HANDBOOK OF RUBBER

Volume 1

Agronomy

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Agalawatta
Sri Lanka
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Contents

Introduction i
Preface iii
Acknowledgements v

Chapter 1 Land suitability evaluation, selection and soil conservation 1
N. Yogaratnam

2 Rubber growing soils and their characteristics 12
D.M.A.P. Dissanayake

3 Management of soil and weed infestation 26
Lalani Samarappuli

4 Rainfall pattern in rubber growing areas of Sri Lanka 40
Wasana Wijesuriya

5 Clones for commercial planting in Sri Lanka 46
D.P.S.T.G. Attanayaka

6 Management of rootstock and budwood nurseries 54
Priyani Seneviratne

7 Budgrafting techniques and types of planting material 68
Priyani Seneviratne

8 Field establishment and management of tree architecture 86
Priyani Seneviratne

9 Common diseases 97
C.K. Jayasinghe

10 Pests 114
K.E. Jayasuriya

11 Conditions caused by physical injuries 121
A.H.R. Jayaratne

12 Important diseases uncommon or absent in Sri Lanka 130
C.K. Jayasinghe

13 Disorders of non-parasitic origin 135
A.H.R. Jayaratne

14 Rubber based intercropping systems 139
V.H.L. Rodrigo

15 Nutrition 156
Lalani Samarappuli

16 Exploitation for economic yields 176
A. Nugawela

17 Use of yield stimulants and tapping notation 191
A. Nugawela

18 Minimizing crop losses due to interference of rain on tapping 198
A. Nugawela and L.M.K. Tillekeratne

19 A greener future with Hevea brasiliensis 207
C.M. Stirling

Index 211
Introduction

The first recorded evidence of the existence of a rubber producing tree was when Christopher Columbus made his voyage to the Americas in 1493 - 1496 and observed inhabitants of Haiti playing with balls of a gum-like substance. The process of vulcanization which converted rubber from a substance of little importance to one of the world's most important raw materials was discovered in 1838 by Charles Goodyear and since then the demand for rubber grew dramatically.

The plant cultivated for natural rubber, *Hevea brasiliensis* (A. Juss.) Muell. Arg. was first introduced to South East Asia from its native South America when seeds sent by Sir Henry Wickham were germinated in the Kew Gardens in England and the seedlings were planted at the Heneratgoda Botanical Gardens in Sri Lanka, in 1876.

The first commercial planting of rubber in Sri Lanka was in 1883 and during the first few years of the 20th century cultivation of rubber expanded rapidly in Sri Lanka. In 1928 the rubber extent in the country was 214,000 hectares to cater to the demand of the European and American manufacturers for this raw material. With this rapid growth rate in the rubber industry, it became necessary to provide the growers with full information regarding processing, manufacture and agronomic practices.

In order to develop technology demanded by the growers a committee consisting of members of British plantation interests in this country was formed in 1909. Therefore, the origin of research on rubber in Sri Lanka goes back to that year. The committee initially engaged a chemist to study the coagulation of rubber. This activity was later expanded to form the Rubber Research Scheme in 1913, with Government providing 60% of the required funds and the balance coming from private subscribers. In 1914, the Rubber Growers' Association, based in London, inaugurated the Rubber Growers' (Ceylon) Research Fund to provide further research facilities. The Ceylon Rubber Research Scheme and the Rubber Growers' (Ceylon) Research Fund amalgamated their work in 1920 and the Government continued to provide 60% of the funds.

In January 1926 the Scheme leased 65 acres of land at Nivitigalakele, Matugama in the Kalutara District to further extend the Rubber Research Scheme activities on planting and testing of new clones. Later the Smallholdings Advisory Department was developed and was ultimately transferred to Colombo. This Department, apart from providing advisory services, helped smallholders by providing high-class planting material at subsidised rates.

With the development of the industry the necessity to disseminate the technology developed to the growers was felt. Therefore, the Rubber Research Ordinance No.10 of 1930 incorporating the Ceylon Rubber Research Scheme became operative. This ordinance provided provision to collect a cess of one-eighth cent per pound of rubber exported from the country and to utilize the funds for research work on rubber administered by a Board of Management.

The 178-acre estate known as Dartonfield in the Kalutara District was purchased in 1933 and was converted into a Research Station with factories, laboratories and bungalows. The experiments laid down at the Research Station created great interest among the rubber planters and the outcome of such studies was disseminated through publications, visits to estates and meetings of District Planters' Associations.
In 1942, a lease of 1,000 acres of land at Hedigalla in the Kalutara District was secured for the purpose of expansion of existing facilities for research. The Rubber Research Scheme was officially styled “Rubber Research Institute” in 1951 by the provisions of the Rubber Research (Amendment) Act No.30 of 1951. The work of the whole Institute was greatly expanded in 1953 with the introduction of the subsidized rubber replanting scheme. The original act of parliament was again amended by the Rubber Research (Amendment) Act No. 39 of 1987.

As in the past this Institute, the oldest of its kind in the world, aims to enhance the performance of the rubber industry by continuous development and upgrading of technology on raw rubber processing, rubber products manufacture and agro-management taking into consideration the prevailing circumstances and also environmental issues. In order to fulfill these aspirations research and extension activities are carried out on all aspects of rubber cultivation and processing, in a cost-effective manner.

A. Nugawela,
Deputy Director Research (Biology)
Preface

The current scenario prevailing in the rubber sector has made research and development mandatory to sustain the growth of the industry. Presently the growers are constrained with increasing cost of production with no corresponding gain in prices. Further, price fluctuations and increasing volatility are commonly evident. In the light of this situation, especially in the smallholder sector responsible for ca. 60% of the rubber extent in the country, replanting and adoption of important agro-management practices are curtailed. The reaction of the plantation sector to this situation is alike but to a lesser degree than in the smallholder sector. Such deviations in management practices in the form of low inputs leads to a vicious cycle. The overall impact of this situation will be a retarded growth rate in the rubber sector of the country. Nevertheless, the natural rubber industry contributes enormously to the economic and social development of the country by generating foreign exchange and employment and by protecting the environment. For researchers and extensionists the challenge is to develop technology best suited for the situation and to encourage its adoption. The technology thus developed needs to be environmentally friendly as well.

The Rubber Research Institute of Sri Lanka published a book titled “A Handbook of Rubber Culture and Processing” edited by Dr. O.S. Peries and Mr. D.M. Fernando in 1983. This book was in great demand and stocks were exhausted recently. In this completely revised Handbook new chapters have been included to accommodate new technological developments and it is designed primarily to disseminate technology developed by the Institute to the relevant stakeholders. If the technology detailed in this book is correctly adopted, productivity levels of 2500 - 3000 kg of dry rubber per hectare per annum can be achieved.

Economists predict rubber trading to improve in future due to increasing demand, limitations in supply and increasing petroleum prices. Through adoption of new technology to enhance productivity growers can benefit immensely from the high rubber prices anticipated in future.

The genetic gain in yield through breeding programmes during the recent past is significant. The RRIC 100, 200 and RRISL 2000 series clones recommended for commercial planting are capable of yielding 2500 - 3500 kg of dry rubber per hectare per annum. Among these are quality timber-producing clones which are capable of enhancing the returns from rubber plantations/smallholdings. Altogether, around 45 clones are recommended for commercial planting as it is important to have genetic diversity in our rubber cultivation.

Lack of an adequate number of vigorous and healthy plants per unit land area has been identified as a major reason for poor land productivity in the country. The young budding technique if adopted fully with special emphasis on culling of weak plants, field establishment methods and infilling, perfect stands with vigorous and healthy plants could be achieved.

In traditional rubber growing areas the current rubber cultivations are about the third or the fourth generation. From uprooting of the old stand to establishment of soil conservation methods and canopy cover there is room for soil degradation. This could also happen during the entire life cycle of the plantation if correct soil conservation methods are not adopted. Such land may not yield sufficiently to achieve currently needed
productivity levels and profitability. Therefore, land selection has become important during replanting to establish a healthy rubber cultivation. Effective and efficient soil and moisture conservation methods have been developed to improve both physical and chemical characters of rubber soils. Site specific fertilizer recommendation based on soil and foliar survey helps in efficient and cost-effective use of chemical fertilizer.

*Corynespora* leaf disease has taken out some high-yielding clones from the recommended list. This deadly disease is a potential threat to all clones and this emphasizes the importance of genetic diversity in our rubber cultivation.

Clones susceptible to *Oidium* and *Gloeosporium* in conducive weather during the refoliation period undergo repeated secondary leaf fall. Incidence of white root disease caused by *Rigidoporus microporus* has been identified as one significant factor in decline of mature rubber stands. Appropriate technology is developed and available to arrest lowering productivity due to these diseases.

Lack of adequate skilled tappers is posing a huge threat to the national as well as global rubber industry. Therefore, technology has been developed to reduce the tapper requirement and also to enhance the earnings of tappers. Adoption of rainguards minimizes interference by rain with latex harvesting and will further improve tapper income levels with equal gains to the grower.

Crops have been identified to intercrop with rubber both in the immature and mature phases of rubber cultivation. Such technology, whilst helping the grower to obtain an income during the uneconomical phase, improves land-use efficiency. Lower income levels from rubber lands due to poor trading or unfavourable weather conditions for tapping could also be overcome by rubber-based intercropping systems with perennials like tea and cinnamon.

The performance of rubber in traditional areas is hindered to some extent by degraded soil resulting from repeated planting and lack of adequate workers due to availability of alternate employment. Also the land available for rubber in traditional areas is becoming limited due to urbanization and industrialisation. Technology developed to move rubber into areas marginal due to low rainfall and higher elevation can help to bridge the possible shortfall in rubber production in the country.

Poor trading and increasing cost of production due to wage increases demand higher productivity levels from rubber cultivations. Technology suited for this situation needs to be adopted to achieve this goal of high productivity. This Handbook describes such technology and it is hoped that it will help growers to enhance the adoption rate of technology suited to the current situation. This is vital to sustain the industry which impacts on modern life more than any other agricultural commodity whilst providing a source of income for more than 500,000 families islandwide, the majority of whom are low-income and land-poor.

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Acknowledgements

“A Handbook of Rubber Culture and Processing” edited by Dr O.S. Peries and Mr D.M. Fernando (1983) is updated in this book in the light of modern developments. The 1983 Handbook provided the model on which this version is based, for which we are most grateful to its editors and writers. The present version includes several new chapters to accommodate some recent innovations.

Prof. M.D. Dassanayake, consultant editor perfected each chapter with dedication. We owe a debt of gratitude for the invaluable contribution made by him.

Mrs W.S.P. Amarasekera, Mrs K.P.R. Gunasekera, Mrs H.D.D.E. Jayawardena and Mrs K.A.D.L. Rupasinghe Perera are thanked for typing the manuscripts and Mr L.W. Amaratunga for the photographs. The support extended by the technical staff in the preparation of this book is appreciated.

The contribution of Mr S.U. Amarasinghe and the efficient and dedicated services of Mrs R. Amaratunga to the compilation of this book are acknowledged. The editors wish to thank Dr N. Yogaratnam for the initial work done in the preparation of this book.

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Finally, it is a pleasure to thank all contributors who so readily wrote on their own specialities. We are thankful to Sarvodaya Vishva Lekha for excellent printing.

L.M.K. Tillekeratne
A. Nugawela
Editors.
Chapter 1

Land suitability evaluation, selection and soil conservation

N. Yogaratnam

1. Introduction

2. Land suitability for rubber
   2.1 Physiography
   2.2 Climate
      2.2.1 Rainfall
      2.2.2 Temperature and altitude
      2.2.3 Relative humidity
      2.2.4 Sunshine
      2.2.5 Wind
   2.3 Soil type
      2.3.1 Desirable physical properties
      2.3.2 Desirable environmental and physiographic features
      2.3.3 Desirable chemical properties
      2.3.4 Minor limitations
      2.3.5 Moderate limitations
      2.3.6 Serious limitations

3. Land preparation
   3.1 Soil conservation
      3.1.1 Agricultural
      3.1.2 Biological
      3.1.3 Mechanical

1. INTRODUCTION

Rubber (Hevea brasiliensis), a native of Amazon tropical forests, can grow in a wide range of climate and soils. Nevertheless, in order to achieve the best possible results the land selected for planting should conform to certain standards.

2. LAND SUITABILITY FOR RUBBER

2.1 Physiography

Most of the world’s commercially grown rubber occurs within 10° of the equator at altitudes of less than 500 m. With increasing distance to the north of the 10° N latitude and south of the 10° S latitude, prospects for successful rubber cultivation diminish. 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 land varying from flat to very steep. Between these two extremes, most of the rubber is grown in Sri Lanka on land ranging from undulating to moderately steep. Rubber grows and yields reasonably well on these steep and usually stony slopes. Nevertheless, the period of immaturity can be shortened and yield capacity enhanced by providing contour terraces or individual tree platforms with linking paths. There are very few drainage problems on rubber plantations in Sri Lanka.

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. 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 1650 mm - 3000 mm and be reasonably uniformly distributed throughout the year. 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 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, trees yielding best during the cool of the morning. 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.

Hence, the main climatic factor affecting rubber cultivation in Sri Lanka is incidence of rainfall, with the wettest rubber growing districts receiving significantly more rain than the generally accepted annual 1650 - 3000 mm and two districts receiving less. The wetter districts can benefit from both the Southwest and the Northeast monsoons whilst the two drier districts have to rely on the Northeast monsoon, which can be irregular.

2.2.2 Temperature and altitude

The temperature conditions in different physiographic regions do not
show much variation. The annual average temperature in the plantation surface of
the lower peneplain is more or less uniform, approximately 27.8°. 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°C ± 2°C. The temperature ranges from 20°C - 25°C in the night
to 30°C - 35°C during the months of December - February.

The ideal mean annual temperature for rubber should be within the range
23°C - 28°C and temperatures should not fall below 20°C for more than a few
weeks. The temperature decreases at about 0.6°C per 100 m in height. 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, so that plantings above 600 m are not normally advisable.
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 by allowing the crops to
absorb moisture and also reduces the 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 April 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 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 shown in Table 1.1. The evaluation of climate should be used in combination with the evaluation of the soils and landscape features.

Table 1.1. Climatic requirements for *Hevea* cultivation

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

*0 - No limitation, 4 – very serious limitation

2.3 Soil type

Many soils of different origin as well as morphological characteristics can support a viable rubber plantation. The important criteria for selection are soil pH, soil depth, soil structure, soil water holding capacity, its permeability and drainage.

In Sri Lanka, those soils that satisfy the primary requirement of an acid soil fall into three major soil groups. The largest of these extents are in red yellow podzolic soils, followed by reddish brown latosolic soils and then immature brown loams.

A land suitability evaluation system for rubber cultivation is made up of a framework of soil and physiographic features which are considered to be desirable for optimal growth of rubber.

On the other hand, the poorer soils have properties which limit the optimal growth and performance of rubber and these limitations are graded as minor, moderate or serious.

The criteria considered in the evaluation system are as follows:

2.3.1 Desirable physical properties

- Soil depth up to 100 cm, free of pan/rock outcrop hindrance
• Well drained
• Good soil aeration
• Good soil structure (strong, moderately strong and moderate medium and fine subangular blocky structure)
• Friable to firm consistency
• Good water-holding capacity
• Soil texture with sufficient clay (preferably a minimum amount of 35% clay to retain sufficient moisture and nutrients and about 30% - 50% sand to allow for expression of good physical soil properties like aeration and drainage).

2.3.2 Desirable environmental and physiographic features

• Gently sloping or rolling terrain with between 0 – 20% slopes and minimal soil erosion and surface run-off
• Water-table should be deeper than 100 cm.

2.3.3 Desirable 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
• Absence of saline/acid sulphate conditions.

Limitations are properties which limit good crop performance and can be graded as minor, moderate and serious according to their degree of severity in affecting crop performance.

2.3.4 Minor limitations

• Weak soil structure within 90 cm
• Moderate drainage conditions
• Massive, thick hard-pan below 50 cm from the surface or loosely packed gravels within 50 cm from the surface
• Less than 50% rock outcrop in a unit area
• Susceptibility to soil erosion
• Sub-optimal soil nutrient status, reflected by low contents of nitrogen, phosphorus, potassium and magnesium

2.3.5 Moderate limitations

• Slopes steeper than 20% but less than 45%
• Massive, thick hard-pan between 20 and 50 cm of the surface
• Between 50% and 75% of rock outcrop in a unit area
• Permanent water-table between 20 and 50 cm of the surface
• Strong compaction influencing permeability and infiltration
• Poor structure (too sandy resulting in no structure or massive due to heavy clay in waterlogged conditions)
• Susceptible to moisture stress as reflected by textural and structural qualities
• Poor nutrient status.

2.3.6 Serious limitations

• Slopes steeper than 45%
• Massive thick hard-pan at or very close (within 20 cm) to the surface
• More than 75% of rock outcrop in a unit area
• Permanent water-table at or near (within 20 cm) the surface
• Acid peat layer thicker than 20 cm at or near the surface
• Land disturbed by mining activities and very sandy deposits, with more than 90% sand.
• Very poor nutrient status.

3. LAND PREPARATION

When land is cleared, especially if it has been cultivated, the closed nutrient cycle is broken, the water regime is changed and the productive potential of the site can deteriorate rapidly unless it is carefully managed. Exposure of the bare soil to the sun and to the impact of rainfall results in accelerated decomposition of the organic matter, leaching of the nutrients, breakdown of the aggregate structure of the surface soil, diminished infiltration of the rainfall and, except on flat land, much runoff of water and erosion of the nutrient-rich surface soil. To avoid these ill effects as far as possible, exposure of the bare soil should be minimized and the clearing and cultivation methods employed should disturb or compact the soil as little as possible and thus do the least damage to its structure. At the earliest opportunity after clearing, terraces or other soil conservation work should be constructed on sloping land and a leguminous ground cover should be established between the rubber rows.

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

Another essential preliminary is to prepare a schedule of the time, labour and equipment required for clearing and planting the area. Strict adherence to a time schedule is essential for the efficient conduct of operations in field and
nursery. In most places the various operations have to be timed to fit in with seasonal variations in the rainfall.

3.1 Soil conservation

Erosion is one of the most serious detrimental effects 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 can be replaced 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 safeways 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

D.M.A.P. Dissanayaka

1. Introduction
2. Classification of rubber growing soils of Sri Lanka
   2.1 Great Soil Groups
      2.1.1 Red Yellow Podzolic (RYP) soils
      2.1.2 Reddish Brown Latosolic (RBL) soils
   2.2 Soil series
      2.2.1 Parambe series
      2.2.2 Matale series
      2.2.3 Homagama series
      2.2.4 Agalawatta series
      2.2.5 Ratnapura series
      2.2.6 Boralu series
      2.2.7 Deniya series
3. Soil characteristics and soil requirements
   3.1 Physical characteristics
      3.1.1 Soil texture
      3.1.2 Soil structure
      3.1.3 Bulk density
      3.1.4 Porosity
      3.1.5 Water holding capacity
      3.1.6 Soil colour
   3.2 Chemical characteristics
      3.2.1 Nutrient status
         3.2.1.1 Soil nitrogen
         3.2.1.2 Soil phosphorus
         3.2.1.3 Soil potassium
         3.2.1.4 Soil magnesium
         3.2.1.5 Soil micronutrients
      3.2.2 Soil pH
      3.2.3 Soil organic carbon
      3.2.4 Cation Exchange Capacity (CEC)

1. INTRODUCTION

*Hevea* has been described as a tree that will grow on most soils, and thrive where other tree crops might fail, although this is an exaggeration. The rubber tree will certainly grow on a vast majority of acid soils of the humid tropics, but its performance and economic viability can be restricted severely where there is a limitation of a particular soil factor. 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 inputs and practices can
be devised, implemented and adopted only upon knowing the physical and chemical characteristics and limitations of a particular soil.

In essence, rubber can best be grown in areas where the soil is deep and readily 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, since soils have different physical and chemical characteristics, the suitability of soils for Hevea culture will vary.

2. CLASSIFICATION OF RUBBER GROWING SOILS OF SRI LANKA

In order to facilitate the extrapolation of experience and experimental work between regions, attempts have been made to fit the rubber growing soils into international systems of nomenclature. This system has received wide attention, but presents a problem in that while it may facilitate pedological comparisons between different climatic zones and cropping areas, its very detail makes it unsuitable for comparison of fertility and production potential of rubber growing soils within the relevant and restricted zone of the humid tropics. With a perennial tree crop such as rubber, the effects of management husbandry on soil characteristics on the one hand, and adaptation of the tree to local soil and climatic features on the other, combine over the years to blur the finer differences between soil types in respect of their suitability for growing rubber. In consequence, tree performance may be similar on taxonomically different soils. There is in addition a limitation to the extent to which field management can be modified to take into account the different taxonomic phases that may be identified within any one planting unit.

2.1 Great Soil Groups

Planting of rubber in Sri Lanka is mostly confined to two Great Soil Groups: Red Yellow Podzol (RYP) and Reddish Brown Latosol (RBL).

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 slope colluvium and residuum on basic intermediate and acid 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
2.2 Soil series

In these rubber growing areas seven important soils units have been identified by the Rubber Research Institute (RRI), taking into consideration only the parent material from which the soils were derived (Table 2.1 and Plate 2.1). While this soil classification is not directly reconciled with the Great Soil Groups, it has practical advantages for research and extension purposes. A brief description of each soil unit (series) is given below.

Table 2.1. Different soil series of rubber growing areas

<table>
<thead>
<tr>
<th>Soils series</th>
<th>Great Soil Group</th>
<th>Soil taxonomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratnapura</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homagama</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agalawatta</td>
<td>Red Yellow Podzolic</td>
<td>Ultisols</td>
</tr>
<tr>
<td>Boralu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Matale</td>
<td>Reddish Brown Latosolic</td>
<td>Ultisols</td>
</tr>
<tr>
<td>Parambe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deniya</td>
<td>Low humic gley</td>
<td>Alfisol</td>
</tr>
</tbody>
</table>

2.2.1 Parambe series

*Parambe* series soils are derived from micaceous parent materials, the most common such parent material being a biotite gneiss. These soils are deep, sandy clay loam 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 the Kegalle and Kandy districts (Plate 2.2a).

2.2.2 Matale series

*Matale* series soils are deep, sandy clay loam 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 (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 of variable depth, with boulders and outcrops of the granitic rocks from which they are derived, a large percentage of them being hypersthene granite. 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. 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. These soils occur only in the Meegahatenne and Ratnapura areas (Plate 2.3a).

2.2.6 **Boralu series**  
*Boralu* 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 mounds and low hills, on which the southern rubber producing areas extend westward towards the coast (Plate 2.3b).

2.2.7 **Deniya series**  
*Deniya* 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 heterogeneous, disperse and porous system, having a large surface area. The dispersed nature of the soil and its consequent interfacial activity give rise to such phenomena as absorption of water and chemicals, ion exchange, swelling and shrinking, dispersion and flocculation and capillarity.

In the wild state, the genus *Hevea* grows on a broad spectrum of edaphic situations. However, the main rubber producing species *Hevea brasiliensis* grows naturally in well drained as well as slightly flooded situations. Under domestic conditions, for optimum growth and productivity of rubber, both the physical and chemical aspects of soil fertility need to be conducive.

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 decreased water storage and hindered development of roots in rubber plants. A good soil physical condition is therefore, important in promoting good growth and yield of rubber.

3.1.1 Soil texture

Physically, soil is made up of sand, silt and clay in different proportions. Soil texture refers to the relative proportion of these primary particles sand (0.02-2.0 mm particle size), silt (0.002-0.02 mm particle size) and clay (<0.002 mm particle size). Other inclusions like gravel and stones are larger than 2 mm in diameter. The sand fraction usually consists of quartz, but may contain other minerals also.

Silt is of intermediate size between sand and clay and resembles sand particles in terms of mineralogy and physical properties. The clay fraction represents the smallest particles, being formed during the course of weathering of primary minerals in the original rock. The various combinations of sand, silt and clay give rise to different textures. For example, a clayey soil has a dominant clay content. Similarly a sandy soil has a dominant sand content. Sometimes a soil can have a lot of stones or laterites within it. In other soils, the major portion may comprise rocks or boulders. The particle size distribution and textural class of the different soil series are given in Table 2.2.

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Particle distribution (%)</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parambe</td>
<td>40-52</td>
<td>15-18</td>
</tr>
<tr>
<td>Matale</td>
<td>42-54</td>
<td>18-20</td>
</tr>
<tr>
<td>Homagama</td>
<td>57-65</td>
<td>17-28</td>
</tr>
<tr>
<td>Agalawatta</td>
<td>42-55</td>
<td>13-18</td>
</tr>
<tr>
<td>Ratnapura</td>
<td>42-54</td>
<td>16-19</td>
</tr>
<tr>
<td>Boralu</td>
<td>49-55</td>
<td>19-22</td>
</tr>
</tbody>
</table>

The texture of soils influences their physical properties and 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. It has high permeability to downward water movement because of its sandy nature. 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 nutrients and water. When water is limiting, the yield of rubber can also be lower on sandy soil compared to clayey soil. 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 35% to retain adequate moisture and nutrients and about 50% sand to allow for expression of good physical soil properties like aeration and drainage can be considered as desirable for optimum rubber cultivation.

3.1.2 Soil structure

Soil structure is perhaps the most important physical property. It refers to the arrangement and organization of the solid particles. The clay and silt fractions bind the soil particles together and various combinations of sand, silt and clay can give rise to different shapes and sizes of soil structure. Soils are made up of natural soil aggregates, also known as soil peds. A soil is said to have a friable consistency if the soil peds are easily broken and if the peds can barely be crushed, the consistency is firm.

From the aspect of soil management, soil structure is the property of a soil that regulates a continuous array of various sizes of interconnected pores and their stability. It governs retention and movement of water, regulates gaseous diffusion and controls root proliferation and development. 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 better effect on the growth of rubber than high soil chemical fertility. In other words, rubber trees will grow better on a well structured soil of lower chemical fertility than on a poorly structured soil with very high chemical fertility. This is obvious since the presence of an insufficient amount of roots in a poorly structured soil will mean that the tree cannot exploit the high fertility to its maximum. Furthermore, the low chemical fertility status of a soil can easily be amended with fertilizer application.

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. Soil compaction renders trees liable to wind damage like the presence of an impenetrable layer. Rubber plants tend to form stunted and knotty roots when grown on compacted soils.
3.1.3 Bulk density
An important measurable property of soil structure is bulk density. Root density of rubber plants has a tendency to decrease with increasing soil bulk density. The bulk density of different soil series is given in Table 2.3.

