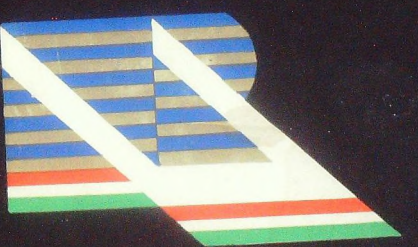
HAND BOOK OF NATURAL RUBBER PRODUCTION IN INDIA



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HANDBOOK OF NATURAL RUBBER PRODUCTION IN INDIA

Published in Commemoration of the Silver Jubilee of the Rubber Research Institute of India

The Rubber Research Institute of India
Rubber Board, Kottayam 686 009
1980

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First published November 1980

Printed at
St. Joseph's Press, Trivandrum 695014

Blocks:
San Jose Process, Trivandrum 695014

Transparencies and Photographs:
KP Sreeranganathan

Cover:
S Rajendran

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FOREWORD

Rubber was known to the civilized world for a few centuries as 'India rubber.' The plantation rubber, as we know it now, has been introduced from Brazil through Kew Gardens, London, by the efforts of the British Colonial Government. As mentioned elsewhere in this book, the expenses for procuring the seeds were met in full by the then Government of India (India Office). However, for various reasons, the rubber plantations developed faster as a major industry in Malaya (Malaysia) and the East Indies (Indonesia) than in the country for which the seeds were originally procured from Brazil.

In the wake of independence, the industry prospered in the developing countries like Malaysia, Indonesia, Sri Lanka and India under the patronage of National Governments, and the exploitation perpetrated by the colonial administration was made to readjust to the realities. Today, natural rubber is produced not by the sweat of indentured labour but by the citizens of independent nations partaking in the noble endeavour of nation-building. The industry, in due course, reached a stage of stability and status necessary to meet the needs of consumers and bargain with them on equal terms. This has paved the way for an international agreement on price stabilisation, a unique development which augurs well for the other commodities traded in the international market.

India is one among the few rubber growing countries in the world where natural and synthetic rubber industries as well as consuming and producing interests co-exist and actively participate in the building up of the national economy even though they have their own conflicting interests. The rubber plantation industry in India also enjoys the distinction of having the highest rate of growth in comparison to other rubber growing countries of the world.

There is an ever-increasing global demand for rubber, a versatile and strategic raw material. The production of synthetic rubber is not only costly, but also dependent on non-renewable, fast-depleting, and undependable resources. The *Hevea* tree, however, utilises solar energy, an abundant, permanent and free resource for the production of natural rubber, and in the process confers several benefits on the environment. Therefore, every effort made to promote natural rubber production is commendable and worthwhile.

Rubber plantations exert a profound influence on the economic and social life of the people in the regions where they have been developed. In India, rubber has been traditionally grown in the hinterlands of south west coast, predominantly in Kerala State. For the 25 million people of Kerala, the rubber plantations, now spread over 225000 hectares in the State, are of vital importance. This is also the case with the adjoining Kanyakumari District of Tamil Nadu and South Canara District of Karnataka. A well conceived and ambitious development programme is now afoot for both modernisation of the existing plantations and expansion of rubber cultivation to non-traditional areas. In the bid to expand production, rubber is now being successfully grown in India even in the sub-tropical areas lying beyond the Tropic of Cancer. Bangladesh and the Peoples' Republic of China are the other countries which are at the threshold of developing rubber plantations in regions hitherto considered as inhospitable for the crop. All these call for application of modern production technology, evolved through years of scientific research, and mounting of massive communication and extension activities.

Even though considerable research work on all aspects of rubber cultivation and processing has been carried out by various research organisations the world over, the results are not available in a condensed form in one publication. There is also demand for comprehensive information on natural rubber cultivation and its processing from prospective entrepreneurs, research scholars and students. I trust and hope that this Handbook will be of great use in meeting these requirements. It is befitting that such a comprehensive book is published in commemoration of the Silver Jubilee of the Rubber Research Institute of India.

The editorial staff has done commendable work in bringing out this book against several odds. The authors of individual chapters deserve special congratulations for carefully drawing up and presenting their material. I am sure that this book will be of immense use to growers, extension workers, research scholars, entrepreneurs, and students and that it will go a long way in the modernisation of the rubber plantation industry in India.

Kottayam
14 November 1980

SG Sundaram
Chairman
Rubber Board

PREFACE

Natural rubber was introduced into India only about a century ago. But the growth of the rubber plantation industry has been phenomenal. The role of scientific agriculture in achieving this notable progress is very significant. There is, however, vast scope for further growth and improvement of the crop. This is evident from the wide gap now existing between the productivity already achieved and the theoretical maximum estimated. For bridging this gap, expeditious transfer of technology from research centres to plantations is most essential. During the last few decades, innumerable innovations in the production and processing technologies of natural rubber have taken place in various research centres the world over. It is often difficult for individuals to locate and gather such information. In this 'Handbook of Natural Rubber Production in India' an attempt has been made to collate and present all such relevant information along with basic aspects of rubber cultivation and processing. This book begins with the history of rubber plantation industry in India and ends with the statistics on rubber. In the intervening chapters, botanical and agronomical aspects of rubber cultivation, latex biosynthesis, exploitation techniques, diseases, pests and their control and processing of the crop into different marketable forms are discussed and information on management, by-products and ancillary activities in rubber plantations, legislations covering the labour, and the Rubber Board and its activities are also included. These chapters are written by authors who are engaged in research work in the subject dealt with or by persons who are intimately connected with the topics concerned. In the preparation of the book, information have been lavishly drawn from published work of our colleagues in sister institutions in this country and abroad. An earnest attempt has been made to cover almost all aspects of rubber cultivation, processing and related topics. However, this book is not claimed to be an exhaustive treatise on the subject.

The publication of this handbook has been made possible by the kind permission granted by the Government of India in the Ministry of Commerce. The guidance and encouragement given by Shri SG Sundaram, IAS, Chairman, Rubber Board at various stages in the preparation of this book are gratefully acknowledged. The efforts made by Shri P Mukundan Menon, Rubber Production Commissioner, Rubber Board, in critically going through the entire manuscript

and giving useful suggestions for its improvement are worthy of record. Shri CM George, Project Officer, Rubber Board also went through the manuscript and effected improvement in the contents of the book. The untiring efforts put in by Shri PN Radhakrishna Pillay, Shri EV Thomas, Dr S Narayanan Potty, Dr MR Sethuraj and Dr AON Panikkar, Deputy Directors, Dr MV Pushpadas, Soil Chemist and Shri VKG Nair, Documentation Officer made it possible to bring out this book on time. Thanks are due to Shri TNV Namboodiri, Assistant Secretary for making improvements in the manuscript. The hard work put in by the authors of different chapters in completing the manuscript in a very short time is most commendable. The assistance rendered by other officers and staff of the Institute in the publication of this handbook is recorded with appreciation.

Shri VT Sivasankaran Nair, Group Manager, Cochin Malabar Estates and Industries Ltd, and Shri K Haridas, Visiting Agent, the Plantation Corporation of Kerala Ltd went through the manuscript of this book and gave us the benefit of their vast practical experience in greatly improving the utility of this book to the planters.

Our thanks are due to the management and staff of both St. Joseph's Press and San Jose Process, Trivandrum for their whole-hearted co-operation in producing this book within a very short time.

With these observations, this book is presented to the readers with the request that mistakes, if any, may be brought to our notice. Suggestions for improvement are also solicited, so that future editions of this book could be made more comprehensive and useful.

VK Bhaskaran Nair
Director
Rubber Research Institute of India

LIST OF ABBREVIATIONS

ADS	..	Air dried sheet(s)
am	..	Ante meridiem
°C	..	Degree(s) Celcius, Centigrade
cm	..	Centimetre(s)
cm^3	..	Cubic centimetre(s)
CV	..	Constant viscosity
DPNR	..	Deproteinised natural rubber
drc	..	Dry rubber content
eg	..	For example
etc	..	Et cetera (⇒ and the rest)
Fig	..	Figure(s)
ft	..	Foot, feet
ft^3	..	Cubic foot (feet)
g	..	Gram(s)
gal	..	Gallon(s)
h	..	Hour(s)
HA	..	High ammonia
ha	..	Hectare(s)
hp	..	Horse power
ie	..	That is
ISI	..	Indian Standards Institution
ISO	..	International Standards Organisation
kg	..	Kilogram(s)
km	..	Kilometre(s)
kw	..	Kilowatt(s)
l	..	Litre(s)
LA	..	Low ammonia
lb	..	Pound
log	..	Logarithm
LV	..	Low viscosity
m	..	Metre(s)
m^3	..	Cubic metre(s)
MA	..	Medium ammonia
Max	..	Maximum

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hp	..	Horse power
ie	..	That is
ISI	..	Indian Standards Institution
ISO	..	International Standards Organisation
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km	..	Kilometre(s)
kw	..	Kilowatt(s)
l	..	Litre(s)
LA	..	Low ammonia
lb	..	Pound
log	..	Logarithm
LV	..	Low viscosity
m	..	Metre(s)
m^3	..	Cubic metre(s)
MA	..	Medium ammonia
Max	..	Maximum

Min	..	Minimum
min	..	Minute(s)
ml	..	Millilitre(s)
mm	..	Millimetre(s)
NR	..	Natural rubber
phr	..	Parts per hundred rubber
PLC	..	Pale latex crepe
pm	..	Post meridiem
pp	..	Polypropylene
ppm	..	Parts per million
PRI	..	Plasticity retention Index
RRIC	..	Rubber Research Institute of Ceylon
RRII	..	Rubber Research Institute of India
RRIM	..	Rubber Research Institute of Malaysia (Malaya)
rpm	..	Revolutions per minute
RSS	..	Ribbed smoked sheet(s)
Sec	..	Second(s)
sp	..	Species (singular)
spp	..	Species (plural)
SR	..	Synthetic rubber
t	..	Tonne(s)
ts	..	Total solids
TPNR	..	Thermoplastic natural rubber
TSR	..	Technically specified rubber
VGC	..	Viscosity gravity constant
viz	..	Namely
vol	..	Volume
<	..	Less than
>	..	More than
/	..	Per
%	..	Per cent

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1 HISTORY OF THE RUBBER PLANTATION INDUSTRY IN INDIA

Chapter 1

HISTORY OF THE RUBBER PLANTATION INDUSTRY IN INDIA

Natural rubber is nature's most versatile vegetable product. This material has multifarious uses and there is hardly any segment of life which does not make use of rubber based materials. It is also a vital raw material having immense strategic importance. During the 19th century, several epoch-making discoveries were made in the processing, compounding and use of natural rubber which resulted in tremendous increase in the demand for this product. The future of natural rubber will also be bright in view of its special qualities and its competitiveness with synthetic rubber, the production of which is dependent on the high-priced and non-renewable petroleum resources.

1.1 Discovery of rubber producing plants

Christopher Columbus is believed to have first found rubber in tropical South America. On return from his second voyage, 1493–1496, he brought a few balls made out of the gum of a tree and used by the inhabitants of Haiti for playing games. There is also documentary evidence that in 1615 the Spanish troops in Mexico wore rubber-coated clothes to guard themselves from rain.

Guayule shrub was probably the first known source of rubber which was discovered in North America. *Castilla* tree from which rubber or *ule* was obtained and made into play-balls at Mexico was found to be the next one. Charles de la Condamine, a Frenchman, first described *Hevea brasiliensis* tree in 1751 as the source of rubber. He found it in the Amazon forests in 1736 during his visit to South America as a member of the party sent by the Academie des Sciences

on scientific expedition. Condamine explained the crude methods adopted by the natives for extracting a milky fluid by cutting the bark off the trees and in using the fluid for coating fabric, making shoes and moulding waterproof containers.

In India, rubber had been in use from time immemorial. In 1810, Roxburgh found that rubber was derived from *Ficus elastica* grown in Assam and he described that in his 'Flora Indica.' A rubber-yielding vine, *Urceola elastica*, was discovered in the Straits Settlements by Howison in 1798. An inferior quality rubber was obtained from *Landolphia* vine in the West Coast of Africa. Though rubber was thus obtained from a variety of plants, only *Hevea brasiliensis* was found to be the most suitable.

1.2 Early developments in technology and use of rubber

The name 'rubber' is derived from the quality of the material in rubbing black lead pencil marks out of paper. Joseph Priestly, the British chemist, is said to have used rubber for this purpose in 1770. And in 1772, small rubber cubes were being sold in London and Paris as erasers. Though Samuel Peal could patent a process in 1791 for preparing waterproof gummed fabrics, it was made a commercial proposition only in 1823 by Charles Macintosh. Thomas Hancock made many remarkable observations and inventions from 1819 which established a real base for the rubber industry. It was he who performed for the first time the operation known as 'rubber compounding'. The 'masticator' fabricated by Hancock and the mixing mill and calender developed by Chaffee in 1836 are landmarks in the history of rubber industry. Charles Goodyear spent his whole life and money on improving the properties of rubber. His work and repeated failures from 1831 finally made him succeed in discovering 'vulcanisation' in 1839 and this laid the foundation upon which the rubber industry is built. The process was patented by him in 1841. Hancock improved upon the process and he also took out a patent for vulcanisation in 1843. The first pneumatic tyre was invented in 1845 by a Scotsman called Thomson but this was not taken seriously for about half a century. It was JB Dunlop, a veterinary surgeon of Belfast, who 'reinvented' pneumatic tyre and he patented it in 1888. The invention of pneumatic tyre was a milestone in the history of rubber

industry as the tyre sector today is the biggest consumer of rubber.

Even before the versatility of rubber was known and rubber was commercially exploited for the manufacture of various products, it was in use in some form or the other wherever available. Ancient philosophers and alchemists are believed to have understood the primary properties of this material. Its application for waterproofing purpose is known since 1615. It is stated that the king of Portugal was presented with a rubber suit by the Government of Para in 1759. Roxburgh was able to trace the rubber-yielding *Ficus elastica* in Assam in 1810 from the latex coating he found on the inner lining of a pot of honey presented to him. And it was obvious that rubber had been in use there for centuries. In the 1820's Britain, Brazil and France were manufacturing a number of rubber based products. The credit goes to Chaffee and Hoskins for having started the first American rubber factory in 1832 and it produced waterproof garments, boots and shoes. Goodrich started his programme of manufacturing rubber goods in 1870 at Akron, and this place turned out to be the leading rubber manufacturing centre in the world. The continuous developments in the technology have helped a great deal in the commercial production of a large variety of rubber goods. And the two world wars recognised the importance of this vital and strategic raw material. All these have contributed to a great extent to the demand for rubber and this marks the beginning and growth of the rubber plantation industry.

