diseases. Further, tapping will be undertaken only at recommended frequencies and the necessity to do recovery tapping will not arise. This will enhance the tapper and land productivity.

Rainguards should be fixed before the onset of the South - West monsoon, *i.e.* in March or April each year. Further, refoliation should be completed prior to fixing of rainguards to avoid direct sunlight falling on the newly fixed rainguards. If direct sunlight falls on newly fixed rainguards there is a possibility of the sealant melting. Also rainguards cannot be fixed effectively if the trunk of the tree is wet and therefore, this has to be done only during dry weather, *i.e.* March to early May, when the surface of the bark is free from moisture.

Once the rainguards are fitted onto the trees before the onset of the South West monsoon they will remain effective until January in the following year. After the completion of the effective period, rainguards will need to be refixed in a new position using new material. During the effective period, the performance of the rainguards need to be monitored. Should leaks develop, the brushable sealant should be applied on the seal using a suitable brush.

4.1 Types of rainguards

Two types of rainguards are recommended to the industry, *i.e.* Apron and Kissan types (Fig. 18.1 & 18.2).

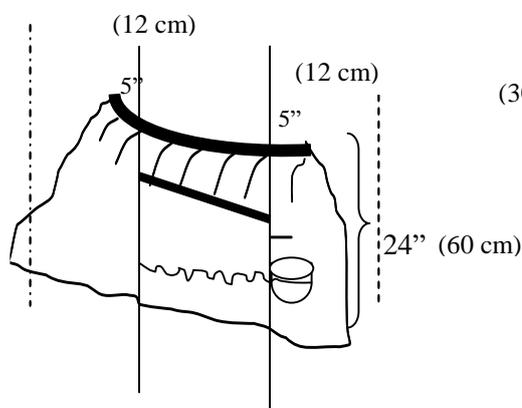


Fig. 18.1. Apron type

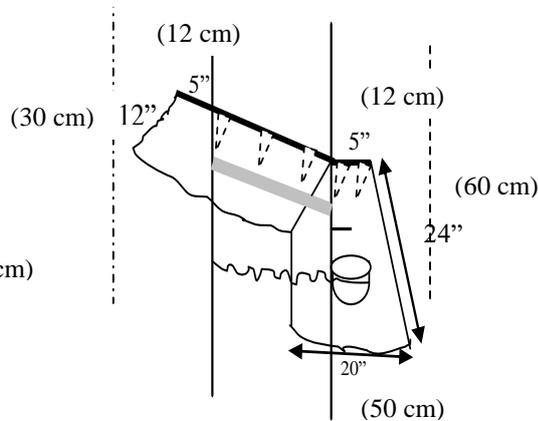


Fig. 18.2. Kissan type

Specifications for the materials other than sealants

Polythene

- Kissan type of rainguard can be made with two strips of 500 gauge high density polythene. Recycled polythene is not suitable for this as they tend to degrade within a few months. The figures 18. 3 & 18.5 illustrate the steps to be followed in preparation of it. One kilo of polythene is sufficient for 28 rainguards
- For apron type, polythene should be of low density and of gauge 300 (gauge 150 for a single sheet), 60 cm in width and transparent. It should be stitched along one edge keeping $\frac{1}{4}$ an inch frill for every inch using a sewing machine. One meter comes to 65 cm after frilling (Fig. 18.4) and 1 kg of polythene is sufficient for 20 trees.
- Cut stitched polythene into 40-45 feet pieces prior to taking into the field in order to minimize wastage caused by differences in the size of trees.

Other items

- Medium size stapler with pins (10 boxes of 24/6 staplers are sufficient for 100 trees).
- 1" width strip of cotton cloth (when using liquid sealant). One yard of 60" width cloth is sufficient for 70 trees.
- 500 gauge polythene cut into 2 cm width strips (when using semi solid sealant). One kg of polythene is sufficient for 400 trees.

Minimizing of crop losses due to interference of rain on tapping

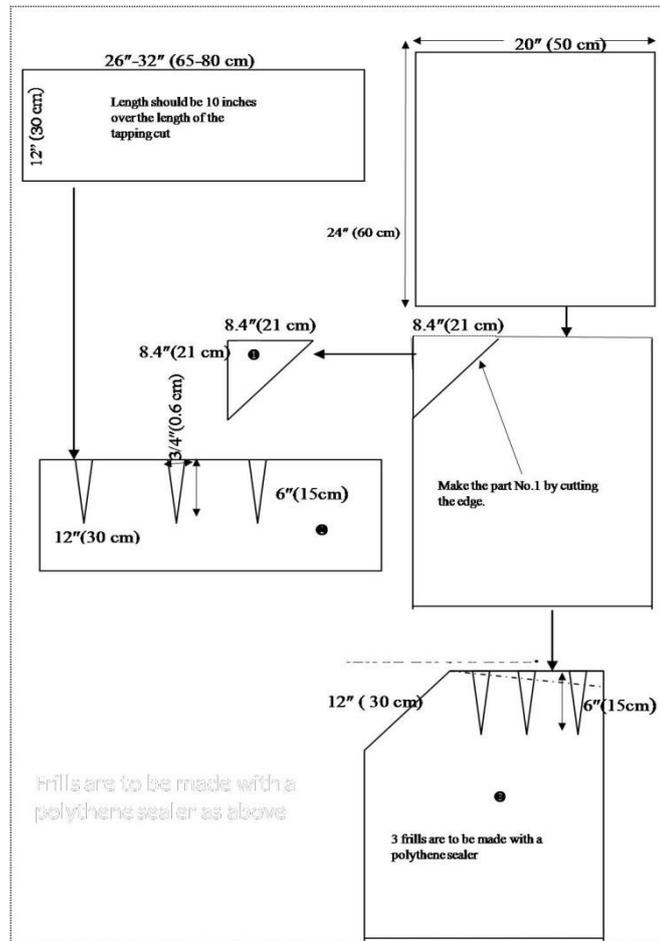


Fig. 18.3. Preparation of polythene for a Kissan type rainguard

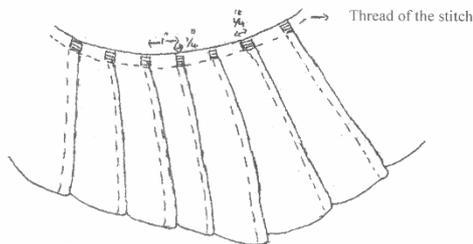


Fig. 18.4. Preparation of polythene for an Apron type rainguard

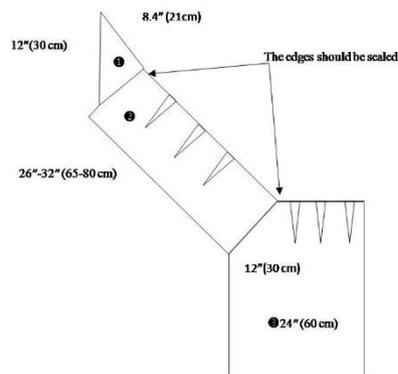


Fig. 18.5. After joining three pieces with a polythene sealer for a Kissan type

Steps to be followed in fixing rainguards

- a. Bark of the rubber tree should be dry to fix the rain guard.
- b. Lightly scrape a 5-7 cm strip on the tapping panel parallel to but 10-15 cm above the tapping cut (Plate 18.1a).
- c. Scraping should exceed the length of the cut by 15 cm at each end.
- d. It is advisable to fix rainguards about two days after scraping.
- e. Clean the bark with a piece of cotton material before fixing rainguards.
- f. In the case of apron type rainguard, cut the frilled polythene to a length two inches less than the total length of the scraped bark. The cutting edge should be parallel to “*neththi kanu*” and “*poi kanu*” in order to cover the latex cup properly.
- g. If liquid type of sealant is used, apply a *ca.* 3-4 cm band of it along the scraped strip of the bark using a brush made out of coconut husk. (Heat the sealant lightly if it is too hard to apply).
- h. In the case of semi solid sealant, apply a little thick band about 2cm width (Plate 18.1b)
- i. The top edge of the rainguard is to be placed along the middle of the sealant strip.
- j. On top of this edge, fix the 2 inch polythene strip (500 gauge) using 6-9 staplers. It is important to extend the polythene strip one inch away from both the side of the rain guard.
- k. If the liquid sealant is used, a cotton strip is to be used instead of polythene strip.
- l. Whilst tapping, rainguard is to be lifted. However, it should be put down soon after.
- m. Regular maintenance should be done as given in the time schedule below;

4.2 Sealant

Two types, *i.e.* liquid and semi solid, of sealants are used for fixing the Apron or Kissan type rainguard. For the rainguards to be effective during the life span of one year the sealant needs to be prepared according to recommended procedures.

4.2.1 Ingredients needed

For both liquid and solid type sealant the ingredients needed are the same. Nevertheless the ratio in which ingredients need to be mixed is different (Table 18.1).

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Table 18.1. Quantities of raw materials required to prepare 100 kg of sealant.

Material	For Liquid type	For Semi Solid type
Tar	67.7kg	58.1 kg
China Clay	22.5kg	29.1kg
Rubber (as field latex)	9kg*	11.6kg*
Sulphur	0.9kg	1.2kg

* Volume of field latex needed will depend on the % dry rubber content of it. 22.5 and 29 litres of 40% DRC latex is needed to obtain 9 and 11.6 kg of rubber.

Steps in sealant preparation

- Add tar into the barrel and heat until it becomes liquid (Plate 18.3).
- Add latex to the hot mixture little by little.
- Heat the mixture till most of air bubbles disappear.
- Add china clay to the mixture gradually (in 5 aliquots) with continuous stirring. Initially a half and then little by little.
- Once everything is mixed properly, remove the fire.
- Add sulphur and mix properly.

Storage

Both semi solid and liquid sealants can be stored in tin.

Warning!

Make sure that the flame does not reach to the brim of the container during the entire process of heating. Keep a wet gunny bag to prevent unnecessary fires.

4.3 Economics of using rainguards

The cost of a rainguard will vary with the cost of material needed and labour rates. Nevertheless, for rainguards to be economical additional income should be generated by the crop harvested from the additional tappings made possible.

During the life span of a rainguard which is about one year the number of additional tapping days needed to cover the cost of the rainguard can be calculated as follows:

1. Net sale average per kg of rubber produced = Rs. N_{SA}
2. Tapping and Manufacture cost per kg of rubber produced = Rs. C_{TM}
3. Profit per kg of rubber produced = Rs. $[N_{SA}C_{TM}]$
4. If the cost of either an Apron or Kissan type rainguard is Rs. C , the amount of additional crop needed from each tree to cover the cost of rainguard

$$= \frac{(\text{Rs } C \times 1000)}{(\text{Rs } N_{NS} - \text{Rs } C_{TM})}$$

5. At an average yield of 25 g/t, additional tapping days needed to cover the cost of a rainguard = 25

With current rubber prices and costs and yields, the number of additional tapping days needed to cover the cost of a rainguard is about 10 days. Nevertheless, *ca.* 40 additional tapping days are reported on a tree per year with the use of apron type rainguards. Therefore, use of rainguards will enable land owners and workers to enhance their income levels significantly.

Minimizing of crop losses due to interference of rain on tapping



Plate 18.1. Fixing of an apron type rainguard. **a.** Scrapping exceeding the length of cut by 10cm-12cm at each end; **b.** applying the semi solid sealant as a strip on the scraped area of the bark; **c.** sticking the frilled polythene onto the semi solid sealant; **d.** a tree fixed with an apron type rainguard.



Plate 18.2. a. Fixing of a kisan type rainguard. b. A tree fixed with a kisan type rainguard; c. Lifting of the kisan type rainguard before tapping.



Plate 18.3. The barrel used for the preparation of rainguard sealant.

Chapter 19

Clone Identification

K.K. Liyanage

1. Introduction
2. Importance of clone identification
 - 2.1 Breeding and selection process
 - 2.2 Maintaining bud wood nurseries
 - 2.3 Poly bag plant supply for planting
 - 2.4 Plantation maintenance
 - 2.5 Pest and disease management
 - 2.6 Plant Breeders' rights
 - 2.7 Descriptor lists used in the characterization of a rubber tree
 - 2.8 Legal cases
3. Morphological characterization
 - 3.1 The Key for Morphological classification
 - 3.2 Explanation of the descriptors
4. Identification of common clones
 - 4.1 Morphological characters of some popular clone at immature stage (<2 years)
 - 4.2 Guidelines for the quantitative morphological characters

1. INTRODUCTION

Use of genetically improved high yielding planting materials of rubber in Sri Lanka has showed spectacular performance in the form of raw rubber production and disease tolerance in both estate and small-holder sector. Though a handful of improved high-yielding new clones are available, the genetic base of the existing population is very narrow.

Systematic characterization of rubber clones based on their morphological diversity and identification of morphological markers useful in the characterization of rubber clones has played a vital role in the crop management system and research. Although clones do not exhibit highly distinct variations, most of them possess certain minor, but more or less stable morphological features, which can be used for identification. Knowledge of relatively consistent characters of a clone either singly or in combination will enable identification of different clones recommended for planting. However, the expression of those characters is the result of the interaction of genotype with an environment in a different magnitude. Hence, it is always desirable to consider the traits that are least influenced by the environmental factor.

Use of morphological markers is cost effective when compared to the use of biochemical and molecular markers for preliminary characterization of a large number of accessions. Morphological classification of rubber clones is done based on the set of minimum but important list of descriptors. All the clones recommended for planting can be identified using a standard set of characters. However, the use of highly discriminating descriptors relevant to the clones would help to save the resources.

2. IMPORTANCE OF CLONE IDENTIFICATION

Knowledge of relatively consistent characteristics of a clone will enable planters to identify different clones recommended for planting. It will help them to make sure that the right clones are procured and used for planting. The clone identification is essential in following spheres such as;

2.1 Breeding and selection process

Crop improvement in *Hevea* is accomplished mainly through hybridization, ortet selection and introduction of new clone from foreign countries. In this process, many steps are involved such as crossing between selected parents, screening of segregation generation, selection, evaluation and then release of the clone. Currently large numbers of new clones are evolved by adopting these techniques. The ability to identify diverse clone is important in order to regulate the accurate breeding and selection of correct cultivars.

2.2 Maintaining bud wood nurseries

Bud wood nursery plays a vital role in the propagation of *Hevea*. Buds required for bud grafting are collected from plants raised in the bud wood nursery. Therefore, proper identity of the bud wood produced from bud wood nurseries is essential because any identification error in the bud wood nursery would be multiplied when they are bud grafted for clonal propagation.

2.3 Poly bag plant supply for planting

At present, poly bag plants are the most commonly used forms of planting material. They are produced in the nurseries of both in government sector as well as the private sector. Knowledge of the characteristic features of different clones in poly bag stage is essential for nursery owners to ensure the authenticity of material supplied and also the planter to make sure that he gets the right material.

2.4 Plantation maintenance

The economic viability of a plantation primarily depends on the use of correct planting material for specific location. Clone selection should be given importance in order to have a successful rubber plantation. The choice of any rubber clone depends upon the specific situation in the area where they are intended to be planted. A certain amount of risk has to be taken by the planter in selecting a clone. If not, both mature and immature stands of rubber are impure especially with the large number of newly recommended clones. Such a mixed stand of rubber plantation has given several drawbacks, such as;

- a) Different clones have different initial growth rates and therefore the immature period may vary from 4 to 7 years. In a mixed clearing, opening the trees can be done when the 70% of the stand is tappable. Therefore, the immature period get lengthen unnecessarily for the whole clearing.
- b) Different clones have different growth habits, some have a dense canopy with early branching and some have erect growth habit with open canopy.

Some clones are more prone to wind damage and some can withstand. Therefore, it is very difficult to maintain a plantation of mixed clones with different characteristics in the manageable condition.

- c) Response to the fertilizer may also vary among the clones. As we have observed some new clones are highly dependent on fertilizer. If these clones are mixed with others, some will grow faster than others causing uneven growth of the stand.
- d) Tapping intensity is decided according to clones and application of the correct tapping system which has significant effect not only on the yield but also for the lifespan of the tree.
- e) At the same time, different clones have different bark thicknesses. During the tapping, tappers are used to shave the same thickness. This may result in either under exploitation or damage to the tree.
- f) Chemical properties of latex are also different in different clones. When latex of different properties is mixed, the processing will be affected.
- g) Furthermore, as the yield potential of the clones vary in greater extent, it is extremely important to know the clone of the plantation to be established specially, due to long life span of the tree.

2.5 Pest and disease management

This is another very important phase which we need to identify clones properly because; the rubber tree is susceptible to various pests and diseases all over the world. However, the economic threat of each disease varies from type of clone planted, micro climate and cultural practices adopted. Some clones are more prone to some diseases and some can withstand. If so, when the rubber strands are mixed with different clones, there will be a chance for one clone to succumb to a deadly disease without any possibility for replanting.

2.6 Plant Breeders' rights

In order to implement the Plant Breeders' rights under the intellectual property act, plant breeders' rights shall be granted in respect of plant varieties which they produced. Therefore, clear and distinguishable characters of the clones need to be identified.

2.7 Descriptor lists used in the characterization of a rubber tree

The International Plant Genetic Resources Institute (IPGRI) (now Biodiversity International) is engaged in the preparation of descriptive lists for various crops. These descriptor lists may be completed by local or international organizations involved in the research field, and it provides universally understood criteria or norms for scoring descriptor status of crop species. It will produce a rapid, reliable and efficient means for information storage, retrieval and communication to assist the utilization of germplasm. But yet, *Hevea* is not included in their descriptor list. Therefore, it is necessary to maintain specific descriptors for every single clone by the respective institute to facilitate preparation of rubber descriptors.

2.8 Legal cases

In order to consider the complaints of supply of spurious planting materials by commercial nurseries for both estate and smallholders, it is necessary to have knowledge on clearly distinguishable parameters for different clones at both morphological and molecular level.