3.1.4 Porosity
Porosity indicates the proportion of soil volume not occupied by solids. Porosity significantly characterizes the gaseous phase and the process of gaseous exchange between soil and atmosphere. Restricted soil aeration inhibits root development, impairs the process of respiration of the root system and inhibits beneficial microbial activities. The total air-filled porosities of some common soil series under Hevea are shown in Table 2.3.

Table 2.3. Bulk density and porosity of different soil series

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Bulk density (g/cm$^3$)</th>
<th>Porosity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parambe</td>
<td>1.49</td>
<td>53.1</td>
</tr>
<tr>
<td>Matale</td>
<td>1.33</td>
<td>54.7</td>
</tr>
<tr>
<td>Homagama</td>
<td>1.12</td>
<td>56.2</td>
</tr>
<tr>
<td>Agalawatta</td>
<td>1.51</td>
<td>52.0</td>
</tr>
<tr>
<td>Ratnapura</td>
<td>1.36</td>
<td>54.6</td>
</tr>
<tr>
<td>Boralu</td>
<td>1.38</td>
<td>53.2</td>
</tr>
</tbody>
</table>

3.1.5 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 2.4). 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 2.4. Availability of moisture in different soil series

<table>
<thead>
<tr>
<th>Soil series</th>
<th>SMSC* (cm)</th>
<th>Volumetric moisture content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>-10kPa</td>
</tr>
<tr>
<td>Parambe</td>
<td>22.9</td>
<td>37.5</td>
</tr>
<tr>
<td>Matale</td>
<td>22.4</td>
<td>36.3</td>
</tr>
<tr>
<td>Homagama</td>
<td>18.3</td>
<td>31.2</td>
</tr>
<tr>
<td>Agalawatta</td>
<td>19.7</td>
<td>33.4</td>
</tr>
<tr>
<td>Ratnapura</td>
<td>20.3</td>
<td>32.9</td>
</tr>
<tr>
<td>Boralu</td>
<td>19.3</td>
<td>32.7</td>
</tr>
</tbody>
</table>

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

Generally soil colour is important to identify a soil and also in soil classification. This parameter depends on some inorganic ions like Fe and Cu. Hydrated Fe usually gives a yellow colour to the soil while dehydrated Fe gives a red colour. Soil colour also depends on the drainage condition and organic matter content of the soil. The soil colour of different soil series is given in Table 2.5.

Table 2.5. Soil colour of different soil series

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Soil colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parambe</td>
<td>Brown</td>
</tr>
<tr>
<td>Matale</td>
<td>Dark brown to reddish brown</td>
</tr>
<tr>
<td>Homagama</td>
<td>Brown to reddish brown</td>
</tr>
<tr>
<td>Agalawatta</td>
<td>Brown to yellowish red</td>
</tr>
<tr>
<td>Ratnapura</td>
<td>Yellowish brown</td>
</tr>
<tr>
<td>Boralu</td>
<td>Brown to reddish yellow</td>
</tr>
</tbody>
</table>

3.2 Chemical characteristics

Owing to the humid tropical climate, the soils of Sri Lanka are highly weathered and leached. Agriculturally speaking, most of the soils are highly improverished and of low chemical fertility, except in some situations where their nutrient supplying power is relatively higher. 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. Desirable 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 Nutrient status

Soils normally play a major role in determining the availability of nutrients to plants. The influence on this availability is primarily through the mineral reserves in the soil and the nutrients added to the soil. Chemically, soils contain different proportions of nutrients considered to be important for rubber trees, viz nitrogen, phosphorus, potassium and magnesium (Table 2.6). Because of the intensely hot and wet tropical climate, the highly weathered soils of Sri Lanka, on their own, are incapable of supplying adequately all the nutrients which are required by rubber plants. Depletion of soil nutrients, attributed to losses such as leaching, immobilisation, volatilisation or uptake by the plant, will inevitably impoverish the capacity of the soil to supply nutrients. In making up for this depletion, nutrients in the form of fertilizers are often added to the soils and rubber trees respond positively to fertilizer applications.

From the point of view of soil nutrient status, rubber will grow reasonably well for some period of time during the immature phase, if planted newly on jungle clearings. However, in replanted areas, growth will not be satisfactory right from the beginning after planting. On all soils generally, growth and latex
production will be depressed, if the trees are not manured from planting. Research
over the years has indicated that fertilizer application will be necessary from the
time of planting on most Sri Lankan soils, in order to sustain optimum growth and
productivity.

Table 2.6. Categorization of nutrient contents in rubber growing soils of Sri Lanka

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Very low</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Very high</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (%)</td>
<td>&lt;0.05</td>
<td>0.05-0.10</td>
<td>0.11-0.25</td>
<td>0.25-0.40</td>
<td>&gt;0.40</td>
</tr>
<tr>
<td>P (ppm)</td>
<td>&lt;100</td>
<td>100-250</td>
<td>250-350</td>
<td>350-600</td>
<td>&gt;600</td>
</tr>
<tr>
<td>K (meq/100g)</td>
<td>&lt;0.25</td>
<td>0.25-0.5</td>
<td>0.5-2.0</td>
<td>2.0-4.0</td>
<td>&gt;4.0</td>
</tr>
<tr>
<td>Mg (meq/100g)</td>
<td>&lt;0.5</td>
<td>0.5-1.0</td>
<td>1.0-4.0</td>
<td>4.0-8.0</td>
<td>&gt;8.0</td>
</tr>
</tbody>
</table>

3.2.1.1 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 low, ranging
between 0.07% and 0.17% (Table 2.7).

3.2.1.2 Soil phosphorus
Total phosphorus contents are highest in the Matale series followed by the
Parambe series and lowest in the Boralu series (Table 2.7).

3.2.1.3 Soil potassium
Reserve potassium is highest in the Parambe series soil, while a relatively
low level is encountered in the Homagama series. In all the other soil series, total
potassium levels are medium to high ranging between 1 and 2 meq/100g (Table
2.7).

3.2.1.4 Soil magnesium
The total magnesium values are highest in the Matale series which has
about 7.3 meq/100g. 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 2.7).

Table 2.7. Approximate major nutrient contents in different soil series

<table>
<thead>
<tr>
<th>Soil series</th>
<th>N (%)</th>
<th>P (mg/kg)</th>
<th>K (meq/100g)</th>
<th>Mg (meq/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parambe</td>
<td>0.148</td>
<td>310</td>
<td>4.47</td>
<td>2.81</td>
</tr>
<tr>
<td>Matale</td>
<td>0.174</td>
<td>317</td>
<td>1.84</td>
<td>7.25</td>
</tr>
<tr>
<td>Homagama</td>
<td>0.088</td>
<td>127</td>
<td>0.29</td>
<td>1.02</td>
</tr>
<tr>
<td>Agalawatta</td>
<td>0.117</td>
<td>233</td>
<td>1.17</td>
<td>0.79</td>
</tr>
<tr>
<td>Ratnapura</td>
<td>0.119</td>
<td>241</td>
<td>1.53</td>
<td>0.95</td>
</tr>
<tr>
<td>Boralu</td>
<td>0.071</td>
<td>112</td>
<td>0.31</td>
<td>1.26</td>
</tr>
</tbody>
</table>
3.2.1.5 Soil micronutrients

The micronutrient status of Sri Lankan soils has not as yet become critical for Hevea cultivation (Table 2.8). Rubber trees are yet to display symptoms of lack of these nutrients for normal growth and yield, although rubber cultivation in Sri Lanka is currently in the third to fourth cycle, with nutrients being removed via the timber from the ecosystem (soil) during each felling at replanting. While lack of macronutrients often limits rubber tree performance, high amounts of trace elements are toxic to rubber plants. For example, high amounts of manganese or boron may cause stunted plants.

Table 2.8. Secondary and micronutrient contents in different soil series

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Ca (mg/kg)</th>
<th>S (mg/kg)</th>
<th>Mn (mg/kg)</th>
<th>Mo (mg/kg)</th>
<th>Zn (mg/kg)</th>
<th>Cu (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parambe</td>
<td>453</td>
<td>409</td>
<td>282</td>
<td>90</td>
<td>21</td>
<td>28</td>
</tr>
<tr>
<td>Matale</td>
<td>654</td>
<td>388</td>
<td>1945</td>
<td>41</td>
<td>45</td>
<td>59</td>
</tr>
<tr>
<td>Homagama</td>
<td>190</td>
<td>205</td>
<td>47</td>
<td>47</td>
<td>09</td>
<td>06</td>
</tr>
<tr>
<td>Agalawatta</td>
<td>201</td>
<td>278</td>
<td>33</td>
<td>51</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>Ratnapura</td>
<td>208</td>
<td>289</td>
<td>689</td>
<td>83</td>
<td>24</td>
<td>37</td>
</tr>
<tr>
<td>Boralu</td>
<td>200</td>
<td>233</td>
<td>22</td>
<td>39</td>
<td>11</td>
<td>06</td>
</tr>
</tbody>
</table>

3.2.2 Soil pH

Rubber generally grows well in acid soils in Sri Lanka. However, extreme pH conditions are not favourable for good performance of rubber trees. Nearly all the soils, except for localised soils formed from limestone outcrops, are of low pH (Table 2.9). Their pH values range from 4 to 5.

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 matter content is maintained at the right level (Table 2.9), although the tropical soils of Sri Lanka in general contain relatively low amounts of organic matter.

3.2.4 Cation Exchange Capacity (CEC)

CEC is the soil’s capacity to hold and exchange cations. The strength of a cation’s positive charge varies, enabling one cation to replace another on a negatively charged soil particle. This is measured as the amount of cation in milliequivalents absorbed by 100g of soil. This gives an indication of the ability to retain nutrients.

CEC of most rubber growing soils in Sri Lanka is low (Table 2.9). Due to the low values of CEC in the Homagama series, when nutrients are supplemented by the addition of fertilizers, losses by leaching can be high. To solve this problem, an integrated approach including the use of appropriate fertilizer levels in split application and proper organic matter/crop residue management practices appears to hold promise.
Table 2.9. Soil pH, organic C and cation exchange capacity (CEC) of different soil series

<table>
<thead>
<tr>
<th>Soil series</th>
<th>pH</th>
<th>Organic C (%)</th>
<th>CEC (meq/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parambe</td>
<td>4.4</td>
<td>1.8</td>
<td>4.7</td>
</tr>
<tr>
<td>Matale</td>
<td>5.0</td>
<td>1.9</td>
<td>7.5</td>
</tr>
<tr>
<td>Homagama</td>
<td>4.2</td>
<td>0.9</td>
<td>2.0</td>
</tr>
<tr>
<td>Agalawatta</td>
<td>4.3</td>
<td>1.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Ratnapura</td>
<td>4.3</td>
<td>1.6</td>
<td>3.6</td>
</tr>
<tr>
<td>Boralu</td>
<td>4.4</td>
<td>1.2</td>
<td>3.2</td>
</tr>
</tbody>
</table>
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; c Deniya series.
Chapter 3

Management of soil and weed infestation

Lalani Samarappuli

1. Ground covers and cover management
   1.1 Introduction
   1.2 Contribution of leguminous cover crops
      1.2.1 Soil and moisture conservation
      1.2.2 Soil organic matter content
      1.2.3 Addition of nitrogen
      1.2.4 Nutrient retention and recycling
      1.2.5 Disease control
   1.3 Selection of cover crops
   1.4 Cover crop species
   1.5 Establishment of covers
   1.6 Seed treatment
   1.7 Manuring of covers
   1.8 Weeding of covers

2. Mulching
   2.1 Introduction
   2.2 Contribution from mulch
      2.2.1 Addition of nutrients
      2.2.2 Source of organic matter
      2.2.3 Prevents soil erosion
      2.2.4 Retains more water
      2.2.5 Controls weed growth
   2.3 Crop residues
      2.3.1 Method of application
      2.3.2 Frequency and time of application
      2.3.3 Rate of application
   2.4 Tree/bush legumes
      2.4.1 Tree bush legume species
      2.4.2 Establishment
      2.4.3 Manuring
      2.4.4 Lopping and mulching

3. Weeds and weed management
   3.1 Introduction
   3.2 Weed management/control
      3.2.1 Hand weeding
      3.2.2 Mechanical method
      3.2.3 Burning
      3.2.4 Ground cover management
      3.2.5 Mulching
      3.2.6 Intercropping
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 their partial canopy cover. It takes at least 3 to 4 years for the rubber tree canopy to cover the ground area. It is therefore, necessary to adopt suitable practices that will provide sufficient ground cover during the early stages of the growth in order to prevent soil erosion and enhance soil fertility status. In this regard, permitting natural vegetation to grow between rubber plants and growing of leguminous cover crops are considered beneficial. But, naturals are known to compete with young rubber plants for nutrients and moisture and are inferior with regard to returning of essential nutrients to the soil and could also release toxic substances resulting in the retardation of growth of rubber plants. Although the initial establishment of leguminous covers in between rubber rows may seem expensive and labour intensive, the overall benefits have made planting them an integral part of rubber cultivation.

1.2 Contribution of leguminous cover crops

1.2.1 Soil and moisture conservation

The fact that legume covers minimize soil erosion during the first 3 years of a rubber plantation is well known. But at the same time more moisture is lost by transpiration from the leguminous cover in comparison with what is conserved by the surface mulch it produces during the early stages. However, with the luxuriant growth of leguminous covers, about 23% more moisture will accumulate under the cover plants. This is possibly due to increased organic matter content of the soil which results in improved structure, which decreases crusting and surface sealing and permits greater infiltration, thereby increasing the water holding capacity.

1.2.2 Soil organic matter content

The value of legume covers in enhancing the organic matter content of the soil under rubber is well known. Although decomposition of organic matter is rapid under tropical conditions, organic matter tends to accumulate in the form of litter, amounting to about 6000 kg/ha/year due to continuous decaying of leaves, stems and roots of legume covers.

1.2.3 Addition of nitrogen

Among the many factors that contribute to the agronomic and economic advantages of legume covers over naturals is the return of a large amount of nitrogen in the region of 120kg/ha/yr to the soil. Non legume covers in addition to not being able to contribute such a large amount of nitrogen could also compete with the rubber plants for available nitrogen in the soil.
1.2.4 Nutrient retention and recycling
Leguminous covers immobilize a large amount of nutrients in their green materials during the first two years after planting. Materials with low C/N ratio would be expected to mineralize rapidly with its nutrients becoming quickly available again for uptake by rubber plants. As leguminous covers do not root deeply, the net effect would have been a rapid re-cycling of nutrients from the upper soil layers.

1.2.5 Disease control
Legume covers have an enhancing effect on the decomposition rate of old stumps which indirectly minimizes the incidence of root diseases, especially white root disease (*Rigidoporus microporus*).

1.3 Selection of cover crops
To be a good cover crop, the plant selected should possess the following characters:

- Easily multiplied, preferably by seed
- The root system should not compete with the rubber, yet should have good soil binding properties and should not require high quality soils
- The growth should be rapid and there should be abundant leaf both in full sunlight and shade
- Should tolerate pruning or slashing
- Should be resistant to drought, pests and diseases
- Be a good competitor and be able to resist and suppress weeds
- Should be easily eradicated when required
- Should be suitable for land reclamation and afforestation
- Should not form products which are toxic to the main crop.

1.4 Cover crop species
Plants that can be grown as cover crops under rubber are:

- *Pueraria phaseoloides* (Plate 3.1a)
- *Mucuna bracteata* (Plate 3.1b)
- *Desmodium ovalifolium* (Plate 3.1c)
- *Calopogonium mucunoides*
- *Centrosema pubescens*
- *Mimosa scandens*

A cover consisting of two or more species of legumes is often preferred in order that the shade or drought resisting or other qualities of one may be complemented by those of the other. In Sri Lanka, a mixture of *Pueraria*
phaseoloides and Desmodium ovalifolium is popular as Pueraria grows rapidly at the early stages of a clearing but withstands only light shade whereas Desmodium exhibits weaker initial growth, but tolerates shade much better and persists more satisfactorily under a fairly dense canopy of rubber. Although another creeping type of legume, Mucuna bracteata, appears to take a longer period to establish fully, it provides higher biomass and litter. It also tolerates drought and suppresses weeds very effectively.

1.5 Establishment of covers
Cover crops are best established immediately after 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.

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 seed which, unless specially treated, do not germinate quickly. 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 3.1) during which period the mixture may be stirred occasionally, the acid should be drained off carefully and the seed should be transferred into cold water. The seeds should be then washed thoroughly in several changes of cold water to remove the acid. The seeds may then be lightly dried to facilitate handling while planting.

<table>
<thead>
<tr>
<th>Species</th>
<th>Quantity</th>
<th>Volume of acid (ml)</th>
<th>Soaking time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pueraria</td>
<td>1kg</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>Desmodium</td>
<td>1kg</td>
<td>200</td>
<td>15-30</td>
</tr>
<tr>
<td>Calopogonium</td>
<td>1kg</td>
<td>50</td>
<td>15-30</td>
</tr>
<tr>
<td>Centrosema</td>
<td>1kg</td>
<td>50</td>
<td>30</td>
</tr>
</tbody>
</table>
1.7 Manuring of covers

When establishing leguminous covers in beds or strips in a plantation, a dressing of 100g of rock phosphate per square meter (3 oz/square yard) is beneficial. Phosphate is one of the important nutrients required by legumes for satisfactory growth. This may be effectively applied by dusting on the cover crops. This could be done at the rate of 100 to 200 kg per hectare (90 - 180 lb/acre/year) in the first few years, depending on the growth of covers. Residual effects of phosphorous applied to an immature plantation will persist for about 8 years.

1.8 Weeding of covers

Since cover plants are cultivated for the benefit of the rubber plants, 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 1.2 m to 1.8 m (4-6 ft.) wide along the planting row or a circle of about 0.6 m to 0.9 m (2 - 3 ft.) radius round each rubber plant should be clean weeded and kept clear of all undergrowth including cover plants. It is also a good practice if 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

During the early years after planting, the young rubber plants provide very little protection to the soil. This is due to the poor canopy cover and inadequate growth of ground cover crops. Most of the legume covers take at least 6 to 12 months to provide a sufficient protection to the soil. 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 and around the base of the rubber plants can therefore, be considered as a very good agronomic practice. In addition to its ability to contribute nutrients and conserve moisture, dead mulch does not compete with rubber for nutrients and moisture. Moreover, mulching had been found to be very effective in avoiding evapotranspiration losses and in controlling soil erosion. Mulching has another advantage in that it could be done immediately after planting, as mulching materials can easily be obtained at that time.

2.2 Contributions from mulch

2.2.1 Addition of nutrients

Rice straw contains about 0.6-0.7% nitrogen (N), 0.7-0.1% phosphorous (P), 1.4-1.9% potassium (K), 0.2-0.3% magnesium (Mg) and 30-40% carbon (C). Incorporation of 23 MT of rice straw per hectare during the 6 year immature period
(2-5 kg/plant/application, once in 6 months) will contribute approximately 120 kg of N, 345 kg of K and 23 kg of P. These quantities represent about 43% of N and more than 100% of K presently recommended as chemical fertilizer for rubber during the immature period.

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, organic matter tends to accumulate in the form of mulch of decaying straw due to continuous mulching at six months intervals.

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 more water
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 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.

2.3 Crop residues
Among the plant 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. Insufficient attention has been paid in the past to finding suitable methods to enhance the efficiency of rice straw as a mulching material.

2.3.1 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 round the rubber plants (Plate 3.1d)
2.3.2 Frequency and time of application

- The first application of straw should be done immediately after planting, round 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 should be done twice per year, during the paddy harvesting period (March/April and August/September) when the mulching material (straw) is freely available

2.3.3 Rate of application

The recommended rates of application of paddy straw (around the base of rubber plants) are given in Table 3.2.

Table 3.2. Rates of application of paddy straw (per tree)

<table>
<thead>
<tr>
<th>Year of planting</th>
<th>Amount per application (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>During the 1st year after planting</td>
<td>2 kg/application</td>
</tr>
<tr>
<td>2nd year</td>
<td>3 kg/application</td>
</tr>
<tr>
<td>3rd and 4th year</td>
<td>4 kg/application</td>
</tr>
<tr>
<td>5th year until tapping</td>
<td>5 kg/application</td>
</tr>
</tbody>
</table>

2.4 Tree/Bush legumes

The main drawback in mulching with paddy straw under commercial estate conditions is often the lack of sufficient mulching material close to the field for the initial mulching operation and for replenishing the mulch layer at suitable intervals. It may therefore be necessary to adopt a 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 Tree/Bush legume species

Bush legume species that can be grown successfully in rubber plantations are, Flemelia macrophylla (F. congesta) (Plate 3.1e) and Crotalaria micans (C. anagyroides) (Plate 3.1f).

2.4.2 Establishment

Bush legumes are best established immediately after 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 spacings between two rows of bush legumes should be about 60 cm.

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.

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
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 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.

3.2.1 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 round 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.

3.2.2 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.

3.2.3 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 practicable and in any case is an undesirable practice.

3.2.4 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.

3.2.5 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.

3.2.6 Intercropping
It is another excellent method of weed management in rubber. Intercropping with banana, passionfruit 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 under both estates and smallholder situations.

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

3.2.8 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 (Round up) is a water-soluble, translocated herbicide and therefore could kill underground parts of many perennial weeds when sprayed on the foliage. It can produce phytotoxic symptoms on any plant it comes in contact with, either when spraying or due to spray drift. The herbicide however is inactivated when it comes in contact with the soil. Glyphosate has been found to effectively control couch grass and illuk when used at the rate of 4.4 kg active ingredient in 600 litres of water per hectare. Paraquat (Gramoxone) is effective in controlling weeds in rubber plantations when used at the dilution rate of 2.5 ml in 9 litres of water. Weeds common in rubber plantations of Sri Lanka and the recommended control measures are given in Table 3.3.
<table>
<thead>
<tr>
<th>Local and botanical names of weed</th>
<th>Distribution in rubber growing areas</th>
<th>Propagation and dispersal</th>
<th>Method of control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grasses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>01. Axonopus affinis</td>
<td>A dominant weed in rubber growing</td>
<td>Bushes grow to about 0.5</td>
<td>Slashing during</td>
</tr>
<tr>
<td>(Carpet grass) Hinpotu Tana</td>
<td>areas, Kalutara and Kurunegala.</td>
<td>m high. Propagation by</td>
<td>tender stages.</td>
</tr>
<tr>
<td>(Sappupal)</td>
<td></td>
<td>wind dispersal of seeds.</td>
<td>Uprooting and</td>
</tr>
<tr>
<td>02. Panicum repens</td>
<td>Distributed in all rubber growing</td>
<td>Has underground rhizomes.</td>
<td>burning of</td>
</tr>
<tr>
<td>(Couch grass) Etora</td>
<td>areas.</td>
<td>Propagation by seed and</td>
<td>rhizomes.</td>
</tr>
<tr>
<td>03. Paspalum conjugatum</td>
<td>A troublesome weed in all rubber</td>
<td>Grows rapidly. Propagation</td>
<td>Repeated slashing</td>
</tr>
<tr>
<td>(Sour grass)</td>
<td>growing areas.</td>
<td>by seeds and fragments.</td>
<td>and grazing.</td>
</tr>
<tr>
<td>04. Imperata cylindrica</td>
<td>A troublesome weed in all rubber</td>
<td>Grows year round to 1-2 m</td>
<td>Application of</td>
</tr>
<tr>
<td>(illuk)</td>
<td>growing areas, particularly in the</td>
<td>high. Silvery white</td>
<td>Glyphosate.</td>
</tr>
<tr>
<td></td>
<td>drier districts.</td>
<td>inflorescence 7 to 20 cm</td>
<td></td>
</tr>
<tr>
<td>05. Lophatherum gracile</td>
<td>Distributed in all rubber growing</td>
<td>Bushes grow to about 80</td>
<td>For smallholdings:</td>
</tr>
<tr>
<td>(Bata thanakola)</td>
<td>areas.</td>
<td>cm high. Propagation by</td>
<td>Digging out of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>seeds and rhizomes.</td>
<td>underground</td>
</tr>
<tr>
<td>06. Digitaria longiflora</td>
<td>A common grass in all rubber lands.</td>
<td></td>
<td>rhizomes, drying</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>and burning.</td>
</tr>
<tr>
<td>07. Pennisetum polystachyon</td>
<td>Distributed in all rubber growing</td>
<td>Bushes grow 1-2 m high.</td>
<td>Slashing during</td>
</tr>
<tr>
<td>(Rilathana)</td>
<td>areas.</td>
<td>Flowering in Nov-Dec.</td>
<td>tender stages.</td>
</tr>
<tr>
<td>08. Cynodon dactylon</td>
<td>A common grass in all rubber</td>
<td>Grows year round.</td>
<td>Uprooting and</td>
</tr>
<tr>
<td>(Kukul atawara)</td>
<td>growing areas.</td>
<td>Propagation by seeds and</td>
<td>burning of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>rhizomes.</td>
<td>rhizomes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Repeated slashing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>and application</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>of Glyphosate.</td>
</tr>
</tbody>
</table>

For smallholdings: Digging out of underground rhizomes, drying and burning.
For large estates: Application of Roundup. 4.4 kg active ingredient in 600 litres of water/hectare.
<table>
<thead>
<tr>
<th>Local and botanical names of weed</th>
<th>Distribution in rubber growing areas</th>
<th>Propagation and dispersal</th>
<th>Method of control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sedges</strong></td>
<td><strong>Cyperus rotundus</strong> (Kalanduru)</td>
<td>Grows vigorously in all rubber growing areas.</td>
<td>Perennial sedge. Bushes grow 30-60 cm high. Propagation by tubers.</td>
</tr>
<tr>
<td><strong>01. Mikania cordata</strong> (Wathupalu)</td>
<td>A troublesome weed in all rubber growing areas.</td>
<td>Annual weed. Propagation by seeds.</td>
<td>Creepers dry up with Jan-March dry spells. Slashing or application of Paraquat.</td>
</tr>
<tr>
<td><strong>02. Exallage (Hedyotis)auricularia (Getakola)</strong></td>
<td>A dominant weed in Kalutara, Kurunegala and Kelani Valley areas.</td>
<td>Annual weed with numerous prostrate branches. Propagation by seeds.</td>
<td>Mammoty weeding and slashing or by hand weeding. Application of Paraquat.</td>
</tr>
<tr>
<td><strong>04. Crassocephalum crepidioides</strong></td>
<td>Distributed in all rubber growing areas.</td>
<td>Annual weed. Propagation by seeds.</td>
<td>Mammoty or hand weeding.</td>
</tr>
<tr>
<td><strong>05. Ageratum conyzoides</strong> (Hulanthala)</td>
<td>Distributed in all rubber growing areas.</td>
<td>Annual weed. Propagation by seeds.</td>
<td>Mammoty or hand weeding.</td>
</tr>
<tr>
<td><strong>06. Centella asiatica</strong> (Gotukola)</td>
<td>Weed in all rubber growing areas.</td>
<td>Spreading by creeping. Rooting at nodes. Propagation by runners.</td>
<td>Hand weeding. Application of Roundup 4.4 kg active ingredient in 600 litres of water/ha.</td>
</tr>
<tr>
<td><strong>07. Merremia umbellata</strong> (Morning glory)</td>
<td>Distributed in all rubber growing areas.</td>
<td>Perennial weed. Propagated vegetatively and by seeds.</td>
<td>Mammoty and hand weeding.</td>
</tr>
<tr>
<td>Local and botanical names of weed</td>
<td>Distribution in rubber growing areas</td>
<td>Propagation and dispersal</td>
<td>Method of control</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>--------------------------------------</td>
<td>---------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>10. <em>Spermacoce prostrata</em> (Getakola)</td>
<td>One of the commonest weeds in all rubber growing areas.</td>
<td>Annual shrub. Propagated by seeds.</td>
<td>Mammoth weeding.</td>
</tr>
<tr>
<td><strong>Ferns</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>01. <em>Dicranopteris linearis</em> (Kekilla)</td>
<td>Abundant weed in Kelani valley and Kalutara rubber growing areas.</td>
<td>Zigzag fronds repeatedly branching. Spore capsules on the back of the frond, one at the end of a veinlet.</td>
<td>Repeated slashing or mammoth digging.</td>
</tr>
<tr>
<td>03. <em>Nephrolepis</em> spp.</td>
<td>Abundant in Kalutara and Kelani valley areas.</td>
<td>Propagated by underground rhizomes and runners.</td>
<td>Repeated slashing or mammoth digging.</td>
</tr>
</tbody>
</table>
Plate 3.1. Soil management practices. a Pueraria phaseoloides; b Mucuna bracteata; c Desmodium ovalifolium; d Mulching; e Flemingia macrophylla; f Crotalaria micans.
Chapter 4

Rainfall pattern in rubber growing areas of Sri Lanka

Wasana Wijesuriya

1. Introduction

2. Rainfall variability in rubber growing areas
   2.1 Seasonal variations
   2.2 Number of rainy days
   2.3 Occurrence of dry spells

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 at least 20 years is required for a standard time series analysis to identify trends, seasonal variation and cycles in long-term records. The simplest way of identifying the pattern of rainfall for a particular region is by establishing probability histograms on monthly or standard week basis. The most widely used method of presenting rainfall behaviour is the exceedance probability at the 25% level (75% expected); the value which can be expected in 3 times out of a 4-year cycle. Moreover, it is important to study the variation in rainfall in different rainfall seasons, analysis of rainy days and frequency of dry spells.