1.3 Initial attempts to plant rubber

Though rubber from various sources was available for centuries, the wild trees of *Hevea brasiliensis* in the South American forests have been the principal source of the world's supply of natural rubber in the early years. Since this was not sufficient to meet the increasing demand, it became an urgent necessity to increase the production by extending rubber cultivation to the Eastern hemisphere. The first suggestion to introduce rubber to this part was made by Thomas Hancock in 1857. But it was not until 1872 that anything was done in this matter. In that year, at the request of Sir Clements Markham of India Office, London, a report of the possibility of growing rubber

in the East was submitted to him by James Collins, an Edinburgh Botanist. In 1873, James Collins supplied 2000 seeds of *Hevea brasiliensis* to the Botanical Gardens, Kew, England, through Farris. Of these, only a dozen germinated and six of the plants were brought to Calcutta and planted in the Botanical Garden in 1873 itself. What happened to these seedlings is not known. Later, Robert Cross was commissioned to collect *Hevea* plants and he brought 1000 seedlings to Kew Gardens in 1876. Of these, only less than 3 per cent could be saved. From this consignment, a few plants were sent to Ceylon (now Sri Lanka), which failed to survive.

1.4 Introduction of rubber to the Far East

Meanwhile, Sir Joseph Hooker, an eminent taxonomist of Kew Gardens, England, became interested in para rubber by the drawings and specimens sent to him by Henry Wickham (later Sir Henry Wickham). Sir Joseph Hooker persuaded Sir Clements Markham to obtain more seeds. Accordingly, Wickham was entrusted with the task of procuring *Hevea* seeds from Brazil. News came to Wickham that a new liner SS *Amazonas* was going to be inaugurated between Liverpool and Amazon. On arrival at the upper Amazon, the vessel was abandoned by the crew without any return cargo. Wickham then wrote to the skipper chartering the ship for transporting *Hevea* seeds to Kew Gardens. Henry Wickham, rightly considered the father of the rubber plantation industry in the Far East, collected and delivered to Kew Gardens about 70000 *Hevea* seeds in June 1876. The report of Dr. Trimen of the New Products Commission, Ceylon, 1881, is worth quoting here: "I am desirous of taking this opportunity of putting upon record something of the history of the introduction of the valuable para rubber into the East which has been effected at a large cost and with much trouble. The cost of procuring the seeds of para rubber, freight, and other expenses, appears to have been no less than £1595 4s. 2d., and the gardener and his passage £163. The whole of this large expenditure was borne by the Indian. Government." However, only three to four per cent of the above consignment of seeds germinated. During the same year, 2000 young seedlings were sent to the Far East from Kew Gardens. Most of these seedlings were sent to Ceylon and a few to Malaya

(now Malaysia). In both the places, this plant thrived beyond all expectations, and thus the foundation of the rubber plantation industry in the Far East was laid firmly. From available records, it is seen that rubber planting material was brought to India in 1878 from Ceylon. Since rubber is a perennial tree, it was thought that it could be raised as a forest crop. The first attempt to plant rubber was therefore made in the teak plantations of Nilambur valley which is now a part of Kerala State. In 1879 twentyeight *Hevea* plants were received from Ceylon, and planted at Nilambur. Small consignments of *Hevea* planting materials were also received in India during 1880 and 1881. All these were planted on an experimental scale in different parts of South India and the Andaman Islands. In 1881, rubber was planted in the Government Botanical Gardens at Burliar in the Nilgiris. In 1886, some more planting materials were brought from Ceylon which were planted in Kozhikode and Poonoor, both now parts of Kerala.

1.5 Early commercial plantations in India

The first commercial plantation of rubber, however, was started by European planters who formed the 'Periyar Syndicate' in 1902 at Thattakad near Alwaye in the erstwhile Travancore State for the purpose. In 1904, further developments took place, particularly in Central Travancore. In that year, planting of rubber was started in 'Yendayar', 'Eldorado' and 'Mundakayam' estates. The Governments of Travancore, Cochin, Madras and Mysore encouraged rubber cultivation by granting land, and the next six years saw considerable activity in *Hevea* planting. Between 1905 and 1907 KE Nicoll and EG Windle planted over 1100 acres (445 ha) at Palapilly and Pudukad with rubber on the forest land obtained as grant from the Govern-ment. By 1910, Mundakayam had become the leading centre of rubber plantations in India, with an area of about 4000 ha. This was about 40 per cent of the then existing rubber area in India. Some enterprising planters took the initiative to plant rubber in Goa by 1906. But the plantations in Goa did not make headway in later years. The United Planters' Association of Southern India (UPASI) evinced keen interest in rubber cultivation and carried out research on various aspects which helped in further development of commercial plantations. The 'Malayala Manorama,' a leading Malayalam news

journal, also played an important role in encouraging rubber plantations in India. Between 1905 and 1910, the paper emphasised the need for planting rubber and succeeded in arousing considerable public interest. The first local joint stock company to plant rubber was floated in 1910 under the name 'Malankara Rubber and Produce Company Ltd.' About that time, individual local farmers also began to enter the field of rubber cultivation. The developments in Travancore had a salutary effect on the development of plantations in the neighbouring state of Cochin also where the 'Vaniambara Rubber Company' was started in 1911.

1.6 International Rubber Regulation Agreement

Considerable improvement in planted area and production took place in the country between 1925 and 1928. The most important aspect of growth during the period was the increase in the area under smallholdings. The increase was about 200 per cent over that of 1925. But the price of rubber came down very low in the international market. Since almost all the rubber produced was exported at that time, this fall in price caused great hardships to planters. To tide over the difficulties, the International Rubber Regulation Agreement was brought into force in 1934. This Agreement was the first comprehensive and compulsory scheme adopted for the control of rubber supplies in the world. It was a treaty between Governments, and India was a signatory to it. By the Agreement, quotas were fixed to each participating country based on average annual exports from 1929 to 1932. In order to prevent further expansion of production capacity, new planting was prohibited and replanting was strictly limited under the Agreement. For experimental purpose, each country was allowed to plant only a very limited area. Under article 3 of the Agreement, local committees were to be appointed for the enforcement of the regulations. Accordingly, a local committee was appointed in India, under the Indian Rubber Control Act, 1934. The legislation was brought into force by the Government of India to enable the country to implement the provisions of the International Rubber Regulation Agreement. The committee which consisted of the representatives of Travancore, Cochin, Madras and Mysore Governments was called the Indian Rubber Licensing Committee. It had its headquarters at Kottayam in

Travancore. The first meeting of the Committee was held on 28 May 1934. The International Rubber Regulation Agreement originally provided for a duration of control from 1 June 1934 to the end of 1938. It was renewed in 1937, with only minor modifications of its provisions, for a five year period ending 1943. The agreement was extended for a few months to facilitate the post-war establishment of a non-regulatory organisation covering major producers and consumers of rubber. However, on 30 April 1944, the Agreement was finally terminated. The International Rubber Regulation Scheme was in operation in India only from 1934 to 1942.

1.7 Rubber Production Board

During the first eight years of its existence, the Indian Rubber Licensing Committee was mainly concerned with restriction of export of raw rubber. By 1942, the situation in India had changed drastically. The occupation of Malaya and other major rubber producing countries in South East Asia by Japan left the Allied Nations with only India and Ceylon as the sources of supply of rubber. As a result, the Government of India decided to requisition all rubber produced in the country. The Government set up a Rubber Purchase Office at Cochin and fixed statutory prices for rubber under the Defence of India Rules in 1942, and under these Rules, the Indian Rubber Control and Production order was promulgated. The Governments of Travancore, Cochin and Mysore also issued separate notifications in conformity with the Government of India notification. With the notifications, the name of the licensing committee was changed into Rubber Production Board. The first meeting of the Rubber Production Board was held on 7 December 1942. All restrictions imposed on new planting and replanting by the International Rubber Regulation Agreement were removed. The rubber growers were encouraged to maximise production by intensive tapping, slaughter-tapping and new planting. Because of the encouragements, the area under rubber increased considerably during the period from 1943–1946.

1.8 The Rubber Board

On 30 September 1946, the Rubber Control and Production Order expired. The Indian Rubber Production Board, constituted

under its provisions, would have normally ceased to exist within six months of the termination of the Order. The Government of India, however, convened a conference of rubber producing interests in December 1945 to examine the necessity of creating a suitable organisation to look after the interests of the rubber industry on the abolition of the Board. An *ad hoc* Committee was appointed to examine the question, which recommended the creation of a Board having preponderant representation of producers. The recommendation was accepted and the Central Government passed the Rubber (Production & Marketing) Act, 1947 which came into force from 19 April 1947. Under this Act, the Indian Rubber Board was constituted in the same year. In the Rubber (Production & Marketing) Amendment Act of 1954, the name Indian Rubber Board was changed to Rubber Board.

1.9 Later developments

When ceiling on ownership of landed assets was imposed by land reform legislations, plantation crops like rubber, coffee, tea and cardamom were exempted from the ceiling, in view of their strategic importance or export potential. This encouraged many land owners to switch over to cultivation of plantation crops like rubber. A sizable part of the arable land in South India, particularly in Kerala, with agroclimatic conditions suitable for growing rubber was thus brought under rubber plantations. The agrarian reforms together with the research, extension and advisory activities of the Rubber Board as well as the various forms of incentives and assistance offered by the Board, and above all, the hard working and enterprising nature of the people and their eagerness to adopt scientific methods of cultivation, all have contributed in a great measure to the systematic development of the rubber plantation industry in India.

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2 RUBBER YIELDING PLANTS OTHER THAN HEVEA BRASILIENSIS

Chapter 2

RUBBER YIELDING PLANTS OTHER THAN *HEVEA BRASILIENSIS*

Natural rubber is obtained from the latex of various plants. Latex is present in 12500 species belonging to 900 genera, predominently distributed over twenty families. Latex of only about 2000 of these species contains rubber as a constituent. The rubber content in latex varies considerably in different species and in many species difficulties are involved in collecting latex. Therefore, only a very few of these plants have been exploited commercially. Among these, *Hevea brasiliensis* is the most important species which supplies the natural rubber of commerce today. Of the other rubber yielding plants, mention may be made about *Parthenium argentatum, Castilla elastica, Manihot glaziovii, Ficus elastica, Cryptostegia grandiflora, Taraxacum kok-saghyz* and *Funtumia elastica.*

2.1 Parthenium argentatum

This plant known as guayule (pronounced wy-oo-lee) or Mexican rubber is a native of North Central Mexico and Southern Texas, with subtropical temperate climate, where rainfall is low and erratic. Guayule provided about 10 per cent of the world's natural rubber in 1910 and continued to be a minor source of commercial natural rubber for over four decades. This plant is again receiving considerable attention as a source of natural rubber in countries like Mexico and USA where cultivation of *Hevea* is not possible. It can withstand a temperature range of – 18° to 49°C. Though heat does not appear to affect this desert adapted plant, low temperatures decrease the growth rate. In nature, it grows in a wide variety of shallow, stony, calcareous and friable soils. Guayule grows best in well drained soils with an annual rainfall of 230–400 mm.

Parthenium argentatum is a member of the sunflower family (Compositae). This is a bushy shrub, attaining about 60 cm height (Fig 2.1). The plants develop a deep tap root with extensive lateral roots that spread up to 3 m. Stem is branched. Leaf is narrow, alternately arranged and wax coated. It is grey green in colour with a characteristic silvery sheen which gives the species its name. Flowers are arranged in heads, borne on long stalks. Pollination is by wind and insects. The plant is a prolific seeder and seeds are tiny. Guayule is propagated by seedlings raised in nurseries. Vegetative propagation through grafts and cuttings can also be successful. Rubber is contained in single, thin walled cells in most parts of the plant except leaves. Such cells are most concentrated in the cortical region and medullary rays. The rubber particles are suspended in the cell sap. Two thirds of the rubber is contained in stem and branches, and roots contain the rest.

Usually in its native habitat, rubber forms about 10 per cent of the total dry weight of the plant. However, the species shows wide genetic variability even in the natural populations. Some of the wild strains are reported to contain as high as 26 per cent rubber. The usual cultivated strains have about 20 per cent rubber after four years' growth. The plant produces little rubber when it grows actively (1). It synthesises more rubber when subjected to environmental stress like cold weather and reduced moisture availability. As the rubber-containing cells are not interconnected, the plants cannot be tapped. Harvesting is by mechanical means. The entire plant with the root system is harvested or the stand is lopped at a height of 5 cm above the ground level. The rubber is usually extracted by mechano-chemical means. The first step is dipping the cut shrubs in hot water of about 75°C for approximately 10 min, which coagulates the rubber in the cells thereby decreasing deterioration during processing and simplifying separation. This process also removes soil and leaves, thus reducing the bulk of the matter to be handled subsequently and improving the quality of the final product. The shrub is then hammer milled and pulped, caustic soda being added during the process. During pulping, rubber and resins agglomerate into a spongy substance known as the guayule worms. The worms and the bagasse are separated in a large slurry tank. The worms which float are skimmed, stirred in a second tank and again skimmed for further

separation. The worms are rinsed in water to remove caustic soda and warmed in water containing a little surfactant. The worms contain about 17–25 per cent of resins which are removed by acetone treatment. The residual acetone is removed by steam sparging and the rubber, which still contains about two per cent of resins and small quantities of debris, is dried with hot air. Further purification can be done by solvent methods to give a product of uniform quality. Guayule cultivation requires a lot of petrochemical energy for mechanised operations and its productivity is low. The rubber is inferior to *Hevea* rubber in several respects.

2.2 Castilla elastica

Belonging to the family Moraceae, this was once used as a source of natural rubber, known as Castilla or Panama rubber(2). The tree is distributed in Mexico, Bolivia and Brazil. It is large, attaining a height of 20 m or more with stout trunk (Fig 2.2). The tap root is rather short with several very long lateral roots spreading horizontally close to the surface. Bark is relatively smooth and difficult to tap. The trees are tapped when eight to ten years of age with a very sharp machete or knife, making deep cuts up to the wood. The latex vessels are elongated single cells and are found in the bark of roots, trunk and branches. They occur in leaves, fruits and pith also. Only the latex vessels of the bark of the trunk are important for extraction of the latex. The latex is relatively stable and its regeneration is slow. The regenerated bark forms thick callus tissues and it is more difficult to tap. Tapping is therefore confined usually to the virgin bark.

2.3 Manihot glaziovii

Ceara rubber is obtained from *Manihot glaziovii* of the family Euphorbiaceae. The plant is a native of South America and it grows well in dry rocky areas. The tree is of medium height, often attaining 9 m (Fig 2.3). Bark is thin, scaly and glossy. Latex vessels are of the articulated type as in *Hevea* and latex could be collected either by the tapping or pricking method. In the latter, after mild scraping, pricks are made through the bark with a pricker such as a roller with numerous needles. Latex oozing out of the incisions coagulates spontaneously and the dried rubber is collected after a few days.