3. MORPHOLOGICAL CHARACTERIZATION

Morphological classification was done based on the following descriptors:

3.1 The key for morphological classification

- | | | |
|----------------|---|--|
| 1. Nodes | i. Axillary bud | a. Sunken, b. Normal, c. More or less protruded |
| | ii. Leaf scar | a. Normal – i) Heart shape, ii) Circular shape
b. With pronounced margin - i) Heart shape, ii) Circular shape |
| 2. Leaf storey | i. Shape of leaf storey | a. Conical, b. Truncate, c. Bow-shaped, d. Hemispherical |
| | ii. Separation of leaf storey | a. Well separated, b. Not well separated, c. Diffuse |
| | iii. External appearance of leaf storey | a. Close, b. Open, c. Intermediate |
| 3. Leaves | i. Pulvinus | a. Normal, b. Swollen |
| | ii. Petiole | a. Shape – i) Arched, ii) Strait, iii) Concave, iv) ‘S’ shape
b. Size – i) Long, ii) Medium, iii) Short |
| | iii. Petiolule | a. Orientation – i) Upward, ii) Horizontal, iii) downward
b. Angle – i) Wide, ii) Narrow
c. Size - i) Long, ii) Medium, iii) Short |
| | iv. Leaflet | a. Colour – i) Dark green, ii) Light green, iii) Yellowish green
b. Lustre - i) Dull, ii) Glossy
c. Texture - i) Leathery, ii) Smooth
d. Shape - i) Elliptical (broad, normal or diamond), ii) Obovate
e. Size (Leaf area) - i) Large, ii) Medium, iii) Small
f. Thickness - i) Thick, ii) Thin
g. Leaf margin - i) Smooth, ii) Regular wavy, iii) Irregular wavy
h. Degree of separation - i) Overlapping, ii) Touching, iii) Well separated
i. Cross sectional appearance - i) “V” shape, ii) Flat, iii) Boat shape, iv) Convex |

- j. Longitudinal sectional appearance - i) Flat, ii) Convex, iii) "S" shape,
- k. Leaf apex - i) Aristate, ii) Acuminate, iii) Cuspidate, iv) Apiculate
- l. Leaf base - i) Cuneate, ii) Attenuate, iii) Obtuse
- m. Colour of vein - i) Yellow, ii) Light green
- n. Nature of vein - i) Prominent, ii) Not prominent

3.2 Explanation of the descriptors

a) **Node** – This is the position of the stem where leaves and branches arise.

i. Auxiliary bud

This is the bud found at the axil of leaves. Branches and flowers are arising from these buds (Plate 19.1a, 1b, 1c). When the buds are inactive, they are known as dormant bud which are sunken into the bark (Plate 19.1a) and some are protruded or very rarely developed into spurs (Plate 19.1c). Others are normal buds (Plate 19.1b).

ii. Leaf scars

The leaf scar is the mark which was appearing after the leaf shedding (Plate 19.2a, 2b). They are flat in certain clones and sometimes prominent with a pronounced margin. Shape of the scars generally varies from heart shape (Plate 19.2a) to circular (Plate 19.2b).

b) Leaf storey (Leaf whorls) -It is the leaf bearing part of the stem. For description, mature whorls are used. It is important not to use too young or too old leaf storey for description because during the tender and older stage, leaf stalk and leaflets of a different whorl show tendency for drooping. Healthy and disease free young plant with three to four primary whorls of mature leaves is preferred for a proper assessment of the leaf storey.

i. Shape of the leaf storey

Shape of the leaf storey can be observed when they are viewed from a distance. There are four different shapes; (Plate 19.3a, 3b, 3c, 3d).

i) Bow shape- Storey resembles a segment of a sphere (Plate 19.3a).

ii) Hemispherical (Globular)- When leaf storey's look like half of the sphere (Plate 19.3b).

iii) Conical - Leaf storey resembles a cone (Plate 19.3c).

iv) Truncate - It appears as the top portion is cut-off straight across (Plate 19.3d)

In addition, various transition forms of these four shapes such as broad conical, narrow conical, large truncate, small truncate *etc.* may also be observed.

ii. Separation of a leaf storey

Leaf storey of a plant is separated from each other by the bare stem (Plate 19.4a, 4b, 4c). Clones show variation in the pattern of separation such that differentiation between two successive whorls is comparatively less noticeable (Plate 19.4b) where as in others they are well separated (Plate 19.4a), or the stem bearing leaves over its entire length (Plate 19.4c).

iii. Leaf density of a storey

It is the relative distribution of leaves within the whorls (Plate 19.5a, 5b). If the leaves are crowded on a storey and, therefore, cannot be seen through the storey they are called closed storey (Plate 19.5a). If leaf stalks are well separated and can be seen through the storey, it is known as open storey (Plate 19.5b).

iv. Size and width of leaf storey

The size or relative dimension of a storey can be small, medium or large depending on the number, size and shape of leaves in the storey. Width of the leaf storey can be categorized either as broad or narrow based on the length and orientation of petiole, petiolule and the size of leaf blades in the storey

c) Leaves - For description of clones, leaf characters are of utmost importance. Leaves of the youngest, fully grown storey or storey nearest to the top one are suitable for characterization. Leaves are palmately compound and consist of a pulvinus, leaf stalk (petiole), where three leaflets are attached by petiolule to distal end of petiole. At that point extra floral nectaries (the nectar secreting glands) are present (Plate 19.3).

i. Pulvinus

It is the slightly enlarged basal end of petiole which shows variation in shape and size.

ii. Petiole

To describe the petiole, its shape, length and orientation (arrangement in relation to stem) are considered. Lower leaves of the storey are the best to observe the petiole characters.

a- Shape

Petiole shape falls in to four categories *viz.* if there is no bending or curving of the petiole, it is straight (Plate 1.6a) and if the basal portion is shaped like an arch, it is called arched shape (Plate 1-.6c). If the middle portion of the petiole is downward, it is concave (Plate 1-6b). In "S" shape, the petiole has a convex bend at the basal portion and concave bend at the distal end (Plate 1-6d). But some small variation can be observed with in a clone.

- b- Size
Length of the petiole can be described as long and slender, medium and short, and thick in relation to other clones.
 - c- Orientation
This describes the arrangement of petiole in relation to the stem (Plate 1-7a,7b,7c). There are three types of orientations of the petiole, *i.e.* upward (Plate 1-7a), horizontal (Plate 1-7b) and downward (Plate 1-7c). All the leaves of a storey may not show the same orientation, but the orientation exhibited by majority of leaves is taken as the clonal characters.
- iii. Petiolule**
- It is the short stalk connecting the leaf lamina to the petiole. It also displays variability in size, orientation and inter petiolule angle.
- a- Size
Relative length of petiolule and it can be long, medium and short
 - b- Orientation
The orientation of the petiolule describes the relative position with respect to the plane of petiole (Plate 1-8a,8b,8c). There are three types of orientations of the petiole, *i.e.* horizontal (Plate 1-8a), downward (Plate 1-8b) and upward (Plate 1-8c). All the leaves of a storey may not show the same orientation, but the orientation exhibited by majority of leaves is taken as the clonal characters.
 - c- Angle of separation
The angle between the leaflets is considered to be broad if it is between 30 – 70⁰ (Plate 1-12a). It is narrow when the angle is less than 30⁰ (Plate 1-12b).
 - d- Petiole and petiolule junction appearance
This junction can be strait or raised.
- iv. Leaf blade**
- In order to compare the leaf blades of different clones, following characteristic features were taken into consideration.
- a- Colour
Colour of leaf blade generally is in a range from dark green, green, light green, yellowish green and bluish green.
 - b- Lustre
Lustre of the leaves can be glossy (shine), semi glossy or dull. This can be measured best under direct sunlight.
 - c- Texture
Leaf texture may be smooth, leathery or even surfaced and can be determined by touching the leaf blade.
 - d- Thickness
Thickness of leaves can be varying from thin to thick and it can be judged by gently feeling the leaflet between fingers.

e- Shape

Shape of leaf blade is very characteristic of each clone and is least affected by the external factors. The middle leaflet of the mature leaves is the ideal leaf for characterization. For that; i) The proportion of the length and width, ii) Location of the maximum width and iii) the way, leaf blade tapers into its base and apex are considered. Three basic forms of leaf shapes are identified and they are elliptical, obovate (pear shape) and diamond elliptical. Among them, elliptical leaf blade has its maximum width in the middle and tapering equally towards base and apex (Plate 1-10a). If maximum width is found between the middle of leaflet and apex, it is considered to be obovate (pear shape) (Plate 1-10b). Diamond elliptical is the diamond shape variation of the elliptical form (Plate 1-10c). On a comparative basis, each shape can further be classified as broad or narrow.

f- Size

The proportion between length and width of leaf blade varies from clone to clone, which was used to differentiate the size of leaf blade from large to small or broad to narrow.

g- Margin

Leaf margins are either smooth (Plate 1-11b) or wavy (Plate 1-11a). Wavy margin can be further differentiated as regular or irregular wavy. In regular wavy, all the curves are uniform and others have varying length.

h- Degree of separation

The leaflets are well separated in some clones owing to the wide angle at the point of attachment of petiolules to the petioles (Plate 2.15a). In others, the angle is so narrow and, therefore, leaflets touch (Plate 2.15b) or even overlap with each other (Plate 2.15c).

i- Leaflet apex

Leaf apex is also a very important feature for identification of clones. Usually, the mature middle leaflet is used for observing characters. There are four types of leaf apices commonly found. They are aristate, acuminate, cuspidate and apiculate. When the apex tapers to a very narrow elongated tip, it is said to be aristate (Plate 1-13a). Acuminate tip refers to an acute apex, sides of which are somewhat concave and taper into an elongated tip (Plate 1-13b). When the apex is sharply concave and end abruptly, it is cuspidate (Plate 1-13c). When the leaflets are characterized by a short tip it is called apiculate (Plate 1.13d).

j- Leaflet base

There are three basic types of leaflet base, *i.e.* cuneate, attenuate and obtuse. Cuneate leaf base appears triangular, with the narrow end at the point of attachment (Plate 2.14a). Attenuate base also triangular but

- show a long and graduate tapering (Plate 2.14b). In obtuse type, the base is blunt and rounded in shape (Plate 2.14c).
- k- Longitudinal sectional (LS) appearance of leaflets
This is judged by viewing the leaflets from the side. LS appearance can be either convex (Plate 1.9a), flat (Plate 1.9b) or “S” shape (Plate 1.9c).
 - l- Cross sectional (CS) appearance of leaflets
This can be viewed by looking at the tip towards the direction of the base. From that four basic shapes can be recognized. They are, “V” shape (Plate 2.16a), boat shape (Plate 2.16b) flat (Plate 2.16c), and convex or arched (Plate 2.16d).
 - m- Colour of veins
Colour of veins varies from light green to light yellow (yellowish green).
 - n- Nature of veins
This is the prominence of veins which exhibits variation in clone to clone. Venation may be normal in most of the clones or prominent in certain clones.
 - o- Lateral veins
Certain clones exhibit numerous lateral veins whereas a few, well separated lateral veins are noticed in some clones.

Most of the clones possess similar traits due to lower genetic diversity as they were derived from common ancestors. Although clones do not exhibit highly distinct variations, most of them possess certain minor, but more or less stable morphological features, which can be used for identification. The present descriptor list of morphological characters provides the basis for broad classification of rubber clones. The extent of the morphological diversity among the clones alone, does not necessarily reflect the genetic diversity of *Hevea* clones and the use of molecular markers along with the morphological markers are necessary for clear identification of the existing clones.

4. IDENTIFICATION OF COMMON CLONE

4.1 Morphological characters of some popular clone at immature stage (<2 years)

Descriptor	RRIC 100	RRIC 102	RRIC 121	RRIC 130
1) Leaf (Middle leaflet)				
Shape	Normal elliptical	Obovate	Diamond elliptical	Obovate
Colour	Green (7.5GY4/6)	Green (7.5GY4/6)	Dark green (7.5GY3/4)	Dark green (7.5GY3/4)
Luster	Dull	Dull	Dull	Dull
Texture	Leathery	Smooth	Leathery	Leathery
Size (Leaf area)	Medium (90–135 cm ²)	Medium (150-220 cm ²)	Small (80-130cm ²)	Medium (90-140 cm ²)
Thickness	Thick	Thin	Thick	Thick
Leaf base	Cuneate	Obtuse	Attenuate	Obtuse
Leaf Apex	cuspidate	Apiculate	Aristate	Apiculate
Leaf Margin	Irregular wavy	Smooth	Irregular wavy	Smooth
Longitudinal Section	Flat	Convex	Convex	Flat
Cross Section	Boat shape	Flat	V-shaped	V-shaped
Degree of leaflet separation	Touching	Touching	Well separated	Touching
Colour of vein	Light green	Light green	Light green	Light green
Nature of vein	Prominent	Prominent	Prominent	Prominent
2) Petiolule				
Length	Medium (0.8–1.2 cm)	Short (0.5-1.0 cm)	Medium (1.0-1.4 cm)	Medium (1.2-1.6 cm)
Orientation	Down word	Down word	Horizontal	Down word
Angle between petiolule	Narrow (45–55 °)	Narrow (45-55°)	Wide (55-60°)	Narrow (45-50°)
3) Petiole				
Shape	Strait	Strait	“S” shape	Arched
Length	Medium (24–32 cm)	Medium (20-28 cm)	Medium (18-25 cm)	Medium (22-28 cm)
Orientation	Upward	Upward	Horizontal	Horizontal
4) Leaf Storey				
Shape	Hemispherical	Conical	Hemispherical	Hemispherical
Separation	Well separated	Well separated	Well separated	Not well separated
Appearance	Closed canopy	Closed canopy	Closed canopy	Intermediate canopy
5) Nodes				
Leaf Scar Shape	Heart shape	Heart shape	Heart shape to round	Heart shape
Leaf Scar margin	pronounced margin	More or less Protruded	More or less Protruded	More or less Protruded

Clone identification

Descriptor	RRISL 201	RRISL 203	RRISL 208	RRISL 211
1) Leaf (Middle leaflet)				
Shape	Obovate	Obovate	Diamond elliptical	Broad elliptical
Colour	Green (7.5GY4/6)	Green (7.5GY3/4)	Green (7.5GY3/4)	Green (7.5GY3/4)
Luster	Glossy	Dull	Dull	Dull
Texture	Smooth	Leathery	Leathery	Leathery
Size (Leaf area)	Medium (70-130 cm ²)	Medium (82-105 cm ²)	Small (65-120 cm ²)	Medium (110-140 cm ²)
Thickness	Thick	Thick	Thick	Thick
Leaf base	Cuneate	Cuneate	Cuneate	Cuneate
Leaf Apex	Acuminate	Cuspidate	Acuminate	Apiculate
Leaf Margin	Smooth	Irregular wavy	Smooth	Irregular wavy
Longitudinal Section	Flat	“S” shape	Convex	“S” shape
Cross Section	V-shaped	Boat shape	V-shaped	Flat
Degree of leaflet separation	Touching	Touching	Touching	Touching
Colour of vein	Light green	Light green	Light green	Light green
Nature of vein	Prominent	Prominent	Prominent	Prominent
2) Petiolule				
Length	Long (1.5-2.0 cm)	Short (1.5-2.0 cm)	Medium (1.5-2.0cm)	Long (1.5-2.4 cm)
Orientation	Down word	Down word	Down word	Horizontal
Angle between petiolule	Narrow (40-45 ⁰)	Narrow (40-50 ⁰)	Wide (50-60 ⁰)	Narrow (42-45 ⁰)
3) Petiole				
Shape	Strait	“S” shape	Strait	Strait
Length	Medium (24-24 cm)	Medium (18-30 cm)	Long (25-32 cm)	Medium (21-24 cm)
Orientation	Upward	Horizontal	Upward	Upward
4) Leaf Storey				
Shape	Bow shape	Hemispherical	Hemispherical	Bow shape
Separation	Not well separated	Not well separated	Not well separated	Not well separated
Appearance	Intermediate canopy	Closed canopy	Closed canopy	Open canopy
5) Nodes				
Leaf Scar Shape	Heart shape	Heart shape	Heart shape	Heart shape
Leaf Scar margin	More or less Protruded	More or less Protruded	Normal	Protruded

Handbook of Rubber

Descriptor	RRISL 217	RRISL 2001	RRISL 2005	RRISL 2006
1. Leaf (Middle leaflet)				
Shape	Broad elliptical	Broad elliptical	Obovate	Obovate
Colour	Light Green (7.5GY4/6)	Green (7.5GY3/4)	Green (7.5GY3/4)	Light Green (7.5GY3/2)
Luster	Dull	Glossy	Dull	Dull
Texture	Leathery	Smooth	Leathery	Leathery
Size (Leaf area)	Medium (100-130 cm ²)	Medium (90-150 cm ²)	Small (65-20 cm ²)	Small (85-115 cm ²)
Thickness	Thick	Thin	Thin	Thick
Leaf base	Cuneate	Cuneate	Cuneate	Cuneate
Leaf Apex	Acuminate	Apiculate	Acuminate	Aristate
Leaf Margin	Smooth	Smooth	Irregular wavy	Smooth
Longitudinal Section	Flat	Strait	Flat	Boat shape
Cross Section	V-shaped	V-shaped	V-shaped	Flat
Degree of leaflet separation	Well separated	Well separated	Touching	Separated
Colour of vein	Light green	Light green	Light green	Light green
Nature of vein	Prominent	Prominent	Prominent	Prominent
2. Petiolule				
Length	Long (1.5-2.0 cm)	Medium (1.2-1.8 cm)	Medium (1.2-1.6cm)	Long (1.4-1.8 cm)
Orientation	Horizontal	Horizontal	Upward	Horizontal
Angle between petiolule	Wide (65-75 ⁰)	Narrow (40-50 ⁰)	Narrow (40-50 ⁰)	Wide (48-58 ⁰)
3. Petiole				
Shape	Strait	Arched	Concave	Arched
Length	Medium (22-28 cm)	Long (2632 cm)	Medium (20-28 cm)	Medium (20-26cm)
Orientation	Upward	Upward	Horizontal	Horizontal
4. Leaf Storey				
Shape	Conical	Hemispherical	Hemispherical	Conical
Separation	Well separated	Well separated	Well separated	Well separated
Appearance	Intermediate canopy	Closed canopy	Closed canopy	Close canopy
5. Nodes				
Leaf Scar Shape	Heart shape	Circular shape	Heart shape	Circular shape
Leaf Scar margin	More or less Protruded	Normal	Normal	Protruded