2. RAINFALL VARIABILITY IN RUBBER GROWING AREAS

Rubber growing areas in Sri Lanka cover 12 administrative districts, namely Kegalle, Kalutara, Ratnapura, Colombo, Gampaha, Galle, Matara, Kandy, Matale, Kurunegala, Moneragala and Badulla. These districts belong to several agro-ecological regions: low country wet zone (WL), low country intermediate zone (IL), mid country intermediate zone (IM) and upcountry intermediate zone (IU). Some rubber growing areas and their agro-ecological regions are given in Table 4.1. The annual average

40
rainfall varies from about 1900 mm in the Moneragala area to 5000 mm in the wettest rubber growing areas (WL1). The rainfall distribution in some of these areas is given in Fig. 4.1.

Table 4.1. Major rubber growing areas and their agro-ecological regions

<table>
<thead>
<tr>
<th>Agro-ecological Region</th>
<th>75% Expected Rainfall (mm)</th>
<th>Rubber Growing Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowcountry Wet Zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WL1</td>
<td>&gt;2540</td>
<td>Ratnapura, Avissawella, Agalawatta, Morawaka, Kegalle</td>
</tr>
<tr>
<td>WL2</td>
<td>&gt;1900</td>
<td>Ambanpitiya</td>
</tr>
<tr>
<td>WL3 and WL4</td>
<td>&gt;1525</td>
<td>Kalutara, Colombo, Galle, Matara</td>
</tr>
<tr>
<td>Midcountry Wet Zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WM2 and WM3</td>
<td>&gt;1400</td>
<td>Kandy, Aranayake, Matale</td>
</tr>
<tr>
<td></td>
<td>&gt;1270</td>
<td></td>
</tr>
<tr>
<td>Lowcountry Intermediate Zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IL1</td>
<td>&gt;1020</td>
<td>Kurunegala</td>
</tr>
<tr>
<td>IL2</td>
<td>&gt;1150</td>
<td>Moneragala</td>
</tr>
<tr>
<td>Midcountry Intermediate Zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IM3</td>
<td>&gt;900</td>
<td>Nalanda</td>
</tr>
<tr>
<td>Upcountry Intermediate Zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IU2 and IU3</td>
<td>&gt;1400</td>
<td>Badulla</td>
</tr>
<tr>
<td></td>
<td>&gt;1150</td>
<td></td>
</tr>
</tbody>
</table>

2.1 Seasonal variations

The usual bimodal pattern caused by the monsoonal influence exists in most rubber growing areas with peaks coinciding with the months May and October. Northeast rains are usually experienced during the period of end of November to mid-January at full strength (NEF) followed by a period of 2 months at partial strength (NEP). In general, the first inter-monsoonal period commences in late March and extends to early May (IM1). Southwest rains begin during late May at partial strength (SWP1), persist for 2 months at full strength (SWF) and continue until the end of August (SWP2) followed by the second inter-monsoonal period (IM2) until mid-November.
Fig. 4.1. 75% expected rainfall values in major rubber growing areas
In wet areas, inter-monsoonal rains contribute nearly 50% to the total annual rainfall. The second inter-monsoon season (IM2) prior to the Northeast rainy season carries more rain which usually lasts for 2 months, when compared to the inter-monsoon season before the commencement of Southwest rains. A graphical illustration is given in Fig. 4.2, prepared from 30 years of rainfall data collected at the Dartonfield meteorological station which is representative of the low country wet zone. The contribution from inter-monsoon rains to the annual rainfall is similar in the Moneragala area but there the Northeast rains are more prominent compared to the Southwest rains, as depicted in Fig. 4.3.

Fig. 4.2. Seasonal variation in rainfall at Dartonfield

Fig. 4.3. Monthly and seasonal variation in rainfall in Moneragala area
2.2 Number of rainy days

The number of rainy days is also a major determinant of rubber yield. In low country wet zone areas, a large number of rainy days is observed during April to November which coincides with the periods of inter-monsoonal and Southwest influence.

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

2.3 Occurrence of dry spells

During the first 7 weeks of the year (Fig. 4.1), there appears a fairly long dry spell which can adversely affect the growth of immature rubber plants, especially when planted with Northeast rains. This statement is supported by the analysis of dry spells at Dartonfield, which is representative of the wet zone area, over the period 1964 to 1997 (Table 4.2). This dry spell during the early part of the year is common to the low country rubber growing areas covering the agro-ecological zones WL_1, WL_2, WL_4, and IL_1 (Fig. 4.1). Hence, planting of rubber during the Southwest 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.4.1, IM_3 and IL_1) there are two dry periods, which are more prominent in the midcountry areas. The Moneragala area which comes under the agro-ecological zone IL_2 has sufficient rains during the early parts of the year. Therefore, in these areas it may be appropriate to adhere to the Northeast planting season with the onset of inter-monsoonal rains. The use of polybag 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 a 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 4.2. The frequency of dry spells during the period 1964 to 1998 - Dartonfield station

<table>
<thead>
<tr>
<th>Month</th>
<th>6-10</th>
<th>11-15</th>
<th>16-20</th>
<th>21-25</th>
<th>26-30</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>21</td>
<td>9</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>February</td>
<td>18</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>March</td>
<td>17</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>April</td>
<td>5</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>May</td>
<td>6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>June</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>July</td>
<td>8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>August</td>
<td>9</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>September</td>
<td>10</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>October</td>
<td>10</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>November</td>
<td>9</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>December</td>
<td>18</td>
<td>7</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Chapter 5

Clones for commercial planting in Sri Lanka

D.P.S.T.G. Attanayaka

1. Introduction
2. Objectives of clone selection
3. Clone recommendation for the plantation sector
4. Main characteristics of recommended clones

1. INTRODUCTION

The rubber tree *Hevea brasiliensis* (A. Juss.) Muell. Arg. was first introduced to Sri Lanka in 1876 when 1919 seedlings of the Wickham collection were planted in Peradeniya and Henarathgoda Botanic gardens. Later in 1883 the seeds and seedlings derived from these trees of Wickham origin were distributed to other Southeast Asian countries and formed the foundation stock for the development of the rubber plantations in Asia. Since there is no positive evidence that the planting material from other sources such as the Cross or Farris material survived in the East, Asian planting material up to the 1980s is commonly called the “Wickham genetic base”.

At the very beginning of the rubber industry, unselected seedlings were used as the planting material. Later high-yielding trees in estates were identified and seedlings raised from seeds collected from these high-yielding trees were used as the planting material. Subsequently with the perfection of the budgrafting technique, clones became the main type of planting material. The next breakthrough in *Hevea* breeding was the perfection of the artificial crossing or hybridisation technique which paved the way for crossing selected parental clones. Seedlings derived from such crossing programmes were selected to produce new clones (Figure 1, pathway A, B and C).

2. OBJECTIVES OF CLONE SELECTION

The main objective should be to identify clones with high yield potential combined with desirable secondary characters. High-yielding clones can increase the intake per tapper and thus reduce the tapping cost which is the main component in the cost of production of rubber. Among the secondary characters, the most important are the vigour or growth rate and the tolerance to important foliar diseases such as *Oidium*, *Phytophthora* and *Corynespora*. Early opening for tapping and good early yield are only possible with clones having vigorous growth in the pre-tapping period and the increasing yield trend for many years could be sustained only if the clone can maintain its growth vigour even after the commencement of tapping. When discounted cash flow is considered clones that reach tappable girth early and high initial yields are preferred over clones with higher yields in later years of exploitation. In addition to the above traits discussed, resistance of a clone to wind damage and Tapping Panel Dryness (TPD) will
reduce the losses of tappable trees from the mature area thereby contributing to increased productivity.

In view of the current surge of interest in rubberwood by the timber industry the rubber tree has now gained recognition as a dual purpose tree providing both latex and timber. Therefore, emphasis is now being placed on breeding and selection of quick-growing trees which are suitable for both latex and timber production. On the other hand, as an industrial crop the technical properties of the natural rubber produced by different clones should be improved in order to cater to the future needs of the industrialists.

It is very difficult to identify high-yielding and vigorous clones that possess all secondary characters such as tolerance to all the foliar diseases, white latex, tolerance to wind damage etc. Most of the new clones are high-yielding and vigorous. But some clones, though possessing these two important traits, may be susceptible to some diseases and tolerant to others. Before choosing a clone for planting in a particular area due consideration should therefore be given to factors such as elevation, rainfall, susceptibility/tolerance of clones to diseases and wind damage. In Sri Lanka, clonal material for conventional planting is classified into three main classes, depending on the amount of experimental and commercial experience that has been acquired on the clones.

3. CLONE RECOMMENDATION FOR THE PLANTATION SECTOR

**Group I - each clone to be planted up to 10% of the extent**

<table>
<thead>
<tr>
<th>RRIC 100</th>
<th>RRIC 102</th>
<th>RRIC 121</th>
<th>RRIC 130*</th>
<th>PB 217*</th>
<th>PB 28/59*</th>
</tr>
</thead>
</table>

* PB 217 and PB 28/59 are not recommended for areas having more than 3750 mm of annual rainfall.

**Group II - Each clone to be planted up to 3% of the extent**

<table>
<thead>
<tr>
<th>RRIC 117</th>
<th>RRISL 201</th>
<th>RRISL 202</th>
<th>PB 235*</th>
</tr>
</thead>
<tbody>
<tr>
<td>RRIC 131</td>
<td>RRISL 205</td>
<td>RRISL 206</td>
<td>PB 260*</td>
</tr>
<tr>
<td>RRIC 133</td>
<td>RRISL 210</td>
<td>RRISL 211</td>
<td>BPM 24</td>
</tr>
<tr>
<td>RRISL 215</td>
<td>RRISL 217</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* These clones should be tapped at 67% intensity until intensification.
Group III - to be planted as Estate/RRI collaborative clone trials
Each clone to be planted up to 2 ha

- RRISL 200
- RRISL 204
- RRISL 208
- RRISL 218
- RRISL 219
- RRISL 220
- RRISL 221
- RRISL 222
- RRIM 717
- RRISL 2000
- RRISL 2001
- RRISL 2002
- RRISL 2003
- RRISL 2004
- RRISL 2005
- RRISL 2006

RRISL 200
RRISL 204
RRISL 208
RRISL 218
RRISL 219
RRISL 220
RRISL 221
RRISL 222
RRIM 717
RRISL 2000
RRISL 2001
RRISL 2002
RRISL 2003
RRISL 2004
RRISL 2005
RRISL 2006

Planting strategy - More clones but in smaller extents

In Sri Lanka, the Natural Rubber (NR) industry today depends totally on two rubber clones, i.e. RRIC 100 and PB 86. This situation demands serious attention of the rubber growers because in an event of a major hazard affecting these two clones the whole rubber industry in Sri Lanka is at stake. The only way to overcome this situation is to maintain a greater genetic diversity in estates by planting as many recommended clones as possible. A desirable composition of clones in an estate can be achieved by adhering to the following guidelines.

Group I clones

The performance of the clones in this group has been confirmed from commercial areas. They are suitable for wide-scale planting but it is always advisable to plant any single clone only up to 10% of the total extent of the Estate.

<table>
<thead>
<tr>
<th>Size of the estate</th>
<th>Area covered by a single clone in group I</th>
<th>Total area under Group I clones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 200 ha</td>
<td>20 ha</td>
<td>100 ha</td>
</tr>
<tr>
<td>200 – 400 ha</td>
<td>20 - 40 ha</td>
<td>100 - 200 ha</td>
</tr>
<tr>
<td>400 – 500 ha</td>
<td>40 - 50 ha</td>
<td>200 - 250 ha</td>
</tr>
<tr>
<td>500 – 1000 ha</td>
<td>50 - 100 ha</td>
<td>250 - 500 ha</td>
</tr>
</tbody>
</table>

It is advisable to limit the area covered by all Group I clones to less than 60% of the total extent of the estate.

Group II clones

This group consists of promising planting material where the performance has not yet been confirmed by commercial plantings. Each clone in this group is to be planted up to 3% of the total extent of the estate.
Size of the estate | Area covered by a single clone in group II | Total area under Group II clones
--- | --- | ---
Below 200 ha | 6 ha | 90 ha
200 - 400 ha | 6 - 12 ha | 90 - 180 ha
400 - 500 ha | 12 - 15 ha | 180 - 225 ha
500 - 1000 ha | 15 - 30 ha | 225 - 450 ha

Around 45% of the total extent of the estate could be covered by all Group II clones.

**Group III clones - Estate/RRI collaborative Clone Trials (ECTs)**

This group includes experimental planting material identified for testing in large scale with the collaboration of the growers. The main aim is to establish promising new clones in large blocks in cooperating estates for large-scale and commercial evaluation. This concept of the ECT programme will help in shortening the breeding time of new clones and accelerate the pace of adopting new clones by estates (Fig. 5.1, pathway C).

Each clone can be planted up to 2 ha.

<table>
<thead>
<tr>
<th>Size of the estate</th>
<th>Extent under ECTs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 200 ha</td>
<td>10 ha</td>
</tr>
<tr>
<td>200 - 400 ha</td>
<td>10 - 20 ha</td>
</tr>
<tr>
<td>More than 500 ha</td>
<td>30 ha</td>
</tr>
</tbody>
</table>

For estates over 500 ha, about 5% of the land area can be planted under the ECT programme.

**Clone recommendation for smallholders and private estates**

RRIC 100, RRIC 102 and RRIC 121.

**Latex - Timber clones**

In view of the growing demand for the rubber tree as a timber producing species, the following clones have been identified as latex-timber clones for the Plantation Sector.

RRIC 121   RRISL 205   RRISL 2000   PB 235
RRIC 133   RRISL 2001   PB 260
Fig. 5.1. Testing duration along different rubber breeding pathways showing the importance of estate, smallholder/RRI collaboration clone trials in accelerating the clone development process.
4. MAIN CHARACTERISTICS OF RECOMMENDED CLONES

RRIC 100
A vigorous clone capable of yielding an average of about 1624 kg of dry rubber per hectare per year (kg/ha/yr) during the first ten years of tapping. The clone requires proper and regular application of fertilizers to obtain best results. RRIC 100 is the highest yielding clone (1625 kg/ha/yr) on the average of first 7 years, in the Multilateral Exchange Clone Trials (MECT) conducted by RRI Malaysia. Latex is white.

RRIC 102
A vigorous clone with a potential of yielding an average of about 1800 kg/ha/year during the first seven years of tapping. Tolerant to Oidium leaf fall disease. Therefore, it is recommended for planting at high elevations. Latex is slightly yellow.

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 1511 kg/ha/yr during the first 10 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 favorable for the spread of these diseases. Latex is slightly yellow in colour.

PB 217
A good yielder. Commercial clearings on some estates have recorded a yield of more than 1500 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 favorable for the spread of these diseases. PB 217 is not recommended for areas with average rainfall of more than 3750 mm and/or at elevations above 300 m mean sea level. Latex is slightly yellow in colour. Susceptible to tapping panel dryness. Therefore tapping at 67% intensity until intensification is recommended.

RRIC 121
A very vigorous clone. After the third year of tapping under experimental conditions RRIC 121 has given an average yield over 3500 kg/ha/yr. Tolerance to Oidium is below average. Girth increment after tapping is very good. It has below average tolerance to Phytophthora leaf fall but is resistant to the second phase, Phytophthora bark rot. Extensive leaf fall can reduce yield. Susceptible to Colletotrichum leaf disease. Tolerant to certain races of the South American Leaf Blight (SALB) fungus. Sometimes RRIC 121 requires induction of lateral branching. Latex is slightly yellow.
RRIC 117

A vigorous clone. But its initial yields are low. RRIC 117 is capable of giving an average yield of 1525 kg/ha/yr during the first 10 years. It is tolerant to some races of the SALB fungus. Latex is white.

RRIC 130

A vigorous clone with very high initial yields of about 4662 kg/ha/yr during the first two years. It is prone to wind damage (trunk snapping) and should not be planted in areas prone to strong winds. Highly susceptible to *Phytophthora* bark rot. It is tolerant to some races of the SALB fungus. Latex is white. 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 2854 kg/ha/yr during the first nine years. Slightly susceptible to *Oidium*. RRIC 131 shows above average susceptibility to *Corynespora* leaf disease. It has 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 2452 kg/ha/yr during the first 10 years. Below average tolerance to *Phytophthora* leaf disease.

PB 260

A clone developed by Prang Besar Research Station in Malaysia. 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 2192 kg/ha/year during first 12 years of tapping. Susceptible to tapping panel dryness and therefore should be tapped at 67% intensity. Latex is pale yellow in colour.

PB 235

A clone developed by Prang Besar Research Station. As 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 2485 kg/ha/year during first 15 years of tapping. Prone to tapping panel dryness. Therefore should be tapped at 67% intensity. Latex is pale yellow in colour.
RRISL 200 series of clones

This new series of clones introduced for planting has been selected from the hybridisation programmes carried out by the institute during the period 1974-1981. All the clones recommended for planting in this series are more vigorous than the presently popular clone RRIC 100. All clones have a good post-tapping vigour, hence are expected to maintain an increasing yield trend. In small-scale trials these clones have recorded an average yield of above 3000 kg/ha/yr during the first 10 years of tapping. These clones are less prone to brown bast than average.

A general indication of the average yield potential of RRISL clones in terms of dry rubber weight (grams) that can be obtained per tapping (g/t/t) is depicted in Fig. 5.2.

Fig. 5.2. General indication of the yield potential (g/t/t) of some clones developed at RRI, Sri Lanka.
Chapter 6

Management of rootstock and budwood nurseries

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1. Introduction
2. Nurseries
3. Rubber seeds
   3.1 Selection of seeds
   3.2 Germination bed
4. Rootstock nurseries
   4.1 Ground rootstock nurseries
      4.1.1 Site selection
      4.1.2 Preparation of nursery beds
      4.1.3 Land preparation for ground rootstock nurseries
      4.1.4 Spacing and plant production capacity of the nurseries
      4.1.5 Up-keep of the nursery and life span
   4.2 Polybag rootstock nursery for raising young buddings
      4.2.1 Soil for filling bags and spacing
5. Budwood nurseries
   5.1 Establishment of budwood nurseries
   5.2 Location and layout
   5.3 Care of budwood nurseries
   5.4 Types of buds and approximate number of buds on budwood
      5.4.1 Brown budwood
      5.4.2 Green budwood
   5.5 Harvesting budwood and nomenclature
   5.6 Labelling packing and storage
   5.7 Management of budwood nurseries
   5.8 Life span of budwood nurseries

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.

After bud-grafting, the budded plants, i.e. budded stumps, can be directly transplanted to fields or can be grown in polythene bags up to 2-3 leaf whorls in a nursery. These nurseries are generally known as polybag nurseries. Furthermore, in order to produce advanced planting material specially to use in infilling of 2-3 year old clearings, budded plants are maintained to be stumped after 1 ½ - 2 years of age and they are called stumped budding nurseries.

3. RUBBER SEEDS

Rubber seeds are the planting material for rootstock nurseries. Rootstock nurseries are established every year during 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 has gone down to very low levels, making it necessary to obtain seeds from where they are abundant i.e. Kegalle, Kurunegala etc. Since rubber seeds remain viable only for a short period, fresh seeds should be collected and germinated 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 even otherwise. 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.

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 6.1a). 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 then select.
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). No material other than pure sand should be used in germination beds. This is important to prevent infection of seedlings by soil-borne pathogens. Generally, a 1 m² germination bed holds about 1000 seeds, i.e. 4 kg of seeds. The number of seeds to be used in the germination bed should be 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.](image)

The seeds should be pressed into the sand and covered with sand until the top of the seed is nearly in level with the surface of the sand (Plate 6.1b). Germination beds should not be exposed to direct sunlight and where necessary a shade should be provided with cadjan or similar material. 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.

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 6.1c). Germinated seeds should be harvested every other day, and for a maximum of four rounds. Only ca. 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 either polybags for young buddings or in
ground nurseries for raising green or brown budded stumps. 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

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 in any case 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 competition for root growth. A well-drained flat land is ideal for a ground 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 laying out nursery beds. On sloping land they should be lined on the contour and levelled. On steep land, it may be necessary to decrease the width of the nursery beds. It is convenient to start levelling beds from the top of the slope and work downwards. A drain 30 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 Land preparation for ground rootstock nurseries

Proper land preparation is very important for the growth of seedlings as well as to avoid damaging the root system at uprooting. The soil should be dug to a depth of at least 60 cm. Stones and roots should be removed during the preparation of nursery beds.

This will help the tap root to grow down vertically without any obstruction. Roots and old stumps should also be removed to avoid risk of root diseases.

4.1.4 Spacing and plant production capacity of the nursery

Once the beds are prepared, germinated seeds can be planted in single rows, 15 cm within row and 45 cm between rows (Fig.6.2b). Also, they can be planted in pairs of rows on a 23 cm triangular spacing with 60 cm space between centres of adjacent pairs of rows (Fig.6.2a).
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. At monthly intervals the nursery should be thinned out by the removal of weak plants. The number of plants will be reduced to about 44,000 per hectare after thinning of weak plants. With 80% bud-grafting success, it should be possible to get about 35,000 budded stumps from one hectare of seedling nursery.

4.1.5 Up-keep of the nursery and life span
Weeding and fertilizing should be carried out as recommended in order to obtain the buddable girth within the anticipated period. Spraying of fungicides as and when necessary should also be carried out to prevent leaf diseases.

Rootstock nurseries should never be kept for more than 2 years. The plants which will not reach the buddable girth within a period of one year will never produce a quality budded stump. The main function of a rootstock nursery is to produce vigorously growing stock plants for grafting.

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 6.2d). Therefore, even a deniya, i.e. low lying land can be used in the absence of good land.

Black polythene of gauge 500 or 300 is used for preparation of bags. Both 15 cm or 17.5 cm width guzzetted polythene tubing made to 37 cm or 45 cm
length bags are suitable. Standard size bags, guzzetted and perforated, are readily available in the market.

4.2.1 Soil for filling bags and spacing

Top soil sieved with a 1 cm sieve, mixed with imported rock phosphate at a rate of 50 g/bag is used for filling bags. Soil-filled bags can be arranged in single or double rows as for ordinary ground nurseries. When the bags are arranged close to each other, within row distance will be 15-17.5 cm. For single rows between row distance is 45 cm and for double rows it is 60 cm.

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. Agromanagement practices such as disease control in time are also essential.

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).

5.1 Establishment of budwood nurseries

Budwood nurseries can be established with green or brown budded bare roots, polybag plants or 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 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 watered.
Budwood plants are planted in planting holes of 60 x 60 x 75 cm. The recommended spacing for planting nurseries to harvest brown budwood is 90 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 harvest of budwood can be spaced closer, according to the space available. Budwood nurseries can be established at a planting distance of 4’ x 4’ (1.2 x 1.2 m) in order to make the plants grow as bushes and to harvest more green shoots. Branches should be cut where 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 develop until a few centimeters of brown bark form 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 in budwood nurseries.

5.3 Care of budwood nurseries

The agronomic practices recommended for budded plants grown in the field are also applicable for budded stumps in a nursery. All lateral shoots, as they appear, should be pruned, up to a height of about 2 m. 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 is important to note that budwood nurseries should not be 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.

For green budding of ground nurseries 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 the pollarding.

5.4 Types of buds and approximate number of buds on budwood

5.4.1 Brown budwood

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 suitable for brown budding (Fig. 6.4).

![Fig. 6.4. Different types of buds on a budwood stick.](image)

61
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 bud-grafts per metre of budwood. A more conservative estimate will be ten successful bud-grafts per metre of budwood.

5.4.2 Green budwood

Green buds for green 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 6.2a) 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 6.2b).

5.5 Harvesting budwood and nomenclature

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 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).

A hand pruning saw or a “Bushman’s” saw with fine teeth is suitable for cutting budwood without damaging the cut ends.

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 (Figures 6.6a, b, & c). Budwood over 1½ years should be cut back for regeneration of more juvenile and fresh budwood. 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. 6.5. Harvesting of a new budwood plant.

5.6 Labelling, packing and storage

The budwood should be labelled on the cut ends with the name of the clone immediately after harvesting from the plant. An indelible pencil 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 (Plate 6.2c).