2.4 Ficus elastica

This plant, known as India or Assam or Rambong rubber tree, was one of the earliest sources of natural rubber in tropical Asia. The tree belongs to the family Moraceae and it is a native of Asia. It grows well under hot climatic conditions with heavy rainfall. The tree is very large and spreading with numerous, huge buttress roots. Under natural conditions, it starts life as an epiphyte. Propagation by cutting is successful and the tree requires 12–15 years for tapping. Stem and buttresses are tapped. The crude rubber is usually collected as scrap, cleaned and dried.

2.5 Cryptostegia

C. grandiflora and *C. madagascariensis*, known as rubber vine, are ornamental woody climbers belonging to the family Asclepiadaceae. Though native to Madagascar, the species are now found in the tropics and subtropics. *C. grandiflora* (Fig 2.4) is commonly found in India. It is adapted to wide variations in soil and climate and it grows well from arid desert to humid tropics. The climber puts forth long, whip-like branches. Leaves are entire, glossy and opposite. Flowers are large, showy, bell shaped and purplish in colour. Leaves of *C. madagascariensis* are thicker, smaller and more glossy. Flowers are smaller with deeper colour. Hybrids of these species are also recognised. Latex vessles are of the non-articulated, branched type and they occur in bark, pith and leaves. The common method of exploitation is tip bleeding. The tender shoots are tied together, and the tips are chopped. The exuding latex, which coagulates and dries on the cut ends, is collected.

2.6 Taraxacum kok-saghyz

The Russian dandelion, *Taraxacum kok-saghyz* of the family Compositae is the source of dandelion rubber and is a native of Asia. It is a perennial herb adapted to severe winter and drought. Natural stands are seen at elevations of 1800—1900 m above sea level. The tap root is long and often twisted. In cultivation, it branches and all the main branches grow vertically. The leaves are arranged in rosettes and they show variation in size and shape. The branched

laticifers are of the articulated type and are chiefly concentrated in the phloem region of the root. The plant is propagated by seeds. The roots are harvested, cleaned and the rubber is extracted by mechano-chemical methods. *T. megalorhizon*, another species commonly known as Krim-saghyz, is also a source of natural rubber and it has greater adaptability.

2.7 Funtumia elastica

Funtumia elastica of the family Apocyanaceae is the source of Lagos silk rubber. The tree which is tall and slender, is found in tropical Africa. It prefers a well drained soil. Bark is thin and latex vessels are single. The tree is tapped with multiple cuts. Latex is stable and its regeneration is relatively very slow. Propagation is by seeds.

HEVEA

The genus *Hevea* grows wild in the Amazon basin and the adjacent areas of Brazil which is its centre of origin. Though different species of *Hevea* prefer varying habitats, all are available in Brazil. *Hevea* also occurs in Bolivia, Columbia, Guyana, Peru, Surinam and Venezuela (4). The centre of genetic diversity of *Hevea* is the Rio Negro. Morphological and cytological investigations have revealed that there are nine species in the genus (3). These are:

(1) *H. guianensis*
(2) *H. benthamiana*
(3) *H. nitida* var *toxicodendroides*
(4) *H. pauciflora*
(5) *H. rigidifolia*
(6) *H. camporum*
(7) *H. spruceana*
(8) *H. microphylla*
(9) *H. brasiliensis*

2.8 Hevea guianensis Aubl.

H. guianesis complex comprises typical *H. guianensis*, a widespread and variable variety *H. guianensis* var. *lutea* and a localised somewhat enigmatic form *H. guianensis* var. *marginata*. *H. guianensis* grows in well drained areas, from the sea level up to 760 m. *Hevea guianensis* is a tall tree attaining a height of 24–27 m with a cylindrical trunk. Branches are produced at a high level and crown is compact. Leaflets are membraneous to subcoriaceous, usually obovate and short acuminate. The leaflets when mature are borne erect and this character is peculiar to this species. Seeds are angular in shape. *H. guianensis* produces a cream yellow latex which is of an inferior quality. Of the other varieties, *H. guianensis* var. *lutea*, is taller and *H. guianensis* var. *marginata* is much smaller in size.

2.9 Hevea benthamiana Muell. Arg.

This tree grows well in areas subject to flooding. It is a medium sized tree 20–24 m in height (Fig 2.5). Trunk is usually swollen at the base. Leaflets are soft reddish, pubescent beneath, papyraceous, lanceolate and horizontal. Flowers are yellow and seeds are small with rich brown mottling. It freely hybridises with other species. Latex is white with rubber of good quality.

2.10 Hevea nitida Mart.

This is a small to medium sized tree, usually growing in quartzitic or sandy areas. It has a cylindrical trunk with characteristic red brown bark. Leaflets are reclinate, thick, membraneous and glossy. Flowers are pale yellow or whitish yellow. Seeds are angular in shape. Latex is pure white in colour with more resin and low rubber content. It has an anticoagulant property. *H. nitida* var. *toxicodendroides* is a bush or shrub about 2 m tall.

2.11 Hevea pauciflora Muell. Arg.

H. pauciflora is a stout tree growing to a height of about 27 m, with a cylindrical trunk and brittle dark brown bark. It prefers well drained rocky hill slopes above the flood levels. Leaflets are usually

reclinate, papyraceous and lanceolate. Flowers are pale yellow and seeds are comparatively large in size with dull purplish red colour. It produces a white or dull sticky latex, rich in resins and containing a weak and hardly elastic rubber. *H. pauciflora* is a rare tree of the Rio Negro. *H. pauciflora* var *coriacea* is widely distributed.

2.12 Hevea rigidifolia Muell. Arg.

This is a rare species in the genus endemic to the upper most Rio Negro. The tree, which grows to a height of about 12 m, has slender cylindrical trunk and small crown. Leaflets are thick, leathery, conspicuously marginate and strongly reclinate. The white latex, which contains resins, does not yield good quality rubber.

2.13 Hevea camporum Ducke

This is a dwarf species of the genus. The tree usually grows in grass land and attains a height below 2 m. Seed is very small, measuring 11 x 7 mm. It produces white latex of unknown properties.

2.14 Hevea spruceana Muell. Arg.

Hevea spruceana usually prefers river banks liable to flooding. This is a medium sized tree with a swollen trunk (Fig 2.6). It has a comparatively dense crown of membraneous leaves with whitish pubescence. Flowers, reddish or brownish purple in colour, are excessively pungent. Seeds, which are the largest in the genus, are ventrally compressed, long and angular. Latex is white and watery.

2.15 Hevea microphylla Ule

This is a slender tree, reaching a height of about 21 m with a whip–like trunk and sparse crown. It grows along deeply flooded river banks. Leaflets are reclinate and papyraceous. The triangular coreaceous capsule and the pyramidal shape are characteristic of the species. Unlike other species, capsule opens slowly. The pistillate flower has swollen torus which is broader than the base of the calyx.

2.8 Hevea guianensis Aubl.

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3 THE RUBBER TREE (HEVEA BRASILIENSIS MUELL. ARG.)

Chapter 3

THE RUBBER TREE
(*HEVEA BRASILIENSIS* MUELL. ARG.)

Hevea brasiliensis, the Para rubber tree, produces 99 per cent of the world's natural rubber. Its yield and quality of rubber are superior to those of all other species. The plant is a sturdy perennial tree which attains a height of about 30 m (Fig 3.1). Latex is present in almost all parts of the plant, but only the bark of the trunk is usually exploited. Latex vessels contain white or yellowish white latex. The tree has a straight trunk with light grey bark. Branches are usually developed in such a way as to form an open leafy crown.

3.1 Morphology

3.1.1 Leaf

The leaves are arranged in groups or storeys. From each storey a cluster of spirally arranged, trifoliate, glabrous leaves is produced. The petioles are long usually about 15 cm and extra-floral nectaries are present in the region of insertion of the leaflets. The leaflets show slight variation in shape, leaf margin etc. They are short stalked, elliptic or obovate, and entire with green or dark green colour above, paler glaucous beneath and pinnate veins (Fig 3.2).

3.1.2 Flowers

This is a deciduous tree that winters during December – February in South India. Wintering may be either complete or partial depending upon the clone, age of the plants, seasonal factors, location where grown etc (9). Refoliation and flowering follow wintering. During September–October, some trees may show occasional off-season flowering. Flowers are short stalked and fragrant. Both male and

female flowers are seen on the pyramid shaped panicles (Fig 3.3). The sex ratio shows wide difference in the number of male and female flowers. Numerous small male flowers occur along with a very few number of female flowers. Female flowers are seen at the tip of the panicles and their branchlets (Fig 3.4). Flower has one whorl of bell shaped perianth with five yellow lobes. There are 10 stamens arranged on a slender staminal column in two whorls of five each. Female flowers are bigger in size with a green disc below the perianth and ovary. Gynoecium is tricarpellary syncarpus with a single ovule in each locule. Stigma is short and three lobed.

Pollination in *Hevea brasiliensis* is by insects. There was no fruit set in inflorescences enclosed in insect proof bags (12). Various morphological characters of the flower, especially the sticky pollen and stigmatic surface, indicate that it is typically entomophilous. From studies made, Ceratopogonid midges of the *Forcipomyia* sp were found to be the major and effective pollinators. There are many other species of insects visiting the flowers.

3.1.3 Fruits and seeds

After fertilisation the ovary develops into a three lobed, dehiscent capsule (regma) with three large mottled seeds (Fig 3.5). Fruit set is generally very low. Fruits ripen five to six months after fertilisation. The dry fruit dehisces with a loud report, breaking the pericarp into six pieces, and seeds are thrown to a distance of about 15 m.

Seed consists of a fairly thick testa enclosing a soft kernel. Seeds of seedling trees and different clones show variations in weight, size, shape and seed coat markings. The weight of seeds may vary from 4 to 6 g. There are large, medium and small seeds. The seed coat shows a mottled or blotched pattern of brown and grey in different shades. As the seed coat is formed by the mother tree, generally the pattern of all the seeds follow the maternal characteristics regardless of the male parent. Characteristics of fruits and seeds are specific for each clone. If the seeds of a number of seedlings are collected, it will be seen that seeds belonging to one tree differ from those of others. The mottling of raphe and micropyle forms infallible characteristics in clone identification(18). Each seed has a dorsal and ventral side. There may be frontal and lateral depressions (Fig 3.6). In the

micropylar end the mottlings are very prominent. The prominence of ridge may vary. Seed coat may be smooth, rough or shiny. The mature seed has a fully developed embryo. The seed contains an oily endosperm. The endosperm is massive and it fills the seed completely. Generally 37 per cent by weight of the seed is shell and the rest kernel. The oil content of air dried kernel is 47 per cent.

3.2 Cytology

Experimental crosses among the nine species of *Hevea* reveal no genetic or chromosomal barriers. Chromosome counts of *Hevea* spp were made by several investigators and in general the number has been confirmed as 2n=36. The chromosome counts made by various workers, particularly those of the earlier ones, do not agree. Different authors have reported the chromosome number of *Hevea* as 2n=16, 34 and 36 (3, 11, 13, 14, 15, 17). A triploid plant (2n=54) in *H. guianensis* and one haploid (2n=18) in *H. pauciflora* have been reported (2).

The meiotic cycle is almost regular and the pollen fertility in *Hevea brasiliensis* is over 80 per cent. Male sterile clones have been observed and cytological investigations indicated varying results. Meiotic irregularities like univalents and abnormal separations in male sterile clones of *H. brasiliensis* and in the hybrids of *H. spruceana* and *H. brasiliensis* were observed (20). But such meiotic irregularities were not noticed in the male sterile clones by others. Abnormal synapsis by formation of multivalents and univalents, which leads to varying number of chromosome separation in meiosis leading to male sterility, has been noted in two clones.

Pachytene chromosome analysis in *H. brasiliensis* was attempted. The chromosome length ranges from 8.33μ – 33.67μ. Two pairs of chromosomes with satellites and two other pairs with homology in morphology were observed, suggesting an amphidiploid origin for *Hevea*.

3.3 Anatomy

The anatomy of *Hevea brasiliensis* was studied by various authors (1, 4, 5, 6, 7, 8, 10, 16). Latex vessels are present in all parts of the

tree except in the wood. Latex, however, has been found occasionally in the xylem vessels. Stomata are present on the tender shoots, petioles and laminae. On the leaf lamina they are present only on the lower surface. On the petiole also they occur predominently on the lower half. Studies have indicated that density and size of the stomata, which vary from clone to clone, have some bearing on clonal susceptibility to abnormal leaf fall disease (19). Wood is diffuse porous (Fig 3.7) and tyloses are present in older vessels (Fig 3.8). Tension wood is of common occurrence (Fig 3.9).

All the tissues outside the cambium are collectively termed bark. Mature bark has an inner zone which is soft, an intermediate zone which is hard and an outermost protective region consisting of layers of cork cells. Stone cells are abundant in the hard bark region. They occur in groups, appear as dark patches and provide mechanical strength and rigidity to the bark. The hard bark also contains sieve tubes and latex vessels which are discontinuous and non-functional. The soft bark contains most of the functional elements of the bark and consists of latex vessels, sieve tubes, phloic rays etc.

The trunk of seedling trees tapers and the thickness of bark decreases upwards. The proportion of hard bark is more towards the base. The latex vessel rings are also more near the base, decreasing towards the level of the first branches. Budded trees, in contrast, have an almost cylindrical trunk. Bark thickness is more or less uniform at different heights on the trunk and the latex vessel rows also do not show very wide variation. The bark of the budded tree is in general thinner than that of seedling tree.

3.3.1 Latex vessels

Latex vessels originate from cells produced by cambium and they are arranged in rows. The vessels do not have straight vertical course within the bark. Generally, they run in anti-clockwise direction, the angle of inclination varying from $3° - 5°$. The latex vessels within the same ring are tangentially interconnected forming a mesh like structure. Latex vessles of *Hevea* thus belong to the articulated anastomosing type. In transverse sections of the bark, they appear in discrete concentric rings. In radial longitudinal view of the bark, they appear as straight tubes while in tangential longitudinal sections,

they look like an expanded mesh (Fig 3.10). The latex vessels are thin-walled and towards the hard bark region they become shrivelled, discontinuous and non-productive. Latex vessels in the stem and branches show the same structure. Their number, however, is comparatively less in the branches.