4.2 Guidelines for the quantitative morphological characters

Characters		Range
Size of the petiole	Long	< 25 cm
	Medium	20 - 25 cm
	Short	> 20 cm
Angle of petiole	Wide	< 50 ^o
	Narrow	> 50 ^o
Size of the petiolule	Long	< 1.5 cm
	Medium	1 - 1.5 cm
	Short	> 1 cm
Size of the leaf	Small	> 100
	Medium	100 - 200
	Large	< 200

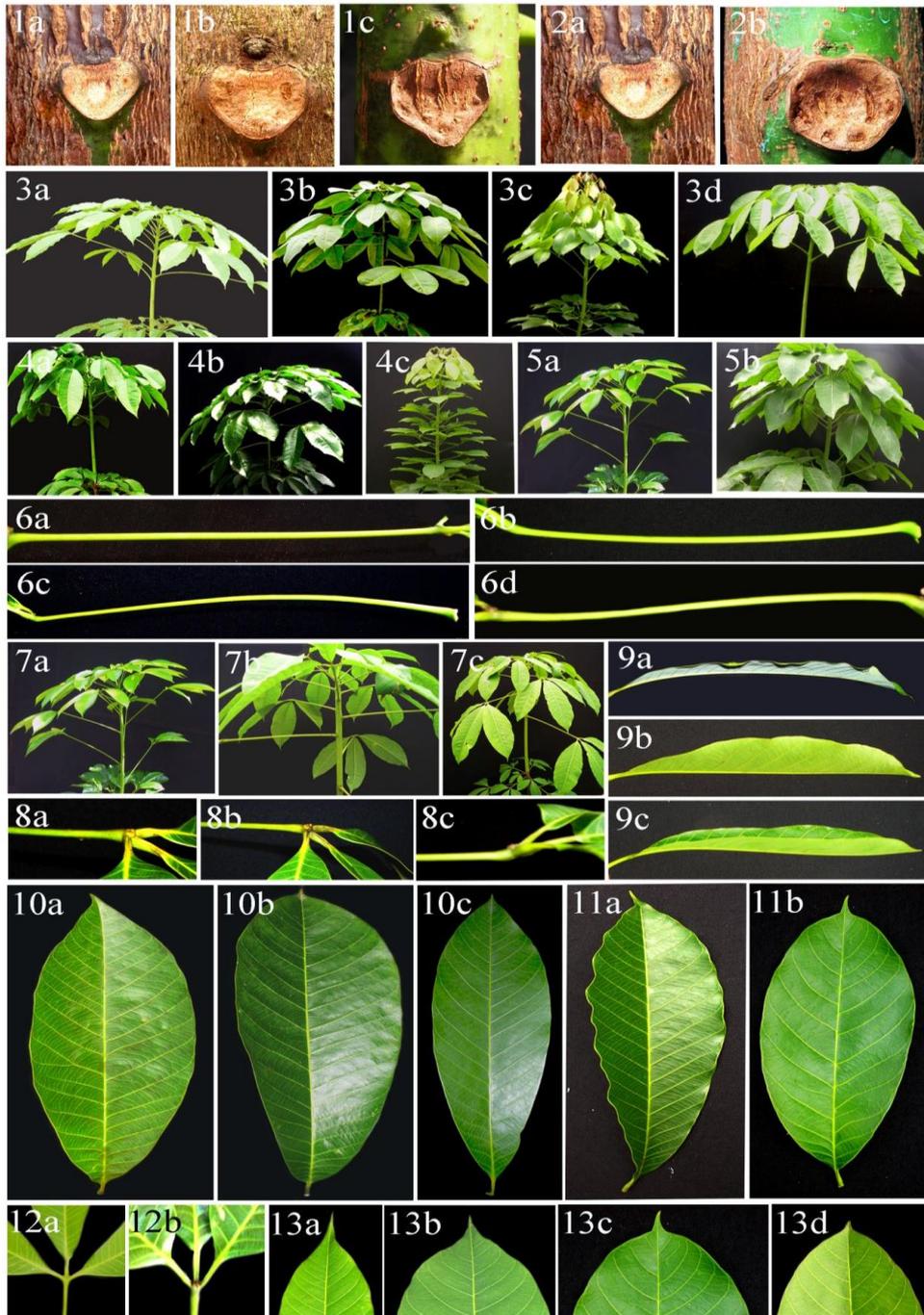


Plate 19.1. Different morphological features used for clone identification.

Clone identification

- 1. Type of axillary buds:** 1a - Dormant bud (Sunken), 1b - Normal bud, 1c - Protruded bud.
- 2. Type of leaf scars:** 2a - Heart shaped and flat, 2b - Circular and protruded
- 3. Shape of the leaf storey;** 3a - Bow shape, 3b - Hemispherical, 3c - Conical, 3d - Truncate
- 4. Separation of a leaf storey:** 4a -Well separated, 4b - Not well separated, 4c - Diffuse
- 5. Leaf density of a storey:** 5a - Closed leaf storey, 5b - Open leaf storey
- 6. Shape of petiole;** 6a -straight, 6b -arched, 6c -concave, 6d - ‘S’ shaped
- 7. Orientation of leaf stalk;** 7a - upward, 7b - horizontal, 7c - downward
- 8. Orientation of petiolule;** 8a -Horizontal, 8b- Downward, 8c -Upward
- 9. Longitudinal sectional appearance of leaflets;** 9a - Convex, 9b - Flat, 9c - “S” shape
- 10. Shape of leaf blade;** 10a-Elliptical, 10b-Obovate, 10c-Diamond elliptical
- 11. Shape of leaf margin;** 11a-Wavy margin, 11b-Smooth margin
- 12. Angle of leaf separation;** 12a-Broad, 12b-Narrow
- 13. Shape of leaflet apex;** 13a - Aristate, 13b - Acuminate, 13c - Cuspidate, 13d - Apiculate

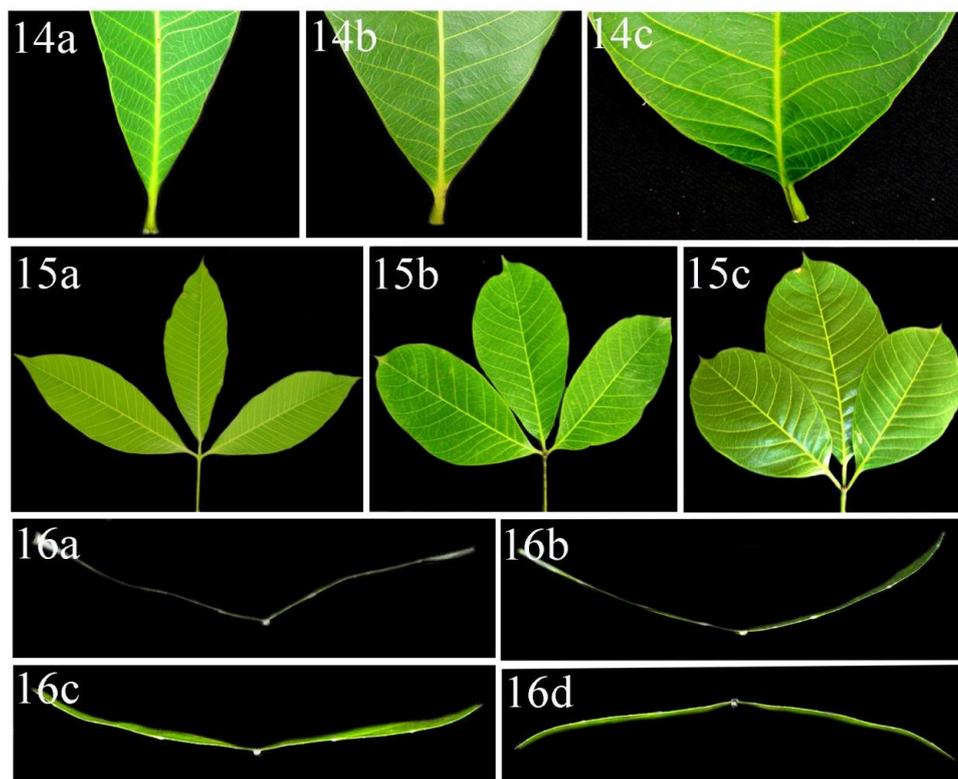


Plate 19.2. Different morphological features used for clone identification (Continued from Plate 19.1).

- 14. Shape of leaflet base;** 14a - Cuneate, 14b - Attenuate, 14c - Obtuse
15. Degree of leaflet separation; 15a - well separated, 15b - touched, 15c - overlapped
16. Cross sectional appearance of leaf blade; 16a - "V" shape, 16b - Boat shape, 16c - Flat, 16d - Convex

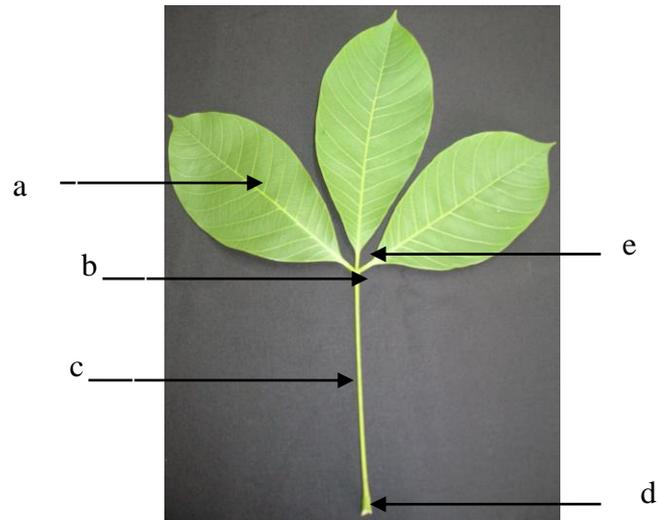


Plate 19.3. *Hevea* leaf. **a.** leaflet; **b.** extra floral nectaris; **c.** leaf stalk; **d.** pulvinus; **e.** petiolule.

Chapter 20

Biochemistry and physiology of rubber

K.V.V.S. Kudaligama and N.P.S.N. Karunarathna

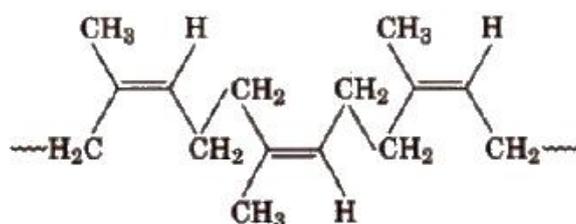
1. Introduction
2. Rubber Biosynthesis
 - 2.1. Rubber biosynthetic pathway
 - 2.2. Composition of latex
3. Latex physiological parameters
 - 3.1 Latex pH
 - 3.2 Total solid content (TSC)
 - 3.3 Latex sucrose content (Suc)
 - 3.4 Latex inorganic phosphorous content (Pi)
 - 3.5 Latex thiol content (RSH)
 - 3.6 Latex magnesium content (Mg^{2+})
 - 3.7. Seasonal variation in physiological parameters and latex yield
4. Effects of ethephon on latex flow and regeneration
 - 4.1. Effects on latex flow
 - 4.2. Effects on latex regeneration
 - 4.3. Influence of stimulation on the metabolism of laticiferous cells
 - 4.4. Long term effects of misuses of hormonal stimulation
5. Effect of biochemical constituents of latex on raw rubber properties
 - 5.1. Colour
 - 5.1.1. Enzymatic discoloration of NR
 - 5.1.2. Non-enzymatic discoloration of NR
 - 5.1.3. Other reasons for discoloration of NR
 - 5.2. Other raw rubber properties
6. Physiology and biochemistry of rubber wood

1. INTRODUCTION

Natural rubber (NR) is an environmentally friendly product obtained from a renewable resource. Rubber is harvested as latex from the tree species known as *Hevea brasiliensis* by periodic excision of its bark. Rubber is regenerated and stored within specific cells in the secondary phloem of the bark modified in to tubular structures called laticifers or latex vessels. They are arranged in concentric cylinders and are dense in the soft bark closer to the cambium. In the rubber tree, laticifers are present in all organs except in wood. Laticifers dense in the secondary phloem are exploited commercially for latex. When the bark of the tree is tapped, turgor pressure of the latex vessels influences to ooze out latex. During the passage of latex down the tapping cut laticifers get damaged and the acidic medium released out results in coagulation of latex and forming a plug on the opening of the latex vessel. Plugging of latex vessels with coagulated rubber particles ceases the latex flow with time.

2. RUBBER BIOSYNTHESIS

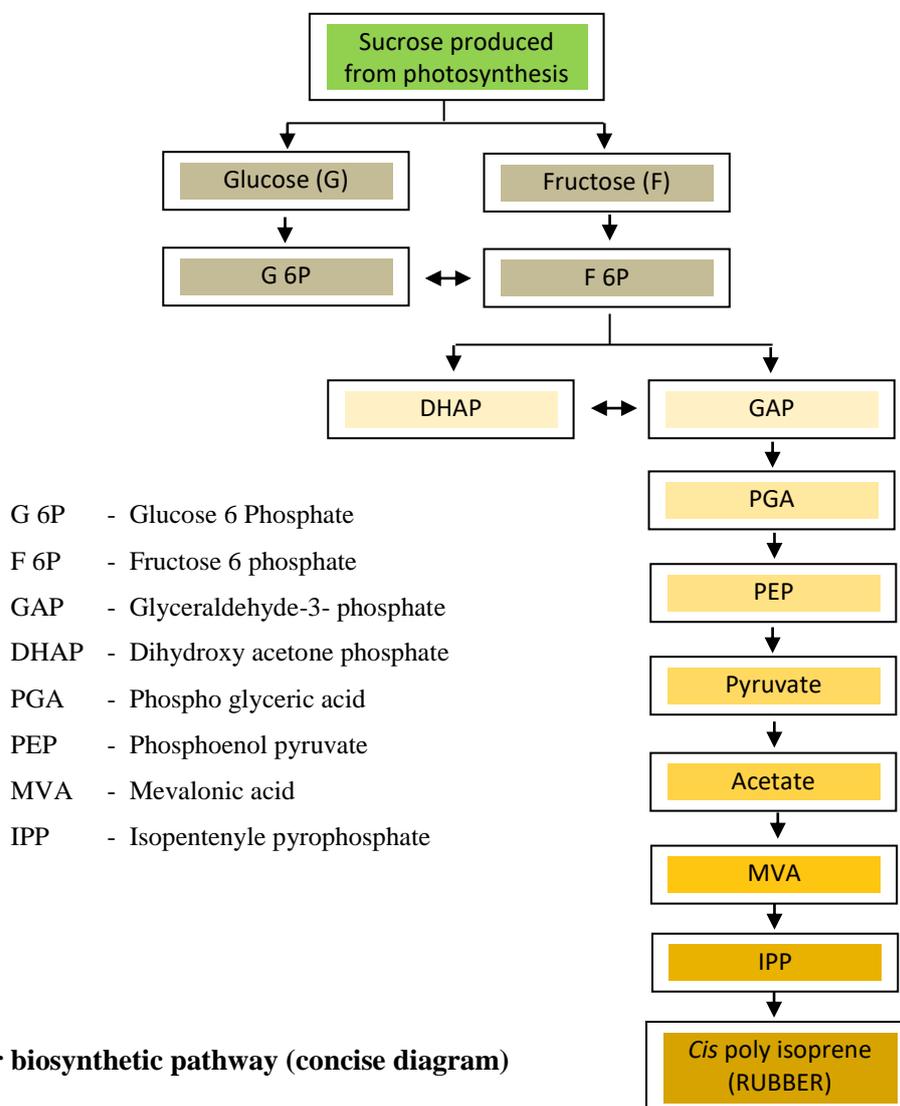
Sucrose produced by photosynthesis and transported by phloem pathways to the laticifers is the main precursor of acetate; the simplest initial precursor of isopentenyl pyrophosphate (IPP) which, in turn is lengthened by the terminal addition of IPP units and forms rubber. Natural rubber is an addition polymer made up of thousands of 5-carbon isoprene monomer (2-Methyl -1, 3 – Butadiene) units. These isoprenic units (C_5H_8) are bonded in *Cis* form leading to a coiled structure which gives characteristic properties to natural rubber. The “Royal Metabolic Pathway” of the laticiferous system synthesizes rubber which forms 25 – 45% of fresh weight and over 90% of dry weight of latex.



A section of the polymeric chain of natural rubber

The molecular weights of rubber molecules range from 1×10^5 and 2×10^6 Da. The natural rubber polymer is found as suspended particles encased by a contiguous monolayer biomembrane. Rubber particles in latex show a wide range of diameter, from 0.01 to 5 μm , with the majority being 0.1–2 μm diameter. The colloidal stability of rubber particles is maintained since they have an overall negative surface charge on the monolayer bio-membrane leading to a charge-to-charge repulsion preventing coalescences under normal conditions. Natural rubber possesses valuable properties of elasticity, plasticity, strength, durability, electrical non-conductivity, and resistance to water enabling production of variety of industrial, constructional, domestic and medical products *etc.*

2.1. Rubber biosynthetic pathway



2.2. Composition of latex

Biochemically, latex is a true cytoplasm and it contains most of the sub-cellular elements together with rubber particles, luteoids and Frey-Wyssling particles. In addition, latex contains numerous organic (*i.e.* carbohydrates, proteins, lipids, quebrachitol, inositols, *etc.*) and inorganic (*i.e.* nitrates, carbonates, sulphates, phosphates, *etc.*) substances.