For local 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 (Plate 6.2d). If the budwood is to be used within the estate the sticks can just be covered with a creeping cover, which will protect the buds sufficiently for transport over short distances.
Fig. 6.6. a 2-3 year old plants; b 4-5 year old plants; c More than 5 years old plants.

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. However, it is better if possible to arrange for a staggered supply according to the bud-grafting programme without storing the budwood for more than a day or two.

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. Authentic material obtained from the RRISL should be used 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 6.2e).

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 quality and juvenile budwood. 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 old. 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.
Plate 6.1 Seed, germination bed and rootstock nurseries. a Variation in seed morphology; b Germination bed; c Germinated seeds; d Polybag rootstock nursery.
Plate 6.2 Budwood nurseries

a Cutting leaves; b Green bud sticks; c Cut ends marked and dipped in wax; d Wrapped in banana sheath and bundled for transporting; e Budwood nursery.
Chapter 7

Bud-grafting techniques and types of planting material

Priyani Seneviratne

1. Bud-grafting
   1.1 Brown budding
   1.2 Green budding
   1.3 Factors affecting grafting success
      1.3.1 Quality of stock plants and budwood
      1.3.2 Season
      1.3.3 Bud-grafting knives
2. Planting material
   2.1 Bare-root budded stumps
      2.1.1 Preparation of bare-root budded stumps
   2.2 Polybag plants
      2.2.2 Soil for filling bags
      2.2.3 Planting budded stumps in bags
      2.2.4 Polybag nursery
   2.3 Young buddings
   2.4 Stumped buddings
      2.4.1 Preparation of stumped buddings
   2.5 Crown budding
   2.6 Rooted cuttings
   2.7 Micropropagation

1. BUD-GRAFTING

Bud-grafting is used for vegetative propagation of selected high-yielding parent trees. A collection 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 nurseries.

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 back 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 developed from the grafted bud or scion. Depending mainly on the age of the stock plant and bud patch used in grafting, two grafting methods are identified:

1.1 Brown budding

In brown budding 1-1 1/2 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 brown in colour.

The base of the stock 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 7.1a). 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 7.1b). One method is to remove an area of bark with a section of the wood (Plate 7.1c). 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 7.1d). 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 7.1e). The size of the bud patch and the panel will vary according to the size of the stock and budwood available.

The core of the bud should be seen as a slight projection from the inner side of the bark (Plate 7.2a). 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 7.2b). 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 7.2c & d).

After three weeks the polythene is removed and the bark flap covering the bud patch cut off (Plate 7.2e). 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 (Plate 7.2f). 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.
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 nurseries. When the seedlings are grown in polybags to raise young budtings 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 lower ends of these cuts are joined by a horizontal cut (Plate 7.3a). The flap of bark is then gently lifted upward using the tip of the bud-grafting knife exposing the budding panel. The flap is then cut off leaving about 1 cm at the top (Plate 7.3b).

The bud patch is prepared in the same way as for brown budding. The upper end of the bud patch so prepared, is gently inserted under the flap (Plate 7.3c) and then the bud patch is tied in position with a 2 cm wide strip of gauge 150 or 200 transparent polythene (Plate 7.3d).

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 budtings may be smaller compared to that of brown budtings, 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 also 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.

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 7.3e). For green budding the same knife can be used, but
ordinary paper cutters (NT-cutters) (Plate 7.3f) having thin replaceable blades have been found to be ideal for this purpose.

2. PLANTING MATERIAL

Rubber plantations are established with bud-grafted plants raised in nurseries. Bud-grafted plants 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. Brown budded stumps can be planted bare-root during both Southwest and Northeast monsoons in traditional rubber growing areas. Nevertheless, green budded bare-root plants should be planted only during the Southwest 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. 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 (Plate 7.4a). Once the plant is uprooted from the nursery, the stock plants should be cut leaving 10 cm and 15 cm long snags from the bud patch for brown and green buddings respectively (Plate 7.4b). 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 (Plate 7.4c). 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 7.4d). 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

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 root system of polybag plants remains undisturbed and 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 to the type of bare root.

Polybags can be made by using guzetted 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.

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.

2.2.3 Planting budded stumps in bags
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 (Plate 7.5a) 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 (Plate 7.5b). 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.

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 (Plate 7.5c), 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.

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 (Plate 7.6a). 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 (Plate 7.6b). However, if desirable and affordable a longer snag can be retained (Plate 7.6c). Though a longer snag supports growth and reduces die back it delays sprouting and also growth 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 stacked separately and a temporary shade given until the first whorl hardens. This will significantly lower the incidence of leaf diseases and the casualty rate after cutback. One of the main advantages with young buddings is the shorter period involved in producing polybag plants. 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 (Plate 7.6d). 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.

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. 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.

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 7.7. 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 7.7a). 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 7.7b) just above a cluster of dormant buds. A waterproof dressing such as Barcosan or Kandarson should be applied on the cut surface. Application of lime on the stump minimizes desiccation of the stem (Plate 7.7c). About 2 weeks after pollarding, the top dormant buds start sprouting (Plate 7.7d) and at this stage the stumps should be uprooted and planted in the field. Leaving the stumps longer than this in the nursery 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 7.7e). 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 7.8a and b) whilst brown budding is recommended for trees over 2 years old (Plate 7.8c and d). Crown budding should not be practised if trees are more than 3 ½ 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 7.9 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 still in its infancy. 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 7.10 a,b,c & d). However, at present production of planting material needed for the rubber industry is done through bud-grafting of stock plants.
Plate 7.1. Brown budding. a Two parallel cuts meet as an arch; b Leaf scar bud marked on the bud wood; c A bud removed with the wood; d Pulling the piece of wood out; e Brown bud ready to be inserted.
Plate 7.2. Brown budding. a The actual bud seen on the reverse side; b Inserting the bud patch between the wood and the flap; c Wrapping with a polythene tape; d Completed graft, e Removing the bark flap after 3 weeks; f Checking for success.
Plate 7.3. Green budding. a Marking the panel; b Opened budding panel; c Bud patch inserted under the flap; d Completed graft; e Budding knife, f Paper cutter used for green budding.
Plate 7.4 Bare root budded stumps. a Bare root budded stump with long laterals; b Snag sizes for brown and green budded stumps; c Brown budded stump with clone marked on the cut surface; d Pruning of lateral roots.
Plate 7.5. Polybag plants. a Planting bare root budded stumps in polybags; b Polybag nursery; c Late removing of stock shoots.
Plate 7.6 Young budding. a Bud-grafting of young buddings; b Short snag of 15 cm; c Long snags with leaves attached; d A young budding with two leaf whorls.
Plate 7.7. 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.
Plate 7.8. 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 7.9. Rooted cuttings. a Mist propagator; b A rooted seedling cutting; c A rooted clonal cutting.
Plate 7.10. Micropropagation. a Bud proliferation on a clonal node; b Elongated axillary shoots of juvenile nodes; c Rooted axillary shoots; d Acclimatized plant.
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
      1.1.4 Planting seasons
   1.2 Planting practices
      1.2.1 Planting of bare-roots
      1.2.2 Transplanting polybag plants in the field

2. Care after planting in the field
   2.1 The growth of the scion
   2.2 Maintaining the stand
   2.3 Branch induction
      2.3.1 Leaf folding method
      2.3.2 Leaf cap method
   2.4 Growth standards

1. FIELD ESTABLISHMENT
1.1 Preplanting practices
1.1.1 Preparation of land
   Correct land preparation to avoid root diseases and soil erosion and to achieve correct stands is one of the most important aspects in the cultivation of rubber.

1.1.1.1 Demarcation of diseased areas
   For replanting, prior to uprooting old stand areas infected with root diseases such as white root disease, they should be demarcated and precautions taken to prevent such diseases affecting the new stand (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 (Plate 8.1a,b,c & d). 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 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.

1.1.2 Planting distances and lining

Three planting distances to give a stand of 500 trees per hectare have been recommended for establishment of rubber plantations. Square planting i.e., 4 x 4.5 m should theoretically give the highest yield. Avenue type planting, 3.5 x 5.5 m and 2.5 x 8 m will save tappers time spent walking from tree to tree. A planting distance of 2.5 x 8 m is also 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.

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 8.1e) 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
1.1.3 Holing and filling

Planting holes can be cut either prior to uprooting or after uprooting and clearing the land are completed. It is important to ensure that the root debris is not allowed to fall in to the planting hole. The size of the planting hole is 60 x 60 x 75 cm (2’ x 2’ x 2 ½’). 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 recommended dosage of fertilizer should be mixed with the top 15-20 cm of soil 2-3 weeks prior to planting (50 g of the appropriate NPK mixture + 100 g of rock phosphate and 25 g or 10 g of kieserite per plant depending on whether it is high or low potassium mixture). If plants in polybags are used as the planting material, refilling the hole with top soil prior to planting and the application of basal fertilizer are not required.

1.1.4 Planting seasons

Field planting to establish rubber clearings/holdings is normally done with the onset of the monsoon rains. The major rainy season in the wet zone is the Southwest (SW) that falls in May-June each year and the minor season the Northeast (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.

In areas where the major rainy season is the Northeast, i.e. in Monaragala, Bibile etc., planting should be undertaken during that period.

1.2 Planting practices
1.2.1 Planting of bare-roots

Prior to planting a bare-root budded stump, 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 bud patch should be placed about 5-6 cm below ground level and facing North or South. After planting the budded stump, 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). When bare-root planting material is used it is advisable to have about 10% extra plants as both polybags and trench plants to fill casualties and replace weak plants.
1.2.2 Transplanting polybag plants in the field

Both, bare-root budded stumps planted in polybags and young buddings are transplanted in the same manner.

Only plants with a hardened top whorl should be transferred to the field (Plate 8.2a). 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 stage 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. In such cases, the root that is 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 8.2b). 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 field planted. However, when plants are transported to the field, if the soil inside the bag is saturated, then there is a chance of it moving and thereby distributing 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 plant or disturbing the root system. If plants are stacked tightly during transportation loosening of soil in the bags can be reduced to a great extent.

Prior to planting the polybag plant, the depth of the planting hole should be checked and it should be adjusted appropriately by removing or filling with soil. When planted, the graft union should be positioned a few centimetres below ground level (Plate 8.2c). Polybag plants can be deep planted as well so that the graft union is buried about 15-20 cm below ground level (Plate 8.2d). This practice has the advantage of minimum rootstock effect on yield when the tapping panel is close to ground level (Plate 8.2e). Deep planting is possible with polybags as basal fertilizer mixture is not added to the planting hole.

Once the depth of the planting hole is adjusted to suit the polybag plant the base of the polybag should be removed by cutting it around with a sharp knife or a blade (Plate 8.2f).

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. 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 lifted out carefully. 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.

2. CARE AFTER PLANTING IN THE FIELD

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 budded stumps should be watered and a suitable mulch placed around it. In bare-root budded stumps the buds start to sprout within about 3-4 weeks after planting, provided that the stock shoots are removed as they appear. Removing stock shoots as they appear early is important for the sprouting as well as the vigour of the scion shoot. This is because the growth of the first whorl mainly depends on the food reserves of the stock. If stock shoots grow they will consume the limited amount of reserves and starve the grafted bud.

All plants should be inspected at weekly intervals and if more than one scion shoot grows from the grafted bud, the most vigorous one should be retained and the others removed.

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.

2.2 Maintaining the stand

The 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 2\textsuperscript{nd} or 3\textsuperscript{rd} year upkeep.

Replacing weak plants is as important as infilling casualties. This should also be done with either polybag plants during the second year or with stumped buddings during the second and the third years.

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.

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 8.3a).

A few intact terminal leaves should be brought together and folded covering the apical bud (Plate 8.3b). 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 8.4a). A leaf cap is made with 3-4 detached mature leaves (Plate 8.4b) and this cap is placed over the stem apex and fastened with a rubber band (Plate 8.4c) 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
the uppermost whorl of leaves (Plate 8.4d). 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.

2.4 Growth standards

Depending on the type of planting material used in replanting, there can be a variation in the initial growth. However, young buddings and normal polybag plants grow more uniformly as well as faster initially than bare-root budded stumps. The potential growth of novel clones as measured by the girth of the plants at 120 cm above ground level is shown in Fig. 8.3.

Fig. 8.3. Yearly growth standards of immature plants.
Plate 8.1. Uprooting and lining. a Fixing the cable in the plant to be uprooted; b Fixing the Monkey Grubber to a support tree; c The tree being pulled; d Root system well exposed; e Using the road tracer to mark planting holes on the contour.
Plate 8.2. Transferring polybag plants. a Two-whorled polybag plant with a hardened top whorl; b Trimming the tap root with a pair of secateurs; c Placing the graft union 5-6 cm below the ground level; d Deep planting – graft union about 15-20 cm below the ground level; e Root system of a deep planted tree after 2 years; f Removing the base of the bag before planting.
Plate 8.3. Leaf folding method. a A tree suitable for leaf folding method; b The tree bent and leaves folded to cover the apex; c Apex covered.
Plate 8.4. Leaf cap method. a A tree with a terminal shoot with no expanded leaves; b 3-4 mature leaves to make the cap; c Tree with the leaf cap; d A tree having 5-6 induced branches.
Chapter 9

Common diseases*

C.K. Jayasinghe

1. Introduction

2. Leaf diseases
   2.1 *Oidium* leaf disease (Powdery mildew)
      2.1.1 Symptoms
      2.1.2 Predisposing factors
      2.1.3 Prevention
      2.1.4 Control
   2.2 *Colletotrichum* leaf disease
      2.2.1 Symptoms
      2.2.2 Predisposing factors
      2.2.3 Prevention
      2.2.4 Control
   2.3 *Corynespora* leaf fall
      2.3.1 Symptoms
      2.3.2 Predisposing factors
      2.3.3 Prevention
      2.3.4 Control
   2.4 *Phytophthora* leaf fall
      2.4.1 Symptoms
      2.4.2 Control
   2.5 Bird’s eye spot disease
      2.5.1 Symptoms
      2.5.2 Predisposing factors
      2.5.3 Prevention
      2.5.4 Control

3. Panel diseases
   3.1 Bark rot
      3.1.1 Symptoms
      3.1.2 Control

4. Stem and branch diseases
   4.1 Pink disease
      4.1.1 Symptoms
      4.1.2 Control
   4.2 *Ustulina* stem rot
      4.2.1 Symptoms
      4.2.2 Control
      4.2.3 Prevention

5. Root diseases
   5.1 White root disease

* Adopted from “A Handbook of Rubber Culture and Processing”, 1983.
1. INTRODUCTION

The rubber tree (Hevea brasiliensis (A. Juss.) Muell. Arg.) is susceptible to various pests and diseases all over the world. However, the economic threat of each disease varies from one country to another, according to the microclimate within the country, cultural practices employed and type of clone cultivated. In Sri Lanka all economically significant diseases are caused by indigenous fungal parasites and can be divided into four categories depending on plant part affected: leaf, stem, panel and root.

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 plant. Although damage by pests is minimal in the case of rubber, yet damage in nurseries and in young plantations has been reported. These abnormalities are discussed in Chapters 10, 11 and 13.

2. LEAF DISEASES

2.1 Oidium leaf disease (Powdery mildew)

One of the main causes of secondary leaf fall in Hevea in Sri Lanka resulting in poor canopies is planting of susceptible clones. It is most pronounced during the refoliation period (February-March) and affects tender leaflets causing defoliation.

The fungus survives in nurseries, self-sown seedlings and in immature leaves of the shaded canopy. The disease spreads by means of wind-borne spores.

Cause: Oidium heveae

2.1.1 Symptoms

Copper-brown and apple-green leaves are most susceptible. The fungus appears as white powdery spots on both leaf surfaces (Plate 9.1a). The lower leaf surface is generally heavily colonised, near the mid rib and veins. Severely infected leaflets shrivel and fall off leaving the petioles for some time. When semi-mature leaves are affected, initially, characteristic translucent spots are seen. These later turn brown and become necrotic. Such leaves remain on the tree until they are shed during the next wintering season.

Flowers are also attacked with consequent loss of seed production. This 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.

### 2.1.2 Predisposing factors

Late wintering clones e.g. RRIC 45, PB 28/59, RRIC 121, RRIM 623 and RRIM 628 generally succumb to the disease. Early winters e.g. 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 RRIC 100, RRIC 117, RRIC 130 and RRIM 600 are generally tolerant to the disease. The clone RRIC 102, another registered clone, 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 next wintering.

### 2.1.3 Prevention

Planting of clones highly susceptible to *Oidium* should be avoided at elevations above 90 m. Application of an enhanced quantity of nitrogenous fertilizer in the mixture will help to reduce the incidence of the disease.

### 2.1.4 Control

Sulphur dusting 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 methods should be adopted depending on the severity of the disease. If repeated defoliation occurs in the same year dusting with sulphur should be carried out immediately.

The recommended dose of sulphur is 8 kg/ha/round. The number of dusting rounds depends on leaf maturity. In any case it should not exceed 3-4 rounds, at weekly intervals.

Dusting should commence when 10% of the trees show signs of refoliation. Spot dusting is recommended when refoliation is uneven.

Dusting should be done using a power driven machine, between 2-7 a.m. to take advantage of the dew on the leaves and still condition of the air. The dusting machine should be carried across the direction of the prevailing wind, moving the machine at a speed of 3.2 km.p.h. Take the machine along parallel tracks about 30 m (100') apart. A machine can cover about 8 ha per hour.

Sulphur should be stored in a cool dry place, and should not be allowed to form hard lumps on storage.

It is advantageous to allow a certain amount of *Oidium* infection to occur, as 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.
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 dieback, flowers and developing fruits. The fungal spores are dispersed by rain splash and currents of damp air.

*Cause:* *Colletotrichum acutatum/ Colletotrichum gloeosporioides*

2.2.1 Symptoms

Leaves are most susceptible when they unfurl after bud break. Copper-brown leaves usually get discoloured, shrivel and fall-off leaving the petioles for some time (Plate 9.1b). Apple-green leaves show tip dieback, which sometimes can extend colonising much of the leaf blade. The unaffected portion of the leaf blade is retained after the diseased tissue dries and drops away.

Older leaves are resistant to infection and show only partial damage along the tip and margins or are extensively spotted. These spots are circular with a narrow brown margin surrounded by a distinct yellow halo. When the leaf matures, such spots appear as raised blisters. These leaves are usually retained on the tree. Infected tissues produce a pink mass of spores in wet weather or when incubated under humid conditions.

Severe infection could kill the shoot up to the bud patch during prolonged wet weather, in budded stumps.

2.2.2 Predisposing factors

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

2.2.3 Prevention

Resistant or tolerant clones e.g. RRIC 100, RRIC 130 should be grown. During continuous rain and overcast conditions heavy shade in polybag nurseries should be removed.

2.2.4 Control

Immature leaves of budded stumps planted in the field and nurseries should be sprayed with one of the following fungicides at weekly intervals giving 3-4 sprayings during the wet season. Bordeaux mixture (freshly prepared), Copper sandoz (3 g in 1 litre), Perenox (3 g in 1 litre), Copper oxychloride (3-4 g in 1 litre), Cobox (3 g in 1 litre), Dithane M 45 (3 g in 1 litre), Mancozeb (3 g in 1 litre), Captan (3 g in 1 litre) or Antracol (3 g in 1 litre).

2.3. *Corynespora* leaf fall (CLF)

*Corynespora* leaf fall disease was first reported in 1958 in India. It has also
been recorded in Nigeria, Cameroon, Malaysia, Indonesia and Brazil. It was recognized for the first time in Sri Lanka in December 1985. Apart from rubber, fifty seven alternate hosts are known to harbour this fungus.

*Cause*: *Corynespora cassiicola*

### 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 (Plate 9.1d). 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 number. 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 and RRIC 133 respectively.

### 2.3.2 Predisposing factors

All plants in seedling nurseries are susceptible to the disease. In budwood nurseries and in the field the following clones are highly susceptible to the disease: RRIC 52, RRIC 103, RRIC 104, RRIC 106, RRIC 107, RRIM 600, RRIC 118, NAB 12, RRIM 725 and RRIC 110.

Clones such as RRIC 100, RRIC 102, PB 86, RRIC 121, RRIC 130, RRIC 117 and PB 28/59 have shown tolerance to the disease in Sri Lanka.

### 2.3.3 Prevention

a) Only clones resistant to the disease should be planted.

b) The seedling nurseries and polybag nurseries should be sprayed at five-day intervals with Dithane M 45 (3 g/litre), Captan (3 g/litre) or Antracol (3 g/litre) as a routine practice.

c) All clearings of RRIC 103, RRIC 110 and other susceptible clones should be uprooted and all leaves completely burnt.

### 2.3.4 Control

*Corynespora* Leaf Fall disease could be controlled using effective fungicides over a long period. However, this is not recommended in field clearing as it is uneconomical.
2.4 Phytophthora leaf fall (abnormal leaf fall)

Occurs during the Southwest monsoon season, caused by the same fungus that causes pod rot, stem dieback, bark rot or black stripe and canker. It requires free water 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.

Cause: Phytophthora meadii/Phytophthora palmivora

2.4.1 Symptoms
The disease starts on the pod, appearing as water-soaked lesions with black globules of latex; 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 9.1c). Leaf blades can also be infected. Infected leaves are shed and the leaflets can be easily shaken off. Wind-damaged leaves have no lesions but will have a coagulated drop of latex at the damaged end of the petiole and leaflets can not be shaken off easily.

Severe infection leads to complete defoliation. 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 Control
Prophylactic treatment with oil-based copper fungicides just before the rainy season in May. This is not done in Sri Lanka but is done as a routine practice in India. The incidence of the disease is mild and confined only to isolated pockets. Therefore, it is not economical to control the disease. Clones RRIC 100, RRIC 102 and RRIC 130 show tolerance to Phytophthora leaf fall.

2.5 Bird’s eye spot disease
It is a common disease of seedling nurseries, which appears during periods of dry weather (December-February) and influenced by factors that predispose seedlings to conditions of stress. It rarely becomes a problem, but if it does, the growth of seedlings can be retarded, delaying the optimum size required for budding.

Cause: Bipolaris heveae (earlier referred to as Drechslera heveae).

2.5.1 Symptoms
Typically, lesions are circular with reddish brown margin and a silvery white...
central area which later falls off, giving a shot-hole appearance and hence the name bird's eye spot. On immature copper-brown leaves, water-soaked lesions appear. These leaves shrivel before they drop.

2.5.2 Predisposing factors
Sandy or lateritic soils and dry conditions with high temperature and low humidity with little or no rain are the main predisposing factors.

2.5.3 Prevention
The site for the nursery should be selected with good well-drained soils and proper manuring of the nurseries should be done. The intensity of the infection is reduced by shade.

2.5.4 Control
Bordeaux mixture or any other copper fungicide should be applied at weekly intervals. Carbamate fungicides (Zineb and Maneb) are highly effective.

3. PANEL DISEASES
3.1 Bark rot (Black stripe, Black thread canker)
This is the only panel disease of economic importance. It infects the inner bark and is severe during the monsoon months, when infected pods are present on the trees. Virgin bark is more susceptible to infection than renewed bark and care should be taken to prevent infection of the virgin bark. Clones that are highly susceptible to bark rot are RRIM 600, RRIM 623 and PB 86, RRIC 130 and RRIC 131.

 Cause: Phytophthora meadii/ P. palmivora

3.1.1 Symptoms
Dark gray sunken vertical lines directly above the tapping cut. These come together to form a continuous depressed patch on the panel. When infected bark is removed, characteristic vertical black lines can be seen on the wood hence the names black thread or black stripe (Plate 9.2e). The disease spreads into the renewed bark as well as into untapped bark causing cracks with exudation of latex and formation of latex pads later. If the disease is neglected it spreads causing gaping wounds resulting in a condition referred to as 'Canker'. A tapping cut remains susceptible for 72 h after tapping. The most critical period is the first 48 h.

3.1.2 Control
Disease tolerant clones viz. RRIC 100, RRIC 102, RRIC 121, BPM 24 and PB 260, should be planted.

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

Fungicides should be applied from May - September only; if the panel is infected, continue fungicide application till the end of the Northeast monsoon. 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.

Water-proof panel dressings such as Candarsan and Barkosan can be applied when the panel is dry. These help to retain the water-soluble fungicides. It is important to note that these panel dressings cannot destroy the pathogenic fungus. Never shift the panels during rainy weather especially from May - August.

(b) 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 very early. 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.

4. STEM AND BRANCH DISEASES

4.1 Pink disease

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 alternate 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.

Cause: Corticium salmonicolor

4.1.1 Symptoms

A cobweb-like film of silky white mycelium appears on woody branches with exudation of latex, usually at the fork region (Plate 9.2f) and gives a pinkish appearance 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.

4.1.2 Control

Early recognition is essential, when there is limited damage to the main stem and branches.

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. Bordeaux mixture should not be used on trees in tapping because of the risk of contamination of latex with copper.

Clones must be carefully selected to avoid planting of susceptible material.

4.2 Ustulina stem rot (Collar and root rot)

It 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.

Cause: Ustulina deusta

4.2.1 Symptoms

Exudation of latex and formation of foul smelling latex pads beneath the bark. The fungus penetrates right into the wood which shows a network of characteristic double black lines, 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.

4.2.2 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.

4.2.3 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.

5. ROOT DISEASES

5.1 White root disease

It is the most destructive root disease of rubber in Sri Lanka. In the 1970s 8-10% of the hectare has been affected by the disease, but at present it has been reduced to 4-5%. It is most serious in the wet rubber growing districts of Kalutara,
Ratnapura, Kegalle, Colombo and Galle and less severe in Kurunegala, Moneragala and Badulla. The spread of the disease is by root contact with infected root debris of the old stand.

_Cause: Rigidoporus microporus_ (Syn: _Rigidoporus lignosus_).

5.1.1 Symptoms

Above ground symptoms include downward buckling of leaves (Plate 9.2g) general discolouration of leaves, usually to yellowish or light green, premature flowering and heavy pod set; this is more pronounced in mature trees, finally the leaves turn brown and fall off and stems dieback.

Thick white rhizomorphs are seen on the lateral roots (Plate 9.3c) and collar of the tap root. On aging, rhizomorphs become flat and reddish-brown. Internally freshly infected roots are creamy white and hard, but on decaying they become soft and friable.

Fructifications develop in tiers on dead trees. Usually these appear at the collar during the wet season (Plate 9.2h). They are semi-fleshy and bracket shaped, orange yellow on the upper surface with distinct zones, the lower surface is light orange with numerous minute pores.

5.1.2 Predisposing factors

Presence of infected roots in the old stand due to improper clearing of the old stand and absence of a proper leguminous cover.

5.1.3 Prevention

Infected roots should be removed when clearing the old stand. Seedling nurseries should never be established in patches affected by white root disease.