3.3.2 Bark regeneration

Tapping causes wounding of the outer hard bark and the major part of the soft bark. Only a thin layer of the innermost soft bark is left intact. The immediate effect of tapping is shrinkage of the outermost cells on the wounded surface. These cells undergo necrosis. The cells below these enlarge and divide in irregular planes. The cell divisions subsequently become oriented parallel to the severed surface, a phellogen gets differentiated and a wound periderm develops. Stone cells in the periphery are compactly arranged. Several cells produced by the wound phellogen are red coloured owing to the presence of anthocyanin. Latex vessels of the regenerated bark develop from cells produced by the cambium in the usual manner.

The portion of soft bark left uncut, the wound periderm and the tissues produced by the vascular cambium together constitute the renewed bark. The thickness of renewed bark varies depending on the period of regeneration. The rate of bark regeneration also varies in different clones.

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4 BREEDING AND TREE IMPROVEMENT

Chapter 4

BREEDING AND TREE IMPROVEMENT

Plant improvement through selection and breeding is the cheapest method to ensure progress in agriculture. The most significant single factor responsible for the advancement of rubber plantation industry is the contribution made by tree improvement research. Productivity primarily depends on the genetic constitution of the planting materials and their adaptability to respond to improved agrotechniques. In *Hevea*, significant achievements have been made in the productivity of planting materials through breeding and selection.

4.1 Mother tree seeds

The early plantations were all raised from unselected seeds. Yield of these seedling trees was very low, only 200–300 kg/ha/annum. Large variability in production among individual seedling trees in a population was recognised in the early part of 20th centruy (5,14,25). It was revealed that 10 per cent of the trees gave 28 per cent of the total yield. Pioneers in the field selected such high yielding trees and advised the use of seeds collected from such trees in plantations. It was found that yield of trees raised from such 'mother tree seeds' were higher than that from completely unselected ones although these trees also showed variations among themselves on account of the highly heterogenous nature of the trees.

4.2 Mother tree selection and vegetative propagation

Search by the pioneer planters and enthusiastic tappers led to the identification of a large number of seedling trees capable of giving

high yield. The problem, however, was to find out a method by which this character could be transmitted to the progenies and perpetuated with certainty. The possibilities were not recognised until 1916, when the vegetative method of propagation through budgrafting was described by Van Helten and Tass almost simultaneously. Preliminary experience in budgrafting was however not satisfactory, as many of the trees selected were not inherent high yielders and the phenotypic variations observed were largely environmental. Commerical planting of budgrafted progenies, started in 1918 in Indonesia, paid rich dividends, and the first clones released were Ct 3, Ct 9 and Ct 88 (Ct = Cultuurtuin). These three clones were of good yield potential and mixed planting of them recorded good yield of 1700 kg/ha in the ninth year of tapping (8).

Initial steps in the establishment of improved planting materials from seedling populations are identification of desirable bud parents, marking them appropriately and watching their performance for 2–3 years to choose the most promising ones. The most important requirement is that the bud parent should be a high yileder, known to yield well from the beginning of tapping. Special advantages of position contributing to higher yields due to environmental influence must be discounted. Secondary characters like vigour, bark characters and resistance to diseases are also of importance. Collection of budwood from the promising selections and establishment of respective clones form the next step. The earlier practice was to make small experimental planting of these clones, make further selections and distribute them as primary clones. This procedure usually takes about 12–13 years. However, a more reliable procedure, though time consuming, would be to subject the clones to small scale trials followed by large scale trials, then select the best and recommend for cultivation.

4.3 Breeding

4.3.1 Cross pollination

Generative method of *Hevea* improvement had a beginning with the establishment of isolated gardens and collection of the seeds resultant of open pollination (9). Breeding and selection cycle was

continued by raising seedling families from the best of the new clones and repeating the method (8). Selection of a few high yielding trees in 1917 and establishment of an isolated seed garden in 1923 with the clones developed from these trees marked the initiation of the work in Java, which was followed by artificial breeding through hand pollination. In Sumatra, hand pollination between primary clones was commenced in 1920. Controlled pollination was started in Malaysia in 1918 and in Brazil in 1937. Breeding programme was initiated in Sri Lanka in 1939 and in Indo–China in 1948. Improvement of *Hevea* planting materials through breeding and selection was initiated in India only in 1954 (4,10,20). Selection of desirable parent clones, hybri isation through hand pollination, testing of the progenies and selection of the best brought about rapid yield improvement of the crop. Generative and vegetative methods of propagation are employed in a complementary manner. Desirable attributes like high yield, vigour, disease tolerance and wind fastness, which are genetically controlled, are scattered in different clones and the main attempt through breeding is to combine these characters. Further, the hybrid vigour can be effectively exploited through vegetative multiplication.

4.3.1.1 Method of hand pollination

First step in breeding procedure is the choice of parent clones with the desirable characters which are heritable. Preparation of the branch of the female parent for pollination is the next step to be adopted. All the male flowers and all the female flowers that have opened as well as the female flowers that are too young are removed leaving only those female flowers that are mature but with the perianth still remaining closed. The mature male flowers from the desired male parent are collected separately. The perianth lobes of the female flowers are carefully forced apart with a pair of forceps. The staminal column of the male flower is then taken out (Fig 4.1) and inserted on the stigma of the female flower. To keep the staminal column in position and to prevent contamination with undesired pollen from other trees, the female flower is closed with a cotton plug and kept in position with a drop of latex (Fig 4.2). After pollinating, labels are properly provided to indicate the parents, date of pollination and other relevant details. The perianth along with the

cotton plug falls off in a few days. The ovary begins to grow into fruit if fertilisation has been successful (Fig 4.3). The fruits mature in about five months. The mature fruit is enclosed in a net bag so that the fruit when dehisces will leave the seeds inside (Fig 4.4).

It is preferable to select well exposed branches for pollination. Pollinated flowers and young fruits may be protected from various diseases and pests present in the locality by adopting suitable plant protection techniques. *Hevea* is a shy seeder and the success of hand pollination may vary. An average fruit set of 5 per cent is considered fair. The seeds after collection from the bags are put to germination and the germinated ones established in the seedling nursery in the usual way with proper records.

4.3.1.2 Juvenile selection of high yielders

Selection of the seedlings in the nursery stage to rogue the undesirable elements is the next step. Studies on the relationship of sieve tubes to yield had shown that high yielding trees had sieve tubes of larger diameter (12). However, anatomical study of the seedling bark with a view to selecting the future high yielders had been dropped due to practical considerations (8). Cramer (6,7) developed a 'testatex' knife to test-tap and grade the nursery seedlings at about the age of 10 months. The equipment consisted of a flexible metal plate on which four 'V' shaped metal knives were fixed 2.5 cm apart. This was pressed by hand at the base of the seedling until the knives were stopped by the wood and in such a way so that the upper knife was 15 cm above the collar. The plate was pulled back to remove the knife from the incisions, allowing latex to exude from the wound. The amount of latex which exuded was visually observed after 30 min and the seedlings were graded as very poor (no exudation of latex), poor (a few drops of latex), intermediate (latex exuded but did not connect the incisions), good (exuding latex connected all the incisions) and very good (latex connected all the incisions and dripped along the seedling stem). This method is subjective and the relation between test class and yield is not close and it does not indicate the best future yielders, though the poorest yielders could be eliminated (8). Recent investigations have indicated that higher the oil content in cotyledon, lower the yield (11). Microtapping the seedlings with needle pricks

has also been recently attempted (24). Further experimentation on a number of characters would be necessary to help in predicting the yield potential at the juvenile stage.

4.3.1.3 Test-tapping

Test-tapping of seedling trees, three to four year old, was developed to select the high yielders (19). When 80 per cent of seedling trees attain a girth of 30 cm or above at the collar region, they are test-tapped. Very weak seedlings are eliminated without test–tapping. The trees are tapped daily for ten days, at 55 cm with a slope of 30°–35° for quick latex flow. The yield from the sixth to the tenth day only is recorded, following cup coagulation method. This method, however, gives only a rough indication of promising trees. Yield on test–tapping was related to that on the first year of normal tapping, but not to yield during subsequent years (8). No perfect method has been developed to select the future high yielding trees at a very young stage. Therefore, selection based on the vigour during immaturity and actual yield during the initial years of tapping has to be followed. The yield data during the first three years would seem adequate for the selection (23).

4.3.1.4 Field experimentation for selection

Field experimentation for selection makes use of either a long duration technique, lasting for a period of about 30 years or a short duration one, covering a span of about 18 years. In the long term trials, the undesirable plants are removed from the seedling nursery, raised from seeds obtained through hand pollination. The remaining seedlings are stumped. The top portions are used as budwood and vegetative progenies are established from each. The seedlings are planted in the field in the usual manner. The budgrafts established from each of the seedlings are also planted in the field for experimentation. Close observation of the characters is made during the testing. The yield of the seedling trees and that of the respective clones are collected separately for at least four to five years of tapping. Selections are then made based on yield, vigour and other parameters and the selected clones are subjected to large scale clone trials and testing under commercial conditions on estates in different regions,

before the final selections are made and included in the planting recommendations. This procedure of systematic breeding and selection takes about 30 years.

Short duration techniques are being attempted in some of the research institutions. One way is to put the outstanding selections directly into the large scale trials (3,22). Another method is to germinate the seeds in polybags and transplant into a field nursery after the third whorl of leaves had hardened, at 1.2 x 1.2 m spacing. The seedlings are test-tapped three times after the second year and other observations recorded. Selection is based on the strength of the performance of the seedling and the selected seedlings are stumped. The stumps are transplanted for seedling trial. The top portion is used for clonal multiplication and small scale clone trials laid out with appropriate controls. Observations at the immaturity phase and yield recording during the first four years of tapping are taken. The most promising clones are selected based on the performance data, multiplied and tested in large scale clone trials on suitable designs for the final selection. It may be possible to reduce the time required for testing to around 18 years by this method. However, most of the trials on hand pollination and development of new clones are put through the entire process described earlier.

4.3.2 Mutation and polyploidy breeding

During the last decade, attempts have been made to induce genetic variation in *Hevea* through mutation and polyploidy using chemical and physical means. Morphological variations like moribund growth, polyphyllous leaves and lamina distortion (Fig 4.5) were noted when open pollinated seeds were subjected to gamma rays at 2000–3000 rad, whereas 4000 rad was lethal (15,16). With vegetative buds, application of gamma rays at a dose above 2000 rad resulted in poor budding success and survival (1). Similar results were obtained with X–rays also (13). Mutation studies in *Hevea* are only in the initial stages. It is likely that minor favourable genetic changes could be effected through mutation. Induction of polyploidy has also been attempted recently (2,16,17,18,21). Application of aqueous solution of colchicine at a concentration of 0.75 – 0.80 per cent could induce polyploidy in meristematic shoot tissues

Though leaves and floral parts were bigger and thicker respectively in the tetraploids, the degree of expression varied with different materials. Some of the clones treated showed very poor growth compared to the untreated control. The polyploids also show a tendency towards reversion. Mutation also appears spontaneously in nature, but is of rather rare occurrence. A genetic dwarf of *Hevea brasiliensis* has been identified in India (Fig 4.6).

4.4 Further promise

Selective hybridisation between superior clones, vegetative multiplication and testing of the most promising selections have so far produced planting materials with a production potential of above 3000 kg/ha/annum. On theoretical consideration, the maximum yield potential in *Hevea* has been placed between 7500–10000 kg dry rubber per ha per year. Thus there is considerable gap between the existing and achievable production potential. It has to be noted that the *Hevea* germ plasm available in the East represents only a very narrow range. Identification, collection and conservation of the diversity of genotypes available in the centre of origin of the genus are essential for future tree improvement. A broad based breeding programme involving divergent genotypes and appropriate selection of offsprings based on definite genetic parameters could help evolve the ideal plant types of *Hevea* suitable for different situations.

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5 HEVEA CLONES

Chapter 5

HEVEA CLONES

A group of plants produced by vegetative propagation from a single tree is termed a clone. All the individual trees of a clone possess identical genetic constitution which is responsible for the uniformity existing among them. Hundreds of *Hevea* clones have been evolved so far in various countries.

5.1 Advantages of clones

Clones as planting material have many advantages. The most important one is the uniformity exhibited by the members of each clone. All the individual trees of a clone, under uniform conditions, show very little variation with regard to their different characters such as vigour of growth, bark thickness, yield, properties of latex, wintering refoliation, nutrition and tolerance to diseases. This enables the planter to carry out cultural operations in a more easy and economic manner. Owing to uniform growth, the number of trees that have to be thinned out is always less than that for seedlings. Hence in the case of clones, the initial stand need be less than that required for seedlings. Thus, the cost of planting and maintenance per ha is reduced. Uniformity in the properties of latex from clones makes it more useful for specific purposes where such uniformity is essential. With clones possessing different specific characteristics, selection of materials suitable for different situations is also possible.

5.2 Classification

Clones are broadly classified into three categories viz primary, secondary and tertiary, based on the method adopted for the development of their mother trees. Clones developed from mother trees of

unknown parentage are called primary clones. These mother trees are selected from existing seedling populations and those which exhibit desirable characteristics are multiplied vegetatively to give rise to the clones. Many popular clones like Tjir 1, GT 1, GI 1, PR 107, PB 86 and PB 28/59 belong to this category. In the case of secondary clones, the mother trees are evolved by cross pollination (hand pollination) between two primary clones. These mother trees are then multiplied vegetatively as in the case of primary clones. Most of the modern clones like RRIM 600 (Tjir 1 x PB 86), PB 5/51 (PB 56 x PB 24), RRII 105 (Tjir 1 x GI 1), RRII 208 (Mil 3/2 x AV 255) belong to this category. Tertiary clones are also produced by controlled pollination of two existing clones, but they differ from the secondary clones in that at least one of the parents is a secondary clone, eg RRIM 719 resultant of a cross between PB 86 a primary clone and RRIM 623 with the parentage PB 49 x Pil B 84. Sometimes both the parents may be secondary clones, eg clone RRIM 708, developed by crossing two secondary clones RRIM 501 (Pil A 44 x Lun N) and RRIM 623. Many of the latest clones such as RRIM 703, RRIM 707, RRIM 712 and PB 260 are also tertiary clones.

5.3 Abbreviation for clones

Clones are named after the institution from which they have originated, following a standard procedure. The relevant rules are (i) Do not abbreviate less known clones; (ii) Omit full stops (iii) Use the first syllable or use first two letters if consonants; (iv) Use the initial letters only, in capitals, in the case of more than one word; (v) Use longer abbreviation, should ambiguity occur; (vi) Write the abbreviated name as a unit; (vii) Use Arabic characters to denote the numbers; and (viii) Leave a space between the abbreviation and number.