Sucrose, glucose, fructose, quebrachitol and inositols are the major carbohydrates present in latex. Among those, sucrose is important as the primary source of rubber biosynthesis and glucose and fructose as the intermediates in the biosynthetic pathway. Quebrachitol and inositols play a major role in regulating the osmolarity of laticifers. Proteins are either associated with rubber particles or dissolved in the aqueous phase known as serum. Enzymes involved in rubber biosynthesis and other metabolic activities in laticifers are the important proteins. Proteins have been considered to be essential components of NR for their characteristic properties. Several proteins in NR have been found to cause type I allergic responses in humans hence need to remove extractable proteins in rubber products manufacturing (e.g., gloves and condoms). Carotenoids and phenolic substances in latex mainly determine the colour of raw rubber. Lipids and phospholipids associated with rubber and the non rubber particles play a vital role in the stability and the colloidal behavior of latex.

3. LATEX PHYSIOLOGICAL PARAMETERS

Generally, latex yield is associated with latex regeneration capacity of trees and the rate and duration of latex flow. Several physiological factors associated with either latex regeneration or latex flow or both affect and determine the productivity of the tree in combine. Latex pH together with total solid content, sucrose, inorganic phosphorous, thiol and Mg^{2+} contents are known as major latex physiological parameters.

3.1 Latex pH

Latex pH has a positive and very significant correlation with production. pH within the laticifers regulates the metabolism considerably and accelerates the activity of enzymes associated with latex biosynthesis. Alkalinization of laticiferous vessel contents subsequently increases sugar availability in laticifers.

3.2 Total solid content (TSC)

Total solids content (TSC) of latex is associated with both latex regeneration and latex flow. It reflects the biosynthetic activity and has a positive correlation with latex regeneration. Low values may indicate either lower level of in situ regeneration or it gives an indication of inadequate regeneration between two tappings. On the other hand, high TSC levels increase the viscosity of latex and limit the yield by reducing the latex flow time. Hence it has a negative correlation with latex flow.

3.3 Latex sucrose content (Suc)

In plants the sucrose produced by photosynthesis is finally the basic molecule in all synthesis. In *Hevea*, sucrose is metabolized into polyisoprene (rubber) in the laticiferous cells. Sugar content in laticifers positively correlates with isoprene production and high sucrose content is an indication of potential production of latex in laticifers. Excessive exploitation decreases sugar content in

laticifers. Under low sucrose levels turgor pressure in laticifers is also decreased and reduces the initial flow rate after in tapping resulting low yields.

3.4 Latex inorganic phosphorous content (Pi)

Latex Pi may reflect its energy metabolism and the energy status of the laticifers and significantly correlates with latex production in trees. Latex Pi content is high in trees that give high yields and gives lower values specially during wintering and refoliation period.

3.5 Latex thiol content (RSH)

Latex thiols consist of cysteine, methionine and glutathionine which are able to neutralize various forms of toxic oxygen species formed during latex biosynthesis. Thiols are capable of scavenging these toxic oxygen species and protect the membranes and of the lactiferous tissues. These chemicals promote colloidal stability and flow of latex hence, directly correlate with production. Thiols are also potential activators of key enzymes involved in rubber biosynthesis and have a favourable effect on regeneration of latex.

3.6 Latex magnesium content (Mg²⁺)

This cation is compartmented in latex and accumulates in lutoids and play more complex and opposing roles on latex production. When referred to latex flow, Mg²⁺ neutralize the electronegative charges around the rubber particles that are responsible for the colloidal stability. It is released in large quantities when lutoids are busted and tends to cease latex flow affecting the yield. Magnesium is also an activator of functioning of certain enzymes such as ATPases, transferases and PEP carboxylase. On the other hand, it plays an inhibitory role on enzymes such as invertase. This diverse functions of Mg²⁺ affect both latex production and flow.

3.7. Seasonal variation in physiological parameters and latex yield

Rubber is a deciduous plant that winters during December to February. Latex yield falls slightly at the onset of wintering and are more markedly reduced during refoliation. During the leaf fall period latex sucrose content decreases due to reduction in canopy leaf content that directly correlates with the photosynthesis. Limited sugar availability reduces latex regeneration capacity in the laticifers and also reduces the turgor pressure. Latex Pi tends to decrease during the wintering and directly associated with the latex yield during this period. Low Pi content in laticifers reflects the less metabolic activity during defoliation and refoliation period. During the refoliation period, dry rubber content (DRC) of latex decreases by the shunting of nutrients into reconstitution of leaves. May to July period is known as the post wintering period and with the maturation of the new canopy a gradual increase in latex yield could be seen. From August to October, the canopy is fully matured and gives comparatively higher yields. With favourable weather

conditions from November to end of January, trees with a good canopy conditions give a peak yield.

Latex production is closely dependent on climatic conditions and in particular on the availability of water in soil, relative humidity and the temperature. Latex total solid content (TSC) is also comparatively higher in the dry seasons than in the wet seasons. Low latex pH observed during dry season reflects the extensive porosity of the lutoids, which leads to acidification of the cytoplasm and cessation of the latex flow earlier resulting low yields.

4. EFFECTS OF ETHEPHON ON LATEX FLOW AND REGENERATION

Increased yields after stimulation with ethephon, is a combined effect of ethylene on latex flow and regeneration of constituents of laticifers (latex).

4.1. Effects on latex flow

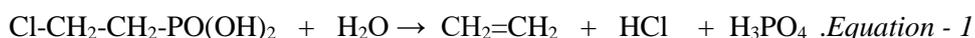
- Extension in drainage area.
- Increase the turgor pressure in laticifers.
- Increase the initial flow rate.
- Increase the stability of lutoids.
- Delay plugging of latex vessels and increase the duration of flow.
- Reduce the action of polyphenoloxidase to decrease plugging.

4.2. Effects on latex regeneration

- Rise in latex pH after stimulation.
- Increase the invertase and other enzyme activity.
- Intensify sucrose mobilization and transported towards laticifers.
- Increase the sucrose availability in latex.
- Increase production of pyruvate and ATP.
- Enhance mevalonate production and ultimately rubber biosynthesis.

4.3. Influence of stimulation on the metabolism of laticiferous cells

The plant hormone ethylene could be effectively used as a yield stimulant in rubber trees. Presently in the rubber plantations ethepho, a well known ethylene generator is used to stimulate rubber trees with low intensity harvesting systems and during period of intensified harvesting. Ethephon is a plant growth regulator with systemic properties, penetrates into the plant tissues, and translocated. In the presence of water, it progressively decomposes to ethylene (Equation – 1) which is a kind of plant hormone that affects the biochemical and physiological status of the tree resulting in high yields. Also there are several methods of applying ethylene directly to the rubber tree to enhance yields.



Increase of yield in stimulated trees is a combine effect of biochemical and physiological changes caused by ethylene.

Yield is mainly increased due to an extension in drainage area. The massive outflow of latex induced by stimulations leads necessity to an increase in the anabolic activities in the cells and specially biosynthesis of rubber and of proteins involved in this renewal. Increased levels of nucleic acids and adenosine tri phosphate (ATP) favour anabolic process. Rise in latex pH after stimulation results in an increase in invertase activity which, intensify sucrose mobilization towards latex vessels where regeneration of latex and metabolism activated. Also increased activity of enzymes involved in the rubber biosynthesis pathway enhances rubber production. Ethylene activates the laticifer metabolism and also enhances the energy status and reflected by increased inorganic phosphorous content.

pH of the latex of stimulated trees elevated 24 hrs. after application and it continues to rise for several days. Ethylene showed marked increase in triglycerides associated with the rubber phase. Increased latex pH and other contents like copper, total phosphorus, free amino acid after stimulation affect directly the osmolarity of cytosol of laticifers and enhance ingress of water and increase the turgor pressure of vessels. Increases in water ingress to the vessels lead to a decrease in total solids content resulting in low viscosity of latex and reduction in plugging of vessel. These result in increased initial flow rate and duration of flow after stimulation.

Stimulation with ethylene greatly reduces latex polyphenoloxidase activity which is known to be correlated positively with plugging index. The action of polyphenoloxidase on coagulation is due to production of substances like quinines and melanins which could denature the protein at the surface of rubber particles affecting the colloidal stability. Ethylene stimulation results in relatively more stable lutoids by increasing the permeability of the membrane and thereby prolonging the latex flow by delaying plugging of vessels resulting in increased latex yields. Stabilized lutoids bring down release of acid phosphatase that degrades essential intermediates in rubber biosynthetic pathway. Hence, stabilization of lutoids has a favourable effect on rubber biosynthesis too.

4.4. Long term effects with the misus of hormonal stimulation

Numerous external and internal factors play a role in response of *Hevea* to stimulation and dangers are inherent in misuse of the stimulant. For long term sustainable yields, stimulation protocols should be duly adopted considering the clone, the prevalent ecoclimatic conditions and the intensity of exploitation of the tree.

Mainly stimulation based harvesting systems affect the physiological nature of rubber tree. As you already know stimulation increase the metabolic activity of laticifers. During dry seasons and the refoliation period, negative responses to stimulation have been observed. Under poor conditions of water supply, stimulation may not only be ineffective but harmful to the tree.

Increase latex production due to stimulation with ethylene leads to high consumption of sucrose which is first compensated by increased migration of sugar into the treated zone. Repeated treatment with high dosages of ethylene decreases sucrose content in laticifers which leads to a fall in production. Initially yield response of trees is always higher with ethylene application and lessens with time due to increased drainage of the mineral nutrients from stimulated trees. However, this was not shown in all clones and its extent varied with the taping system used. Much greater discharge of minerals from the tree will result in decrease in volume of assimilatory roots and foliar surface.

Turgor pressure of laticiferous tissues was markedly reduced in stimulated trees due to reduction of sucrose, quebrachitol and other cyclitols in latex. Electron microscopic studies have revealed an increase of stone cells in the soft bark and partial emptiness of latex vessels of stimulated trees expressing increased incidence of tapping panel dryness. The dry rubber content of latex in stimulated trees is lower than that of unstimulated trees even they tapped under the same frequency. Ethylene showed a negative effect on tree growth. Appropriate usage of stimulant does not effect on properties of raw rubber and may not increase allergenic proteins in *Hevea* latex. Ethylene does not have any adverse effect on quality of rubber wood.

Repeated over exploitation and continuous application of high ethephon/ethylene dosages fatigue the laticifers and reflected by physiological and biochemical symptoms given below.

- Low dry rubber content and total solid content in latex.
- Low sucrose levels in latex.
- Low thiol and inorganic phosphorous contents in latex.
- Reduced turgor pressure of laticiferous tissues.
- Partial emptiness and accumulation of stone cells in laticifers.
- Higher incidence of tapping panel dryness.

5. EFFECT OF BIOCHEMICAL CONSTITUENTS OF LATEX ON RAW RUBBER PROPERTIES

Organic and inorganic non-rubber substances in latex have an impact on raw rubber properties of natural rubber directly and indirectly.

5.1. Colour

Colour of rubber is primarily a clonal factor and one of the major quality parameter as grading of natural rubber is mainly done visually. Darkening/changes in colour of rubber happens during both processing and storage of the rubber. Enzymatic and non-enzymatic darkening are considered to be the major reasons for rubber latex discoloration.

5.1.1. Enzymatic discoloration of NR

The reason behind the enzymatic discoloration is the oxidation of phenolic compounds which is a type of plant secondary metabolites. The amount of phenolic compounds varies largely among different genotypes. Polyphenol

oxidase (PPO) in Frey-Wyssling particles and lutoids is considered to be the key enzyme which is responsible for the oxidation of phenolic compounds in rubber. In the presence of oxygen, phenolic compounds are oxidized to o-quinones by PPO. The resultant quinones react with amino acids and other phenolic compounds present in latex and ultimately produce dark brown, red or black melanin type pigments. Tyrosine is one of the most common substances related with the enzymatic discoloration by oxidizing into melanin type pigments and has an impact on latex browning. Thiols (glutathione and cysteine) a type of antioxidants contains in latex naturally inhibit enzymatic discoloration by reacting with oxidized phenolic compounds to form colorless products. Polyphenols were found at concentration of about 2×10^{-2} % wt/wt in latex whereas, of the total absorptivity in the yellow-brown region and contributed for about 2.3% of absorbance.

5.1.2. Non-enzymatic discoloration of NR

Non-enzymatic browning can be resulted from several biochemical processes *viz.* degradation of ascorbic acid, lipid peroxidation, sugar-sugar caramelization and Maillard reaction. Of them, Maillard reaction is the key reason for the non-enzymatic discoloration where proteins react with reducing sugars to form brown color polymeric compounds. Latex of *Hevea* is having about 1% wt/wt protein showing a proportion of about 0.1% from total absorbance in the yellow-brown region.

5.1.3. Other reasons for discoloration of NR

In addition to the enzymatic and non-enzymatic discoloration, compounds such as carotenoids also play a considerable role in natural rubber discoloration. Latex consists about 3×10^{-5} % wt/wt carotenoids contributing for about 0.01% of the total absorptivity related to the yellow-brown region. Biochemical compounds such as tocotrienols, tocotrienol esters, monoglycerides, diglycerides, fatty alcohols, fatty alcohol esters and unsaturated fatty acids are also important as the coloring compounds in natural rubber.

5.2. Other raw rubber properties

Plasticity of the natural rubber measures as plasticity retention index (PRI) varies with the molecular weight distribution and the gel content. It's also measure of oxidisability of the rubber. Mooney viscosity depends on the average molecular weight of the polymer and the extent of plasticization imparted by the non-rubbers present. Protein is the major source of nitrogen contentment in rubber. Latex contains about 1% proteins, of which 20% is adsorbed on rubber particles and rest 80% is associated with the sedimentable particles in cytosol. Proteins are responsible for water absorption and heat build with friction. On the other hand, another major importance of proteins is allergy problems associated with direct contact of human skin.

6. PHYSIOLOGY AND BIOCHEMISTRY OF RUBBER WOOD

Rubber wood is a medium hard wood with white to pale cream in color. Occasionally a pinkish tinge is present, thus it is a favorable timber in the market due to the natural color and the pleasant appearance. The color can be turned to light brown/light straw by weathering. Furthermore, good machining properties, ease in finishing and acceptable durability have made rubber wood a good substitute for the conventional timber. Identifying rubber clones that can give both high quality timber and good yield of latex is important in order to be used as a raw material in the wood based industries in Sri Lanka.

Wood density reflects the actual wood component present in a unit volume and it mainly depends on the chemical composition of the wood. Accordingly, it reflects the properties of wood such as machining, stiffness, strength, hardness and ease of drying. Wood having density between 500-640 kgm⁻³ belongs to the category of medium density wood and rubber wood also belongs to this category with an average density of 570 kgm⁻³(at 12% moisture content). Moisture content of fresh rubber wood can vary from 60% to 80%.

Total extractives in rubber wood include alcohol-toluene solubles such as resins, waxes, gums and fats and hot water solubles such as starch, tannins, sugars and coloring materials. Lignin acts as a binding agent that keeps the individual fibers together in wood and its content can be affected by clone, tree height and growth. It gives a rigid structure to the cell wall and distinguishes wood from other fibrous plant parts with lesser lignin content. The content of α -cellulose plays a role in increasing wood strength and resistance to crushing. Cellulose microfibrils are responsible for the tensile strength of wood. Holocellulose is the combination of cellulose and hemicellulose contents of a wood. Hemicellulose has a shorter chained, random, amorphous structure with lower strength. α -cellulose, hemicellulose and lignin contribute to the thickness of the cell wall and cell density, therefore collectively lignin and holocellulose could give a better strength to the structure of plant. Rubber wood has an acceptable amount of lignin within the range of hardwood and comparable amounts of total extractives, holocellulose, hemicellulose and α -cellulose contents. To date only few rubber clones have been assessed for wood quality and average values recorded for clone RRIC 121 is given in Table 20.1.

Table 20.1. Physical properties and biochemical components of wood of RRIC 121 clone.

Physical properties	RRIC 121 clone
Moisture content %	67.37
Density (kgm ⁻³)	634.58
Specific gravity	0.63
Biochemical properties	
Total extractives %	8.7
Lignin %	19.2
α -cellulose %	63.2
Hemicellulose %	23.2
Holocellulose %	86.4

Chapter 21

Rubber cultivation in non-traditional drier climates

E.S. Munasinghe, V.H.L. Rodrigo and S.M.M. Iqbal

1. Need for expansion and targeted regions
2. Climatic and social conditions of targeted regions
3. Lessons learnt from firstly planted rubber in Eastern and Northern regions
4. Recommendations for drier climates
5. Present status of rubber planting in drier climates
6. Environmental benefits
7. Social benefits
8. Way forward

1. NEED FOR EXPANSION AND TARGETED REGIONS

The rubber product manufacturing sector in the country has reached a level that in-country production of raw rubber is not sufficient to cater to the demand. Whilst allowing to export only about 17% in-country production for the specialty market, the product manufacturing sector has to depend on imports to meet *ca.* 50% of its needs. In absolute terms, this is about 65,000 MT. According to the Rubber Industry Master Plan, the in-country demand for raw rubber exceeds 150,000 MT by 2025. Uninterrupted supply of raw rubber to the product manufacturing sector is to be assured in a cost-effective manner whilst meeting the targets in foreign exchange earnings. Therefore, the country's production of raw rubber has to be increased somehow in a substantial manner. Productivity increase in existing lands allocated for rubber is the best option in this regard, but obviously not sufficient. The next option is to allocate more lands for rubber cultivation. Unfortunately, there is a little scope for this option in the traditional rubber growing areas, *i.e.* in the Wet Zone (WZ) of the country, as this is the area subjected to a high level of urbanization and industrialization. Therefore, the only possibility is to expand the rubber cultivation to non-traditional drier climates where a large extent of sparsely populated lands are available.