(a) _Pre-planting practices_

Inspect mature clearings before uprooting and demarcate all infected patches, 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.

Remove as much of the infected roots as practicable especially from the trees at the edge of the patch.

Decaying stumps (usually lateral roots of 2-3 trees at the centre of the patch have viable inoculum) from the edge of the patch should be removed.

There is no need to excavate soil in the centre of the patch as the roots become moribund when the inoculum has decayed completely.

Collect all roots and stumps from within the patch and burn them _in situ_.

106
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 hitherto free of the disease.

Change the planting points and the inter-row distance between replanting cycles. This helps to reduce the incidence of the disease, as it would take a longer time for roots of the budded stumps 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 like *Tephrosia* spp., are less desirable as their woody roots are capable of sustaining the disease and helping to transmit it to 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.

(b) **Planting practices**

Sprinkle 114 g (1/4 lb) 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 requires more labour and is more expensive. Also, the latter method helps to check whether sulphur was applied or not.

The application of sulphur should be confined to planting points which fall within the demarcated patch. This helps to economise on the use of sulphur.

Keep the leguminous cover well away from the base of trees.

(c) **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.
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.

Prop up the trees on either side of an infected tree. Excavate the soil, taking care not to damage the roots.

Examine the root system, remove all infected roots which are dead and protect the cut ends with tar. If roots are healthy (recognized by the fact that latex oozes out on pricking with a pen knife) but there are superficial rhizomorphs on them, such roots should be scraped free of the fungus.

Carefully remove the soil particles adhering to the roots.

Apply a suitable fungicidal "Collar protectant" preferably in a grease or bituminous based formulation to cover about 30 cm (12") on the tap root starting at the collar region and upper end of the laterals where they join the bole. Apply the protectant dressing on all the collar-inspected trees. Refill the soil round the treated trees immediately after the treatment.

Care should be taken not to leave behind infected roots. Identify treated trees with a distinctive paint band and also mark the date of treatment, so that these trees could be reinspected regularly. Adjoining trees on either side of an infected tree should be treated similarly as a preventive measure.

It is also possible to use systemic fungicides as a soil drench, e.g. tebuconazole or hexaconazole. Ten to twenty ml of the commercial preparation in 1 l of water should be poured around the base of the tree.

Carry out quarterly rounds of foliar inspections up to 5 years after planting and finally do a random tree-to-tree survey before final thinning, to detect any late infections.

Establish about 25 polybag plants per hectare to supply vacancies created by removal of dead trees, in the first year. If bigger bags are used it would be possible to raise seedlings to about the 6-whorl stage. This will help to use the same plants during the second year as well.

To supply vacancies that occur when the canopies of the replanting begin to close up, raise about 15-25 budded stumps per hectare in trenches. These could be used as stumped buddings from about the 2nd year after planting.

Never select patches infected with *R. microporus* in the old stand to raise seedlings in trenches to be used as supplies.

**Mature clearings**

The spread of white root disease in mature clearings 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.
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 dividends 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 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 siting is difficult. Trenches can be useful only as an emergency measure.

Trees blown over by wind should be uprooted and should not be cut at ground level leaving the exposed stumps.

5.2 **Black root disease**

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

*Cause: Xylaria thwaitesii*

5.2.1 Symptoms

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

Fructifications (Plate 9.3d) 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 9.3a). 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.
5.2.2 Control
Same as that for white root disease. When mature trees are treated it is essential to cut heavy branches to prevent the trees from falling over, before the exposure of the root system.

It is also important to cut the healthy laterals about a metre away from the base of the tree leaving a gap. This will eliminate the risk of fungus advancing towards the collar region, if such roots are infected somewhere along their length.

5.3 **Fusarium wilt**
It is a new root disease assuming some importance in Sri Lanka. This fungus has been able to kill trees in the early stages of growth of the plants.

*Cause*: *Fusarium solani*. A wound is essential for this fungus to gain entry into the host.

5.3.1 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 (Plate 9.3c) at points of entry of the fungus.

5.3.2 Control
Drenching the soil with systemic fungicides such as Benlate, Bavistin and Derosal is useful if root pruning has been done.

5.3.3 Prevention
Pruning of roots at the point where they join the tap root should be avoided. Seedlings which have been kept for more than 18-24 months in the nursery should not be used for budding as roots will have to be pruned when over-sized stocks are planted.
Plate 9.1. Common leaf diseases of rubber. a Semimature leaflets infected with *Oidium heveae*. Note the white powdery colonies of the fungus; b Mature leaflet showing raised spots as a result of *Colletotrichum* infections; c Leaves infected with *Phytophthora* spp. Note the exudation of latex droplets from the blackish lesions on the petioles; d Leaflet showing typical ‘fish-bone’ symptom due to *Corynespora* infection.
Plate 9.2. Common stem and root diseases. a Tapping panel dissected to show the black stripes on the wood; b Stem affected with *Corticium salmonicolor*. Note the pink crust and the exudation of latex; c Young plant affected with *Rigidiporus microporus* showing characteristic buckling (downward) of leaves; d Fructifications of *Rigidiporus* arranged in tiers.
Plate 9.3. Common root diseases. a Root infected with *Xylaria thwaitesii*; b Root infected with *Fusarium solani* split longitudinally to show brownish lesion; c Root infected with *Rigidiporus microporus*. Note the characteristic rhizomorphs on the surface; d Fructifications of *Xylaria*. 

113
Chapter 10

Pests*

K.E. Jayasuriya

1. Introduction
2. Insect pests
   2.1 Scale insects
      2.1.1 Nature of damage
      2.1.2 Control
   2.2 Mealy bugs
      2.2.1 Nature of damage
      2.2.2 Control
   2.3 Cockchafer grubs
      2.3.1 Nature of damage
      2.3.2 Control
   2.4 Mites
      2.4.1 Nature of damage
      2.4.2 Control
   2.5 Nematodes
      2.5.1 Nature of damage
      2.5.2 Control
3. Slugs
   3.1 Nature of damage
   3.2 Control
4. Rodents
   4.1 Nature of damage
   4.2 Control

1. INTRODUCTION

Generally, the rubber tree is free from serious damage 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 colonise and infest rubber trees causing considerable damage. Insects, mollusks and rodents are listed as pests of rubber in Sri Lanka.

2. INSECT PESTS

   Insects with 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.

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

2.1.1 Nature of damage
Their feeding mechanism is to insert specialized tube-like mouth-parts into plant tissues and suck the sap. The adult females and both sexes of pupal stages 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 scale insects. Under favorable weather conditions seedlings may be completely killed. In addition to their direct damage, sooty moulds can develop on their sugary excreta. As a result, the photosynthesis of the mould-colonised tissues is affected.

2.1.2 Control
Normally, these insects are biologically controlled by natural enemies such as predatory insects and parasitic fungi. But the natural balance could be destroyed in situations such as in large-scale nurseries which are a favourable habitat for scale insects. In heavy outbreaks use of pesticides such as Endosulfan 25% would be necessary.

2.2 Mealy bugs
They belong to the order of Hemiptera and class Pseudococcidae. This is another group of insects having similar feeding habits to scale insects, but unlike scales, the female mealy bug is covered with a protective white waxy material. However, the males are tiny, active fly-like insects having two wings. They are incapable of feeding at the adult stage. Young stages of the both sexes are flattened, oval, light yellow, six-legged bugs. They are destructive to rubber plants by feeding on them. They also have sap-sucking mouth parts.

2.2.1 Nature of damage
Mealy bugs are mainly found feeding at the axils of branching stems and leaves and on the upper and lower surfaces of leaves. When heavily infested, plants or infected parts may become stunted, defoliate or die back (Plate 10.1b).

2.2.2 Control
Like scales, mealy bugs also have many natural enemies. If the infestation is heavy and alarming, an insecticide could be sprayed for their control.
2.3 Cockchafer grubs

The larval stage of *Oryctus rhinoceros* beetle feeds on rubber roots. They are large, white or creamy fleshy grubs with incurved bodies. The head is distinct and hard, chitinous, brown and equipped with a powerful pair of jaws and biting mouth parts.

2.3.1 Nature of damage

Eggs are laid in soil and grubs hatch out in 2-3 weeks and feed on organic matter, and gradually begin to attack plant roots. The lateral roots may be eaten off and similarly the cortex of the taproot may also be eaten away (Plate 10.1c). The larvae of another beetle also bores into the taproot or base of the stem. They are large fat grubs, with segmented and tapering bodies and triangular dark brown or black heads. The larvae bore a large cavity in taproots. 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.

2.3.2 Control

Like the other pests cockchafers have many natural enemies that generally keep down their breeding. However, the plantation should be cleaned of decaying woody tissues to eliminate breeding grounds for beetles. Application of an insecticide such as Dimethoate 40 or Monocrotophos 60 to the infested soils gives satisfactory control of cockchafer grubs. Instead, nursery plants can be treated with insecticide liquids at the appropriate dilution recommended by manufactures, poured into holes 10-15 cm deep and 40-50 cm apart made with a crow-bar or pointed stick. Similarly, the first year field plants could also be treated and in older plantings of up to 6 years, only the taproot and the basal portion of laterals can be protected by this treatment.

2.4 Mites

Mites belong to the order Acarina of class Arachnida. Mites in rubber plantations include yellow tea mites, red spider and scarlet mites. They are minute creatures hardly visible to the naked (Plate 10.2a) eye but their presence on the leaves could be easily detected by the characteristic symptoms - irregular twisting and distortion of leaves (Plate 10.2b). The damage could be more serious in small plants and seedlings under crowded and heavily shaded conditions.

The yellow tea mites (*Hemitarsonemus latus*) are wide-spread, having a wide host range. It is a common pest of rubber in all rubber growing countries often bringing damage to the new flushes. In mature rubber, the new flush after wintering can also be attacked.

Adult males of the tea mite are yellow with four pairs of legs and are visible to the naked eye. Nymphs and females are dirty white, and lay large white eggs on the lower surface of the leaves.

Red spider mites (*Tetranychidae*) are also important insects, which appear as tiny red spots on mature leaf surfaces. While feeding on plant sap they construct...
a characteristic web over the leaves. The infestation generally occurs on the lower story leaves in over-crowded nurseries or heavily shaded lower branches on mature trees.

2.4.1 Nature of 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.

2.4.2 Control
Mites are naturally controlled by predators such as lady bird beetles, small spiders and other predatory mites such as Typhlodromus. Sulphur dusting or Kelthane MF42 can be used to control a severe infection.

2.5 Nematodes
Present incidence is not serious on rubber and is limited only to nurseries. The root-knot nematode Meloidogyne incognita has been identified as the causative agent.

2.5.1 Nature of damage
Affected seedlings become stunted showing symptoms like those of nutrient deficiency. Conspicuous swellings (Plate 10.2d) on the lateral roots or rootlets are characteristic of plants infested with root-knot nematodes. Pear-shaped females could be dissected out from the galled tissue of the roots.

2.5.2 Control
Affected seedlings are removed during the thinning process of seedling nurseries. Only heavy nematode infestations in nurseries need to be managed.

3. SLUGS
Slugs bear characteristic soft shiny, legless bodies pointed at both ends with a head bearing 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.

3.1 Nature of 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 10.2c). This process is
repeated for as long as plant produces more and more side shoots 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.

3.2 Control
Slugs have a number of natural enemies. However, in a sudden outbreak in rubber plantations, slugs should be controlled by distributing poisoned bait. Suitable rain-proof bait can be prepared by mixing bran, hydrated lime and powdered metaldehyde (6:4:1 by weight). All ingredients are thoroughly mixed and the same volume of fresh rubber latex diluted with an equal volume of water is added. Then from the paste small crumbs/balls can be prepared by air-drying.

4. RODENTS
Porcupines, bandicoots, rats and squirrels are the mammalian pests of rubber plantations. Generally, they damage clearings adjoining jungles or clearings where the cover is thick.

4.1 Nature of damage
Porcupines gnaw away pieces of bark from ground level as far up as they can reach. Sometimes the base of the stem of a 3-5 year old plant may be completely ring-barked (Plate 10.1d). They also may wrench the plant out and feed on the taproot. Bandicoots usually live underground and attack the roots and the collar region. Yellowing and wilting of leaves can result from an attack. Later, 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. However, they mainly feed on the pith in the stem of growing seedlings by splitting it open.

4.2 Control
Poor sanitation is the main factor that encourages rodent infestation of young clearings. Therefore, it is really important to keep the plantations free of weeds and covers removed around the base of trees. As a preventive measure, it would be suitable to protect the base of the young plants of clearings bordering jungles with pieces of bamboo. Suitable repellents or poisoned baited material may be used in areas where the problem is severe. Affected trees must be immediately treated if they are not completely ring-barked. Bark should be scraped out to clear the wound area and a wound dressing applied.
Plate 10.1. Pests on rubber. a Heavy infestation of scale insects on immature stem; b Mealy bug attack on a young plant; c Cockchafer grub damage on an immature plant at base; d Rodent damage on a young plant. Note ring-barked stem.
Plate 10.2. Pests on rubber.  

a Photomicrograph of mites;  
b Leaves damage by mites;  
c Slug attack on immature plants;  
d Nematode infestation on lateral roots. Arrow indicates nodules.
Chapter 11

Conditions caused by physical injuries*

A.H.R. Jayaratne

1. Introduction
2. Fire damage
   2.1 General
   2.2 Symptoms
   2.3 Prevention
   2.4 Treatment
3. Lightning strike
   3.1 General
   3.2 Symptoms
   3.3 Treatment
4. Sun scorch
   4.1 General
   4.2 Symptoms
   4.3 Prevention
   4.4 Treatment
5. Wind damage
   5.1 General
   5.2 Symptoms
   5.3 Prevention
   5.4 Treatment
6. Drought and wilting
   6.1 General
   6.2 Symptoms
   6.3 Prevention
   6.4 Treatment
7. Flooding and waterlogging
   7.1 General
   7.2 Symptoms
   7.3 Prevention
   7.4 Treatment
8. Poisoning
   8.1 General
   8.2 Symptoms
   8.3 Prevention
   8.4 Treatment
9. Exposure of bud union (Elephant foot condition)
   9.1 General
   9.2 Symptoms
   9.3 Prevention
   9.4 Treatment

* Adopted from “A Handbook of Rubber Culture and Processing”, 1983
1. INTRODUCTION
In rubber plants there could be occasions when injuries due to either natural forces of the environment or accidents could occur, producing effects which are easily mistaken for disease symptoms. However, the affected parts may be invaded sooner or later by parasitic or saprophytic fungi, some of which may enhance the injury and cause serious damage resulting in death of trees if no treatment is given.

2. FIRE DAMAGE
2.1 General
They are common in rubber plantations, specially during the wintering season, when there is a thick carpet of dry leaves on the ground and the weather is dry. Fires in rubber plantations start accidentally, mostly by carelessly throwing away cigarette butts or because of inadequate precautions taken in organized burning of unwanted materials.

2.2 Symptoms
When young trees are burnt they may be killed outright. Scorched leaves become brown and brittle either partly or entirely and the dead tissues are invaded by saprophytic fungi. In older trees the lower portion of the trunk is the most vulnerable portion. The affected portion may be charred or show cracks with profuse exudation of latex (Plate 11.1a) or there may be no external indication until the stem starts to ooze out latex. The dead tissues may be invaded by borer-beetles and saprophytic fungi such as Botryodiploida 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 some days later.

2.3 Prevention
Precautions should be taken when building a fire for any purpose. It should be done far away from the boundary of any field of rubber. Special care should be taken during the wintering period. Clearing the ground of dried leaf litter might help to establish fire breaks, especially if the public has access to roads going through the estate.

2.4 Treatment
The damaged trees should be treated as soon as possible before they are attacked by 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, it is not possible to save such trees. 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 in the following manner. All affected bark should be removed so as to leave a smooth edge to the resulting wound. The wound should then receive an application of a water miscible fungicide such as Brunolinum plantarium (15 parts in 85 parts of water) and Dithane M 45 (3-4 g in a litre of water). Once this is dry the entire wound must be painted with a panel dressing such as Barkosan or Candarsan. If the wounds are large it may be advisable to protect the wood with an application of tar to prevent borers causing any damage. When carrying out this operation care should be taken not to apply tar on the exposed bark as tar is known to scorch bark.

The affected locality should be inspected daily for about a week 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 in any way. Such trees may be easily overlooked, until the borers find them out. Generally the borers attack trees which are lightly scorched more readily than those which are severely scorched.

3. LIGHTNING STRIKE
3.1 General
Lightning injury can occur both in mature and immature rubber.

3.2 Symptoms
Lightning strike could affect trees in the field in the following manner:

(1) 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 other cases one or more trees are killed and the tops of the neighbouring trees wither, as in pathogenic die-backs.

(2) Trees which have been struck by lightning, but not killed, may bear short vertical wounds on the stem, sometimes arranged spirally. They may be accompanied by a wound at the collar.

(3) Exudation of latex 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 centre 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 cambium, which turns chocolate brown, rapidly turning black. Subsequently the bark dies, cracks and comes off with time. The bark and wood of trees affected by lightning are very 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 and painted using a waterproof panel dressing such as Candarsan or Barkosan. It is advisable to give an additional dose of fertilizer to the affected plants in order to allow the shoots to regenerate and develop into 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 quartzitic soils are present.

Sun scorch 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 leaf as bleached and papery areas clearly marked off from any unaffected portions. Young leaves in addition are severely puckered and deformed. The bleached area corresponds to a droplet of water and this is a characteristic symptom. 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 scorch. It commonly occurs in clearings where a good cover is absent. 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 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 eliminated 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 minimise the scorching and desiccating effects of the sun.
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 Brunolimum plantarium (15%) and seal off the wound with a waterproof panel dressing, such as Barkosan, Candarsan and Kankerdoed.

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.

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 Ustulina deusta and Botryodiplodia theobromae.

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. RRIC 100 has shown some resistance to wind damage.

5.4 Treatment
When wind-blown trees are removed it is advisable to protect the cut ends of stumps from colonisation 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 fungicidal 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.

6.2 Symptoms

Wilting of leaves is the first symptom. Tender leaves wilt first. If the drought persists, the temporary wilting becomes a permanent wilting causing shrivelling 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 shrivelled young leaves. Dieback 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, dieback of twigs and a reduction in 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 upto the healthy stem and preferably a protective dressing such as Barkosan should be applied at the cut end.

6.4 Treatment

Dead plants should be uprooted and vacancies filled with a suitable advanced planting material.

7. FLOODING AND WATERLOGGING

7.1 General

Flooding and waterlogging are common during the monsoon period due to heavy and prolonged rains specially in poorly drained areas. This is likely to occur more frequently in low-lying areas close to rivers and in areas with clayey 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 drainaged clayey 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.

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 minimise 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.

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 occur.

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.

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 *Ustulina 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 fungicide and a wound dressing as above.
Plate 11.1 Physical injuries. a Fire damage; b Lighting strike; c Sun scorch; d Elephant foot condition.
Chapter 12

Important diseases uncommon or absent in Sri Lanka

C.K. Jayasinghe

1. Introduction
2. South American leaf blight
   2.1 Symptoms
   2.2 Resistant clones
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

Several diseases which were of minor importance in the past have now gained considerable importance 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. Tar spot, a relatively insignificant disease which normally develops slowly on old leaves, now occurs widely and causes leaf fall in Brazil and Colombia. Two other leaf diseases, Phytophthora leaf wither and Thanatephorus cucumeris, which were of little concern a decade ago in Brazil, now require regular spraying to prevent extensive leaf fall and die-back.

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

2.1 Symptoms

Very young leaves are the most susceptible to SALB and the leaves become more resistant and finally immune as they age. The type of symptom produced on the leaves is greatly influenced by (a) the age of the leaves at the time of infection, (b) the susceptibility of the clones and (c) 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 12.1a).

When infection is less severe 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 12.1c). 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 at the fringes of the disease lesions (Plate 12.1d).

Subsequently, (about a month later) more prominent raised bodies called perithecia are formed at the same site as the pycnidia. The perithecia produce another type of spore referred to as 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 the black spherical perithecia (Plate 12.1e).

*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.

2.2 Resistant clones

Presently there are no high-yielding clones that are resistant to all the races of *Microcyclus ulei*.

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 in those countries.

Cause: Thanatephorus cucumeris

3.1 Symptoms
Young leaves are the most susceptible. The first visible symptoms are 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.

4. **FUSICOCCUM LEAF BLIGHT**
This disease was first detected on *Hevea* in 1987, in Malaysia. So far no reports have been made from any other rubber growing country.

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. The rows of dots on lesions are made up of black partially embedded pycnidia. On incubation under high humidity salmon-coloured spore masses, sometimes forming a long coil, ooze out from the pycnidia. These spores are of two distinct sizes. Affected leaves gradually turn bronze prior to abscission.

4.2 Susceptible clones
The most susceptible clones are RRIM 937, PB 350, RRIM 600, RRIM 901 and RRIM 905 while PC 119, PR 261, PR 255 and GT 1 show very high resistance.

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.

Due to the serious nature of South American Leaf Blight, no suspected material should be sent to the RRI under any circumstances, unless it has been disinfected and packed in the manner described 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 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 tin and dispatch it to the RRI, marked “Suspected SALB”.

133
Plate 12.1. South American leaf blight. a Severely infected copper brown leaves. Note the shrivelled leaves (left) and intact petioles (right) after the leaf fall; b Conidiospores (up) and ascospores (down) of Mycrocyclus ulei; c The typical dull velvety lesions which are olive to greyish green in colour. These lesions are covered with masses of conidia; d The pycnidia on the lower surface of the leaf; e The perithesia of Mycrocyclus ulei. The leaf tissues at the centre of the lesion die and eventually tear off leaving a hole on the mature leaves (courtesy: Association of the Natural Rubber Producing Countries).
Chapter 13

Disorders of non-parasitic origin

A.H.R. Jayaratne

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 forms of malformations occur in the actively growing parts of rubber plants. Of these the most common are:
   
   (a) fasciation,
   (b) kinked stem and
   (c) elongated leaves.

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.

   These fasciated shoots are frequently inhabited by mealy bugs 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.

* Adopted from “A Handbook of Rubber Culture and Processing”, 1983.
2.1 Treatment
Fasciated shoots should be pruned at least 30 cm below the fasciated portion. If the damage due to slugs is high, control of slugs 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. 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. So far 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, e.g. RRIM 623. If infection caused by bark rot is neglected, fissures develop in the cortex of the renewed bark. 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 yellowing.
Chapter 14
Rubber-based intercropping systems

V.H.L. Rodrigo

1. Introduction
2. Importance of rubber-based intercrops
3. Present status 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
6. Crops suitable for intercropping only at the mature phase of rubber
7. Intercropping throughout the life-cycle of rubber
   7.1 Crops to be grown without compromising on the rubber density
   7.2 Crops that can be grown if the planting density of rubber is reduced
8. Other intercropping systems
9. Incorporation of animal husbandry with the rubber crop

1. INTRODUCTION

Intercropping, which involves growing two or more crops simultaneously on the same piece of land, has a very long history, even for rubber. Intercropping has been adopted in many parts of the world, one of the earliest examples being that of shifting cultivation, locally referred to as Chena cultivation. During the last century, agricultural mechanisation and the introduction of new high-yielding crop varieties have placed increasing emphasis on monoculture systems; however, whilst these systems have been important in raising productivity in the short-term, their long-term sustainability has been seriously questioned. The negative impact of intensive modern agricultural systems on the nature resource base has led to growing interest in developing methods of raising agricultural productivity without further serious erosion of natural resources and as a result there has been a resurgence of interest in more environmentally friendly systems such as intercropping.

After rubber was introduced to Sri Lanka in 1876, it was interplanted with tea and cocoa on large estates. By 1905, there were 7256 acres of rubber/tea intercrop and in those areas where agroclimatic 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 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 revitalised at the Rubber Research Institute of Sri Lanka (RRISL) with the overall aim of improving productivity and income generation of smallholder rubber lands.

2. IMPORTANCE OF RUBBER BASED INTERCROPS

The recognised advantages associated with mixed cropping systems also apply to rubber intercropping. A common goal of these systems is to maximise land use efficiency and to achieve this, crops need to maximise use of resources such as light, water, and nutrients. In the more successful systems, the heterogeneous resource capture surfaces (i.e. canopy and roots) of intercrops enable resources to be utilised in a complementary rather than competitive manner with the result that land use efficiency is improved. The major advantages of intercrops over sole crops can be summarised as:

- Improved total yield and economic return
- Greater variety of produce and seasonal spread of income
- Reduced susceptibility to market crashes
- Reduced crop losses due to pests and diseases
- Reduced dependency on fertilizer inputs due to more efficient use of nutrients
- Perennial intercrops such as banana help bind the soil and so reduce land degradation
- Presence of rubber offers physical protection to weaker crops
- Increased demand for labour provides an improved opportunity cost for labour in the smallholder sector.

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 underutilised 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 affect 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) increases girth expansion of the rubber tree which has been related to increased 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 inference by rain. Whilst rainguards offer one solution to this problem, intercropping with 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 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 that these efforts are 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. PRESENT STATUS OF RUBBER-BASED INTERCROPPING IN SRI LANKA

Except for a few plantation companies, intercropping on rubber lands is generally confined to the smallholder sector and mainly to the immature phase of growth. Recent studies has revealed that ca. 50% of the smallholdings in the major rubber growing areas of the country intercrop during the immature phase of rubber, with banana being the most popular companion crop due to its financial and socio-cultural importance (i.e. low cost of production, ready market, ubiquitous presence at social events and low labour demand). Cultivation of pineapple, vegetables and other cash crops depends on the area and whether climate and market conditions are
conducive. 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 according to recent studies few smallholders apply fertiliser to their crops. On average, ca. 50% of the farmers do not apply fertiliser to the banana intercrop, with values ranging from 77% in Kegalle and to 23% in the Colombo region. However under commercial cultivation, cultivators try to maximise the profit with more inputs such as fertiliser, 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). No payment passes in either direction but the contractor is responsible for upkeep of the rubber and any labour inputs. In return, the contractor would normally expect an income from other crops such as banana, pineapple and aubergine which are intercropped on the young rubber land. In general, these contract farmers are well-off people 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 these cropping systems.

The estate sector labour force is generally under-utilised with poor wages and working hours which in practice are often limited to mornings 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.

4. FACTORS TO BE CONSIDERED IN INTERCROPPING

Crops that are suitable for one area and set of circumstances may not be suitable for another and selection requires consideration of not only biophysical factors but also socioeconomic conditions. In this context, 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. 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 understorey crop throughout the course of the day. However, most rubber is grown on sloping land and in order to minimise soil erosion, contour planting must be practised. For the same reason, planting of tuber crops should be restricted to flat lands only.