A few examples are given below:—

AVROS	Algemene Vereniging Rubber planters Oostknst Sumatra
BD 10	Bodjong Datar 10
Ch	Chemara
CHM	C. H. Meares
GI	Glenshiel

GT 1	Gondang Tapen 1
IAN	Institute Agronomico du Norte
IRCI	Institute des Recherches sur le Cauotchouc en Indochine
KW	Kali Wining
LCB	S' Lands Caoutchouc Bedrijven
Lun	Lunderston
Mil	Millakande
Nab	Nabutenne
PB	Prang Besar
Pil	Pilmoor
PR	Proefestation voor rubber
RRIC	Rubber Research Institute of Sri Lanka
RRII	Rubber Research Institute of India
RRIM	Rubber Research Institute of Malaysia
Tjir	Tjirandji
Wagga	Wagga
War	Waringiana

5.4 International registration and clone exchange

International authorities are functioning for various crops to register new cultivars bred or developed and to maintain a complete record of the cultivars which will be available for research purposes and crop improvement programmes. The necessity for having a similar body for *Hevea* was felt at a meeting of the breeders and selectionists in 1968 and it was decided to organise such an international authority. Accordingly, the International Registration Authority for *Hevea* Cultivars was formed with its headquarters at the Rubber Research Institute of Malaysia.

When an institute or organisation evolves a new clone, type specimens are deposited with this Authority along with its name, origin, morphological description, performance etc, and the Authority keeps all the records. Only clones registered with this Authority could be exchanged between the member Institutes. The Rubber Research Institute of India has registered four of its outstanding clones

viz, RRII 105, RRII 118, RRII 203 and RRII 208 with the International Registration Authority for *Hevea* Cultivars.

5.5 Clones of commercial importance

5.5.1 Indian clones

5.5.1.1 RRII 105

This is a promising clone evolved by the Rubber Research Institute of India. The parents of this clone are Tjir 1 and GI 1. It is sturdy with average vigour and good branching habit (11). The tree is tall with straight trunk (Fig 5.1). Canopy is dense, mostly restricted to the top. Foliage is dark green with glossy leaves characteristic of the male parent GI 1 (12). Vigour at opening and girth increment on tapping are average. Virgin bark and renewed bark are of above average thickness. Bark contains a high number of latex vessel rings.

The initial yield and yield during subsequent years were high in the experimental plantings. In the small scale trial, average yield for first 15 years of tapping was 77 g/tree/tap. The mean estimated yield is 2880 kg/ha/annum. Under large scale trial, average yield for the first seven years' tapping was 76 g/tree/tap. The estimated yield is 2827 kg/ha/annum. Promising yield trend is reported from commercial plantings. It is a partially wintering clone and is not prone to wind damage. The clone has a fair degree of tolerance to abnormal leaf fall disease under normal prophylactic measures (Fig 5.2) Pink disease incidence is reported. It is fairly tolerant to drought.

5.5.1.2 RRII 116

It is a vigorous clone with parents Mil 3/2 and Hil 28. The tree is straight with balanced branches. Canopy is mostly restricted to the top. Vigour at opening is above average. Thickness of bark is below average and number of latex vessel rings average. Mean annual yield for the first 15 years of tapping in small scale trial was 65 g/tree/tap. The estimated yield is 2418 kg/ha/annum. This clone shows good vigour in large scale trials.

5.5.1.3 RRII 118

This is another promising clone and the parents are Mil 3/2 and Hil 28. Tree of this clone has tall and straight trunk, well balanced branches and moderately dense canopy (Fig 5.3) (12). Vigour at opening is high. Bark thickness is average and bark contains average number of latex vessel rings. Initial yield is above average and subsequent yields show a rising trend. The mean yield from the small scale trial during four years of tapping was 50 g/tree/tap. The estimated yield is 1845 kg/ha/annum. In commercial planting also this clone shows encouraging growth and yield trend.

5.5.1.4 RRII 203

A promising clone of the parents PB 86 and Mil 3/2, it has a tall and stout trunk with heavy main branches and thin and well distributed minor branches (Fig 5.4). Vigour at opening is above average and girth increment on tapping is good. Thickness of virgin and renewed bark is above average. Bark contains a high number of latex vessel rings. Initial yield and subsequent yield are above average. The mean yield from small scale trial during 12 years of tapping was 80 g/tree/tap and the estimated yield is 2990 kg/ha/annum. In the large scale trial as well as in the estate trials, this clone shows good vigour.

5.5.1.5 RRII 208

The parents of the clone are Mil 3/2 and AVROS 255. Tree of this clone has straight trunk and good branching (Fig 5.5). Canopy is light. Small scale trial for the first 12 years' tapping gave an average yield of 83 g/tree/tap. The clone is susceptible to *Phytophthora* diseases.

5.5.1.6 RRII 300 series

New clones in this series are under experimentation. Some of these clones indicate high production potential in the preliminary trials.

5.5.2 Clones of other countries

5.5.2.1 RRIM 600

This is a secondary clone evolved by the Rubber Research Institute of Malaysia(2). Parents are Tjir 1 and PB 86. Tree of this clone is tall with straight stem and many upright, moderately to fairly heavy branches arising at right angles producing weak forks (Fig 5.6). Crown is narrow and broom shaped. Foliage is sparse with small yellowish green leaves. Young buddings show spindly growth and late branching with a tendency to slight leaning during the first two years. Vigour up to tapping is below average, but girth increment on tapping is good. Thickness of virgin bark is below average, while that of renewed bark is good. The renewed bark often bulges out above the tapping cut. The clone also shows good recovery from wounding. This is one of the highest yielding clones available at present. In commercial plantations of Malaysia, its average yield during the first 14 years of tapping was 1819 kg/ha/annum. In India the yield was 1185 kg/ha/annum over five years, the corresponding figure in Malaysia being 1386. The clone exhibits a rising yield trend. Even-though initial yield is only average, subsequent yield is very high(8). Yield during summer (wintering period) is also high. Latex is white and unsuitable for concentration owing to low mechanical stability. Eventhough it shows some tolerance to powdery mildew, brown bast and wind damage, the clone is highly susceptible to *Phytophthora* diseases and pink disease.

5.5.2.2 RRIM 605

It is a secondary clone resulting from a cross between Tjir 1 and PB 49 (7). Tree of this clone is tall with straight stem, low branching, a few heavy acute-angled main branches and many light to moderately heavy branches. Canopy is heavy, dense and fan shaped with dark green leaves of average size. Vigour is average both before and after tapping. Thickness of virgin and renewed bark is also average. This is an average yielder with a mean yield of 1127 kg/ha/annum, over 13 years. Initial yield is high but subsequent yield is not. Summer yield is only above average. The clone shows average tolerance to brown bast, below average tolerance to pink disease and wind

damage, high susceptibility to *Phytophthora* diseases and moderate susceptibility to powdery mildew.

5.5.2.3 RRIM 623

This is another clone developed by crossing PB 49 and Pil B 84. Tree of the clone has tall straight stem with tall, heavy, acute-angled branches forming weak fork junctions. Branches show a characteristic banding at high level. Crown is narrow and confined to the top. Canopy has moderately dense foliage with fairly large and dull green leaves. Vigour before tapping is very high and girth increment after tapping is good. Thickness of both virgin bark and renewed bark is below average. It is a very high yielding clone giving an average yield of 1575 kg/ha/annum during the first 12 years of tapping. Initial yield is high and subsequent yield is very high. But summer yield is very poor. The clone shows average tolerance to brown bast, powdery mildew and *Phytophthora* diseases. Wind damage is below average. Tolerance to pink disease varies from average to below average.

5.5.2.4 RRIM 628

It is a secondary clone evolved by crossing Tjir 1 and RRIM 527. The tree of the clone has a straight or slightly leaning trunk which sometimes shows bending during immaturity. It has many moderate branches growing upwards. Though the clone shows average vigour before tapping, it is very poor after opening. Thickness of virgin bark is average and that of renewed bark below average. A fairly high yielding clone with an average yield of 1468 kg/ha/annum during seven years in commercial plantations. Its initial yield and subsequent yield are above average, showing a steady yield trend. Summer yield is very poor. It shows average tolerance to *Phytophthora* diseases and wind damage, below average tolerance to pink disease and poor tolerance to brown bast and powdery mildew.

5.5.2.5 RRIM 701

It is a clone developed by crossing the clones 44/553 and RRIM 501. Tree has straight stem with a few heavy acute-angled branches

with a high, heavy and broom or oval shaped canopy. Thickness of both virgin and renewed bark is above average. It is fairly high yielding with a commercial yield of 1390 kg/ha/annum during seven years of tapping. Initial yield is average and subsequent yield above average with a rising yield trend; summer yield is very poor. It shows above average tolerance to brown bast and it is highly susceptible to pink and *Phytophthora* diseases in India. Poor tolerance to powdery mildew and below average tolerance to wind damage are noticed.

5.5.2.6 RRIM 703

This is a very promising clone developed by crossing RRIM 600 and RRIM 500. Tree of the clone has upright and slightly kinked stem. Branching is late with a few heavy narrow-angled laterals. Crown is narrow, open and oval shaped. Vigour at opening is average. Virgin bark and renewed bark are very thick. It gave an yield of 1766 kg/ha/annum from experimental plantation during the first 12 years of tapping. Both initial and subsequent yield are very high with steady yield trend (9). Summer yield is below average. It exhibits average tolerance to *Phytophthora* diseases, below average tolerance to pink disease and high tolerance to *Oidium* disease. The clone is highly susceptible to brown bast.

5.5.2.7 PB 86

It is an average yielding primary clone developed by the Prang Besar Rubber Estate Company in Malaysia. Tree of the clone is very poor in vigour; canopy is open and light with yellowish green foliage(1). The clone is a prolific seeder. It gave an average yield of 1366 kg/ha/annum under commercial planting during the first 15 years of tapping. It is tolerant to wind damage and powdery mildew but not to poor soil. The clone is highly susceptible to *Phytophthora* diseases. It performs well in Kanyakumari district where the incidence of these diseases is very mild.

5.5.2.8 PB 217

This is evolved by crossing PB 5/51 and PB 6/9. The tree has straight trunk, many light branches and one or two heavy branches

with strong unions. Crown is moderately heavy. Vigour during immaturity period is average and after opening above average. Virgin bark is thin but thickness of renewed bark is average. It gave an average yield of 1776 kg/ha/annum in 12 years in large scale trials. It has a rising yield trend with average initial yield and high subsequent yield. Summer yield is very high. It has poor resistance to *Phytophthora* diseases, below average tolerance to pink disease and powdery mildew and high tolerance to wind damage and brown bast.

5.5.2.9 PB 5/51

This is a promising clone developed by crossing PB 56 and PB 24 (6). The tree has straight upright stem with a regular spread of light horizontal branches (Fig 5.7). Crown is conical with light and sparse foliage consisting of small yellowish green leaves. Vigour is average before tapping but below average after tapping. Thickness of virgin bark is average and that of renewed bark below average. Owing to its peculiar branching habit, it is highly resistant to wind damage and hence ideal for wind prone areas. This is an average yielder with high summer yield. Average yield obtained under commercial conditions during 15 years was 1514 kg/ha/annum. Tolerance to *Phytophthora* diseases and pink disease is average and that to brown bast below average. It is highly susceptible to powdery mildew.

5.5.2.10 PB 28/59

It is another promising primary clone of very high yield, particularly during early years of tapping. Vigour before opening is average, but poor after opening. Thickness of virgin bark is below average and that of renewed bark is above average. Commercial yield during 11 years of tapping was 1747 kg/ha/annum. Summer yield is poor. Resistance to *Phytophthora* diseases, pink disease and powdery mildew is below average. The clone is highly prone to brown bast and hence only low intensity tapping should be adopted.

5.5.2.11 GI 1

This is a primary clone developed in Glenshiel Estate, Malaysia (13). It has average vigour and an open, well balanced canopy with

characteristic dark bluish green and glossy leaves. It is tolerant to high water table. Virgin bark is rough and flaky towards the bud union. Renewed bark is good. It is a clone of average yield, giving a mean yield of 1173 kg/ha/annum during 15 years of tapping. Tolerance to leaf diseases and wind damage is fairly good. It is highly prone to brown bast and hence only low intensity tapping should be adopted.

5.5.2.12 Tjir 1

This is a primary clone developed in Indonesia. The tree has straight stem, heavy branches with weak union and a wide-spreading canopy. It possesses average to above average vigour before tapping and average vigour subsequently. Seed production in this clone is relatively high. It gave an yield of 1197 kg/ha/annum during 15 years of tapping in commercial plantings, with very poor summer yield. The clone is highly susceptible to *Phytophthora* diseases and is of average susceptibility to other diseases and wind damage.

5.5.2.13 PR 107

This is a primary clone developed in Indonesia(5). It was originally known by the name LCB 510 but subsequently became popular as PR 107. The tree is tall and sturdy with a straight erect trunk, strong heavy primary branches and light secondary branches which self prune leaving prominent branch scars. Crown is narrow, well balanced and dense. Leaf is dark and elongated with wavy margin. Vigour at opening is average and after tapping below average. Both virgin bark and renewed bark have good thickness. It is highly susceptible to *Phytophthora* diseases. The clone is a fairly high yielder giving an average yield of 1553 kg/ha/annum during 15 years of tapping. The initial yield is very poor, but subsequent yield progressively rises. Summer yield also is high. Tolerance to pink and powdery mildew is average. Being highly resistant to wind damage and brown bast, it is adopted for wind prone areas and high intensity tapping.

5.5.2.14 GT 1

This is a primary clone developed at the Gondang Tapen Estate in Indonesia (3). It is a high yielding clone with desirable secondary

characters. The tree has upright stem which is slightly kinked and sometimes fluted (4). Branching habit is variable. Some trees have only one leader while others have several. One heavy side branch is common. Main branches are ususally long and acute-angled with light secondary branches (Fig 5.8). Crown is narrow and open with globular shape. Foliage is dense, dark green and glossy with small leaves. Vigour at opening is average to above average. Girth increment on tapping is average. Thickness of virgin bark is average while that of renewed bark is below average. Yield obtained from commercial plantations in Malaysia during the first 15 years of tapping was 1615 kg/ha/annum. In India it has given an yield of 1337 kg/ha/annum during the first six years of tapping (10). This clone also shows a rising yield trend with average initial yield and high subsequent yield. Summer yield is high. Latex is white and suitable for concentration. It shows good tolerance to pink disease and brown bast, average to above average tolerance to powdery mildew and wind damage, and average to below average tolerance to *Phytophthora* diseases. The clone withstands high intensity tapping.