Monaragala district in Uva Province was the first focus and then to the adjoining boundary in the Badulla district of the same province. With recent success stories, the Ampara district of Eastern Province has become the present focus in the large-scale cultivation of rubber. In addition, the practicality of rubber cultivation in Northern Province and North Central Province is under investigation.

2. CLIMATIC AND SOCIAL CONDITIONS OF TARGETED REGIONS

Rubber cultivation in Monaragala and Badulla districts of the Uva Province was initially confined to the areas under Intermediate Zone (IZ) where mean annual rainfall is in the range of 1,750-2,500 mm (*i.e.* Monaragala, Badalkubura, Madagama and Bibile District Secretaries (DS) divisions). Rainfall is mostly received from October to January (Maha season) and then in the months of May and

Rubber cultivation in non-traditional drier climates

June showing a bimodal pattern (Fig. 21.1). In the Eastern Province also, rubber cultivation was introduced to the IZ in Padiyathalawa DS divisions in 2003. However, the rainfall distribution is rather unimodal with most rains received during the months of October and November and a distinct dry period prevails from March to September (except convective showers in March to May). With the lessons learnt from the unimodal rainfall conditions in the Ampara district of IZ, the cultivation of rubber was extended to the Dry Zone (DZ) of the country (mean annual rainfall below 1,750 mm), particularly to the Vavuniya district in the Northern Province in 2010/2011 and also to the DZ of Ampara and Monaragala districts. Also, blustery weather condition exists in these regions with low humidity.

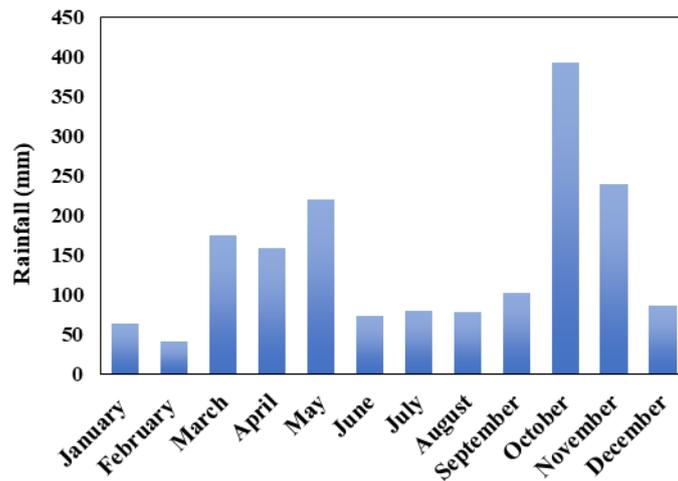


Fig. 21.1. Monthly rainfall distribution in the Intermediate Zone of Sri Lanka

The livelihood of the majority living in these areas depends on farming, particularly with seasonally grown short-term crops. As expected, participatory rural appraisals conducted in Padiyathalawa and Vavuniya to identify Strengths, Weaknesses, Opportunities and Threats for rubber cultivation (Table 21.1) revealed that land availability has been the biggest strength for rubber cultivation. The majority of lands was uncultivated and dominated by forests whilst the rest utilized for short-term crops and home gardening under rain-fed condition. On average, over *ca.* 75% of farmers were able to allocate a minimum of ½ acre of land to cultivate rubber. The second place in strengths was secured by farmers’ interest in rubber cultivation. More importantly, farmers were prepared to dedicate their family labour to facilitating rubber cultivation. Environment and soil fertility were recognized as moderate strengths. Lack of knowledge on rubber cultivation, problems associated with land ownership to secure subsidy payments, poor infrastructure facilities particularly the poor roads, dry spells and seasonal labour demand were categorized as weaknesses involved. Further, the income of the farmers was seasonal and the

average annual income of a household was limited to LKR 55,000/=. Therefore, the lack of own finance for initial investment was found as a weakness among the majority of farmers. As opportunities, access to the rubber subsidy scheme, securing the land ownership and chances for new income-generating activities related to rubber processing were recorded. Unexpected droughts and cyclones, pest and disease incidences and market price fluctuations were recorded as threats.

Table 21.1. Strengths, Weaknesses, Opportunities and Threats (SWOT) identified for rubber cultivation in nontraditional areas

<p>Strengths</p> <ul style="list-style-type: none"> Land availability Farmers' interest Labour availability Suitable environment Soil fertility Farming experience Interfamily relationships 	<p>Weaknesses</p> <ul style="list-style-type: none"> Lack of knowledge Problem on land ownership Poor infrastructure Distinct dry period Seasonal demand for labour Initial investment Lack apparatus for rubber processing No local marketing systems
<p>Opportunities</p> <ul style="list-style-type: none"> Ownership of land Knowledge of new cultivation New income generation Cultivate empty lands Loan facilities for intercropping Comfortable environment 	<p>Treats</p> <ul style="list-style-type: none"> Droughts Wild animal damages Diseases Cyclones Price drop in rubber

3. LESSONS LEARNT FROM FIRSTLY PLANTED RUBBER IN EASTERN AND NORTHERN REGIONS

Estimations made with feasibility studies have shown that about 10,000 ha and 4,000 ha could be assigned for rubber cultivation in the Eastern and Northern Provinces, respectively. The terrain in these regions is mostly undulating or flat and in selecting lands, potential waterlogging areas during the rainy period is to be avoided. Groundwater availability is a key factor in the land selection of rubber; however, if land selection is done during dry weather, care must be taken for proper identification of such potential water logging areas. In addition to the nature of the soil (*e.g.* high proportion of sands *etc.*) and the position in the terrain, existing vegetation provides clear guidance in land selection. Obviously, wet-grown paddy fields can easily be identified and the areas used for rain-fed highland rice (Kakulan) farming areas are to be avoided. Sparsely grown bushes are also an indication of occasional waterlogging. In general, the predominant soil types appeared to be suitable for rubber cultivation.

Whilst providing knowledge, material required (*i.e.* plants, fertilizer) and other technical assistance, farmer motivation for timely adherence to the key agronomic practices is essential for the success of rubber cultivation. There are

several incidences of failures due to the lacunas in these aspects. In successful sites, the annual average growth rate of rubber (in terms of trunk girth at 1.2 m height) has been recorded as 7.4 cm in IZ under rain-fed and 8.6 cm in DZ under irrigated conditions. In general, about 75% of crop establishment rate has also been reported. Allowing farmers to use their indigenous knowledge on traditional farming practices in rubber is also advantageous.

Solar radiation loads received under usual conditions seem too high for small rubber plants as it results in down-regulation of photosynthesis and reduced water status in leaves. Nevertheless, agro-management practices such as shade plant establishment and intercropping have been found to alleviate the situation to an appropriate level. Also, mulching around rubber plants with the crop residues of seasonal crops has supported to conserve the soil moisture.

4. RECOMMENDATIONS FOR DRIER CLIMATES

With the observations made in feasibility studies, the following set of recommendations can be adopted for successful rubber cultivation in drier climates.

Land suitability

In general, lands having clay loamy soils in the great soil groups of Reddish Brown Earth (RBE) and Red-Yellow Latasol (RYL) are suitable for rubber cultivation. Waterlogging areas are to be avoided. Areas with Low Humic Gley (LHG) soil are subjected to waterlogging hence not suitable for rubber cultivation. Also, it is not advisable to undertake rubber planting, if the level of quartz is high in the soil. Nevertheless, the soil should be deep (over 1.5 m) without any rocky layer. Considering all the above, it is recommended to get the land suitability checked by RRISL or qualified personnel.

Land preparation

Avenue planting (2.5m x 7.75m) of rubber is preferred allowing farmers to grow their traditional crops with rubber (Plate 21.1). Intercropping becomes a must as it ameliorates the crop microclimate (particularly taller crops provide partial shading at early stages of rubber plants) and provides involuntary care to rubber plants with the activities of other crops (intercultivation).

Where possible, it would be suitable to change the size of the planting holes from 0.6 m x 0.6 m x 0.75 m (what is practiced at present) to 1 m x 1 m x 1 m to facilitate the root penetration in the early establishment. Further, the addition of organic manure to the planting hole such as dried cow dung, compost and decayed crop trash (*ca.* 3-5 kg) is recommended depending on the availability. In order to provide proper drainage during the rainy season and allow more water to percolate down the soil as rainwater harvesting, lock and spill lateral drain system is recommended.

Planting materials

Since no special clones have been selected for the drier areas, all five clones used in the smallholder sector, *i.e.* RRIC 100, RRIC 102, RRIC 121, RRISL 203 and RRISL 2001 are recommended for planting. It is necessary to use healthy and well-grown polybagged plants having leaves in two whorls. As generally recommended, the selection of only the top whorl hardened plants and tailing the taproot 10-14 days before planting are mandatory.

Planting and crop upkeep

With little rainfall received during the Yala season (South-West monsoon), planting rubber should be undertaken at the beginning of Maha season (North-East monsoon) (Fig. 21.2).

	January	February	March	April	May	June	July	August	September	October	November	December
Land selection	■	■										
Land clearing			■	■				■				
Lining and pegging				■	■				■			
Holing						■			■			
Planting rubber									■	■	■	
Planting intercrops								■	■	■	■	■
Fertilizer application				■					■			■

Fig. 21.2. Activity chart for rubber cultivation in Dry climates

Planting rubber with the polybag intact (only the bottom of the bag removed), was found to be unsuitable for this zone due to the high level of swelling and shrinkage of the soil in wet and dry periods, respectively resulting in weak contact of the roots with the soil in the ground. Therefore, the total removal of the polybag at planting is recommended for this zone (Plate 21.2).

During the initial establishment period, extreme care should be taken to conserve the soil moisture and to minimize evapotranspirative losses. Rubber plants are to be provided with temporary shades either by dead plant material or shade plants. Being cost-effective, growing traditional crops like banana and maize as an intercrop of rubber would be the best option and also, *Crotalaria* (sun hemp) could

be grown around the rubber plants in this regard. In absence of any taller crop for intercropping, four *Gliricidia* sticks (*ca.* 1.5 m tall) are to be planted as a square keeping a gap of *ca.* 1 m to the rubber plant (Plate 21.3).

Thick mulch is to be provided around the plant base using weeded or any dead plant material. Further, the use of artificial mulches such as Power Mat developed by RRISL could also be an option. However, it is necessary to avoid any direct contact of the mulching material with the greenery stem of the plant and so, mulching is to be placed *ca.* 10 cm away from the plants (If contacted with the greenish stem, the heat built up in the mulch may result in heat injuries on the stem). Application of lime on the brownish area of the stem in immature rubber trees during the dry spells is also a good practice to reflect solar radiation and thereby reducing the desiccation. Mulching around the rubber plants is to be continued throughout (Plate 21.4).

Irrigation during the dry spells of the first 3-4 years is required for proper establishment. Ideally, this should be designed based on the evapotranspirative demand, water holding capacity of the soils and root penetration. In order to facilitate irrigation, a basin could be formed keeping the plant base *ca.* 20 cm below the usual ground surface (Plate 21.5). However, it is required to let water drain off from the basin during the rainy period.

With drip/pitcher irrigation or more frequent watering systems, the amount of water to be applied could be reduced (Plate 21.6). Socker tube developed by RRISL would also be an option.

Considering the rainfall distribution, fertilizer application in the early stages of growth has to be confined to three instead of four in the traditional wet zone. The annual fertilizer dose is to be split into three and applied at the beginning of October, at the end of December and in April. (Fig. 21.2) Due to relatively high soil pH and high temperature, urea-based fertilizer may not be suitable for this zone. Instead, Sulphate of Ammonia could be used with other ingredients at the ratio of 7:9:9:3 (N:P:K:Mg).

5. PRESENT STATUS OF RUBBER PLANTING IN DRIER CLIMATES

Being the first major province in a drier climate to plant rubber, an extent of 4,800 ha had been planted with rubber in the Monaragala district and then 1625 ha in Badulla district by 2019. In the Eastern Province, after the success shown with tapping commenced in 2010 in the initial farmer participatory adaptive research trials established in Padiyathalawa DS division of Ampara district, cultivation was gradually extended to *ca.* 1,750 ha with 2,500 farmers by 2019. Rubber extent under tapping in this region is *ca.* 110 ha with 145 farmers.

In Northern Province, though rubber cultivation was initially launched in the Vavuniya, Kilinochchi and Mullaitivu districts, only Vavuniya South cultivations became effective. In total 72 ha of rubber that have been cultivated with *ca.* 200 farmers in the Province, however over 140 holdings had abandoned the cultivation. It appeared to have a high level of impediments to promote rubber cultivation among the farmers in Kilinochchi and Mullaitivu districts due to their

negative attitudes towards practicing the recommended protocol for rubber cultivation. Harvesting of latex in DZ was commenced in 2019 with a pioneer farmer in Vavuniya South (Plate 21.7).

The average annual latex yield of the rubber fields under adaptive research trials in the Eastern Province was in the range of 1,250 - 1,450 kg per ha. The total number of potential tapping days per tree under S/2 d2 system has been recorded in the range of 145-170 per year in this region.

6. ENVIRONMENTAL BENEFITS

With the maturity of rubber cultivation, changes in crop microenvironment were evident. Studies have revealed that rubber canopy resulted in a 3.7°C reduction in air temperature and maintaining an 11% increase of relative humidity during daytime providing a comfortable environment for people to live in. Further, rubber soil has reported a 100% higher moisture value than that of seasonal crop fields.

Being a new planting done on unproductive or lands used seasonal crops, rubber cultivation provides fixing atmospheric CO₂ enabling to mitigate the Climate Change effect, the biggest global level environmental issue. Some lands allocated for rubber cultivation belong to the Forest Department and this intends to build up the forest cover in the county by participatory means.

7. SOCIAL BENEFITS

Based on the evidence found from the Eastern Province, rubber cultivation has been confirmed as a livelihood improvement tool in rural development programmes in Sri Lanka. Farmers were able to secure permanent and year-round income from rubber cultivation ranging between LKR 100,000 to LKR 555,000 with an average of LKR 280,000 reaching a higher status in financial capital. As a result, the expenditure of rubber farmers has increased by 40% compared to the non-rubber growing farmers. Expenditure pattern showed that rubber farmers spend more on children's education, family health and charity gaining a higher level of human capital. Further, rubber-associated development in physical capital has made farmers have basic infrastructure facilities for their houses, some luxury appliances for convenience, facilities to strengthen social connectivity and improvement in farming. Enhancements in the interactions with relations and fellow villagers, their participation in community activities and involvement in more charity works have added an unseen social value to the rural economy in the socioeconomic context.

8. WAY FORWARD

By seeing the advantages in Uva and Eastern Provinces, farmers in other dry areas have shown their interest in the rubber cultivation. At present, farmer participatory adaptive research trials have been established in appropriate areas of the North-Central Province to identify the feasibility of cultivation. Having understood the reasons for failures, adaptive research trials have been reestablished in the Kilinochchi district for assessing a new strategy to attract the Tamil community for this crop.

Rubber cultivation in non-traditional drier climates

Having no special clones, research programmes have been streamlined on clone screening to identify best-suited clones for dry climates. Developing agronomic practices for higher water use efficiency, identifying new intercropping systems for greater economic returns and refining latex harvesting and manufacturing technologies to outfit with social and climatic conditions in the regions have also been targeted. Disease screening is also underway with special trials established and regular inspections. Social life cycle assessment on rubber cultivation is also expected to be conducted in the Eastern Province. Considering the additionality of atmospheric CO₂ fixing with new rubber cultivation, a carbon trading project is in the process of establishing the voluntary carbon market. Further, tools of technology transfer can effectively be used to promote rubber cultivation for the areas having low perception rates.

Success to date in the establishment of rubber cultivation in dry regions has been a collective achievement of the organizations working on rubber *i.e.* Rubber Research Institute, Rubber Development Department, Thurusaviya fund and Smallholder Tea and Rubber Revitalization (STaRR) project, with the assistance given by the community development programmes and local administration (*e.g.* Divisional Secretariats) of the area. Therefore, such links are to be strengthened further to improve the expansion process of rubber cultivation.