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 8.1 m (i.e. 8' x 27') 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.

a. Banana

Banana appears to be the most popular rubber-based intercrop in most parts of Sri Lanka due to the ready local market, fewer demands in the form of 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 cannot withstand strong winds. Banana appears to be less competitive 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

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 a & b). Within 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.

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 minimise 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. Fertiliser and other management practices should be done as per the recommendations of the Department of Agriculture.

b. Pineapple
Although pineapple can be grown in all rubber growing areas, in practice it is limited to the Gampaha and Colombo regions due to the close proximity of well-developed marketing systems. Moreover, pineapple is considered to be highly profitable, but it requires high labour and capital inputs. 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:

Two paired rows of pineapple with a gap of 1.5 m at the centre, can be planted between the rubber rows (Plate 14.1c). Within the paired rows, suckers are 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 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 management activities are to be done as per the recommendations of the Department of Agriculture.

c. 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 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 ‘Mani’, 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 14.1d). 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 (galvanised 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.

d. 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 growth. 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 14.1e).

e. Annual and seasonal crops
In general, all crop types are compatible with rubber during the early stages of the immature phase. Therefore, suitable crops should be identified according to 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, brinjals and upland paddy are grown in combination with rubber/banana intercrops (Plate 14.1f). 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.

f. 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 for a long time and productivity has declined drastically. 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 after canopy closure 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.

a. 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 8.1 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 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.

b. 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, freedom 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.

c. 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. 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 be expected to cause problems when undertaking intercultivation activities of rubber, in practice this is not the case as the thicker cane varieties 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 practically feasible. In addition, rattan requires a minimal amount of intercultivation 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).

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 available 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 8.1 m (8' x 27').

a. 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 liming is necessary for highly acidic rubber 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 from the sea-coast to 1800 m. 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 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.

b. 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.

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. An experiment with 2.4 x 2.4 m within and 13.8 m between paired rows (standard sole crop density) has been shown to result in greater competition within the paired rows causing reduced growth after the 4th year of planting, compared with the performance of the traditional 2.4 x 8.1 m spacing. However, in the proposed systems, spacing within the paired rows is increased and the density reduced minimizing any adverse effect on rubber.

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.

a. 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 causalities when compared with sole tea.

When grown with the single row planting system of rubber (Plate 14.2a), 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 14.2b), at the same spacing 12 rows can be incorporated leaving 2.4 m on each side for intercultivation 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 agroclimatic conditions. In general, tea clones used in rubber growing areas are TRI 2025, TRI 2027 and S 106. Planting holes are dug of the size 0.6 x 0.6 x 0.75 m and all other management practices for individual 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.

b. Cinnamon

This is another economically important crop (Plate 14.2c & d) 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.

Intra- and inter-row spacing of cinnamon is identical to that of tea and so planting densities, spatial arrangements including 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.

c. 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 8.1 m, pepper does not produce well under the heavy shade of the mature rubber canopy. Consequently, success of pepper/rubber intercrops will require a reduction in the planting density of rubber 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. 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.

d. 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 INTERCROPPING 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 utilised 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. On the boundaries, most timber crops could be raised at the time of planting of rubber and, in the case of replacing dead rubber plants, planting timber crops which requires shade conditions for better establishment is advantageous (e.g. Mahogany – damage due to stem borer attack is reduced under shade). Areca nut which survives well under high crop densities, is another potential tree crop for these purposes. Particularly in the case of tree crops grown along boundaries, other economically important vines, such as pepper, could be trained on them. 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 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 rubber lands in Sri Lanka. 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 practised by rubber smallholder farmers.
Plate 14.1. Intercropping of rubber during immature phase of rubber a. and b banana grown in two and three rows in a rubber inter row; c with pineapple; d with passionfruit; e with sugarcane; f with a combination of crops, i.e. banana, maize/upland paddy.
Plate 14.2. Intercropping of rubber with long-term crops. a and b with tea; c and d with cinnamon. Paired-row planting system of rubber is shown in d.
1. Introduction
2. Nutrients required by rubber
   2.1 Macronutrients
   2.2 Micronutrients
   2.3 Role of different nutrients
      2.3.1 Nitrogen
      2.3.2 Phosphorus
      2.3.3 Potassium
      2.3.4 Magnesium
3. Rubber growing soils
   3.1 Group I – Parambe series
   3.2 Group II – Matale series
   3.3 Group III – All other soil series
      3.3.1 Homagama series
      3.3.2 Agalawatta series
      3.3.3 Ratnapura series
      3.3.4 Boralu series
      3.3.5 Deniya series
4. Fertilizers for rubber
   4.1 Sources of fertilizers
   4.2 Fertilizer mixtures
   4.3 Organic manures
5. Fertilization of nurseries
   5.1 Stock nurseries
   5.2 Budwood nurseries
   5.3 Polybag plants
   5.4 Young budding
      5.4.1 Preparation of fertilizer
      5.4.2 Method of application
6. Fertilization of immature field plants
   6.1 Rates of application
   6.2 Frequency of application
   6.3 Fertilizers for areas previously planted with tea
   6.4 Time of application
   6.5 Method of application
7. Fertilization of mature trees
   7.1 Site-specific fertilizer recommendation
   7.2 Frequency of application
   7.3 Time of fertilizer application
   7.4 Methods of fertilizer application
8. Fertilization of ground-cover crops
9. Nutrient deficiencies
   9.1 Symptoms and diagnosis
      9.1.1 Nitrogen deficiency
      9.1.1.1 Symptoms
      9.1.2 Phosphorus deficiency
      9.1.2.1 Symptoms
      9.1.3 Potassium deficiency
      9.1.3.1 Symptoms
      9.1.4 Magnesium deficiency
      9.1.4.1 Symptoms
   9.2 Correction of deficiencies
      9.2.1 Nitrogen deficiency
      9.2.2 Phosphorus deficiency
      9.2.3 Potassium deficiency
      9.2.4 Magnesium deficiency

1. INTRODUCTION

Nutrient management in rubber cultivation has gained greater importance in recent years because of two reasons: firstly, rubber plantations are no longer raised in virgin forests and secondly, most of the plantations are either in the second or third cycle of replantation. Eventhough 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 mineral resources through cycles of replantation warrants appropriate nutrient management and at the same time, more and more marginal and depleted soils are being brought under rubber cultivation and under such situations proper soil and nutrient management is essential to sustain productivity at 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. Additionally, the quantity of fertilizers required by rubber is relatively low and therefore the use of fertilizers in rubber causes no problems.

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 the 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 all the thirteen known essential mineral 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 P and particularly N in most replantings have been observed in Sri Lanka. Often responses to K and Mg 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 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
- for increased growth of plant tissues
- essential constituent of chlorophyll
- some proteins function as enzymes

2.3.2 Phosphorus
- essential for cell division and development
- important for 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 part 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.

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 - 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.

3.3 Group III - All other soil series

3.3.1 *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.

3.3.2 *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.

3.3.3 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.

3.3.4 Boralu series

*Boralu* soils are shallow, gravelly loam in texture, brown to reddish yellow in colour and overlying *cabook*. 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.

3.3.5 Deniya series

*Deniya* soils are shallow soils, variable in texture, poorly drained, frequently water-logged 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.

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 by implementation of a well-planned manuring programme. Systematic application of fertilizers throughout the pre-tapping phase leads to build up of plant nutrient reserves.

4.1 Sources of fertilizers

Concentrated chemical fertilizers usually are the easiest and cheapest to apply. Other considerations include physical state, solubility and stability of the material. Fertilizer cost 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 as follows:
<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Fertilizer source</th>
<th>Nutrient content</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Sulphate of ammonia</td>
<td>21% N</td>
</tr>
<tr>
<td></td>
<td>Urea</td>
<td>46% N</td>
</tr>
<tr>
<td>P</td>
<td>Imported rock phosphate</td>
<td>28.5% P₂O₅</td>
</tr>
<tr>
<td></td>
<td>Eppawela rock phosphate</td>
<td>30% P₂O₅</td>
</tr>
<tr>
<td>K</td>
<td>Muriate of potash</td>
<td>60% K₂O</td>
</tr>
<tr>
<td>Mg</td>
<td>Kieserite</td>
<td>24% MgO</td>
</tr>
<tr>
<td></td>
<td>Dolomite</td>
<td>20% MgO</td>
</tr>
</tbody>
</table>

4.2 Fertilizer mixtures

The currently recommended fertilizer mixtures that should be used in different soils and their composition are given in Table 15.1 and Table 15.2, 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 15.1. Fertilizer mixtures for the different soil series

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Sulphate of ammonia-based fertilizers (R/SA)</th>
<th>Urea-based fertilizers (R/U)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homagama</td>
<td>}</td>
<td></td>
</tr>
<tr>
<td>Boralu</td>
<td>}</td>
<td></td>
</tr>
<tr>
<td>Agalawatta</td>
<td>}</td>
<td></td>
</tr>
<tr>
<td>Ratnapura</td>
<td>}</td>
<td></td>
</tr>
</tbody>
</table>

Table 15.2. The compositions of the rubber fertilizer mixtures

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Sulphate of ammonia</th>
<th>Urea</th>
<th>Rock phosphate</th>
<th>Muriate of potash</th>
<th>Kieserite</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>R/SA 9:12:4:2</td>
<td>43</td>
<td>-</td>
<td>42</td>
<td>7</td>
<td>8</td>
<td>100</td>
</tr>
<tr>
<td>R/SA 7:9:9:3</td>
<td>36</td>
<td>-</td>
<td>33</td>
<td>15</td>
<td>16</td>
<td>100</td>
</tr>
<tr>
<td>R/U 15:15:7</td>
<td>-</td>
<td>33</td>
<td>55</td>
<td>12</td>
<td>-</td>
<td>100</td>
</tr>
<tr>
<td>R/U 12:14:14</td>
<td>-</td>
<td>26</td>
<td>50</td>
<td>24</td>
<td>-</td>
<td>100</td>
</tr>
<tr>
<td>R/SA 9:11:11</td>
<td>43</td>
<td>-</td>
<td>39</td>
<td>18</td>
<td>-</td>
<td>100</td>
</tr>
<tr>
<td>R/SA 11:11:5</td>
<td>52</td>
<td>-</td>
<td>40</td>
<td>8</td>
<td>-</td>
<td>100</td>
</tr>
</tbody>
</table>
4.3 Organic manures

The exclusive use of chemical fertilizer results in diminishing soil organic matter and declining soil fertility. Proper soil management is dependent on adequate organic matter that would stabilize soil structure, provide a favourable medium for the development of the root system and increase the water holding capacity of the soil, which are essential during nursery as well as immature stages of rubber plants. Another advantage in using organic manures is the ability to cut down the cost of using chemical fertilizers by substituting with organic manures. However, rubber plantations are known to undergo a very effective self-sustaining nutrient recycling system where the soil organic matter and related soil physical characteristics are maintained at the required levels. The organic manures that can be used in rubber cultivation are:

- animal wastes
- farmyard manures
- compost
- crop residues and
- green manures

5. FERTILIZATION OF NURSERIES

The objective of fertilization of nurseries is to produce the maximum number of vigorous and healthy plants from a unit area within the shortest period. The following practices are recommended for achieving this objective:

5.1 Stock nurseries

The initial manuring of a nursery bed should be done with a 3:1 mixture of imported rock phosphate and dolomite lime for Group I and III soils. This should be applied at the rate of 500 kg per hectare (4 cwt/acre) and well forked into the surface of the nursery beds to a depth of 15-20 cm. In Matale series soils (Group II), where dolomite is not recommended, initial manuring should be done with imported rock phosphate only, at the rate of 350 kg per hectare (3 cwt/acre). One month after planting germinated seeds, urea-based fertilizer mixture R/U 12:14:14 or R/U 15:15:7 should be applied at the rate of 25 g/plant + 5 g of kieserite per plant. Where a sulphate of ammonia-based fertilizer mixture R/SA 9:12:4:2 or R/SA 7:9:9:3 is used it should be applied at the rate of 30 g/plant every three months up to about two months before budding. In Matale series soils, R/SA 9:11:11 fertilizer mixture should be used in the same manner as above. No further fertilizer should then be given until after budding.

5.2 Budwood nurseries

These nursery plants should be manured in the same manner as the plants in field clearings according to age.
5.3 Polybag plants

The manuring schedule for polybag plants (green and brown budding) is presented in Table 15.3. Initial fertilizers should be thoroughly mixed with the soil in the polybag prior to planting the bare root. The source of phosphate for plants in the polybags should be imported rock phosphate (IRP).

Table 15.3. Manuring schedule for green and brown polybag plants

<table>
<thead>
<tr>
<th>Time of application</th>
<th>Quantity/plant (Group I and III soils)</th>
<th>Quantity/plant (Group II soils)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urea-based</td>
<td>Sulphate of Ammonia-based</td>
</tr>
<tr>
<td>In the polybag</td>
<td>50 g NPK mix. + 100 g IRP+25/10 g Ks</td>
<td>75 g NPKMg mix.+ 100 g IRP</td>
</tr>
<tr>
<td>2 months a.p.</td>
<td>20 g NPK mix.</td>
<td>25 g NPKMg mix.</td>
</tr>
<tr>
<td>3 months a.p.</td>
<td>20 g NPK mix.+ 25 g Ks</td>
<td>25 g NPKMg mix.</td>
</tr>
<tr>
<td>4 months a.p.</td>
<td>20 g NPK mix.</td>
<td>25 g NPKMg mix.</td>
</tr>
<tr>
<td>5 months a.p.</td>
<td>20 g NPK mix.</td>
<td>25 g NPKMg mix.</td>
</tr>
<tr>
<td>6 months a.p.</td>
<td>20 g NPK mix.</td>
<td>25 g NPKMg mix.</td>
</tr>
<tr>
<td>7 months a.p.</td>
<td>20 g NPK mix.</td>
<td>25 g NPKMg mix.</td>
</tr>
<tr>
<td>8 months a.p.</td>
<td>30 g NPK mix.</td>
<td>50 g NPKMg mix.</td>
</tr>
<tr>
<td>9 months a.p.</td>
<td>30 g NPK mix.</td>
<td>75 g NPKMg mix.</td>
</tr>
</tbody>
</table>

5.4 Young budding

The recommended soluble fertilizer mixtures for young budding plants, composition and preparation of fertilizer mixtures, manuring schedule and method of application are presented in Tables 15.4, 15.5 and 15.6, respectively.

Nutrient contents of the fertilizer sources used in young buddings are as follows:

- Sulphate of Ammonia: 20.6% N
- Diammonium Phosphate: 18.0% N, and 46.0% P$_2$O$_5$
- Sulphate of Potash: 48.0% K$_2$O
- Commercial Epsom salt: 16.0% MgO

Table 15.4. Recommended fertilizer mixtures for young budding plants

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Soil type</th>
<th>District/Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>R/YB 13:17:6:3</td>
<td>Parambe</td>
<td>Kegalle and Kurunegala</td>
</tr>
<tr>
<td>R/YB 13:16:16</td>
<td>Matale</td>
<td>Matale</td>
</tr>
<tr>
<td>R/YB 9:11:11:4</td>
<td>All other soils</td>
<td>Kalutara, Ratnapura, Galle, Avissawella, Badulla and Monaragala</td>
</tr>
</tbody>
</table>
5.4.1 Preparation of fertilizer

Formulation I
Dissolve 112 g of mixture in 4.5 litres of water for 90 plants at the rate of 50 ml per bag.

Formulation II
Dissolve 168 g of mixture in 4.5 litres of water for 90 plants at the rate of 50 ml per bag.

Table 15.5. Composition of soluble fertilizer mixtures

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Sulphate of Ammonia</th>
<th>Diammonium phosphate</th>
<th>Sulphate of potash</th>
<th>Epsom salt</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>R/YB 13:17:6:3</td>
<td>31</td>
<td>38</td>
<td>13</td>
<td>18</td>
<td>100</td>
</tr>
<tr>
<td>R/YB 9:11:11:4</td>
<td>23</td>
<td>25</td>
<td>23</td>
<td>29</td>
<td>100</td>
</tr>
<tr>
<td>R/YB 13:16:16</td>
<td>32</td>
<td>35</td>
<td>33</td>
<td>-</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 15.6. Manuring schedule for young buddings

<table>
<thead>
<tr>
<th>Time of application</th>
<th>Dosage</th>
<th>Formulation I</th>
<th>Formulation II</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the polybag</td>
<td>50 g IRP</td>
<td>112 g of mixture. Dissolve in 4.5 litres of water and apply to 90 plants (50 ml/bag) once in 2 weeks.</td>
<td>168 g of mixture. Dissolve in 4.5 litres of water and apply to 90 plants (50 ml/bag) once in 2 weeks.</td>
</tr>
<tr>
<td>After planting</td>
<td></td>
<td>2 weeks after planting until 2 weeks before bud grafting</td>
<td>After first whorl of leaves (approximately 4 weeks) until 2 weeks before planting</td>
</tr>
<tr>
<td>After cut back</td>
<td></td>
<td>112 g of mixture. Dissolve in 4.5 litres of water and apply to 90 plants (50 ml/bag) once in 2 weeks.</td>
<td>168 g of mixture. Dissolve in 4.5 litres of water and apply to 90 plants (50 ml/bag) once in 2 weeks.</td>
</tr>
</tbody>
</table>

5.4.2 Method of application

Prior to planting germinated seeds in the polybag 50 g of imported rock phosphate should be thoroughly mixed with the soil in the polybag. Dissolve required quantities in 4.5 litres of water and apply 50 ml of this solution per bag at 14 day intervals (Table 15.6). Constant stirring is essential to make sure that every bag receives the required amounts of nutrients.

6. FERTILIZATION OF IMMATURE 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 nutrient requirement is estimated to be much
greater than the fertilizer input. The deficit has to be met from nutrients gradually
released by the leguminous ground cover once the canopy of rubber closes. The
response to fertilizers is highest in the pre-tapping stage and the trees attain tapping
girth two to three years earlier with proper fertilizer application. Systematic
application of fertilizers throughout the pre-tapping 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 and ammonium sulphate (SA) - based mixtures for Group I
and III soils are given in Table 15.7 and the recommended rates of fertilizer
application for Group II Matale series soils are given in Table 15.8. The urea-
based mixtures should be applied at lower rates than their sulphate of ammonia
counterparts because of their higher nutrient contents.

6.2 Frequency of application
It is recommended that the annual requirements of fertilizers be split and
applied in as many doses as possible (Table 15.7 & 8). The number of applications
may be reduced without harmful consequences where conditions are favourable; but
doing so increases the risk of waste should the weather turn inclement.

6.3 Fertilizers for areas previously planted with tea
In addition to the fertilizers recommended in Table 15.3 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 in areas which were
previously planted with tea.

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 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.
Application of dolomite lime is recommended during the pre-tapping
period, (except in the Matale series), as it will serve as a reservoir of the plant
nutrient, magnesium. It should be given in a single application each year, separated
by at least one month from the nearest application of urea-based fertilizer. Since
ammonium carbonate readily gives off ammonia in the presence of lime contained
in dolomite, there is a risk of loss of ammonia when urea and dolomite are mixed.
Table 15.7. Manuring schedule for immature rubber on group I and group III soils

<table>
<thead>
<tr>
<th>Year of planting**</th>
<th>Frequency &amp; Time of application</th>
<th>Quantity/tree</th>
<th>Urea based</th>
<th>Sulphate of ammonia based</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planting Hole</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st year 4 applications/year</td>
<td>2 months after planting</td>
<td>50 g NPK mixture + 100 g IRP + 25/10 g kie.</td>
<td>275 g NPK mix. + 75/50 g kie.</td>
<td>100 g NPKMg mix. + 450 g NPKMg mix.</td>
</tr>
<tr>
<td></td>
<td>5 months after planting</td>
<td>50 g NPK mix.</td>
<td>50 g NPK mix.</td>
<td>75 g NPKMg mix.</td>
</tr>
<tr>
<td></td>
<td>7 months after planting</td>
<td>75 g NPK mix. + 50/25 g kie.</td>
<td>100 g NPK mix.</td>
<td>250 g NPKMg mix.</td>
</tr>
<tr>
<td></td>
<td>10 months after planting</td>
<td>275 g NPK mix. + 75/50 g dol</td>
<td>900 g NPKMg mix.</td>
<td>500 g NPKMg mix.</td>
</tr>
<tr>
<td>2nd year 4 applications/year</td>
<td>13 months after planting</td>
<td>800 g NPK mix. + 200/100 g dol</td>
<td>800 g NPK mix. + 200/100 g dol</td>
<td>1350 g NPKMg mix.</td>
</tr>
<tr>
<td></td>
<td>26 months after planting</td>
<td>265 g NPK mix.</td>
<td>265 g NPK mix.</td>
<td>1350 g NPKMg mix.</td>
</tr>
<tr>
<td></td>
<td>27 months after planting</td>
<td>200/100 g dol</td>
<td>200/100 g dol</td>
<td>450 g NPKMg mix.</td>
</tr>
<tr>
<td></td>
<td>30 months after planting</td>
<td>265 g NPK mix.</td>
<td>265 g NPK mix.</td>
<td>450 g NPKMg mix.</td>
</tr>
<tr>
<td></td>
<td>34 months after planting</td>
<td>265 g NPK mix.</td>
<td>265 g NPK mix.</td>
<td>450 g NPKMg mix.</td>
</tr>
<tr>
<td>3rd year 3 applications/year</td>
<td>38 months after planting</td>
<td>800 g NPK mix. + 200/100 g dol</td>
<td>800 g NPK mix. + 200/100 g dol</td>
<td>1350 g NPKMg mix.</td>
</tr>
<tr>
<td></td>
<td>39 months after planting</td>
<td>265 g NPK mix.</td>
<td>265 g NPK mix.</td>
<td>1350 g NPKMg mix.</td>
</tr>
<tr>
<td></td>
<td>42 months after planting</td>
<td>265 g NPK mix.</td>
<td>265 g NPK mix.</td>
<td>450 g NPKMg mix.</td>
</tr>
<tr>
<td></td>
<td>46 months after planting</td>
<td>265 g NPK mix.</td>
<td>265 g NPK mix.</td>
<td>450 g NPKMg mix.</td>
</tr>
<tr>
<td>4th year 3 applications/year</td>
<td>50 months after planting</td>
<td>1100 g NPK mix. + 250/150 g dol</td>
<td>1100 g NPK mix. + 250/150 g dol</td>
<td>1800 g NPKMg mix.</td>
</tr>
<tr>
<td></td>
<td>51 months after planting</td>
<td>365 g NPK mix.</td>
<td>365 g NPK mix.</td>
<td>600 g NPKMg mix.</td>
</tr>
<tr>
<td></td>
<td>54 months after planting</td>
<td>365 g NPK mix.</td>
<td>365 g NPK mix.</td>
<td>600 g NPKMg mix.</td>
</tr>
<tr>
<td></td>
<td>58 months after planting</td>
<td>365 g NPK mix.</td>
<td>365 g NPK mix.</td>
<td>600 g NPKMg mix.</td>
</tr>
<tr>
<td>5th year until tapping</td>
<td>**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Depending on low potassium (Group III) or high potassium (Group I) soils.
** Planting hole application is not necessary in areas where polybag plants are planted.

IRP - Imported Rock Phosphate  kie - Kieserite  dol - Dolomite

166
Table 15.8. Manuring schedule for immature rubber on group II soils

<table>
<thead>
<tr>
<th>Year of planting</th>
<th>Frequency &amp; Time of application</th>
<th>Quantity/tree (urea based)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting hole</td>
<td></td>
<td>75 g NPK mixture + 100 g IRP</td>
</tr>
<tr>
<td>1st year</td>
<td>4 applications/year</td>
<td>375 g NPK mix.</td>
</tr>
<tr>
<td></td>
<td>2 months after planting</td>
<td>50 g NPK mix.</td>
</tr>
<tr>
<td></td>
<td>5 months</td>
<td>75 g NPK mix.</td>
</tr>
<tr>
<td></td>
<td>7 months</td>
<td>100 g NPK mix.</td>
</tr>
<tr>
<td></td>
<td>10 months</td>
<td>150 g NPK mix.</td>
</tr>
<tr>
<td>2nd year</td>
<td>4 applications/year</td>
<td>750 g NPK mix.</td>
</tr>
<tr>
<td></td>
<td>13 months after planting</td>
<td>150 g NPK mix.</td>
</tr>
<tr>
<td></td>
<td>16 months after planting</td>
<td>200 g NPK mix.</td>
</tr>
<tr>
<td></td>
<td>19 months after planting</td>
<td>200 g NPK mix.</td>
</tr>
<tr>
<td></td>
<td>22 months after planting</td>
<td>200 g NPK mix.</td>
</tr>
<tr>
<td>3rd year</td>
<td>3 applications/year</td>
<td>1125 g NPK mix.</td>
</tr>
<tr>
<td></td>
<td>26 months after planting</td>
<td>375 g NPK mix.</td>
</tr>
<tr>
<td></td>
<td>30 months after planting</td>
<td>375 g NPK mix.</td>
</tr>
<tr>
<td></td>
<td>34 months after planting</td>
<td>375 g NPK mix.</td>
</tr>
<tr>
<td>4th year</td>
<td>3 applications/year</td>
<td>1125 g NPK mix.</td>
</tr>
<tr>
<td></td>
<td>38 months after planting</td>
<td>375 g NPK mix.</td>
</tr>
<tr>
<td></td>
<td>42 months after planting</td>
<td>375 g NPK mix.</td>
</tr>
<tr>
<td></td>
<td>46 months after planting</td>
<td>375 g NPK mix.</td>
</tr>
<tr>
<td>5th year</td>
<td>3 applications/year</td>
<td>1500 g NPK mix.</td>
</tr>
<tr>
<td>until tapping</td>
<td>50 months after planting</td>
<td>500 g NPK mix.</td>
</tr>
<tr>
<td></td>
<td>54 months after planting</td>
<td>500 g NPK mix.</td>
</tr>
<tr>
<td></td>
<td>58 months after planting</td>
<td>500 g NPK mix.</td>
</tr>
</tbody>
</table>

IRP - Imported Rock Phosphate

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.
In the planting hole fertilizer should be thoroughly mixed with the top 10-20 cm of soil, 2-3 weeks prior to planting. 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 and round it with light forking. 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 cover crops around the tree within a radius of 100-120 cm. Where mulching is carried out fertilizers should be spread on the soil before spreading the mulch.

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. If proper initial management is given, especially with respect to optimum nutrition during the pretapping phase, it is concluded that fertilizer use during the mature stage could be minimized.

7.1 Site-specific fertilizer recommendation

The concept of discriminatory fertilizer recommendation envisages supply of an adequate quantity of nutrients to the plants taking into consideration the nutrient reserves and the available nutrient content in the soil, plant nutrient status, site characteristics and other specific parameters. This practice has been widely accepted and extensively used as the basis for formulating site-specific 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 nutrient elements. For the interpretation of leaf nutrient data to determine the deficiency and sufficiency of nutrients, a range of values has been suggested (Table 15.9).