5.6 Identification of clones

There are morphological variations among different clones of *H. brasiliensis*. For the identification of clones, certain distinguishing characters are helpful. Shape and size of seeds and markings on them show variations. Seeds of PB 5/51 and RRII 118 are small compared to those of RRIM 623 or RRII 105. Seeds of RRII 118 have more prominent white mottlings. The growth form and appearance of young buddings are characteristic of certain clones. The spindle growth of young buddings of RRIM 600 can be easily distinguished. In mature trees, shape of the trunk in most of the clones is cylindrical, but there are crooked stems as in PB 6/9 and leaning stems as in Tjir 16. Texture of the bark is another distinguishing feature. The bark of GT 1 is rough while that of RRIM 600 is comparatively smooth. Branching habit, growth of main trunk and branch union also vary with different clones. Regular spread of light horizontal branches in a storey like pattern from the main trunk is characteristic of PB 5/51. In clones like GT 1 and RRIM 605, a few heavy branches start from the branching point. The shape of crown is another identifying characteristic. The crown of GT 1 is globular or slightly

conical and that of RRIM 600 fan shaped. PB 5/51 has a crown appearing like a pagoda. Appearance of leaf is another guide to identification of clone. Leaves of RRII 105 and GT 1 are dark green and glossy, those of GI 1 glossy and bluish green and those of AVROS 255 glossy and yellowish. Leaf lamina shows wavy margin in clones like PR 107. Colour of latex also can be considered as a clue to identity of clones. Latex of RRIM 600 and PB 86 is white while that of Tjir 1 shows pale yellow tinge.

5.7 Choice of planting materials

The most important factor influencing the profitability of a rubber plantation is the planting material. Therefore, choice of planting materials should be made judiciously after considering all the factors which can influence their performance. These factors are: (i) inherent characteristics like high yield potential, good vigour and other growth habits, tolerance to pests, diseases and wind damage; (ii) good response to various exploitation methods; and (iii) adaptability to environmental factors such as terrain, soil, drought and excessive rainfall. Size of holding, efficiency of management and related aspects also can influence the selection of planting materials.

Preference of a planting material in a given locality primarily depends on the interaction between its genetic constitution and the environment prevalent in that locality. Clones suited for different situations could be chosen on the basis of their genetic potentiality and susceptibility to environmental conditions as indicated below.

Area	*Clones*
Severe *Phytophthora* diseases	GT 1, PB 5/51, RRIM 623, RRIM 628 and RRII 105.
High incidence of *Phytophthora* and pink diseases	GT 1, PB 5/51 and RRII 105.
Severe wind	GT 1, PB 5/51, PR 107 and GI 1.
Severe wind and pink disease	GT 1, PR 107 and PB 5/51.

Severe *Oidium* disease	GT 1, PR 107, RRIM 600 and RRII 105.
Severe wind, and pink and *Oidium* diseases	GT 1 and PR 107.
Strong wind, low rainfall and moderate to high drought	GI 1 and RRII 118.
Undefined areas	GT 1, PB 5/51, PR 107, RRIM 600, RRII 105, RRII 118 and PB 28/59.

It may, however, be remembered that the clones indicated are not the ideal ones suited for each locality. It only indicates that the performance of these clones will be better than that of other clones currently available. The ideal condition would be the choice of specific clones possessing characters best suited to each locality. Until such specific clones are evolved for different agroecological locations, choice of planting materials may be made as indicated.

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6 METHODS OF PROPAGATION AND MATERIALS FOR PLANTING

Chapter 6

METHODS OF PROPAGATION AND MATERIALS FOR PLANTING

6.1 Methods of propagation

Hevea brasiliensis is propagated both by seeds and through vegetative methods. During the initial periods of rubber cultivation, generative method through seeds was followed. Vegetative method of propagation through budgrafting became popular subsequently. Budgrafting is currently the most popular method of propagation. Among seed materials, only polyclonal seeds are now used for commercial planting.

6.1.1 Propagation through seeds

Fruits mature in about five months' time. The seed fall season ıu eıpul is July-September.

The following terms are used to denote the different kinds of *Hevea* seeds:

(i) Ordinary seeds: Seeds obtained from seedling trees;

(ii) Ordinary unselected seeds: Ordinary seeds collected indiscriminately;

(iii) Ordinary selected seeds: Ordinary seeds collected from the selected trees;

(iv) Clonal seeds: Seeds collected from clones;

(v) Monoclonal seeds: Clonal seeds collected from monoclonal areas; and

(vi) Polyclonal seeds: Clonal seeds collected from polyclonal areas.

When both the parents are known, the term legitimate seed is used and the term illegitimate when the parents are not known. In case one parent alone is known, the seeds are called illegitimate seeds of the particular parent.

Variation in seed production among clones has been noted. There are prolific seeders as well as shy seeders. The highest recorded production of seed is 280 kg/ha (11). An average production of 250 kg/ha of seed may be considered reasonable.

6.1.1.1 Polyclonal seed garden

Rubber seeds of good quality are produced in certain specially maintained rubber plantations called polyclonal seed gardens. In seed gardens, only clones from which seeds are intended to be collected are planted. The number of clones planted in polyclonal seed gardens usually varies from three to six. Clones selectdd for this purpose should possess, apart from the usual desirable characters like high yield, disease resistance and vigour, other additional attributes. They should:

(i) Produce good seedling families;

(ii) Yield plenty of seeds; and

(iii) Flower simultaneously so that there are adequate chances for cross pollination among them.

Some of the common clones suitable for inclusion in polyclonal seed gardens are RRIM 600, RRIM 605, RRIM 623, RRIM 628, GT1, PB 5/51, PB 28/59, Tjir 1 and other modern clones which produce dependable seedling families. The various clones included in polyclonal seed gardens are planted interspersed so that there is maximum chance for cross pollination among them. For this purpose, certain specific designs are usually used.

A design of a polyclonal seed garden with five clones A,B,C,D and E is given below:

A B C D E
C D E A B
E A B C D
B C D E A
D E A B C

Repeat

Repeat

Each letter represents a tree or a group of trees.

In another simpler design, each row is planted with a different clone as shown below:

A A A A A A A A A
B B B B B B B B B
C C C C C C C C C
D D D D D D D D D
E E E E E E E E E
B B B B B B B B B
D D D D D D D D D
A A A A A A A A A
C C C C C C C C C
E E E E E E E E E

The first design is superior, as it provides better chances for cross pollination among the clones.

For profuse flowering and fruit set, good crown development is essential. To attain this, it is necessary to plant trees in a wider

spacing. An initial stand of 358 trees/ha (spacing 910 x 300 cm), subsequently reduced to 247 by thinning out by the sixth year of planting, is considered very suitable (2).

Pollen grains carried by pollinating insects from adjacent rubber trees to the seed garden may contaminate the seeds produced. It is assumed that the flight range of pollinating insects may not exceed 100 m, and hence an isolation belt of this width has to be kept around each seed garden. This area can be left as forest or planted with some other crop or with one of the clones included in the garden. The number of seeds harvested from a garden varies widely depending on various factors. However, an average of 150 seeds can be expected per tree from a properly maintained garden. The Rubber Research Institute of India collaborated in the establishment of polyclonal seed gardens in Kanyakumari district (19).

6.1.1.2 Seed collection, pocking and storage

When fruits mature and dry, they dehisce and the seeds fall. As the seeds lose viability very rapidly, collection is made as early as possible. The usual method adopted under commercial practice is to pick up the seeds every day so that the seeds never remain on the ground for more than a day.

Seeds should be sown for germination as soon as they are collected. Germination is the only reliable method for testing the viability. Discolouration of the endosperm indicates poor quality of seeds. Viability can be prolonged by adopting different methods which check loss of moisture and rate of respiration. Fresh seeds can be kept under shade without much loss of viability for about seven days. An early study showed that by packing seeds not too tightly in well aerated containers with powdered charcoal having 40 per cent moisture, 70 per cent viability was retained up to 30 days (15). Viability of seeds is reported to have been kept unimpaired for two months by mixing the seeds with an equal volume of saw dust (10 per cent initial moisture content) in perforated polythene bags (8). Storage of seeds at 4°C is also considered to be a reliable method.

Immediately on collection, seeds are generally packed with powdered charcoal of 20 per cent moisture, saw dust of 10 per cent

moisture, or a mixture of the two (27). Containers usually used are wooden boxes, double gunny bags, bags lined with polythene or polythene bags. For long distance transport, seeds may be packed tightly in layers in aerated cases with damp saw dust-charcoal powder mixture, at least 2 cm thick between layers. Germinated seeds are packed in boxes between layers of damp coconut fibre, saw dust or charcoal powder. They should be laid in such a manner that the curved end of the radicle points downwards. The top side of the box must be kept up.

6.1.1.3 Germination

Germination of seed is the commencement of the active growth of embryo and emergence of the young plant. Seeds start germination within 6–7 days after sowing. The mode of germination is hypogeal, ie the cotyledons remain within the seed coat. Vivipary (germination of the seed still on the parent plant) is observed when climate is not favourable for pod dehiscence and air is moist during seed fall season. On germination, the radicle pushes open the circular cap which closes the germpore or micropyle and emerges as a small white stump with flattened end (13). As it lengthens, the tip becomes conical and a number of minute points develop around its margin. The conical point develops into tap root and the marginal points emerge as laterals. The two cotyledons remain within the seed and absorb stored food materials in the endosperm. Then the epicotyl elongates and comes out of the seed forming a hump which subsequently straightens, bringing out the plumule (Fig 6.1).

On each day, the sprouted seeds should be picked up and planted in the nursery or in the field as the case may be. Fresh and heavy seeds show early germination (22). Light and shrunken seeds are discarded. Removal of seed coat greatly accelerates germination but results in low germination percentage and in poor growth of the seedlings.

6.1.2 Propagation through vegetative methods

Propagation by asexual parts such as buds and cuttings is termed vegetative propagation. Vegetative propagation of rubber is carried

out mainly by budgrafting (budding). The principle involved in budding is the replacement of the shoot system of a plant by that of another more desirable plant. In this process, a strip of bark with a dormant bud, named budpatch, is inserted under the bark of a seedling which is the stock plant. The bud thus inserted gets attached to the stock permanently and becomes a part of it. The stock is then cut off above the budded portion and the grafted bud develops into the shoot exhibiting the characters of the plant from which it was taken. The new tree thus formed is a two-part tree, comprising a root system belonging to the stock plant and a shoot system contributed by the donor of the bud.

Depending on the colour and age of the buds used, two types of buddings are recognised. These are brown (conventional) budding and green budding. In the former method, older buds with brown colour are made use of while in the latter tender buds, green in colour, are used. In India brown budding is more commonly adopted.

6.1.2.1 Brown budding

This is generally carried out by grafting buds taken from budwood of about one year's growth, on to stock plants of ten months or more growth. Seedlings of age about ten months, raised in nurseries or field, are generally used as stock plants for budding. Vigorously growing healthy stocks having a girth of 7.5 cm are ideal for budding (1,14). Stocks of slightly less girth can also be used. Stocks should be budded when the bark peels off very easily. This usually happens when the top whorl of leaves have fully expanded but not hardened. Since all stock plants may not attain this stage simultaneouly, a few rounds of budding may be necessary.

Buds required for budding are usually obtained from budded plants specially maintained in budwood nurseries. They are called budwood plants (Fig 6.2). Budwood is collected when it is about one year old (Fig 6.3). Buds found in the axils of fallen leaves are generally utilised for budding. Budwood is collected using a pruning saw leaving about 15 cm at the base. New shoots develop from this portion and one or two are allowed to develop for future use. Budwood should be collected when the top whorl of leaves have fully expanded but not hardened to ensure proper peeling quality

of the bark and high budding success. Test peeling may be carried out before harvesting the budwood. Collection and packing of budwood should be done with sufficient care to avoid bruising and drying up of the buds. Budwood should, as far as possible, be collected in the morning or evening, and should be preferably used for budding as soon as it is collected. If it has to be stored, special measures should be adopted for preventing loss of water. As per requirement the budwood is cut off and made into pieces of convenient length, usually 1 m. The cut ends are waxed and properly packed for transit.

In plantation practices the brown sticks are packed individually in banana sheath or rolled in fresh damp coconut fibre for transit. Damp sacking with grass or cover crop also forms a suitable temporary packing. For longer storage and transport each budwood piece is put into a polythene cover and packed in boxes with layers of coconut fibre in between. For identification, proper labelling is of utmost importance while handling different types of budwood.

Budding is usally carried out with a specially designed knife called budding knife. However, an ordinary pen knife with a blade of 7–8 cm also could be used for budding. First step in the preparation of the stock plant for budding is thorough cleaning of the basal portion of the stock off dirt, soil etc. with cotton waste, rag or cuttings of cloth. Then two parallel vertical cuts starting from about 2.5 cm above the collar are made. Length of the cuts should be a little more than 5 cm and the distance between the two a little more than 1.5 cm. Then a horizontal cut, joining the bottom ends of the above two cuts, is also made (Fig 6.4). All the three cuts should be made deep enough to reach the wood. After making these cuts the plant is left for a few minutes for the latex to ooze out completely through these cuts. During this time the budder can mark a few more stocks in a similar manner. After the flow of latex ceases, it is wiped off from the surface. The flap of bark separated by the three cuts is then gently lifted with the aid of the knife and peeled upwards (Fig 6.5). The stock is now ready to receive the bud. An alternate method of connecting the upper ends of the vertical cuts by the horizontal cut and peeling the flap downwards is also followed (Fig 6.6). The practice of removing the flap is also adopted.

A piece of bark with a dormant bud in the centre is termed the budpatch. Budpatch used for brown budding has a length of about 5 cm and a width of about 1.5 cm. For preparing the budpatch, two parallel vertical cuts having a length of a little more than 5 cm and a little over 1.5 cm apart are made on the two sides of a bud. Then two horizontal cuts are made connecting the lower and upper ends of these cuts (Fig 6.7). A little time is allowed for the latex to ooze out. During this time incisions are made around neighbouring buds of the same budwood. When the oozing of latex is over, it is wiped away and the budpatch marked out by the four cuts is stripped by gently pushing to one side.

After removing the budpatch from the budwood the inner side is examined carefully to see whether the core of the bud, which appears as a slight projection, is there. If it is not present the budpatch is useless and should be discarded. The budpatch with the core of the bud is then trimmed further to the required size (Fig 6.8). Inside of the budpatch and the portion of the stock exposed by peeling the bark should not be touched.