Plate 21.1. Intercropping with annual/perennial crops



Plate 21.2. Complete removal of polybag at planting



Plate 21.3. Planting Gliricidia to provide shade for rubber plant



Plate 21.4. Placing mulch around rubber plants leaving a gap of 10 cm to the plant

Rubber cultivation in non-traditional drier climates

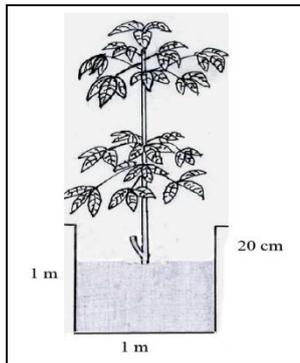


Plate 21.5. Forming a basin (with a drain) around the plant base by positioning 20 cm below the ground surface



Plate 21.6. Irrigation during dry spells at initial ages - Pitcher (bamboo) irrigation technique

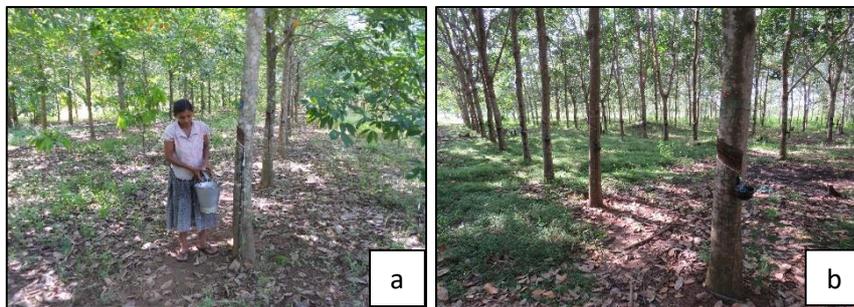


Plate 21.7. Successful mature rubber clearings in **a.** Padiyathalawa of Intermediate Zone and **b.** Vavuniya of the Dry Zone

Chapter 22

Carbon trading for the sustainable rubber industry

E.S. Munasinghe and V.H.L. Rodrigo

1. Climate change and greenhouse gases
2. Carbon footprint
3. Global interventions for stabilization of greenhouse gas concentration
4. Carbon trading potential
5. Contribution of rubber cultivation

1. CLIMATE CHANGE AND GREENHOUSE GASES

Climate change refers to global warming driven by anthropogenic emissions of Greenhouse Gases (GHGs) and the large-scale shifts in weather patterns. Heat balance in the atmosphere is influenced by the increased accumulation of GHGs towards higher temperatures as those gases absorb the heat emitted in terms of longwave radiation by the earth. The primarily responsible factors for the crisis are increased population, industrial developments and consumption patterns that are headed to the increased emission of GHGs. Intergovernmental Panel on Climate Change (IPCC) of United Nations; a dedicated body providing the scientific information relevant to the risk of human-induced climate change has projected that warming continues over 1.5 °C during 2030 relative to the pre-industrial level. Carbon dioxide (CO₂), Methane (CH₄), Nitrous oxide (N₂O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF₆) are the key GHGs involved in this process with the biggest share from CO₂ contributing over 60% to this phenomena. The global Warming Potential (GWP) of an individual GHG has been standardized against CO₂ on unit basis with the assumption that one kilogram of CO₂ absorbs 1 unit of heat (*i.e.* GWP of 1 kg of CO₂ = 1). Accordingly, GWP of one kilogram of CH₄ and N₂O is considered to be 25 and 298, respectively. Fossil fuel burning (coal, oil, and natural gas) for energy consumption is the main source for this emission, with additional contributions from agriculture, deforestation. With the increased quantity of those GHGs, heat accumulated in the atmosphere leads to phenomena of Global Warming. Desert expansions, common heatwaves, wildfires, intense storms and weather extremes are the ultimate consequences of enhanced temperatures. Further, it contributes to melting permafrost, glacial retreat and sea ice loss, rising sea levels and rising ocean temperatures. The above changes make obvious influences on many physical and biological systems of the environment. Drastic changes in ecosystem compositions are experienced and threatening of people with food insecurity, loss of freshwater, flooding, infectious diseases, extreme heat, economic losses are some other drawbacks of global warming. During the pre-industrial period (1850 - 1900), CO₂ concentration was 280 ppm; but in 2020, it came to the level of about 410 ppm showing the gravity of human influence. Amidst measures taken to minimize the emission of GHGs, plants on the other hand, sequester

atmospheric CO₂ through the process of photosynthesis and thereby help to mitigate the Climate Change effect.

2. CARBON FOOTPRINT

The Carbon Footprint (CF) is the net GHG emission caused by an individual, event, organization, service, or product, expressed as CO₂ equivalent. This can be measured by undertaking a GHG emission assessment/Greenhouse Gas Protocol or a Life-Cycle Assessment (LCA) denoted as carbon accounting. The method of assessment consists of a set of standards for tracking GHGs across three scopes (*viz.* Scope 1, 2 and 3 emissions) within the value chain. Scope1/Direct emission refers to the emissions directly from the activities of an entity related to stationary, mobile, fugitive and process on development. Scope2/Indirect emissions involve in the purchase of energy to a particular entity. Scope3 covers all indirect emissions which do not come under Scope 2 and associated with upstream and downstream activities. In carbon footprint calculations, emphasis under Scope1 & 2 are mandatory whilst Scope 3 is voluntary.

The International Organization for Standardization has a standard; ISO 14064:2006 that consists of the framework for conducting assessments. The standards are based on the identification of GHG sources and sinks, selection of quantification methodology, collection of activity data, development of GHG emission or removal factors, monitoring, reporting and validating or verifying GHG emissions and removals. Once the size of a carbon footprint is known, a strategy can be devised to reduce it by technological developments, energy efficiency improvements and better process & product management.

GHG emission in the process of cultivating rubber for its lifespan (30 years) is 65.15 CO₂eq MT/ha. Processing of Ribbed Smoked Sheets (RSS) throughout the productive lifespan of 24 years is responsible for additional 93.49 CO₂eq MT/ha emission whilst that for processing Crepe Rubber (CR) is limited to 50.14 CO₂eq MT/ha. The total CO₂ sequestration capability of rubber during the 30 years is estimated as 1,660 MT/ha. Accordingly, the carbon footprint (Net GHG emission) of cultivating rubber to produce RSS is -1501CO₂eq MT/ha/30 years whilst that for CR is -1544 CO₂eq MT.

3. GLOBAL INTERVENTIONS FOR STABILIZATION OF GREENHOUSE GAS CONCENTRATION

To stabilize the potential detriments of increased greenhouse gas concentrations in the atmosphere, the global community has developed an international environmental treaty in 1992; United Nations Framework Convention on Climate Change (UNFCCC) that was negotiated and signed by 154 states at the Earth Summit. UNFCCC adopted a regulatory mechanism; the Kyoto Protocol in 1997 with an obligation to cut down the emissions by 5.2% from the values in 1990 during the first commitment period of 2008-2012. Based on differences in the level of GHG emissions, signatory states had been categorized into three; developed countries (Annex I), developed countries with special financial responsibilities

(Annex II) and developing countries. In that, Annex I countries are responsible to adopt national policies and take corresponding measures on the mitigation of climate change by limiting their anthropogenic emissions of greenhouse gases and reporting on steps adopted to return individually or jointly to their 1990 emission levels. Annex II countries are responsible to provide new and additional financial resources to meet the costs incurred by developing countries in complying with their obligation to produce national inventories of their emissions by sources and their removals by sinks. The developing countries are then required to submit their inventories to the UNFCCC.

In order to facilitate those emission reduction targets, the Kyoto Protocol introduced three flexibility mechanisms. They are Emission Trading (ET), Joint Implementation (JI) and Clean Development mechanism (CDM). ET enables industrialized countries that over fulfill the GHG reduction obligations to transfer credits for the excess GHG abatement to other industrialized countries that have not met their GHG reduction targets and receive mutually negotiated payments for such credits. JI allows firms in industrialized countries that are subjected to domestic GHG regulation to obtain GHG credits from firms in other industrialized countries that undertake projects to reduce GHG from a defined baseline and share the Emission Reduction Units (ERU) instead of monetary payments or technology transfer. CDM which is associated with exchange or trade carbon abatements between country parties, received a high attraction among them as the only mechanism that both developed and developing countries can participate. Being mostly responsible for Climate Change, CO₂ is considered to be standard GHG in developing credits. With that GHG credits are named as carbon credits and accounted for a number of tons of CO₂ or its equivalent on GWP in the case of other GHGs.

With little success in the first phase, a second commitment period of 2013-2020 was agreed (though not entered into force) based on the negotiations and decisions made as per the Bali Action Plan (2007), the Copenhagen Accord (2009), the Cancun agreements (2010), Durban Platform for Enhanced Action (2011), the Doha abatement (2012) and the Paris Agreement (2016) to keep global warming not more than 2.0 °C above the pre-industrial level. As at 2020, UNFCCC consists of 197 signatory parties.

The supreme decision-making body of the UNFCCC, the Conference of the Parties (COP) first met in Berlin, Germany in 1995 (COP1) in dealing with climate change regulations. The scientific findings on climate change offered by the IPCC were accepted in the COP2 held in Geneva, Switzerland. The Kyoto Protocol was adopted in COP3 held at Kyoto, Japan, 1997 and the remaining unresolved issues were finalized in Buenos Aires, Argentina at COP4 in 1998. The Bonn agreement that resumed several negotiations on Flexible Mechanisms, Carbon Sinks, Compliance Action Plans and Financing of carbon credits in COP6 held in Bonn, Germany, 2001. The complete package of decisions taken at the COP7 in Marrakech, Morocco; the Marrakech Accords was for a wrapped up of the Buenos Aires Action Plan. Transfer of technologies from developed countries to developing

countries was approved in the COP8 held in New Delhi, India on Article 6 of the Convention. It consists of the Action for Climate Empowerment (ACE), focusing on six priority areas: education, training, public awareness, public participation, public access to information, and international cooperation. These pivotal factors together guide in solving the challenges of climate change. Adaptation and mitigation are the key actions that can be implemented effectively to face those challenges of climate change. Mitigation is either to reduce the sources or enhance the sinks of GHGs and adaptation is to adjust existing or expected climatic stimuli and their impacts. Nevertheless, the former provides long-term stability in the environment; hence the same has been focused more on international treaties. Accordingly, the parties agreed to use the Adaptation Fund in supporting developing countries through technology transfer at COP9 in Milan, Italy, 2003.

The Montreal Action Plan; an agreement to extend the life of the Kyoto Protocol beyond 2012 and negotiation on deeper cuts in greenhouse-gas emissions was an invention of COP11/ The first Conference of the Parties serving as the Meeting of the Parties to the Kyoto Protocol (CMP1) held in Montreal, Canada in 2005. An agreement on a timeline and structured negotiation on the Post-Kyoto-2012 framework was achieved in 2007 with the adoption of the Bali Action Plan of COP13/CMP3 held in Bali, Indonesia. The Ad Hoc Working Group on Long-term Cooperative Action under the Convention (AWG-LCA) was established as a new subsidiary body to conduct the negotiations beyond 2012. Further, it was proposed to create United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation (or UN-REDD Programme) to reduce forest emissions and enhance carbon stocks in forests while contributing to sustainable development at national levels. These negotiations took place during 2008 and 2009 at COP14/CMP4 in Poznan, Poland and COP15/CMP5 in Copenhagen, respectively. As the outcome of the COP16/CMP6 held in Cancun, Mexico in 2010, the parties adopted an agreement on Green Climate Fund (GCF) and Climate Technology Centre. Further, all parties recognized that climate change represents an urgent and potentially irreversible threat to human societies and the planet, and thus requires to be urgently addressed. The COP17/CMP7 held in Durban, South Africa agreed to start negotiations on a legally binding deal comprising all countries that governing the post-2020, but with a warning alarm on insufficiency of a deal to avoid global warming beyond 2°C. The Doha Climate Gateway that came out from COP18/CMP8 held in Doha, Qatar in 2012 contained the Doha Amendment to the Kyoto Protocol featuring a second commitment period running from 2012 until 2020. The COP21/CMP11 held 2015 in Paris, France fully adopted the Paris Agreement that governs climate change reduction measures by entering to force from 2020. A focal issue discussed at COP22/CMP12, Marrakech, Morocco in 2016 was to reduce greenhouse emissions and utilize low-carbon energy sources. Both COP23/CMP13 held in Bonn, Germany, 2017 and COP24/CMP14 in Katowice, Poland, 2018 dedicated on the completion of the Paris Agreement work programme. Further, more ambitious carbon reduction commitments were suggested for governments in COP25/CMP15 held in Madrid, Spain, 2019. Though

COP26/CMP16 was originally scheduled to take place in Glasgow, United Kingdom, was postponed due to the COVID-19 pandemic.

4. CARBON TRADING POTENTIAL

Under the Kyoto Protocol, developing countries have an advantage in participating in CDM targeting new economic ventures through carbon trading. Particularly with a high rate of plant growth under tropical climatic conditions, such countries have an added advantage for tree growing projects. Carbon trade is an exchange of carbon credits (in terms of number tons of CO₂) or equivalent between two parties in view of meeting the obligatory abatements of GHGs. No matter anywhere in the world who reduces the emissions as it ultimately helps to stabilize the concentration of GHGs in the atmosphere. Under the carbon trading, a country or an organization which requires to reduce its emission level but faces difficulty in doing so by itself is able to purchase the required amount from the right to emit of another country.

The process of developing a CDM project for carbon trading is rather rigorous and several steps are to be followed to ascertain and assure the level of emission reduction. Submission of Project Idea Note (PIN) and obtaining the approval from the Designated National Authority (DNA) of the country, developing the Project Design Document (PDD), validation and verification obtained from the Executive Board (EB) of CDM and Issuance of Certified Emission Reductions (CER) are the key steps in this process (Fig. 22.1). Strict compliance with the regulations is required to be qualified for a CDM project. Additionality in CO₂ abatement is to be proven against the business as usual and potential leakages of emissions from the project are to be considered. Also, a reasonable level of allowance has to be kept to overcome the uncertainty and risk in the emission reduction process associated with uncounted factors.

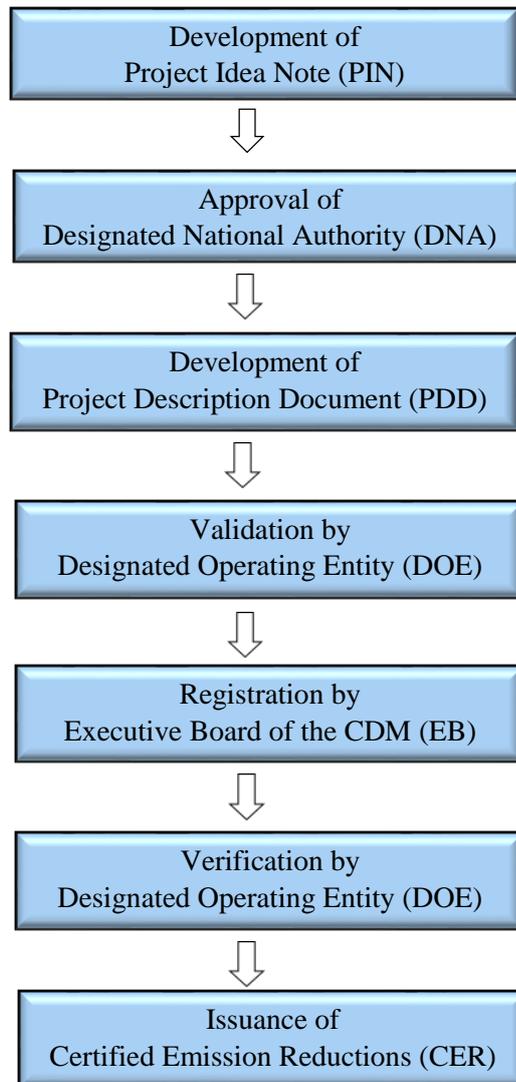


Fig. 22.1. Project Cycle for Clean Development Mechanism.

The cost involved in developing a CDM project is very high (particularly in developing PDD and then for validation and verification process); therefore, large projects are always preferred and bundling of similar types of small projects can be undertaken. The trading value of CO₂ depends on the demand and supply in the first place and then the quality of the project (*e.g.* level of assurance in CO₂ abatement and other social benefits). The present market rate for an MT of CO₂ equivalent varies from US\$ 1.5 to 20 and quality matters a lot in determining the overall income

from carbon trading. However, the issuance of CERs is a much more complicated process.

In contrast to the strict rules set out for the Compliance Market under CDM, Voluntary Market provides different options to acquire emissions reductions. Needs of emission reduction on voluntary basis (Voluntary Emission Reductions) are met here with the carbon credits generated from non CDM projects. Verified Emission Reductions (VERs) that are verified outside of the Kyoto Protocol are used as carbon credits to offset the emissions. Though not be stringent as CDM, a standard certification process is to be followed in developing carbon credits as VERs (Fig. 22.2). Project types in the voluntary market range from avoided deforestation, afforestation/reforestation, industrial gas sequestration, increased energy efficiency, fuel switching, methane capture from coal plants and livestock and renewable energy. The available carbon offset standards depend on the above types, such as Verified Carbon Standards (VCS) and Plan Vivo for forestation, Gold Standards for renewable energy and Climate Action Reserves for Methane. In the voluntary carbon market, industries and individuals voluntarily compensate/offset for their GHG emissions contributing to mitigate climate change. With the certification of carbon neutral status in this manner, industries are benefitted with adding cosmetic value to their businesses.

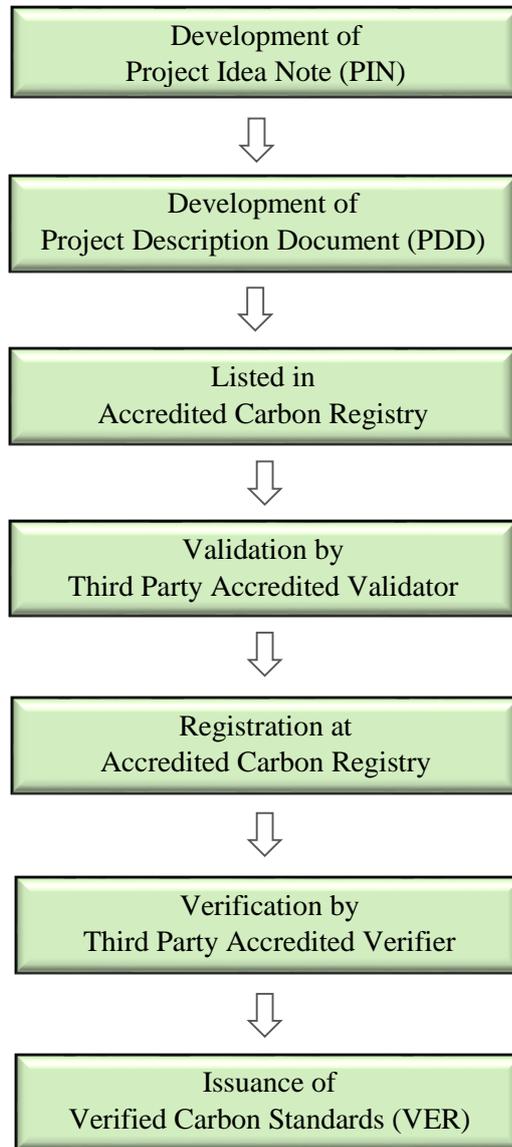


Fig. 22.2. Project Cycle for Voluntary Carbon Market.