Table 15.9. Nutrient assessment of low shade leaves of Hevea in all clones

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Very low</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Very high</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (%)</td>
<td>&lt;2.90</td>
<td>2.90-3.40</td>
<td>3.40-3.50</td>
<td>3.51-3.70</td>
<td>&gt;3.70</td>
</tr>
<tr>
<td>P (%)</td>
<td>&lt;0.17</td>
<td>0.17-0.19</td>
<td>0.20-0.25</td>
<td>0.26-0.27</td>
<td>&gt;0.28</td>
</tr>
<tr>
<td>K (%)</td>
<td>&lt;1.21</td>
<td>1.21-1.40</td>
<td>1.40-1.69</td>
<td>1.70-1.85</td>
<td>&gt;1.85</td>
</tr>
<tr>
<td>Mg (%)</td>
<td>&lt;0.18</td>
<td>0.18-0.21</td>
<td>0.21-0.26</td>
<td>0.26-0.28</td>
<td>&gt;0.29</td>
</tr>
</tbody>
</table>

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 in Sri Lanka by the RRISL in 1973, and is currently catering to mature areas only. The fertilizer recommendations are intended to cover 3 years of manuring, after which a resurvey falls due and new recommendations for the next 3 years are formulated. In areas where fertilizers are not recommended on the basis of soil and foliar survey, conventional mixtures (Table 15.10) could be used.

Table 15.10. Manuring schedule for mature rubber on group I, II and III soils

<table>
<thead>
<tr>
<th>Stage of maturity</th>
<th>Urea based</th>
<th>Sulphate of ammonia based</th>
<th>Sulphate of ammonia based</th>
</tr>
</thead>
<tbody>
<tr>
<td>While tapped on virgin bark.</td>
<td>800 g NPK mix. + 200/100 g* kie.</td>
<td>1350 g NPKMg mix.</td>
<td>1125 g NPK mix.</td>
</tr>
<tr>
<td>While tapped on renewed bark to five years before uprooting.</td>
<td>550 g NPK mix. + 150/75 g* kie.</td>
<td>900 g NPKMg mix.</td>
<td>750 g NPK mix.</td>
</tr>
</tbody>
</table>

1 For those areas where fertilizers are not recommended on the basis of soil and foliar survey.

2 The source of phosphate for mature rubber should be Eppawela rock phosphate (local product).

* Depending on low potassium (Group III) or high potassium (Group I) soils.

7.2 Frequency of application

If the recommended fertilizer dosage is less than 1 kg, it should be applied in one single application. If it is more than 1 kg, two applications are recommended.

7.3 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 (depending on weather conditions at the time). If it is more than one application the 2nd application should be done within two months after the 1st application. It is important that all fertilizer for mature rubber should be applied before June.
7.4 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 spread on the soil before spreading the mulch.

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. Subsequently, phosphate may be effectively applied by dusting some rock phosphate on the cover crops. This should be done 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 plantings where fertilizer usage has been restricted, and in cases of severe competition N deficiency is likely to occur.
9.1.1 Symptoms

The usual symptoms are 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 15.1a) 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 15.1b). 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 15.1c). 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 midstem whorls. In mature trees potassium deficiency symptoms are found on leaves exposed to full sunlight. Seen from afar, 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 15.1d). 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 15.11) 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 is used it should be applied at the rate of 100-200 g/plant with 200-400 g of the appropriate sulphate of ammonia-based NPK 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 symptoms of the deficiency could be corrected by applying 50-100 g of MOP along with 25-50 g of kieserite and 100-200 g of NPK mixture depending on the age of the plant.
### Table 15.11. Corrective measures for nutrient deficiencies of Hevea

<table>
<thead>
<tr>
<th>Deficiency</th>
<th>Age</th>
<th>Dosage</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>During 1st and 2nd years of planting</td>
<td>50 g of urea or 100 g of sulphate of ammonia</td>
<td>100 g of urea based NPK fertilizer mixture or 200 g of Sulphate of ammonia based NPK fertilizer mixture should also be applied.</td>
</tr>
<tr>
<td></td>
<td>2nd year - until tapping</td>
<td>100 g of urea or 200 g of sulphate of ammonia</td>
<td>200 g of urea based NPK fertilizer mixture or 400 g of Sulphate of ammonia based NPK fertilizer mixture should also be applied.</td>
</tr>
<tr>
<td></td>
<td>Mature stage</td>
<td>100 g of urea or 200 g of sulphate of ammonia</td>
<td>200 g of urea based NPK fertilizer mixture or 400 g of Sulphate of ammonia based NPK fertilizer mixture should also be applied.</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>visual symptoms are not common. Recommendations should therefore, be made based on a foliar analysis.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>During 1st and 2nd years of planting</td>
<td>50 g of MOP + 25 g of Kieserite</td>
<td>100 g of urea based NPK fertilizer mixture or 200 g of Sulphate of ammonia based NPK fertilizer mixture should also be applied.</td>
</tr>
<tr>
<td></td>
<td>2nd year - until tapping</td>
<td>100 g of MOP + 50 g of Kieserite</td>
<td>200 g of urea based NPK fertilizer mixture or 400 g of Sulphate of ammonia based NPK fertilizer mixture should also be applied.</td>
</tr>
<tr>
<td></td>
<td>Mature stage</td>
<td>100 g of MOP + 50 g of Kieserite</td>
<td>200 g of urea based NPK fertilizer mixture or 400 g of Sulphate of ammonia based NPK fertilizer mixture should also be applied.</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>During 1st and 2nd years of planting</td>
<td>50 g of Kieserite</td>
<td>100 g of urea based NPK fertilizer mixture or 200 g of Sulphate of ammonia based NPK fertilizer mixture should also be applied.</td>
</tr>
<tr>
<td></td>
<td>2nd year - until tapping</td>
<td>100 g of kieserite</td>
<td>200 g of urea based NPK fertilizer mixture or 400 g of Sulphate of ammonia based NPK fertilizer mixture should also be applied.</td>
</tr>
<tr>
<td></td>
<td>Mature stage</td>
<td>100 g of kieserite</td>
<td>200 g of urea based NPK fertilizer mixture or 400 g of Sulphate of ammonia based NPK fertilizer mixture should also be applied.</td>
</tr>
</tbody>
</table>
9.2.4 Magnesium deficiency

This disorder could be corrected by applying 50-100 g of Kieserite with 100-200 g of the NPK mixture.

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.
Plate 15.1. a Nitrogen deficiency; b Phosphorus deficiency; c Potassium deficiency; d Magnesium deficiency.
1. **INTRODUCTION**

The 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 16.1a). Therefore, methods employed to tap the *Hevea* tree for latex are determined by the anatomical features, i.e. arrangement of various tissue layers, of the bark. Hence, a knowledge of the anatomy of *Hevea* bark with special reference to the distribution of latex vessels is essential to develop and understand appropriate tapping systems.

The rubber tree is commercially planted for its latex. Tapping is a process of systematic wounding of the bark of the rubber tree to extract latex. An ideal 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.

2. ANATOMY OF THE BARK

2.1 The bark

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).

![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]]
2.2 Latex vessels

The latex vessels of *Hevea* are arranged in concentric rings or mantles in the bark of the tree. Within each ring they are vertically and laterally connected, resulting in a continuous network (Fig. 16.2). Vessels run at an angle of 2.5 - 7° to the vertical. The most active latex vessels are near the vascular cambium; towards the outside they are old, disorganized and inactive. But vessels in the 1 mm adjacent to the vascular cambium (40% of the total active vessels) cannot be tapped for fear of injury to the cambium (Fig. 16.3).

![Diagram of latex vessels](image)

**Fig. 16.2.** Concentric rings of latex vessels. The vessels are inclined at 2-7° 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].

178
A 10 year-old tree of a modern clone of *Hevea brasiliensis* would have about 30 latex vessel rings at a height of 150 cm from the union on virgin bark and something like 15 latex vessels per mm in each of the rings.
3. PHYSIOLOGY OF LATEX PRODUCTION

The tree canopy synthesises carbohydrates through photosynthesis and the genetic make up of the tree determines the partitioning of these carbohydrates to dry matter production, metabolic activities and latex production. The latex production take 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 is at high hydrostatic pressure in the latex vessels. This hydrostatic pressure increases with its osmotic pressure and is sensitive to changes in the osmotic concentration of the conducting system. The tension of the walls between latex vessels and the neighbouring parenchyma is dependent only on the difference in osmotic concentration between the two. Immediately after tapping the pressure in the vessels is reduced to atmospheric pressure and hence latex flows out. The turgor pressure in the latex vessels is in the range of 10 - 15 atmospheres. Therefore, with latex flowing out after tapping the hydrostatic pressure exerted by the latex vessels on the neighbouring cells is also reduced. As a result the cell walls of the neighbouring cells will arch into the latex vessels and a pressure is exerted and this expresses further 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

The flow of latex after tapping is 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 rate of plugging is clone-dependent. This can be determined by calculating the plugging index using the formula given below:

\[
\text{Plugging Index (PI)} = 100 \times \frac{\text{mean flow rate (ml/min) during first 5 mts. after tapping}}{\text{Total volume (ml)}}
\]

A high plugging Index indicates that plug formulation 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.
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).

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 and poor yields. Such tapping resulted in very early abandonment of trees.

   The first attempt to develop a systematic way of exploiting rubber trees to allow sustained yields was carried out by 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. 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
   Girthing of a rubber tree is reduced after commencement of tapping. Nevertheless, girthing of trees under tapping is essential to obtain sustained yields during the entire tapping cycle. *Hevea* trees can be regarded as tappable with the continuous excision method, only when a girth of at least 50 cm, measured at 120 cm from the highest point of the stock-scion union is reached (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.
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: Gomez, J.B. (1983). *Physiology of Latex (Rubber) Production*. Malaysian Rubber Research and Development Board, Malaysia.]
4.3.2 Tappable clearing

For economic reasons, 60% of a clearing/smallholding should be of tappable girth before tapping is commenced. In a tappable clearing, trees having a girth of 45 cm may also be marked for tapping.

In trees brought into tapping later once the tappable girth is reached tapping should commence at the initial height of opening adopted (see para 4.3.4) for the other trees in the clearing.

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

Tapping cuts should commence at a height of 120 cm from the highest point of the union to the lower end of the tapping cut. Generally, on the base panels tapping is done from high left to low right using a Michie - Golledge Knife (Plate 16.1c). There is no significant difference in yield due to opening of cuts at other heights. This may be due to the cylindrical nature of the trunk of the budded *Hevea* tree. 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. Nevertheless, the height of opening will have to be lowered if the tapper cannot reach 120 cm due to his/her low stature.

The height of opening may be increased upto 150 cm from the highest point of the union with the use of the Jebong knife (Plate 16.1c).

4.3.5 Slope and direction of cut

As the latex vessels run at an angle of 2.5 - 7° to the vertical in an anti-clockwise manner, a greater number of latex vessels is cut and 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 cut 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 16.1d). 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 can commence.

For marking of guide lines, 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 (Plate 16.3c). Subsequent guide lines are marked every year before commencement of tapping (Plate 16.3d).

4.3.7 Depth of tapping

The majority of active latex vessels are concentrated in tissues close to the vascular cambium. As new cells are continuously being formed by the cambium the older cells are pushed away. They become disorganised, sparsely distributed and discontinuous. Such latex vessels become increasingly less productive and therefore, those vessels in the hard bark contribute little or no latex during harvesting.

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). However, these cannot be reached without injury to the cambium. Tapping to a depth of up to 1 mm from the vascular cambium is therefore 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. This gives reduced yields. Therefore, high yields coupled with smooth, even, uninjured renewed panels are good indications of correct depth of tapping.

4.3.8 Bark consumption

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 ½S d/2 system. Hence, for the ½S d/2 tapping system, the
annual bark consumption will be approximately 20 cm (0.125 cm x 160). Similarly for the /2S d/3 tapping system the annual bark consumption will be ca 14 cm (0.125 cm x 107).

4.3.9 Time of tapping
The heighest yield of latex is obtained by tapping in the early hours of the morning and late tapping will reduce latex yield due to increased transpiration leading 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.

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, terrain of the 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.

4.4 Current tapping systems
Tapping systems are clone-specific and they 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. d/3 frequency, whilst the other clones will need a higher frequency of tapping, i.e. d/2 frequency. If high g/t/t clones are tapped at d/2 frequency such clones are unable to sustain high yields and this will also lead to high incidence of Tapping Panel Dryness.

Due to reasons discussed above the clones recommended for planting are broadly classified as d/2 and d/3 tapping clones. Anyhow, the length of the tapping cut is the same for both d/2 and d/3 clones, i.e. half spiral (½S) (Table 16.1).

Table 16.1. Recommended clones and their tapping systems

<table>
<thead>
<tr>
<th>Tapping System</th>
<th>Clones</th>
</tr>
</thead>
<tbody>
<tr>
<td>½S d/2</td>
<td>RRIC 100, RRIC 102, RRIC 117, RRIC 121, RRIC 131, RRIC 133, BPM 24, All RRISL 200 Series Clones, RRIM 717, PB 255, PR 255, PR 305</td>
</tr>
<tr>
<td>½S d/3</td>
<td>PB 28/59, PB 217, PB 235, PB 260, RRIC 130, RRII 105</td>
</tr>
</tbody>
</table>

185
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 $\frac{1}{2}$S d/2 and $\frac{1}{2}$S d/3 systems respectively.

4.4.1 Intensified 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.

There are two schemes recommended for intensified tapping and they are common to both d/2 and d/3 clones. The duration of the intensification period is six years (Table 16.2).

Table 16.2. Intensification scheme for last six years of tapping

<table>
<thead>
<tr>
<th>Year</th>
<th>Scheme 1</th>
<th>Scheme 2'</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,2,3</td>
<td>$2 \times \frac{1}{2}$S (↑↓),d/3</td>
<td>$\frac{1}{2}$S (↑) + $\frac{1}{2}$S (↓) d/2</td>
</tr>
<tr>
<td>4 &amp; 5</td>
<td>$2 \times \frac{1}{2}$S (↑↓),d/2</td>
<td>$2 \times \frac{1}{2}$S (↑↓),d/2</td>
</tr>
<tr>
<td>6</td>
<td>$4 \times \frac{1}{2}$S (↑↓),d/2</td>
<td>$4 \times \frac{1}{2}$S (↑↓),d/2</td>
</tr>
</tbody>
</table>

The upward cuts should be at an angle of 45° to the horizontal. Further, when two cuts are introduced they should be at least 52 cm apart to prevent overlap of the drainage area.

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.

4.5 Novel methods

Continuous excision tapping requires skilled tappers. As they are becoming scarce, research is being conducted on incision tapping methods, i.e. puncturing of the bark which does not require any skill. To harvest economic yields from incision tapping the use of yield stimulants is mandatory. The long-term effects of using yield stimulants on rubber trees, i.e. bark cracking and death and declining yields have so far prevented the commercial adoption of such systems.

4.6 Tapping panel dryness

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.
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 \( \frac{1}{4} S \) cut can be introduced on the higher panel opposite to the dry panel. When exploiting previously dry trees, i.e. recovered or \( \frac{1}{4} S \) 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 Tapping knives used in Sri Lanka; d d/2 and d/3 stencils made out of aluminium sheets
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. Pre-tapping procedures. a Drawing of guidelines using appropriate stencil; b Guidelines drawn on a tree with a high left to low right orientation; c After the marking of guidelines spout, cup hanger and cup should be placed correctly; d Guidelines should be marked each year to guide the tapper for correct tapping.
Chapter 17

Use of yield stimulants and tapping notation

A. Nugawela

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

The use of yield stimulant Ethrel, i.e. 2-chloroethylphosphonic acid, is recommended to obtain high yields from the renewed bark. Further 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 low frequency tapping other advantages such as increased tapper productivity and tapping cycle also exist.

1.1 Mode of action of stimulants

The action of Ethrel is mediated through ethylene produced by hydrolytic decomposition of Ethrel. 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 Ethrel are due to delaying of plugging and increased rate of latex biosynthesis.

Higher yielding trees 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.

Generally low g/t/t clones respond better to yield stimulation when compared to high g/t/t trees. Therefore, both renewed and virgin bark stimulation is not advocated for clones recommended for d/3 frequency tapping.
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. Renewed bark stimulation with ½S d/2 tapping may demand more fertilizer than unstimulated trees.

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.

1.2 Renewed bark stimulation
The trees should be tapped at ½S d/2 or at a lower intensity to undertake stimulation on renewed bark. Trees can be stimulated by either 5% or 2.5% Ethrel. Commercially available 5% Ethrel could be mixed with an equal volume of warm water to obtain 2.5% Ethrel. With 5% and 2.5% Ethrel, 2 and 4 rounds of stimulation per tree can be undertaken per year, respectively. Stimulating 4 rounds with 2.5% Ethrel gives a better yield response than 2 rounds of 5% Ethrel. Nevertheless, 4 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>
<thead>
<tr>
<th>Round</th>
<th>Months for stimulation with 2.5%</th>
<th>Months for stimulation with 5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>January</td>
<td>July/August</td>
</tr>
<tr>
<td>2</td>
<td>June</td>
<td>November/December</td>
</tr>
<tr>
<td>3</td>
<td>August</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>November</td>
<td></td>
</tr>
</tbody>
</table>

On the renewed bark, panel application (Pₐ) of the stimulant is recommended. For Pₐ remove the tree lace (Plate 17.1a) and apply Ethrel on a 1.25 cm band 1 cm above the cut on the tapping panel. (Fig. 17.1b). The quantity to be applied is 1.6 g of either 2.5% or 5% Ethrel per tree per application.

1.3 Virgin bark stimulation
Rubber trees should be tapped at ½S 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 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 (Plate 17.1c) and 1.6 g of 2.5% Ethrel is applied per tree per application (Plate 17.1d).

2. TAPPING NOTATION

Tapping notations are sets of symbols and numbers describing a tapping procedure. Many tapping practices have evolved through the years. Local names were given to each system and this led to confusion and difficulties. Hence 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.

The tapping notation consists of different parts to indicate,

- tapping method
- panel position and type
- stimulation method.

2.1 Tapping method

a). Symbol of cut  - A capital letter denotes the shape of cut used.
    e.g.  S  - Spiral cut
          V  - ‘V’ cut

b). Length of cut  - This is expressed as a relative proportion of the circumference of the trunk. A fraction preceding the symbol of cut denotes the relative length of cut.
    e.g.  $\frac{1}{2} S$  - One half spiral
         $\frac{3}{4} S$  - Three quarter spiral.

c). Number of cuts  - The number of cuts is represented by a figure before the length of cut notation, followed by the multiplication sign.
    e.g.  $2 \times \frac{1}{2} S$  - Two half spiral cuts
         $2 \times \frac{3}{4} S$  - Two quarter spiral cuts.
d) Direction of tapping - When tapping is downward only, no symbol is necessary. However, when upward tapping is practised 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. (↑↓).

\[
\begin{align*}
e.g. & \quad \frac{1}{2} S & & \text{- One half spiral tapped downward.} \\
2 \times \frac{1}{2} S (\uparrow \downarrow) & & \text{- Two half spirals, one tapped upwards and the other downwards.} \\
\frac{1}{2} S (\uparrow) & & \text{- One half spiral tapped upwards.}
\end{align*}
\]

e) Combination tapping - This describes the use of different cuts on a single tree per tapping. The notations for the length of cut are joined by a plus sign (+).

\[
e.g. \quad \frac{1}{2} S + \frac{1}{4} S & & \text{- One half spiral and one quarter spiral tapped on the same day.}
\]

2.2 Panel position and type

The panel notation describes the area and type of bark on the rubber tree which is being exploited. The old convention of panels A and B for virgin bark and C and D for first renewed bark has been discarded as it does not take into account short cuts. The new panel notation is also mindful of high level tapping and second renewed bark.

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’.

A number of panels is possible around the circumference of the trunk.

e.g. B-1, B-2, B-3, etc.

The type of bark on which tapping is being carried out is indicated by using the letter ‘O’ for virgin bark and the Roman numerals I and II to indicate first and second renewed bark.

\[
\begin{align*}
e.g. & \quad \text{BO - 1 : First cut on virgin bark of base panel.} \\
& \quad \text{BI - 2 : Second cut on first renewed bark of base panel.}
\end{align*}
\]

2.3 Stimulation

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. Full stops are inserted between these units to differentiate these clearly.

Example:
ET5%. Pa1.6 (2.5).2/y Stimulated with Ethrel (ET) of 5% concentration. Place of application is on the panel (Pa) with 1.6 g of stimulant per application on a 2.5 cm band. Two such applications are done each year.

2.3.1 **Method of application**
The method of stimulant application is described by a symbol consisting of two letters describing the place of application.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pa</td>
<td>Panel application</td>
</tr>
<tr>
<td>La</td>
<td>Lace application</td>
</tr>
<tr>
<td>Ba</td>
<td>Bark application</td>
</tr>
<tr>
<td>Ga</td>
<td>Groove application</td>
</tr>
</tbody>
</table>

2.4 **Complete notation for exploitation system**
Tapping and stimulation notations are given together as a complete notation, with a full stop inserted between them.

Example:
½ S d/3.ET2.5%.Ba1.6(2.5).4/y.
One - half spiral cut tapped every third day stimulated with Ethrel of 2.5% concentration. Ethrel applied on bark (Ba) with 1.6 g per application on a 2.5 cm band and 4 such applications per year.

3. **TAPPING INTENSITY**
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 (RI)**
This may be calculated as follows:
The length of the cut multiplied by the fraction of tapping frequency, multiplied by 400 and expressed as a percentage, i.e. length of cut x tapping frequency x 400. e.g. for ½S d/2 system,

\[
RI = \frac{1}{2} \times \frac{1}{2} \times 400 = 100\%.
\]

195
3.2 Actual tapping intensity (AI)
This is calculated using the formula given below:

\[
\text{AI} = \frac{4 \times \text{length of cut} \times \text{actual number of tappings}}{\text{days in period concerned}} \times 100
\]

eg. for \( \frac{1}{2} \) S d/2 system if the actual number of tappings per tree is 12 during a 30 day period.

\[
\text{AI} = \frac{4 \times \frac{1}{2} \times 12}{30} \times 100 = 80\%
\]
Plate 17.1. Stimulation of renewed and virgin barks. a Removal of tree lace; b Application of stimulant on the tapping panel; c Scraping of bark; d Application of stimulant on bark of the tree.
Chapter 18

Minimizing of crop losses due to interference of rain on tapping

A. Nugawela and L.M.K. Tillekeratne

1. Introduction
2. Grooming
3. Recovery tapping
4. Rotation tapping
5. Rainguards
   5.1 Types of rainguards
      5.1.1 Apron type
      5.1.2 Gutter type
   5.2 Economics of using rainguards
   5.3 Sealant
      5.3.1 Ingredients needed
      5.3.2 Preparation

1. INTRODUCTION

Tapping of panels made wet by rain is not recommended as it leads to panel diseases and interrupting flow of latex leading to wastage. Each year around 100 days of tapping are lost due to wet panels. Further, on about 50 days of the year tapping is commenced only ca. 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 such washouts are reported.

No tapping, late tapping and washouts lead to about 30 - 35% loss of potential crop each year. This 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

Mosses grow on the bark of some rubber trees and are capable of retaining moisture (Plate 18.1a). The moisture is released slowly and as a result a longer time is taken for the panel to dry even after the rains have ceased. If the mosses found surrounding the tapping cut are removed it will help to dry up the panels quickly (Plate 18.1b). Removing the mosses from an area 60 cm above the tapping cut and about 30 cm on either side and below the cut will be sufficient for this purpose (Plate 18.1c). This process, i.e. Grooming, should be undertaken annually, before the onset of monsoons, on trees where mosses are found. This helps by
increasing tapping days and converting 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

Ideally a rubber tree should be tapped every other day or once in three days depending on the clone. This will make it possible to sustain the potential tapper and land productivity levels throughout the tapping cycle. Anyhow, 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. Recovery tapping leads to daily tapping and it negatively affects the growth and yield of trees. Hence for all clones recovery tapping is not recommended during the first three years of tapping. In clearings where recovery tapping is recommended, i.e. from the 4th year of tapping, only 2 or 6 such tappings are recommend per week or per month respectively. Also, if uninterrupted tapping is possible for a period in excess of a month recovery tapping during such periods will not enhance yields.

4. ROTATION TAPPING

In addition to the normal tapping gang another tapping gang is employed for tapping. If an additional 25% of tappers are used in the second tapping gang, each tapping block will get an additional tapping once in about 8 days. This system may not be practical at present due to the scarcity of skilled tappers. Further, this method also results in daily tapping of a tree to some extent.

5. RAINGUARDS

The tapping panel of a rubber tree gets wet during rain due to rain water trickling down the trunk and also due to splashing of water from the sides especially when both rain and wind occur simultaneously. The wetting of tapping panels due to these reasons can be minimized with the use of 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 Southwest 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 on to the trees before the onset of the Southwest 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. If leaks develop, the brushable sealant should be applied on the seal using a suitable brush.

5.1 Types of rainguards

Two types of rainguards are recommended to the Industry, i.e. Apron and Gutter types.

5.1.1 Apron type

A 60 cm wide sheet of gauge 300 transparent polythene is fixed using a sealing compound parallel to the tapping cut exceeding the length of cut by 7-8 cm at each end to cover the tapping panel (Plate 18.2a).

Material needed

a) 60 cm width, gauge 300 transparent polythene (40 trees per kg)
b) No. 10 staples and stapling machines.
c) Sealing compounds both liquid and solid (50 and 25 trees per litre and a kg of liquid and solid sealants respectively).

Fixing

a) Lightly scrape a 3 - 4 cm strip on the tapping panel parallel to the tapping cut, about 10 cm above the cut. Scraping should exceed the length of the cut by 8 - 10 cm at each end (Plate 18.2b).
b) Apply the liquid sealant as a strip on the scraped area of the bark in about 100 trees (Plate 18.2c).
c) The polythene should be frilled using a sewing machine. The frills should be about 1 cm in length and 2-3 cm apart. Cut a piece of frilled polythene to suit the size of the tree (Plate 18.2d).
d) Stick the frilled polythene on to the liquid sealant commencing with the first tree (Plate 18.2e).
e) Fasten the polythene on to the tree with 5 - 6 staples placed at equal intervals (Plate 18.2f).
f) Seal the polythene on to the tree firmly using a strip of solid sealant on the following day (Plate 18.2a).