The budpatch prepared in the above manner is then gently placed under the flap of the stock after raising it (Fig 6.9). The budpatch should be placed in such a way that the bud is above the leaf scar and its inner side is in contact with the exposed side of the wood of the stock. Budpatch should not rub against or slip over the stock wood as it may damage the cambium. Utmost care should be taken to keep clean the cambium layers of the stock and the budpatch which should be left untouched. This tissue should not be left exposed to direct sunlight or otherwise kept exposed for long. All these factors can adversely affect the success of budding. Exposure of too much area of the stock around the budpatch is an unfavourable factor affecting budding success. After placing the budpatch in the budding panel, the flap, if retained, is placed back over it and is then bandaged using polythene (250 guage) strips of 20–25 mm width and about 30 cm length. Bandaging should commence at the bottom and move upwards in close spiral (Fig 6.10). During the first few turnings of the bandage the lower end of the flap should be kept pressed over the budpatch gently to prevent it form slipping. The end is finally kept intact by a knot. In field and along the edges of seedling nurseries, it may be necessary to shade the budpatch against

sunlight. It can be conveniently done by tying rubber leaves over the budpatch.

If the budding is a success, the cambium of the stock plant and that of the budpatch get united and the budpatch establishes itself as a part of the stock. This process requires 10–20 days. Twenty days after budding the bandage is therefore removed. Then the flap, if retained, is cut at a point a little above the upper end of the budpatch and carefully separated from the stock exposing the budpatch. If the opening is delayed a thin white callus layer may be found, completely covering the budpatch, which also should be removed carefully while opening up to expose the budpatch. Presence of green colour on gently scratching the budpatch below or above the bud indicates success of budgrafting. The final success is again ascertained in a similar manner after ten more days.

6.1.2.2 Green budding

This is a comparatively new method of vegetative propagation It differs from the other mainly in the type of bud used for grafting. Both the stock plant and budwood used for budding are very young. Seedlings, two to six month old, are used as stock while the budwood used is only 6–8 week old. Budpatches taken from this kind of budwood, commonly called budshoots or budsticks, are green in colour and hence the name green budding.

Young, vigorous seedlings are used as stock plants for green budding. Plants having a girth of about 2.5 cm at the base with brown bark up to a height of about 15 cm can be used for this purpose. Under the climatic conditions in India, it usually takes about four to five months for the stock plants to attain this size. By intensive manuring and watering this period could be further reduced.

Green budwood also is obtained from budwood plants (source bushes) kept in nurseries for this purpose. For preparing the bush, the scion of a well established budded plant is first cut back at a height of about 75 cm. A number of shoots emerge below the cut end. Among them, only three to five of the most vigorous ones are allowed to develop and the rest removed (6). When these shoots have grown and produced brown wood at the basal portion to a

length of a few centimeters, they are again pruned to produce more shoots. The green sticks thus removed can be used for budgrafting. By repeating this process a bush with a number of branches can be established (Fig 6.11) (26). For producing green budshoot, lateral branches of this source bush are pruned above a whorl of buds six to eight weeks before the budshoot is required. Each of these lateral branches then produces several green shoots which are harvested when required. By repeated pruning of the lateral branches several crops could be obtained from a plant in the same year. Each budshoot, when six to eight week old, will have a length of 30–60 cm with a whorl of leaves at the top. The budshoots are harvested by cutting at the base with a sharp knife. For proper peeling of the budpatch, harvesting should be done when the leaves are pinkish green in colour. After harvesting, the leafy portion of the shoot is cut off. The no-leafy portion shows two to five scale leaves with axillary buds which are utilised for budding (Fig 6.12). Since green budshoots are very tender, they should be used immediately after harvesting. The budshoot is carried carefully without any bruising and kept loosely in a bag or jute sac in shade. Carrying them in a tray with water is also found very convenient. For storage and long distance transport they are packed in boxes in layers, each layer separated by 30 mm thick saw dust. A box of 107 x 30 x 26 cm size will hold about 500 green sticks. For small quantities polythene bags can be used.

After cleaning the basal portion, two vertical incisions 5 cm long and 1 cm apart are made starting from a point about 2.5 cm above the soil level. The lower ends of these cuts are joined by a horizontal cut. The flap of bark thus separated out is gently lifted upwards exposing the budding panel. The flap is then cut off leaving a short tongue of about 1.5 cm at the top. The stock is now ready for grafting.

Budpatch can be stripped from the budshoot in the same way as in the case of brown budding. For stipping the budpatch another method also is employed. In this method, the budpatch along with a thin slice of wood is first cut off from the budshoot. This is the budslip. Two sides of the budslip are trimmed to the required width. Then the budpatch is gently separated from the wood by pulling them apart. While doing so care should be taken to see that the budpatch does not

bend. Only the slice of wood is bent. After separation, the lower and upper ends of the budpatch are trimmed. When finally prepared, it should have a length of 5 cm and a width of 1 cm approximately so that it snugly fits into the budding panel (Fig 6.13) (16).

The upper end of the budpatch prepared in the above manner is gently inserted under the tongue. Then the budpatch is secured firmly by bandaging with a transparent polythene strip of about 2 cm width around the bud, as in the case of brown budding. Transparent tape is insisted upon as it allows light to fall on the green budpatch which enhances budding success. For the same reason no shading is also provided. Buds are examined three weeks after budding by observing through the bandage. Retention of the green colour is indication of success. Since no further observation is needed, the bandage is removed and the plant is ready for cutting back.

Budding can be carried out at any time of the year. However, too dry or too wet weather is unsuitable (12). Generally, more success is obtained during rainy season than in summer. Experiments have shown that in India the period from April to December is generally suited for budding except days with heavy rainfall (17). The best time of the day for budding is morning as well as evening. However, in nurseries shaded properly, budding can be done at any time of the day.

For obtaining good results it is always advisable to use stock plants and budwood of more or less the same girth. Buds taken from budwood fits correctly into the stock of the same girth. Too much difference in the size of the stock and budwood causes bending of the budpatch resulting in damage to its tissues, thus adversely affecting budding success.

Both brown budding and green budding have certain advantages and disadvantages. Advantages of green budding are: (i) It utilises the growth of the stock more efficiently, ie when green budded plants are cut back, only a small amount of stock growth is lost (4); (ii) Green budding is simpler and faster than brown budding and hence more number of plants can be budded reducing the cost per budding; (iii) It is more adaptable for production of advanced planting materials and for crown budding; (iv) During summer, it gives higher percentage of success than brown budding; (v) Opening the budding and

cutting back can be done simultaneously, thus saving labour cost; (vi) Yield of green buds from a unit area of nursery is two to three times that of brown buds; and (vii) Since the polythene strip used for green budding is smaller than that used for brown budding, cost incurred for this material is reduced.

Green budwood cannot be kept in the nursery in a viable state for long duration (5). Once it becomes mature enough for harvesting it should be harvested within a few days. After harvesting it cannot be kept for long periods, unlike in the case of brown budwood. Scion of green budding is less vigorous than that of brown budding and hence it requires very careful attention during early periods of growth.

6.1.2.3 Crown budding

Top working through budgrafting to replace an undesirable crown is of practical significance. In the case of many of the modern clones, though the trunk possesses capacity for high yield, the crown shows many undersirable characters such as susceptibility to diseases, and wind damage. Undesirable crown can be replaced by a desirable one through crown budding.

The technique of crown budding was initiated in South America in the 1930's to prevent the damage caused by South American leaf blight. The tree thus produced is a three-part-tree comprising the root system of the stock plant, trunk of a clone and the crown of another. Thus the desirable characters of the trunk of one clone and crown of another clone are combined (28).

Crown budding is ideally carried out when the scion of the budded plant has attained a height of 2.4–3.0 m. One to two years are usually required for the plants to attain this much growth. Plants having height up to 4.5 m can also be used. For crown budding, height of the plant is more important than age. Crown budding may be commenced when 50–60 per cent of the plants in the field are buddable. Those which are left out in the first round may be crown budded in subsequent rounds. Budding is carried out at a height of 210–240 cm on the inter-whorl region between the two whorls of leaves at the top. Budding should be done only when the top flush of leaves is fully expanded and hardened. Stem tissue

should be green or dark green at the time of budding. This ensures maximum budding success, while too tender or too mature stem tissues adversely affect budding success. If the top most flush of leaves are not mature enough, budding could be done below the second whorl of leaves provided all other conditions are satisfied. In the case of overgrown plants, having the green tissue at a height more than that prescribed, site of budding may be raised to above 240 cm. For crown budding, the green budding technique is followed. Since the budding has to be done at a higher level, a self supporting ladder should be used. On no account should the plant be bent for budding or any other operation. The successful ones are cut back leaving a snag of about 5 cm. If the budding is a failure, rebudding is done on the opposite side of the stem, 5 cm above or below the first budding. Treating the cut ends of the stem with some wound dressing compound is desirable. After cuttng back, usually many trunk shoots arise. All of them should be pruned regularly at fortnightly intervals with a knife having a long handle. This should be continued until the bud sprouts and the crown shoot grows to a length of about 2.5 cm. After that, two or three trunk shoots arising about 15–45 cm below the budpatch are allowed to grow. These shoots should be spaced apart and be on different sides of the stem as far as possible. But they should never be allowed to become more dominant than the crown shoot, as this may suppress the growh of the latter. For this, if necessary, the top portion of the trunk shoots may be pruned. About nine months after cutting back, when the crown-trunk union is firmly established, the trunk shoots are pruned. Necessary precautionary measures are taken for the protection of the crown shoot which later on fully establishes itself and in due course develops to be the crown of the three-part-tree (Fig 6.14). If the crown shoot is lost by some reason before the pruning of the trunk shoots, the most vigorous among them is again crown budded, if possible, or allowed to develop as the crown.

6.1.2.4 Over budding

Budwood plants are sometimes budded at higher levels for converting an existing budwood nursery of a clone to another clone without replanting. This is termed over budding. The method adopted is to carry out budding at the basal portion of the new shoot before harvesting the budwood. Since the budding is carried out

on a well established plant, the scion grows very vigorously producing more bud...od compared to a newly established nursery.

6.1.2.5 Other methods

Apart from budgrafting, certain other methods are also attempted for the vegetative propagation of rubber. Important among them are rooting of cuttings (3), approach grafting, cleft grafting (25), root grafting (20), layering, tissue culture etc. These methods, however, are not easy and practicable and hence they have only little commercial importance at present. Rooting of cuttings is carried out by placing terminal cuttings with a whorl of leaves in beds prepared with sand, saw dust etc in a special chamber called mist propagation chamber. A fine spray of water is applied to these cuttings during day time for about five to nine weeks by which time they produce roots. Rooted cuttings are then hardened by gradually reducing the duration of mist and exposing them to sunlight for about three to four weeks, after which they are planted in the field. In the case of approach grafting, six to eight week old green shoots are grafted without separating them from the source bush on the stock plants of comparable thickness, raised in polythene bags and placed near them. When the stock and scion are firmly united, the shoot is severed from the source bush by cutting below the grafted portion and the stock plant cut back above this region. For root grafting, one week old seedlings are cut at the epicotyl region and the roots are grafted on to the base of young terminal shoots. The grafted plants are placed in a mist chamber for three weeks, transferred to polythene bags and hardened over a period of about four weeks before field planting. Attempts are now in progress to propagate *Hevea* through tissue culture.

6.2 Materials for planting

Different types of planting materials are commercially used for establishment of rubber plantations. The important ones among them are seeds, seedling stumps, budded stumps and advanced planting materials comprising stumped buddings, polybag plants and soil core plants. A brief description of the different planting materials is given below. More details are given in Chapter 8.

6.2.1 Seeds and seedling stumps

Seeds can be used either for seed-at-stake planting or for preparing seedling stumps. For seed-at-stake planting, two or three germinated seeds are planted in each pit in the field. The most vigorous one is used either for raising seedling tree or for field budding. The usual practice in India is, however, to prepare seedling stumps for field planting. Seedlings, aged about one year and raised in seedling nurseries, are pulled out and pruned at a height of 45–60 cm from the collar. A stump with plenty of food reserves gives a vigorous and healthy seedling after planting and hence only vigorous stumps are used for planting. In the case of seed materials, only polyclonal seeds are recommended for raising plantations.

6.2.2 Budded stumps

The budgrafted seedlings prepared for planting are known as budded stumps. After successful budgrafting, the seedlings are pulled out and the stock stem cut back at a height of 7–10 cm above budpatch with a slope towards the opposite side, so that less of rain water runs down over the budpatch. This is the most popular form of planting material. Depending on the type of the bud used, the budded stumps are categorised as green budded stumps (when green buds are used) (Fig 6.15) and brown budded stumps (when brown buds are used) (Fig 6.16). The green budded stumps are observed to shorten the immaturity period. However, on account of the limited planting season in India, immediate planting of green budded stumps in the field is not practicable.

6.2.3 Advanced planting materials

Recent advances in the field of propagation techniques are centred on shortening the period of unproductive phase in the field (23). Maintenance in the field is more expensive than in nurseries. So the new techniques of growing the planting materials in nurseries for longer period and transplanting them to the field without disturbing the root system were developed. Stumped budding, stumped three-part-tree, polybag plants and soil core plants are all different techniques developed in this line.

6.2.3.1 Stumped budding

Stumped buddings are prepared by budgrafting just as in the case of budded stumps. The grafted bud is allowed to grow in the nursery after cutting back the stock stem before field planting. According to the stage at which the stumped budding is transplanted to the field, the materials are termed as mini stumps or maxi stumps. For raising stumped three-part-tree, the basal budding is allowed to grow to a height of 3 – 3.6 m. It is then crown budded and the crown shoot is stumped at the brown portion just below the second cluster of buds (10). The cut end is treated with a wound dressing compound and the stump white-washed immediately with hydrated lime. Extraction of the stumps for transplanting is carried out immediately after bud swelling to ensure minimum failure and damage to the buds. The cost of raising stumped buddings of convenient sizes in nursery is less than that of polybag plants. However, in India, the use of stumped buddings on a commercial scale is not popular because of the long period of drought.

6.2.3.2 Polybag plants

Green budded stumps are planted in polybags of appropriate size and transplanted in the field without disturbing the shoot and root systems (9). Transplanting is done either at two to three whorl stage or at six to seven whorl stage. In another method, stocks are raised in polythene bags by planting germinated seeds. These are green budded at the appropriate stage, the successful budgrafts are cut back and the scion allowed to grow to the required size before transplanting.

The first method is more advantageous as more uniformity could be achieved. Loss of bags due to bud failures could also be avoided. Further, the entire period of retention of the plant in the polybag is exclusively utilised for the growth and development of the scion shoot. Polybag plants are definitely advantageous for easy establishment and shortening the immaturity period. The method is also useful for reducing vacancies to the minimum.