5. CONTRIBUTION OF RUBBER CULTIVATION

Being a tree crop with over 20 years of economic lifespan, 5 m (upper limit) in height and over 30% canopy cover, rubber has an entitlement to be recognized as a forest plantation. UNFCCC has emphasized the importance of the forest sector in climate change mitigation in three aspects; existing carbon sink conservation,

expanding carbon sinks and fossil fuel substitution. The eligibility comes under the Afforestation and Reforestation categories of CDM. Nevertheless, with no additional amount of CO₂ fixed, replanting of rubber does not qualify for this category. Hence, only the new planting of rubber in non-traditional areas where forest lands have been cleared well before 1990 for shifting cultivation, is allowed under forestry of CDM. In the voluntary carbon market, the lands are traced back only for 10 years from the inception of the project.

Further, the cultivation of rubber as business as usual is also not an option as it cannot prove the need for financial additionality. In order to promote the cultivation in nontraditional areas, farmers are to be provided additional material and service inputs, market facilities, financial and insurance schemes as an encouragement. They are also to be well educated on the cultural practices of rubber through technology transfer tools. Adaptive research is required to refine the existing technologies to be matched with regional needs. Therefore, financial additionality can be justified.

The amount of carbon fixed in the rubber tree has been assessed in different genotypes and geographic locations. In Sri Lanka, simple allometric models to quantify the amounts of carbon fixed in the rubber tree have been developed for convenience in non-destructive field assessments. Further, the amount of carbon sequestered through the process of photosynthesis has been investigated. In particular, growth curves of rubber under wet and dry conditions in Sri Lanka have been established for average management conditions and so, the amount of carbon fixed in rubber trees at varying age levels can be estimated and also monitored. Therefore, sufficient information is available to build up carbon trading projects on rubber cultivation.

On average, a mature rubber tree contains *ca.* 1 MT of CO₂ and therefore, within a hectare having *ca.* 300 - 400 rubber trees, 300-400 MT of CO₂ is available. Obviously, with good management strategies, more carbon could be fixed. In addition to carbon retained in the tree, rubber trees add *ca.* 84 MT of CO₂ to the soil during its 30-year economic lifespan through the annual leaf fall. Further, cover crops and/or intercrops in rubber lands add a huge amount of organic matter to the soil. Also, *ca.* 84 MT of CO₂ is available in rubber latex harvested throughout the usual 24 year harvesting period (Fig. 22.3).

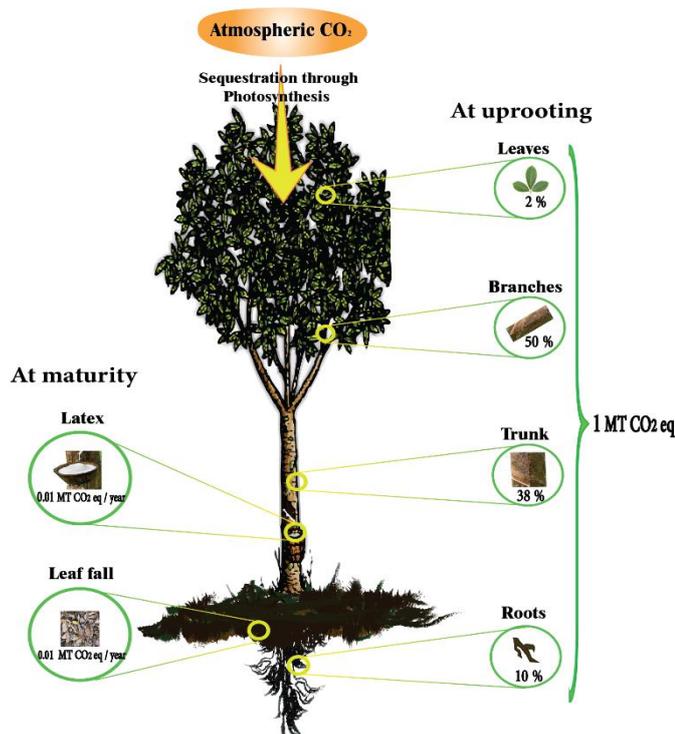


Fig. 22.3. CO₂ fixing by the rubber tree

This information can effectively be used in developing a carbon trading project along with the government agenda of the new planting of rubber in non-traditional areas of the country. As per the Rubber Industry Masterplan, the target set for new planting in non-traditional areas is 22,000 ha. At present, a special project has been launched to cultivate rubber in 3,000 ha in Monaragala and Ampara district. With that, Carbon trading project for the Voluntary market is underway and it is expected to provide some community benefits to the growers with the funds generated. Further, rubber product manufacturers are expected to make their products carbon neutral by offsetting their carbon footprint with the carbon credits generated from the above project.

In establishing a carbon trading project, a cost of about LKR 12.5 Mn is initially required for preliminary arrangements and building up necessary documentation and then about LKR 4 Mn per year as running cost. If such project is built up with 2,500 ha of rubber, *ca.* 470,000 MT of CO₂ equivalent could be traded bringing an income of about LKR 350 Mn (at a rate of 5 US\$). To develop project description documents with relevant registration, project validation and output verification and then marketing of carbon credits, expert involvement is essential.

Over the additionality in carbon fixation, rubber in those areas provides a stable and greater income to the poor farmers who face uncertainties with seasonal/traditional crops. Reclamation of degraded soils (due to continuous shifting cultivation) with the addition of organic matter and change in regional climate with increased tree cover are the other important environmental benefits in rubber cultivation. Further, employment opportunities arise with associated industries and trading. Such additional social and environmental benefits provide a decorative effect to carbon trading projects hence would increase the value of carbon traded.

With no provision in CDM to claim on carbon stocks or sequestration in existing forests under current regulations, another approach named “Reduce Emission by Deforestation and forest Degradation” (REDD) is under consideration. In that, continuous sequestration of atmospheric CO₂ by the existing forest and not damaging the carbon stocks in forests for alternative ventures are considered for remuneration. Accordingly, existing rubber plantations may be eligible for carbon trading; but modalities are yet to be explored. Therefore, it is necessary to be ready with the information on carbon stocks and sequestration levels in existing plantations to reap the benefits of REDD.

In addition to the direct sale of carbon in the rubber tree, there are numerous ways to work on carbon trading with rubber. If the rubber tree is used for firewood as a renewable source of energy replacing the fossil fuel burning, the CO₂ equivalent in this replacement can be claimed for carbon trading either in the Compliance or Voluntary market. In power generation, three kilograms of biomass are required to compensate for one kilogram of fossil fuel. On this basis, the biomass of rubber in one hectare of land (at the end of 30 years) is equal to 64 MT of fossil fuel.

Biogas generated from rubber factory effluents could also be used as a replacement for fossil fuel, thereby qualified in carbon trade. The emission reduction potential by biogas generation from the rubber effluents in Sri Lanka has been reported to be as high as 12,000 MT of CO₂ per year. In Sri Lanka, thermal power generated from diesel or coal has been one of the principal sources of energy in electricity generation. Therefore, power factor correction and factory modernization for electricity saving in the rubber processing industry and also electricity generated by solar power are qualified for carbon trading due to emission reduction.

Chapter 23

Stimulation based latex harvesting and latex diagnosis

V.H.L. Rodrigo and K.V.V.S. Kudaligama

1. Need for guidance in stimulation based harvesting systems
2. General benefits of stimulation based low intensity harvesting
3. Protocols for stimulant use in low intensity harvesting systems and management benefits
 - 3.1 On base panels
 - 3.2. On high (upper) panels
 - 3.2.1 Ethephon based system
 - 3.2.2. Gaseous stimulation methods
4. Use of latex diagnosis as a tool to identify adverse effects of stimulation
 - 4.1 Effect on latex sucrose content (Suc. mM)
 - 4.2 Effect on Latex inorganic phosphorous content (Pi mM)
 - 4.3 Effect on Latex thiol content (RSH mM)
 - 4.4 Effect on TSC/DRC (%)
5. Principals and applications of industrial latex diagnosis

1. NEED FOR GUIDANCE IN STIMULATION BASED HARVESTING SYSTEMS

Harvesting latex is considered to be the costliest operation in rubber cultivation contributing to over $\frac{1}{3}$ of the cost of production, particularly in commercial plantations. It requires a high level of skill and this together with poor wage structure has led to a shortage of skilled harvesters. In particular, percentage daily out turn of harvesters appears to be *ca.* 12% hence the fields allocated to absentees are either left without being tapped regularly or tapped by unskilled workers damaging to long-term yield potential of the rubber tree. Generally, 37% of harvesters employed in the plantation sector are not skilled enough.

Traditionally, rubber trees of most popular genotypes are tapped half of the tree trunk circumference spirally ($S/2$) downward with the frequency of once in two days (d2); hence each harvester is given two blocks of trees (tapping blocks). Increase in worker use efficiency is a must for any industry to be competitive in present day market dynamics. Therefore, a high level of worker use efficiency in latex harvesting is to be the first focus in rubber cultivation. Mechanized tapping has not been successful so far; hence low intensity harvesting (LIH) systems have become a practical agronomic approach to address this issue.

In LIH, there are three options, *i.e.* reducing the frequency of harvesting, or reducing the tapping cut length or both. In general, more emphasis has been given to the first option and then, to the last. If rubber clones selected for d2 tapping are harvested at reduced intensities, latex yield becomes low. Therefore, trees are stimulated to compensate for low yields due to lowering the intensity of

harvesting. As stimulants, ethylene releasing chemicals such as ethephon or ethylene gas are used. These chemicals enhance latex synthesis, increase turgor pressure in latex vessels and extend the period of latex flow after tapping. Due to the convenience in application and slow release nature, ethephon is the widely used yield stimulant in rubber plantation industry. Direct application of ethylene gas is practical only during harvesting on upper panels at last stage of the tree lifespan as it tends to over stimulate the latex production. In the application of any stimulant, its concentrations and application frequencies are to be decided only to achieve the potential yield of the tree. Response of different genotypes (rubber clones) to stimulation differs and also depend on the climatic conditions. Ad hoc application of yield stimulants has been found to be unsafe affecting the long term sustainability of latex yields. Hence, its judicious application is quite important in LIH systems. Over application disturbs the latex synthesis pathway and ultimately leads to either partial or complete cessation of latex, named as Tapping Panel Dryness (TPD). It would also affect the latex quality giving high levels of pigments and/or lead to necrosis of bark cells named as Brown bast (BB). Therefore, with the application of stimulants, latex yield is just one parameter to be considered and in addition, its effects on latex physiological parameters, raw rubber properties and overall tree health are to be considered. With proper assessment in latex physiological parameters, adverse effects associated with potential over stimulation can be avoided. Therefore, required guidance is provided here with a view of allowing the rubber growers to practice LIH in sustainable manner to achieve its benefits.

2. GENERAL BENEFITS OF STIMULATION BASED LOW INTENSITY HARVESTING

Time gap between two tappings are extended by few days more in low frequency harvesting (LFH). Therefore, each harvester can be allocated to a greater number of tapping blocks resulting in reduced worker requirement. In order to compensate the yield loss due to lesser number of tapping days per tree, yield stimulants are applied; thereby yield per tree per tapping increases. This results in enhanced daily intake per harvester, which provides a way of increasing the remunerations of harvesters. Furthermore, overall increase in harvesters' productivity results in reduction of cost of production. With lesser number of tappings per year, economic lifespan of the tree increases providing an additional benefit to the growers. In large plantations, this results in a higher proportions of revenue (income generating) land area. Therefore, overall profitability of the plantation will further increases.

3. PROTOCOLS FOR STIMULANT USE IN LOW INTENSITY HARVESTING SYSTEMS AND MANAGERIAL BENEFITS

3.1 On base panels

At the moment, three LIH systems have been recommended to Sri Lankan rubber growers to harvest on base panels with appropriate ethephon stimulation protocols (Table 23.1).

Table 23.1. Recommended low intensity harvesting systems (LIH) for base panels with appropriate stimulation protocols.

LIH system	Ethephon application procedure		Method of application
	Concentration (%)	Amount (g/application)	
S/2 d3	2.5	1.6	Quarterly or every two months except during wintering. 4-5 rounds/year
S/2 d4	2.5	0.6 (Panel BO-I 1 st -3 rd year)	Monthly except during wintering. 10 rounds/year
		1.0 (Panel BO-I 4 th -12 th year)	
		1.6 (Panel BO-II onwards)	
S/4 d3	2.5	0.3 (Panel BO-I 1 st -3 rd year)	Every two weeks except during wintering. 20 rounds/year
		0.5 (Panel BO-I/II 4 th -16 th year)	
		0.8 (Panel BO-III onwards)	

Appropriate ethephon amount could be applied on panel/bark of rubber tree with the appropriate size paint brush (Fig. 23.1).

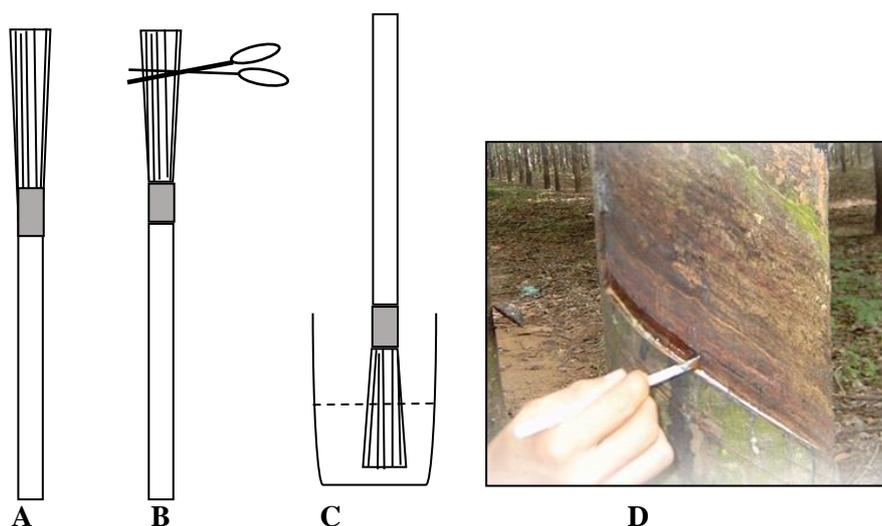


Fig. 23.1. Illustration of general steps in panel application of 1.6g of ethephon formulations. A - Paint brush size ¼", B - Remove 1cm of bristles from the tip of the brush to maintain a length of 3 cm in the case of 1.6g, C - Dip ¾ of bristles in ethephon mixture, D - Apply as a 2.5cm band along the tapping cut.

Best time to start stimulation is at the last week of April with the new green canopy and then continue to practice the appropriate stimulation rounds with correct frequency. Ready mixed commercial ethephon formulations with correct active ingredient content should be used to avoid unnecessary dilutions at the field. This ensures the application of the correct dosage. Late collection or delaying the collecting time during initial three tappings after stimulation and proper rainguarding will maximize the benefits. Double tapping should be completely stopped. Recovery tapping can be practiced immediately after the due date for tapping or before as a proactive measure maintaining the maximum possible time gap between any two tappings. Stimulation should be avoided during severe droughts or if tapping has to be suspended for a long period during heavy rainy periods. Instead of two tapping blocks to a harvester in the traditional S/2 d2 system, three tapping blocks can be allocated to a harvester in d3 systems and four tapping blocks in d4 system. Therefore, labour use in latex harvesting is reduced by 33% and 50%, respectively with d3 and d4 harvesting. In general, latex harvesting requires 0.7 workers per hectare under the S/2 d2 system of tapping. This worker requirement is to 0.4/ha in d3 and 0.3/ha in d4 systems (Fig. 23.2).

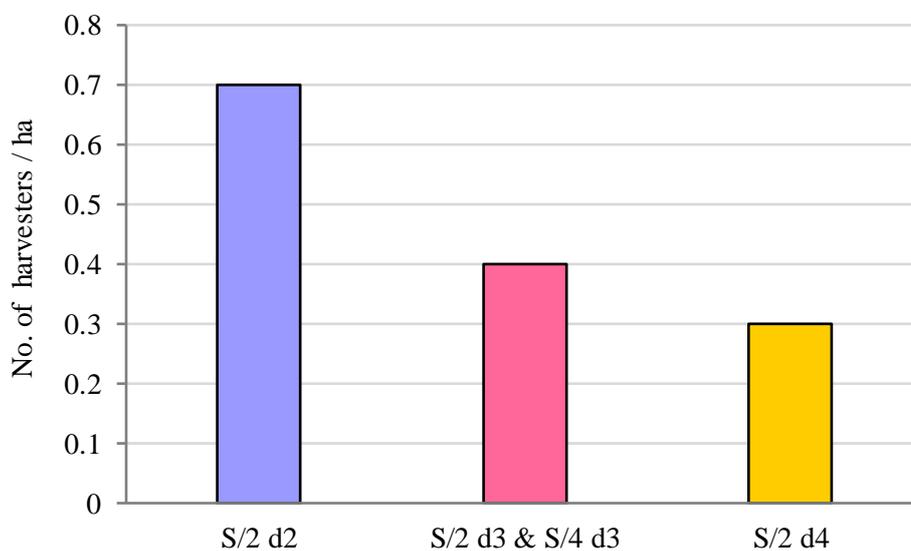


Fig. 23.2. Worker requirement can be reduced with low intensity harvesting systems.