The Apron type rainguard protects the tapping panel from water trickling down the trunk and from water splashing from the side. Therefore it is much more effective than the Gutter type.
5.1.2 Gutter type

This is relatively more effective in rubber plantations on flat or slightly undulating land with a well-developed canopy cover than on steep land. In such areas falling of rain water directly on to the tapping panel is not possible.

A polythene strip is fixed using a sealing compound, 2 cm above and parallel to the tapping cut, exceeding the length of the cut by 8 - 10 cm at each end. A “V” shaped diversionary gutter is formed and the water trickling down the trunk is diverted away from the cut (Plate 18.3a).

Material needed

a) 7-8 cm wide guage 700 curved black polythene strips (Plate 18.3b)

b) Sealing compound.

Fixing

a) Lightly scrape a 2 - 3 cm strip on the bark parallel and 2 cm above the cut. Scraping should exceed the length of the cut by 8 - 10 cm at each end (Plate 18.3c).

b) Stick the solid sealant as a strip on to the scraped area of the bark. Relatively more sealant than for the Apron type is needed (Plate 18.3d).

c) Cut the required length from the 7-8 cm wide, guage 700 black curved polythene strips.

d) Place about 2-3 cm of the curved polythene strip on the sealant stuck on to the tree, to form a “V” shaped diversionary gutter above the tapping cut (Plate 18.3e).

e) Seal the curved polythene strip on to the tree, using more sealant (Plate 18.3a).

5.2 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. $[N_{SA} - C_{TM}]$

If the cost of a Apron and Gutter type rainguard is Rs. $C_A$ and Rs. $C_G$ respectively,
4. Amount of additional crop needed from each tree to cover the cost of

\[ \text{a) Apron type rainguard} = \frac{(Rs \ C_A \times 1000)}{(Rs \ N_{NS} - Rs \ C_{TM})} = g_A \]

\[ \text{b) Gutter type rainguard} = \frac{(Rs \ C_G \times 1000)}{(Rs \ N_{SA} - Rs \ C_{TM})} = g_G \]

5. At an average yield of 25 g/t/t, additional tapping days needed to cover the cost of a

\[ \text{a) Apron type rainguard} = \frac{g_A}{25} \]

\[ \text{b) Gutter type rainguard} = \frac{g_G}{25} \]

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.

5.3 Sealant

Two types, i.e. liquid and solid, of sealants are used for fixing the Apron type rainguard. Only the solid sealant is used for fixing the gutter 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.

5.3.1 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).

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Liquid</th>
<th>Solid</th>
</tr>
</thead>
<tbody>
<tr>
<td>China Clay</td>
<td>100 g</td>
<td>12.5 kg</td>
</tr>
<tr>
<td>Rubber Solution*</td>
<td>200 g</td>
<td>0.5 kg</td>
</tr>
<tr>
<td>Tar</td>
<td>300 g</td>
<td>10.0 kg</td>
</tr>
<tr>
<td>Sulphur</td>
<td>4 g</td>
<td>200.0 g</td>
</tr>
<tr>
<td>Final quantity</td>
<td>500 g</td>
<td>23.0 kg</td>
</tr>
</tbody>
</table>

*(1 kg of scrap rubber or RSS cut into small pieces dissolved in 9 litres of kerosene, 2 weeks before using)
5.3.2 Preparation

Heat the rubber solution in a suitable container. Add tar to the hot rubber solution and mix thoroughly using a ladle. Add clay, a little at a time, while mixing continues. Put the flame off and add sulphur, a little at a time, while the container is on hot embers. Please make sure that the flame does not reach above the container during the entire process. For mixing of solid sealant and also for manufacturing of liquid sealant in a large quantity an empty tar barrel with \( \frac{1}{4} \) removed on the vertical axis can be used. A small container can be used if only a smaller amount of liquid sealant is needed.
Plate 18.1. Grooming for increasing tapping days. a A rubber tree with moss grown on the bark; b Removing of moss surrounding tapping cut; c A rubber tree after the removal of moss.
Plate 18.2. Fixing of apron type rainguards. a A tree fixed with an apron type rainguard; b Scraping exceeding the length of cut by 8-10 cm at each end; c Applying the liquid sealant as a strip on the scraped area of the bark; d Frilled polythene cut to suit the size of the tree; e Sticking the frilled polythene onto the liquid sealant; f Fastening the polythene onto the tree using staples.
Plate 18.3. Fixing of gutter type rain guards. 

(a) A tree fixed with a gutter type rain guard; 
(b) A 7-8 cm wide gauge 700 curved black polythene strip; 
(c) Scraping exceeding the length of cut by 8 - 10 cm at each end; 
(d) Sticking the solid sealant as a strip onto the scraped area of bark; 
(e) Sticking the curved polythene strip onto the sealant.
Chapter 19

A greener future with *Hevea brasiliensis*

C.M. Stirling*

1. Introduction
2. Natural versus synthetic rubber
3. Importance to rural livelihoods
4. Environmental benefits
   4.1 Biodiversity
   4.2 Soil conservation
   4.3 Forest conservation
5. Conclusions

1. **INTRODUCTION**

The rubber tree (*Hevea brasiliensis*) is a unique crop; it yields a major industrial raw material that impacts on modern life more than any other agricultural commodity, its cultivation is environmentally friendly and it provides a source of income for more than 20 million families worldwide, the majority of whom are low income and land-poor.

2. **NATURAL VERSUS SYNTHETIC RUBBER**

Before the second world war, natural rubber (NR) provided almost all of the world's elastomer, but during the war America became cut off from its supply of natural rubber and so stepped up production of synthetic rubber (SR). Since then, the use of SR has gradually increased with the result that the pattern of consumption has now almost reversed, with natural and synthetic rubber accounting for a relatively constant 40% and 60% respectively, of the total elastomer consumption. The main advantage of SR is that it can be mass-produced to meet a wide range of specifications, although in reality more than 80% of SR products could be produced using NR. Certain industrial products, however, require the unique properties of NR with the largest single market being the tyre industry, which accounts for ca. 70% of world NR consumption. NR is the strongest of all rubbers and has excellent dynamic properties (e.g. resistance) which accounts for the fact that aircraft tyres comprise 100% NR. In other aspects such as tolerance to environmental damage (e.g. by ozone and oils) NR competes less favourably with SR. In addition to its unique dynamic properties, NR has the advantage that it is a renewable, non-polluting source of elastomer as opposed to SR, which is manufactured from crude oil. Furthermore, in a world where increasing consideration is given to the environmental costs of production, NR compares much more favourably with SR. For example, production of 1 t of NR

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207
requires 15 to 16 Gj of energy compared to 108 to 174 Gj for SR, depending on
the grade of SR produced. In addition to the high energy costs, SR production is
also a source of pollution whereas NR cultivation has few detrimental effects on
the environment. It is the processing rather than cultivation of NR that has the
potential to pollute, although this can be minimised through effective process
management.

3. IMPORTANCE TO RURAL LIVELIHOODS
The majority of the world’s natural rubber is produced on smallholdings,
which account for 83% of the total 9.5 million hectares of land under rubber
cultivation. At the country-level in Sri Lanka, 32% of the total 197,000 ha of
rubber belongs to the smallholder sector, defined here as holdings of less than 4 ha
during 1992. Recent studies in Sri Lanka have highlighted the importance of
rubber in providing a secure and long-term source of income to smallholder
farmers, particularly when integrated with traditional short-term subsistence and
cash crops. Rubber is an ideal crop for smallholders because of its adaptability to
local topography, soils and cropping systems, low capital inputs (when the rubber
subsidy is in place), relative ease of latex harvest and storability and long-term
security in terms of income, theft and pest damage. Furthermore, as a provider of
employment to ca. 500,000 people in Sri Lanka, the rubber sector plays an
extremely important role in maintaining the socio-economic fabric not only of
rural communities, but also of the country, as a whole.

4. ENVIRONMENTAL BENEFITS
4.1 Biodiversity
Traditionally, rubber was grown as a monoculture on large estates but in
more recent years the smallholder has become the predominant cultivator and with
this rubber-based intercropping has surfaced in importance. Furthermore, rapid
population growth in NR producing countries has led to a progressive reduction in
the size of land holdings with the result that smallholders are under increasing
pressure to maximise the productivity of the land. A wide variety of crops and
trees can be found on smallholder rubber plantations, including food, cash and
medicinal plants, as well as timber and fruit trees. Many other native plant and
animal species have been shown to coexist with rubber and whilst biodiversity
may not approach that of tropical rain forests, smallholder rubber plantations do
have the potential to support a relatively rich mix of forest species.

4.2 Soil conservation
Trees such as rubber play an important role in conservation of soil and
water resources, they not only provide a long-term canopy, which protects the soil
from erosion by wind and rain, but they also root over a greater area, depth and
duration than short-term crops and so help bind and protect the soil. Litterfall from
trees adds organic matter to the soil, which improves the surface soil properties so
that rainfall infiltration is increased and surface run-off is reduced. In Sri Lanka,
rubber tends to be cultivated on land where few crops, other than tea, can be
grown commercially and in the major rubber growing areas of Kegalle, Kalutura and Ratnapura, as much as 50% of the rubber lands have slopes of between 45 to 60%. Because of the steepness of the land, the soil is extremely fragile and prone to erosion. By protecting and binding the soil, the canopy and root system of rubber and the establishment of cover crops play an important role in preventing further loss of soil from these fragile slopes. Although tea is also grown on steep land, it fails to offer the same degree of protection to the soil as rubber, with an average soil loss of 35 MT ha⁻¹ yr⁻¹ compared to just 10 MT ha⁻¹ yr⁻¹ for rubber.

In terms of soil conservation, the properties of rubber plantations have been likened to that of native forests. Properly managed rubber plantations have been shown to improve soil organic matter content, with downstream benefits for soil properties such as bulk density, soil porosity and moisture retention. Similarly, a study in India showed that rubber significantly improved the physical properties of soil degraded by continuous shifting cultivation and deforestation. It was concluded that soil fertility under rubber was maintained to a similar extent to that of soil under teak plantations or natural forests. Maintenance of soil fertility under rubber is due to the continuous turnover of fine roots and the semi-deciduous growth habit which results in the foliage being shed yearly adding abundant leaf litter to the soil surface. Annual litter addition in rubber plantations amounts to 7 t ha⁻¹. Although the actual litter accumulated is lower in rubber plantations than in teak or natural forests, this is thought to be due to the higher rates of decomposition rather than lower quantities of litterfall per se. A study by indicated that forests can recycle about 8.33 t of dry litter per year as compared to 3.7 to 7.7 t yr⁻¹ in rubber plantations; it is only in the older rubber lands where nutrient recycling via litter approaches that of native forest ecosystems.

4.3 Forest conservation
The rapid loss of forest cover in Sri Lanka had been a major cause of concern, not only in terms of the environmental impact but also in terms of the consequences for those communities whose livelihoods depend on forest products. Amongst the world’s forests, tropical rain forests are the most diverse and dynamic ecosystem and due to the warm temperatures and high rainfall, carbon fixation is rapid. Consequently these forests contribute most to the fixation of atmospheric CO₂, which is a major greenhouse gas responsible for around 55% of the predicted global warming. Rubber is a rain forest tree and as such, its plantations act as a carbon sink along with native forests. Indeed, the Food and Agricultural Organisation (FAO) has included rubber plantations as forest, from the point of view of a carbon sink, in its Forest Resources Assessment 2000.

The forested area in Sri Lanka has declined from 70% in 1900 to less than 23% in 1995, which translates into an annual rate of deforestation of more than 40,000 ha yr⁻¹. This compares with a replanting rate of only 2000 ha yr⁻¹. Parallel with the decline in forested area has been the rapid increase in population, rising from 11.5 to 18.5 million over the same time period. Inevitably, the rise in population has placed tremendous pressure on the remaining forest resources and were it not for the valuable contribution of trees from the non-forest sector in
supplementing the increasing demand for timber and fuel wood, the loss of forest cover would have been even greater. In fact, in the major NR producing countries, rubber has now become the main alternative source of timber helping to reduce logging pressure on natural forests and teak plantations.

In the wet zone of Sri Lanka, most of the potential areas have already been brought under rubber cultivation but there is still ample potential to utilise the environmental and economic attributes of rubber as a means of protecting the existing forest resources in the dry/intermediate zones of Sri Lanka. In this region of the country, shifting cultivation is still practised, with chena crops grown for a couple of years after which the land is abandoned due to declining soil fertility. Government policy restricts access to new land and the limited size of lands available in the buffer areas of the forest means that farmers find it difficult to access additional new land. Because of this, they prefer to grow perennial crops, which require less frequent inputs but give a stable income. Studies have shown that rubber is compatible with a wide range of crops and can be intercropped without any detrimental effects on either component crop; in fact growth of both rubber and the intercrop is improved. Being a forest tree, which provides a luxurious canopy and stable income to growers, rubber fulfils many of the needs of traditional smallholder farmers in terms of security and low capital inputs. Whilst at present rubber is not grown extensively in the intermediate and dry zones, recent research funded by the UK Department for International Development, Plant Science Research Programme has shown that farmers are very interested in the long-term income secured by rubber. Provided that these farmers have the necessary extension information and support, studies have shown that rubber can be successfully cultivated and integrated with traditional cropping systems and supported by appropriate adaptive research, the potential is there to expand the growth of rubber into non-traditional areas.

5. CONCLUSIONS

There are several unique ecological and socio-economic advantages in adopting rubber as a model for conserving our natural resource base and for rehabilitation of degraded marginal lands. Natural rubber has considerable environmental credentials not least in that it is a rainforest tree that provides a cover comparable to that of natural forests whilst yielding an important industrial material in the form of a renewable resource. Rubber also has the advantage that it can be established on poor soils and on slopes that are particularly prone to erosion and degradation. In these situations, the uninterrupted presence of tree roots and abundant litterfall offers invaluable protection to the soil and long-term soil enrichment. A major constraint to the adoption of sustainable agricultural practice is the lack of security and land tenure and it is only when farmers have secured long-term access to land and receive the benefits of their investments in the land are they likely to pursue sustainable farming practices. The environmental and economic credentials of rubber, and its role in securing property rights provides an important step on the road to more sustainable practice and hence conservation of Sri Lanka’s natural heritage.
## Index

Abnormal leaf fall 102  
Advantages 14, 27, 71, 73, 140-141, 150, 191, 210  
Agro-ecological regions 40-41, 44  
Agro-management 7, 12, 157, 191  
Agronomic practices 60, 141, 158  
Allelopathy 142  
Altitude 1-2, 147-149  
Anatomy 176-177  
Animal husbandry 139, 153  
Apical bud 91, 115, 135  
Assimilatory leaves 61-62  
Authenticity 59, 62, 64  
Avenue type planting 87  
Axillary buds 62, 85  
Axes 61-62, 91, 115  

**Bacteria** 136  
**Banana sheath** 63, 64  
**Bare roots** 44, 59, 72, 79-80, 163  
consumption 176-177, 183-185  
renewal 99, 103, 124, 137, 168-169, 177, 181, 183, 191-192, 194  
**Barkosan** 104, 123-126  
**Bark rot** 2, 51-52, 97, 102-103  
**Bee-keeping** 153  
**Biodiversity** 207-208, 211  
Birds eye spot 97, 102-103  
**Bipolaris hevea** 102  
Black root disease 98, 109  
Black stripe 2, 102-103, 112  
**Bleak thread canker** 103  
**Botryodiplodia spp.** 122, 125  
**Botryodiplodia theotromae** 125, 128  
**Brown bark** 60, 62, 73  
**Brunolium plantarium** 105, 123, 125  
**Bud patch** 68-71, 73, 77-78, 88-89, 100  
**Buds** 54-55, 59-64, 68-70, 72, 74, 83, 90, 104, 135-136, 149, 183  
Budded stumps 44, 55, 57-58, 60, 68, 71-74, 79-80, 89-90, 92, 100, 107-108  
**Budwood nurseries** 54, 59-61, 64-65, 67-68, 70, 101, 156, 162  

**Bugs** 114-115, 135  
**Bulk density** 12, 18, 209  
**Calamus** 147  
**Cambium** 69, 123, 136-137, 177-179, 181, 184  
**Cash crops** 141, 208  
**Cation exchange capacity** 12, 19, 21-22, 159  
**Chena crops** 210  
**Circumference** 62, 184, 189, 193-194  
**Clay** 2, 5-7, 14-17, 72, 126, 149, 159-160, 202-203  
**Clone recommendation** 47, 55, 91, 185  
**Coffee arabica** 148  
**Coffee canephora** 148  
**Coffee liberica** 149  
**Collectotrichum leaf disease** 51, 97, 100, 111  
**Collectotrichum acutatum** 100  
**Collectotrichum gleosporium** 100  
**Colour bands** 62  
**Contour** 2, 7-10, 57, 87, 93, 143, 150, 183  
**Contour planting** 7, 143  
**Corticium salmonicolar** 104, 112  
**Corynespora cassicola** 101  
**Corynespora leaf fall** 46, 52, 97, 100-101, 111, 130  
**Cowpea** 139, 146  
**Crude oil** 207  

**Dead level contours** 87, 93  
**Deforestation** 209  
**Desiccation of the stem** 64, 74, 131  
**Die-back** 123-124, 126-127, 130-131  
**Discolouration** 106, 109-110, 123  
**Diseases** 2-3, 28, 33, 46-47, 51-52, 57-58, 73-74, 86, 97-98, 103-105, 111-113, 130, 136-137, 140, 142-144, 147, 149, 198-199  
**Dithane M45** 100-101, 123  
**Dolomite** 144, 161-162, 165-166  
**Dormant buds** 74, 104, 136  
**Drechslera hevea** 102  
**Drought** 28-29, 33, 40, 44, 121, 126, 151, 165  
**Dry spells** 29, 40, 44-45, 57, 145  

**Elastomer** 207  
**Elongated leaves** 74, 85, 135-136, 138  
**Environment** 1, 5, 31, 122, 139, 207-210
Erosion 5-9,16,26-27,30-32,34,86,126-127,139,142-143,148,208-210
Estate RRI collaborative clone trials 49
Ethrel 191-193,195
Ethylene 191
Fasciation 135,138
Fasciated shoots 135-136
Fertilizer mixture 59,72,156,161-164,172
Field establishment 71,86
Fire damage 121-122,129
Fissures 135-137
Flooding 15,121,126-127,160
Forastero 149
Forest 157,160,208-210
conservation 207,209
ecosystems 209
Frequency of application 156,165,169
Fungicidal wound dressing 105,125
Fusarium wilt 98,110
Fusarium solani 110,113
Fusicoccum 132
Fusicoccum leaf blight 130,132
G/t/t 53,185,186,191,193,202
Galls 135-136
Genetic diversity 48
Genetic yellowing 135,137-138
Genus 15,54,131,147
Gliricidia 35,151
Glyphosate 35
Graft union 62,90,94,184
Grooming 198,204
Harvesting 32,54,61-63,65,141,181,184,186
Hedges 8,11
Hevea 3-4,12-13,15,17-18,21,33,46,54,75,130-133,157-158,169,176-178,181,183,193
benthamiana 54
brasiliensis 1,15,46,54,98,177,179,207
camporurum 54
microphylla 54
nitida 54
pauciflora 54
guianensis 54
spruceana 54
rigidifolia 54
Hybridisation 46,53
Infection of seedlings 56
Injuries 98,121-122,129,184
Insect control 115
Insects 102,114-116,119,123
Intercrop 139-143,146,149-153,210
arecanut 152
banana 35,140-144,146,149,154
cinnamon 148,151,155
cocoa 139-140,148-149,152
coffee 140,148-149,152
maize 139,146,154
passion fruit 35,140,143,145
pepper 148,151-153
pineapple 35,140-145,153-154
tea 139,141,148,150-151,155,208-209
vanilla 147
Intercropping 26,34-35,139-143,146-148,150-155,208
Inter-monsoon 41,43,44
IRRDB 193
Juvenile 63,65,75,85
Kinked stem 135-136,138
Land preparation 1,6-7,54,57,86,145
Lateral drains 9
biosynthesis 180-181,191
flow 176,180,191
vessel plugging 176-180,183-185,191
Latex-timber clones 47,49,51,53,74
Layout 54,56,59
axils 61,91
diseases 3,51-52,58,73,97-103,111,116-117,120,122,124-125,127,130-134,136-137,169,171-172
folding 86,91,95
litter 35,122,209
whorls 55,60,72,81,91
Lining 86-87,93
Litter fall 27,29,35,208-210
Loams 4,149
Location 14,40,51,54,59,142
LSCT 50
Macro nutrients 21,156,158
Main drains 8-9,11
Market crashes 140
Mature clearings 57,59,106,108
Meristematic 136
Microcyclus ulei 131
Micro nutrients 12,21,156,158
Mist chamber 74
Mites 114,116-117,120,135-136
Moisture retention 2,26-27,30-33,198,209
Monkey grubber 86,93
Monoculture 139,208
Monsoons 2,7,41,43,71,73,87-88,100,102-103,104,107,125-126,198-199
Murate of potash 161
Natural rubber 47-48,134,207-208,210
Nematodes 114,117
Nodules 120,135-136
Non-polluting source 207
Nursery fertilizer
Nutrient 5-8,12-13,17,19-21,26-28,30-33,117,140-142,156-165,168,170,172-173,192,209

Oidium leaf disease 3,51,97-99,102
Oidium heveae 98,111
Organic manure 144-145,147,156,162
base 194
diseases 2,97-98,103-104,112,198-199
height 194
virgin 191
Parasitic fungi 115,128
Particle size distribution 16-17,21
Pests 28,33,98,114,116,118-120,140,142,147,149
Petiole 62,98,100,102,111,115,131-132,134
Phyllachora huberi 133
Physiography 1
Phytophthora capsici 132
leaf fall 3,51-52,97-99,102,111
leaf wither 130,132
meadii 102-103
palmivora 102-103
Pink disease 51,97,104
Plugging 176,180,191
Pollarding 61,65,70,74,82,105,125
Polythene bags 44,54-56,58-59,64,66-68-73,77,80,86,88-92,94,100-101,108,124,149,156,163-164,166
Porosity 12,16,18,209
Powdery mildew 97-98,111
Pruning 60-62,71-72,74,79,89-90,149
Public vigilance 130,133
Quartzitic soils 124
Rainfall 40-41,43,47,51,88,142,149,167,198-199,201,208-209
Rainguards 44,141,192,198-202,205-206
apron 198,200-202,205
gutter 198,200-202,206
Rainy days 40,43-44,59,88,90,99-100,102-104,126,141,150,192
Replanting 21,33,59,65,86-87,92,107-109,140,157-158,170,209
Rhizogenesis 75
Rigidoporus lignosus 106
Rigidoporus microporus 28,106,112
Rock phosphate 30,33,59,88,161-164,166-167,169-170,
Rodent 114,118-119
diseases 28,57,86-87,97-98,105-110,113,125,127
Rubber industry 46-48,75
Run off 8
Sand 5,7,14-17,56,103,126,144,160,171
Scales 48-49,53,115
Scorched tissue, 122,123,125
Sealant 198,205-206
ingredient 198,202
solid 200-203,206
liquid 200,202-203,205
Seasonal variation 7,40-41,43
Secondary leaf fall 3,98
Seed 26,28-29,32,34,46,54-59,66,73,98,136,149,162,164
Silt 16-17,126,159,166
Silt pits 9
Site selection 54,57,59
Smallholder RRI collaborative clone trials 50
Soil 1-2,4,6,8,16,19-21,26-28,30,39,54,56-
57,59,68,70,72,88-90,103,106-108,110,
115-116,124,126,128,140-141,144-149,
151,156-172,174,208-209
colour 12,19
conservation 1,6-7,9,11,26-27,35,57,
139,207-210
erosion 27,30-32,86,143,208
fertility 12,15,17,27,162,209-210
loss 8,32,209
magnesium 5,12,20,156-159,165,171-
172,174-175
moisture 2-8,33,40,44,87,167,209
nitrogen 5,20,156-
158,161,167,170,172,175
organic matter content 6-7,12,19,21,26-
27,31,147,149,151,159,162,209
pH 4-5,12,19,21,142-144,148,159
phosphorous 12,20,156-158,161,171
potassium 5,12,20,156-161,166,169,
171-172,175
series 12,14-22,24-25,156,159-162,165
type 1-2,4,16-17
South American Leaf blight 51-52,130,133-
134
Sprouting 62,71-74,90
Stem and branch diseases 97-98,101-102,
104-106,112,123-127
Stimulation 180
mode of action 191,193
notation 194-195
renewed bark 191-192,197
virgin bark 191-193
Stock shoots 62,80,90
Storage capacity 18,31
Sulphate of ammonia 161-166,169,172
Sun-scorch 124
Synthetic rubber 207
Tapping 32,33,44,46,51-53,103-105,118,
135-137,140-141,160,164-168,176,180-
182,184,186,189-191,198-199,201-202
commencement 46,176,181,183-184
days 44
depth 176,181,184
direction 176,181,183,194
frequency 185,191-193,195
height 176,179,183-184,189,194
intensified 176,186,191,195-196
latex 2,176-186,191-192
marking 176,183-184,189-190
notation 191,193-195
pane 90,104,112,124,136-137,176-
177,187,191-195,197,199-201
recovery 187,195,199
rotation 199
slope 176,183
systems 176,180-181,183-187,191,193,
195-196
time 176,185
tissue 176-177,180,184
system 176,180-181,183-187,195-196
Tapping Panel Dryness (TPD) 46.51-52,135.
137,177,185-186
Tar spot disease 130,133
Target leaf spot 130-131
Temperature 1-4,99,102-103,142,147,149.
209
Terraces 2,6,8-11,142
Texture 12-17,72,142,159-160
Timber 21,47,49,52,74,141,152,157,208,210
Thanatephorus cucumeris 130,132
Tree architecture 86
Ustulina deusta 105,125,128
Ustulina stem rot 97,105
Vessels (distribution) 114,176-180,183-185
Vetiver grass 8
Viruses 136
Washouts 198
Waterlogging 15,56-57,121,126-127,160
Waterproof panel dressing 62,73-74,104.
124-125,136
Water holding capacity 12,18,162
Wax 63-64,67,71,115
Weeding 7,26,30,34,36-39,57-58,72,128,144
White root disease 28,86-87,97,105-106,108-
110,125
Wickham genetic base 46
Wilting 18,118,121,126
Wind 1-3,7-8,17,46-47,52,74,98-99,102,104-
105,108-109,121,125,128,137,142-143,
199,208
Wounding 137,176,181
Xylaria thwaitesi 109,113
Yield 2,12,16-17,21,33,35,44,46-47,51-55,
68,74,87,90,99,102,126,131-132,137,
139-141,143,146-149,152,157,160.
168,176,180-181,183-187,191-192,199,
202,207,210
Young budding 54,56,58-60,68,70-73,81,
89,92,136,156,163-164