With high level of worker use efficiency, LFH reduces harvesting cost. For instance, S/2 d4 and S/4 d3 reduce the harvesting cost by 19% and 29% hence overall cost of production by 8% and 7%, respectively if hired workers are used for tapping. With a greater amount of latex harvested on each day, LIH systems also provide an opportunity to have higher wages for harvesters. Under general

Stimulation based latex harvesting and latex diagnosis

circumstances, harvesters' daily income increases by 18% in d3 systems and 37% in d4 system (Table 23.2).

Table 23.2. Some financial indicators of low intensity harvesting systems with stimulation.

Tapping system	Tapping blocks/ tapper	Expected daily intake (kg)	Daily income of a tapper (Rs.) (Wage + payment for additional latex, @ Rs. 45/kg over 7 kg)	Total tapping cost per kg (Rs.) (Tapping cost + stimulation cost)
S/2 d2 (nil stimulation)	2	7.0	855.00	122.00
S/2 d3	3	10.5	855.00+157.50=1012.50	96.43+2.21= 98.64
S/2 d4	4	14.0	855.00+315.00= 1170.00	83.57+3.55 =87.12
S/4 d3	3	10.5	855.00+157.50=1012.50	96.43+2.21= 98.64

Because of the low bark consumption in d3 and d4 systems, the usage of the base panels (B0 and BI) could extend up to 33 and 41 years, respectively. With the reduction of tapping cut length in S/4 d3 system, bark consumption is further reduced and tapping on virgin panels (BO) could be extended to 25 years. If the lifespan of the rubber trees in a plantation is maintained up to about 30 years, tapping on renewed bark may not be required in such instances and so, some level of relaxation in the skill factor of the tapping seems possible. Nevertheless, potential extension of tree lifespan with reduced bark consumption in LIH will have a positive impact on both overall economics of an estate and the environment. Whilst increasing the profitability, it also addresses the issues of existing high level of bark consumption and employing semi-skilled workers in rubber estates.

3.2. On high (upper) panels

Tapping on high panels is undertaken during the last stage of the rubber tree as a way of intensified harvesting for high yields. Intensification of harvesting can be done either by increasing the frequency of harvesting and/or increasing the tapping cut length. At the verge of uprooting no matter how much latex is taken out. However, latex harvesting at the beginning of last six years is to be planned as a gradual increase in intensification from 150% at the beginning to 400% at the end.

In addition to mechanical intensification, chemical intensification for high yields could also be undertaken with either ethephon or ethylene gas as a latex stimulant; with that the period of tapping could be extended. Untapped virgin bark of the higher panels have the capacity to give greater yields. In particular, upward tapping in high panels also facilitates the tapping cut with a greater area of latex

drainage resulting in high yields. Therefore, careful exploitations of high panels are essential in estate management.

3.2.1 Ethephon based system

Control upward tapping (CUT)

Please refer to Chapter 16 for details of CUT system.

During 2-3 years before uprooting, site specific stimulation protocols could be used by considering the factors such as clone, tapping intensity, bark area left for tapping and time period left for uprooting.

3.2.2. Gaseous stimulation methods

Instead of ethephon, direct use of ethylene is advocated as a method of extracting greater amounts of latex from high panels and also to address the labour shortage in tapping. Puncture tapping was initially tried with ethylene [*e.g.* Hypodermic Latex Extraction (HLE)] but failing that, mini cuts were introduced. Another system called 'REACTORRIM' was also introduced with a smaller size jacket coupled with a buffer tank for ethylene gas. The Rubber Research Institute of Malaysia made some modifications to the ethylene based gaseous stimulation and introduced a system called 'RRIMFLOW'. Considering the difficulties in fixing jacket, another gaseous stimulation system with sticker type jacket named as Patch n' Tap was also introduced. These systems had two inherent problems – to wit- water trapped in the jacket could not be removed and the gas penetration to the tree was weaker in some cases. Later an improved version of this system, G-Flex was introduced facilitating to remove the water trapped inside the jacket. In Sri Lanka, RRIMFLOW and G-Flex were popular among growers in some RPCs and smallholdings.

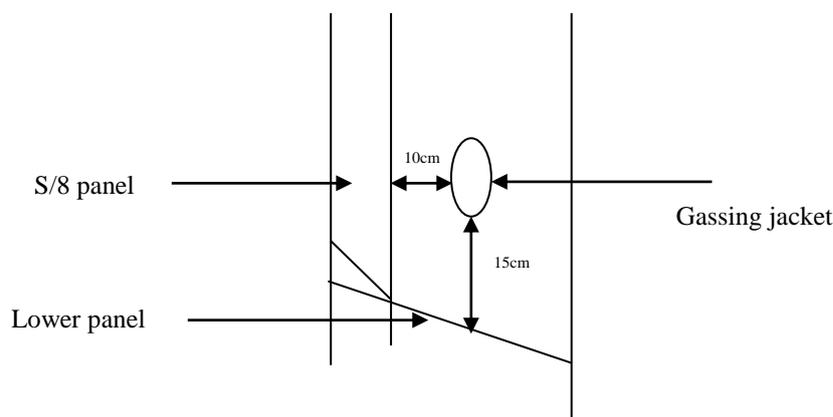


Fig. 23.3. Schematic diagram illustrating the placement of the jacket for ethylene stimulation.

Gaseous stimulation in upper panels could be used as a suitable method of controlled upward tapping (CUT) with an upward S/8 (one eighth) cut at the verge

of uprooting. Placement of the jacket along with the tapping panel is illustrated in Figure 23.3. Despite the recommendations made by the manufacturers to inject ethylene in every 12 days, research carried out in Sri Lanka on RRIMFLOW and G-Flex have shown the ideal/sustainable gassing frequency as once a month. Ethylene gas and accessories needed are imported from Malaysia, hence the cost is high. Use of rainguards is a necessity to maximize the yield. Bark wounds and cracks with latex oozing out are frequently seen when tapping suspended in stimulated trees during rainy period. When such conditions occur, affected area should be cleaned and a suitable fungicide/insecticide (please contact Rubber Research Institute if needed) is applied followed by a water resistant dressing such as candasan during wet weather.

For fixing jackets and gassing, cost per tree at the present market price is about Rs.450/= per tree per year. This is totally an additional cost on tapping and needs to harvest about 1.5kg of additional amount of rubber (@ Rs.300/= NSA) per tree per year to cover the cost, if no additional payment is given to harvesters. During the first 4 - 6 months average intake per harvester (from 300 trees) varies about 30 - 45 kg per day and then, gradually decreases to about 8-10 kg per day. Under normal circumstances, harvesters' daily income increases according to the additional quantity of latex brought. Especially during initial four tappings after gassing, latex dripping time prolongs and late collection is necessary to maximize the profitability. At very low rubber prices, gaseous stimulation systems may not be financially attractive to the growers.

4. USE OF LATEX DIAGNOSIS AS A TOOL TO IDENTIFY ADVERSE EFFECTS OF STIMULATION

Latex Diagnosis (LD) is currently used worldwide by most of rubber agro industries as a routine physiological tool to adapt methods to optimise yields in rubber plantations, particularly under stimulated conditions. In LD, assessments on following properties of latex (physiological latex parameters) are used to understand the functional status of the physiology of latex cells and to derive a conclusion on whether the level of latex harvesting is suboptimal or optimal or leading to over exploitation.

- latex sucrose content (Suc), an indicator of physiological stress level of the tree under latex harvesting
- latex inorganic phosphorus content (Pi), an indicator of the energetic level of latex cells metabolism);
- latex reduced thiol content (RSH), an indicator of cell and luteoidic membranes protection against Reactive Oxygen Species (ROS) released during latex metabolic activation
- latex dry rubber content (DRC)/ total solid content (TSC), indicators of the balance between water importation to the latex cells and cytoplasmic biosynthesis resulting from latex regeneration.

Assessment units used for these parameters are, milimoles/litre (mM) for Suc, Pi and RSH and a percentage value (%) for DRC/TSC. These values are generally considered under five levels (very low, low, normal, high and very high) with limits established for each clone. Interpretation of these values are important understanding how these parameters are influence by stimulation based harvesting.

4.1 Effect on latex sucrose content (Suc mM)

Irrespective of the tapping frequency, increase in ethephon stimulation intensity generally results in a hyperbolic decrease of latex sucrose content. This decrease (from very high Suc values to very low Suc values) is due to increased sucrose consumption from the latex regeneration metabolism. It is however remarkable that over-exploitation, due to excessive stimulation intensity, results in a simultaneous drop of rubber production and latex sucrose content (Fig.23.4).

4.2 Effect on Latex inorganic phosphorous content (Pi mM)

Regardless the tapping frequency, increase of ethephon stimulation intensity generally results in a parabolic evolution of latex Pi content. When increasing stimulation intensities, metabolic activity also increases (increase Pi) until reaching a maximum level and thereafter a drop appears with the further increase of stimulation intensity. This drop of Pi is a typical and significant sign of over-exploitation and is always associated with a drop in production (Fig. 23.4).

4.3 Effect on Latex thiol content (RSH mM)

Increase in ethephon stimulation intensity generally results in a linear decrease of latex RSH content. This decrease (from very high RSH values to very low RSH values) is due to an enhanced synthesis of reactive oxygen species (ROS) produced during latex cells metabolic activation. These ROS scavenged by RSH groups, leading to the decrease of their content in latex (Fig. 23.4). Sometimes, under low intensities of stimulation and/or for low metabolism clones, RSH curve may show a slight increase initially with a subsequent decrease which is due to metabolic activation of RSH synthesis.

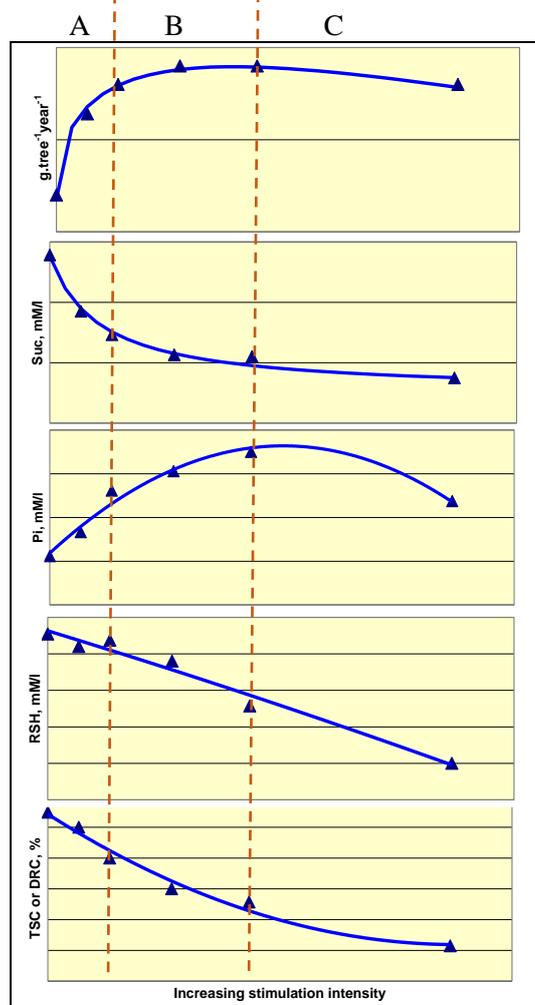


Fig. 23.4. Illustration of the effect of ethephon stimulation intensity on latex yield; rubber production (g tree⁻¹ year⁻¹), latex sucrose (Suc), inorganic phosphorous (Pi), thiol (RSH) and dry rubber (DRC)/Total solid (TSC) contents (general trend curves). General guidance for stimulation is given with vertical dotted lines depicting the zones for; A-under stimulated, B-optimum and C-over stimulated.

4.4 Effect on TSC/DRC (%)

At any tapping frequency, increase in ethephon stimulation intensity generally results in a linear or hyperbolic decrease of latex DRC/TSC. This decrease is initially due to enhanced water importation to the latex vessels. With low stimulation intensities and/or in low metabolism clones, DRC/TSC curve may show a slight increase initially with a subsequent decrease. Such a transient increase is due to the effect of metabolic activation on total cytoplasm syntheses,

permitted by the metabolic activation of latex cells and concurrent release of metabolic energy. In fact, DRC and TSC give an overall view of the balance between two antagonist effects of stimulation: Decrease of DRC/TSC is due to the enhancement of water importation into the latex and the increase of DRC/TSC is due to enhancement of rubber bio-synthesis. DRC/TSC is therefore an integrated parameter of which significance is less precise than other three LD parameters (Suc, Pi and RSH). Therefore, DRC/TSC is mainly used as a confirmation of LD interpretation derived from combination of Suc, Pi and RSH levels (Fig. 23.4).

5. PRINCIPALS AND APPLICATIONS OF INDUSTRIAL LATEX DIAGNOSIS

In rubber plantations, latex diagnosis (LD) could be performed and used as a physiological tool to assess the healthiness in exploitation. With that, the stimulation intensity can be advocated precisely in LIH systems avoiding potential adverse effects. Best time to do sampling is end April to end August after completion of refoliation when the tree is physiologically stable.

The latex clonal typology lays in classification of rubber clones in a 2 dimensions-matrix (Table 23.3) containing five different metabolic types (low, low-medium, medium, medium-high and high) and three different latex sugar loading types (low, medium and high). This typology permits, in particular, to describe the response of any rubber clone to ethephon stimulation. Stimulation intensity is to be increased when clonal latex metabolic activity decreases and/or when clonal latex sugar loading capacity increases. Conversely, stimulation intensity is to be decreased when clonal latex metabolic activity increases and/or when clonal latex sugar loading capacity decreases. Latex clonal typology provides accurate guide for stimulation in all physiological types of clones, depending on their respective position in the matrix.

This physiological modelling thus allows predicting, in case of adopting reduced tapping frequencies (*e.g.* d/3, d/4, d/5, d/6 and d/7), the appropriate ethephon stimulation intensity that will be required for obtaining the potential yield of a particular clone (*i.e.* clonal yield potential). In fact, these stimulation recommendations can be associated to 5 matrix diagonals, limiting to 5 total number of possible stimulation recommendations for all clones as given in the Table 23 4.

Stimulation based latex harvesting and latex diagnosis

Table 23.3. The level of stimulation intensities to be considered in low intensity harvesting systems (categorised as Very Low, Low, Medium, High & Very High) based on the physiological basis of clones. Values given for sucrose level (Suc) and inorganic phosphorous (Pi) are for non-stimulation conditions to identify the clonal typology (according to CIRAD Clonal Latex Typology, 2019 update).

		Metabolic rate				
		Low metabolism	Low – medium metabolism	Medium metabolism	Medium-high metabolism	High metabolism
Sugar loading rate	Low sugar loading	High Suc <10mM Pi <5mM	Medium Suc <10mM Pi 5-10mM	Low Suc <10mM Pi 10-15mM	Very Low Suc <10mM Pi 15-20mM	Low probability
	Medium sugar loading	Very high Suc 10-20mM Pi <5mM	High Suc 10-20mM Pi 5-10mM	Medium Suc 10-20mM Pi 10-15mM	Low Suc 15mM Pi 15-20mM	Very Low Suc 10-20mM Pi >20mM
	High sugar loading	Low probability	Very high Suc >20mM Pi 5-10mM	High Suc >20mM Pi 10-15mM	Medium Suc >20mM Pi 15-20mM	Low Suc >20mM Pi >20mM

Table 23.4. Clonal characterization for stimulation as per the physiological grouping.

Stimulation level/intensity	Associated Physiological groupings	Examples for clones identified
Very high	Low metabolism x medium sugar loading	AF 261
	Low-medium metabolism x high sugar loading	PB 217
High	Low metabolism x low sugar loading	AV 2037
	Low-medium metabolism x medium sugar loading	PB 86, PR 107
	Medium metabolism x high sugar loading	RRIC 121
Medium	Low-medium metabolism x low sugar loading	Yet to be identified
	Medium metabolism x medium sugar loading	GT1, RRIC 100, IAN 710
	Medium-high metabolism x high sugar loading	IRCA 41, IRCA 19, RRIM 921, PB 254

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Stimulation level/intensity	Associated Physiological groupings	Examples for clones identified
Low	Medium metabolism x low sugar loading	Yet to be identified
	Medium-high metabolism x medium sugar loading	RRIM 600, BPM 24, RRIC 110, RRIT 251, IRCA 18, PR 255
	High metabolism x high sugar loading	IRCA 230, RRIM 712, PB 255
Very Low	Medium-high metabolism x low sugar loading	Yet to be identified
	High metabolism x medium sugar loading	PB 235, PB 260, RRIM 911 IRCA 317

Latex diagnosis reflects the physiological status of the tree hence provides means to alter the stimulation intensities based on the latex harvesting level. This modelling is of great importance as it also helps in selecting parentage in breeding programme and permits significant reduction of time usually required to introduce newly selected clones to the industry. Yield and physiological data obtained from these new clones along with those of control clones under same tapping conditions, are sufficient to position them in the typology matrix and then, provide early and accurate recommendations for stimulations.

Based on the relationship between Suc and Pi, the analysis of these LD data confirms the latex physiological positioning in clonal typology of all clones. It confirms, in particular, the high latex sugar loading capacity of clones. It also reveals a systematic positive correlation between latex RSH and Suc contents. Clones with higher latex Suc content maintains a higher latex RSH concentration than clones with lower Suc. High clonal latex sugar loading allows high level of stimulation rates and improved stimulation response, and also well maintains higher latex RSH levels resulting in an improved resistance to oxidative stress caused from latex metabolic activation. Obviously, this is a scavenging protection which provides membranes integrity in the secondary phloem, latex stability, latex flow and minimizes tapping panel dryness (TPD). Irrespective of the site and tapping system (including downward or upward tapping), the clones showing the well balanced physiological profiles (with the highest RSH and Suc under maximum metabolic activation) are more resilient to TPD and hence, sustainable in the long run.