6.2.3.3 Soil core plants

In this method, a healthy budding, complete with most of its root system in a block of soil, is directly transplanted from the nursery

to the field (7). Extraction of the buddings in soil cores may be done at the budded stump stage when the scion buds begin to swell or at any subsequent mature leaf stage up to the fifth but excluding plants at the first whorl stage (24). It has been reported that extraaction at the third whorl stage is advocated in order to reduce the immature period to a minimum and that extraction at the fifth whorl stage will cause a set back in growth. Soil core method is being tried in Malaysia. The success, however, mostly depends on the texture of the soil. Handling of soil core plants is also difficult.

6.2.3.4 Seedlings versus clones

Both seedlings and buddings have advantages as well as disadvantages. Seedlings are generally more vigorous and hence attain tappability earlier than buddings. They show more tolerance to adverse soil and climatic conditions and hence they are more easy to establish and maintain. Seedlings generally possess thicker bark as a result of which tapping can be done more easily. Recovery from wounds, renewal of bark etc are also more rapid in the case of seedlings. Owing to the genetic diversity, damages caused by diseases and unfavourable climatic factors are also generally less in seedling population. Because of the high vigour, seedlings give higher timber yield. However, these materials have certain serious defects such as high susceptibility to brown bast and tolerance to only low intensities of tapping. Moreover, high variations in growth vigour and yield necessitate initial higher stand and subsequent thinning out which cause wastage. Variations exhibited by seedlings in thickness of bark and properties of latex also cause much practical difficulties in tapping and processing. Seedlings have tapering trunk and therefore initial opening has to be made at a lower level, resulting in bark island formation during the openings of subsequent panels. On the other hand, clones are noted for their uniformity in characters. Since there are different clones possessing different specific characters, selection of materials suited for specific purposes is possible. Above all, production of true progeny is possible in the case of clones, which ensures duplication of the desired characters. The production potential of many modern clones is higher than that of seedlings. Under ideal agroecological conditions clones are considered better planting materials than seedlings. Seedlings are usually preferred in areas

where establishment of plants is difficult or when early maturity and yield are desired.

6.3 Pulling out and packing

The care with which the plant is uprooted from the nursery is an important factor deciding the chances of its survival. The plant is pulled out by an upward lift, minimising damage to the lateral roots, especially at the points of contact with the tap root. The budded plants should be held only on the portion above the budpatch during pulling out.

In the case of seedling stumps, cutting back is generally done at the portion of brown bark at a height of 45-60 cm or more, depending on the size of the plants, bigger the plants higher being the cut. It is also important that the cut should be slanting and that there should be a whorl of dormant buds near the cut end. The cut end is waxed soon after cutting back. The tap root should be pruned to the maximum practicable length with a clean cut while the side roots should be neatly pruned retaining a length of about 10 cm.

In the case of budded stumps also, general procedures are the same as in the case of seedling stumps. The pruning in this case should be done 7–10 cm above the budpatch. This is better done in one cut with a sharp knife and the pruned surface should be slanting away on the opposite side of the budpatch at about 45°. For transporting stumps over long distances, they should be properly treated and packed. In the packing of stumps the aim should be to protect the stumps adequately against drying out or bruising during transit. Waxing the cut ends of seedling and budded stumps and greasing the cut ends of stumped buddings seal the cut surface and ensure prevention of moisture loss. Bundles of seedling and budded stumps are wrapped in damp sacking or covered with leaves for transporting them to the field. When budded stumps are packed, the buds should be well protected to avoid bruising and damaging of the grafted bud. For this purpose, the budpatch is covered with a piece of banana sheath and tied in position. Budded stumps and mini stumps can be consigned in bundles up to 50 stumps with adequate protection against bruising (10). For special requirements the brown budded stumps can be stored up to four weeks



Fig 2.1 *Parthenium argentatum*



Fig 2.2 *Castilla clastica*

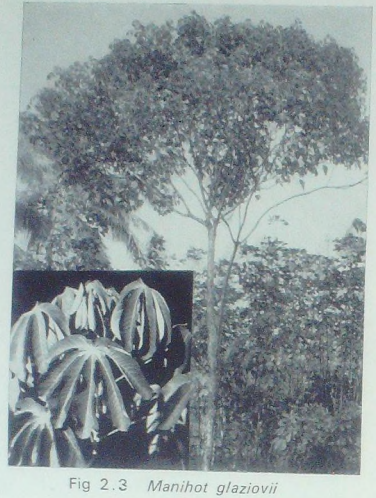


Fig 2.3 *Manihot glaziovii*



Fig 2.4 *Cryptostegia grandiflora*



Fig 2.5 *Hevea benthamiana*



Fig 2.6 *Hevaa spruceana*



Fig 3.1 *Hevea brasiliensis*



Fig 3.2 A leaf of *Hevea brasiliensis*



Fig 3.3 Inflorescence of *Hevea brasiliensis*



Fig 3.4 Male and female flowers on inflorescence



Fig 3.5 Fruits of *Hevea brasiliensis*

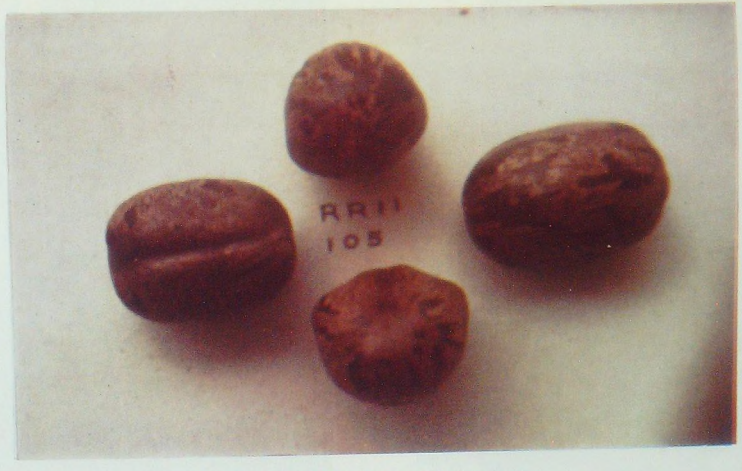


Fig 3.6 Seeds showing different views

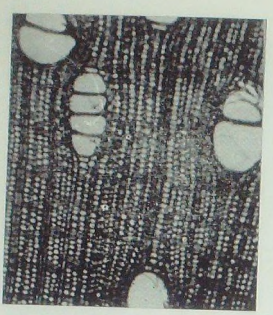


Fig 3.7 Transection of wood showing diffuse porous nature

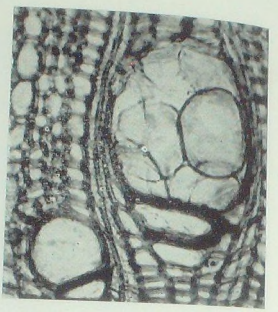


Fig 3.8 Transection of wood showing tyloses

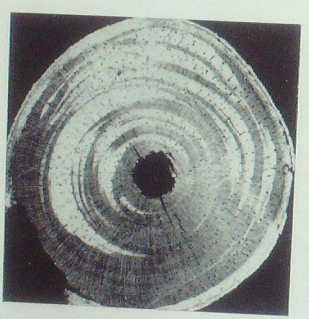


Fig 3.9 Transection of a leaning stem showing tension wood

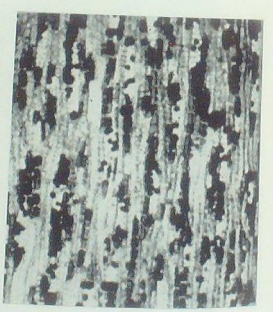


Fig 3.10 Tangential longitudinal section of bark showing latex vessels



Fig 4.1 Staminal column taken out for hand pollination



Fig 4.2 Inflorescence showing the female flowers after hand pollination

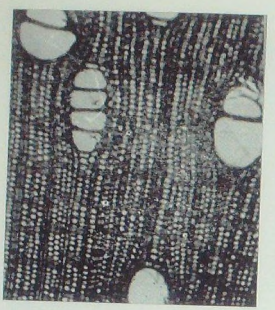


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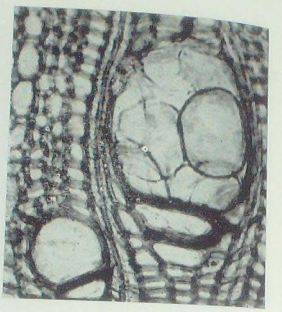


Fig 3.8 Transection of wood showing tyloses

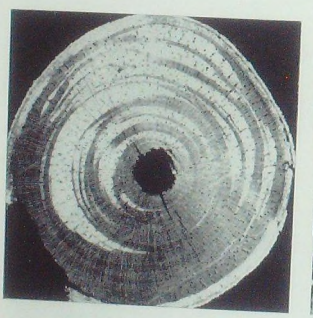


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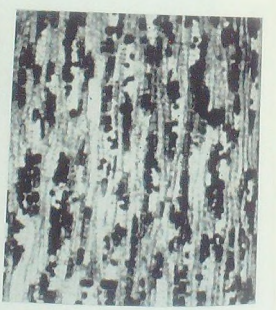


Fig 3.10 Tangential longitudinal section of bark showing latex vessels



Fig 4.1 Staminal column taken out for hand pollination



Fig 4.2 Inflorescence showing the female flowers after hand pollination



Fig 4.3 Young fruits resultant of hand pollination

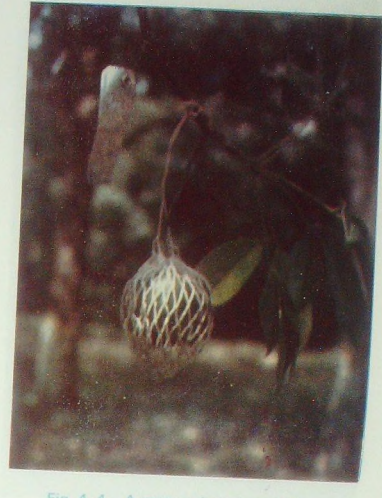


Fig 4.4 A mature fruit bagged for collection of seeds

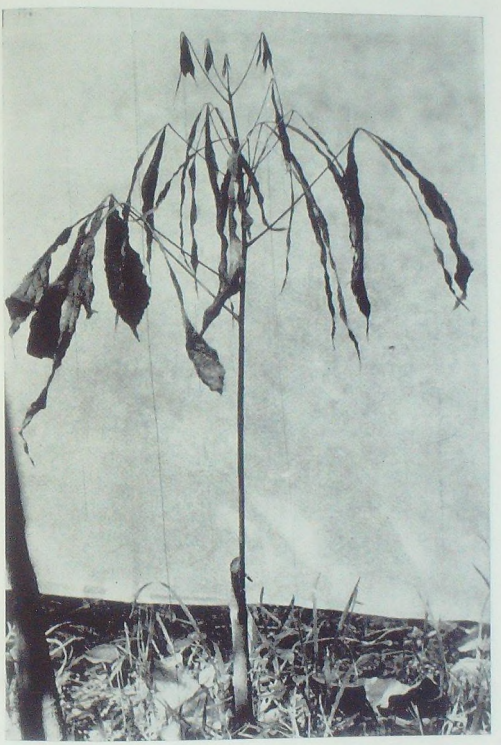


Fig 4.5 A mutated plant showing lamina distortion



Fig 4.6 A genetic dwarf of *Hevea brasiliensis*



Fig 5.1 Clone RRII 105



Fig 4.6 A genetic dwarf of *Hevea brasiliensis*



Fig 5.1 Clone RRII 105



Fig 5.2 Leaf retention of RRIM 600 and RRII 105 under uniform prophylactic treatment



Fig 5.3 Clone RRII 118



Fig 5.4 Clone RRII 203



Fig 5.5 Clone RRII 208



Fig 5.6 Clone RRIM 600



Fig 5.5 Clone RRII 208



Fig 5.6 Clone RRIM 600



Fig 5.7 Clone PB 5/51



Fig 5.8 Clone GT 1



Fig 6.1 A germinated seed

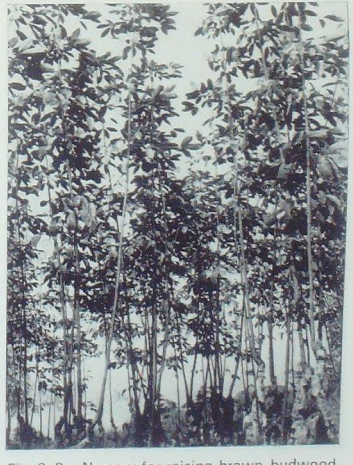


Fig 6.2 Nursery for raising brown budwood



Fig 6.3 Brown budwood



Fig 6.4 Making incisions on the stock for budgrafting



Fig 6.5 Upward peeling of the bark of the stock



Fig 6.6 Downward peeling of the bark of the stock



Fig 6.7 Marking of the budpatch



Fig 6.8 Brown budpatch trimmed to the required size



Fig 6.9 Insertion of budpatch

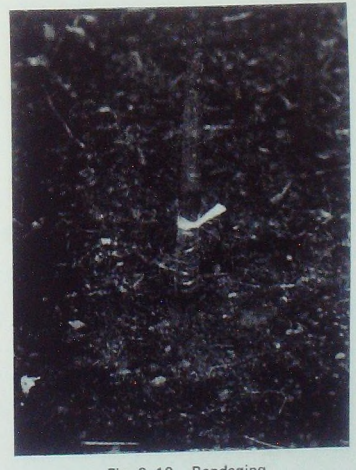


Fig 6.10 Bandaging



Fig 6.11 Source bushes for green budsticks



Fig 6.12 Green budstick



Fig 6.13 Green budpatch trimmed to required size



Fig 6.14 A budgraft of RRIM crown budded with GT 1



Fig 6.15 A green budded stump



Fig 6.16 A brown budded stump

without appreciable damage by proper packing, after waxing the cut ends and dipping the stumps in a 5 per cent aqueous solution of Captan (21). Each treated stump is rolled in polythene film, bundled, packed in jute hessian and labelled.

Advanced planting materials like stumped buddings may be packed head to tail on to the lorry or trailor with sufficient litter or other such materials to prevent bruising and drying up.

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7 AGROECOLOGICAL REQUIREMENTS

Chapter 7

AGROECOLOGICAL REQUIREMENTS

Crops vary in their agroecological requirements which are mostly defined by the climate, the features of physiography and the physico-chemical characteristics of soil. Some crops are so fastidious in these requirements that they will not complete the vegetative or reproductive phase satisfactorily unless these are scrupulously fulfilled. However, certain other crops, which include rubber, are more adaptable to their environment.

7.1 Climate

This is the most important ecological factor since the characteristics of soil are also to a great extent dictated by the climate in which it occurs. The dependence of crops on climate is so much that it is possible to assign different crops to distinct climatic zones. Thus, plantation crops like rubber, coffee, tea and oil palm come mostly under the tropics.

The tropics, however, is not a well defined term. Traditionally, the tropics are considered to lie between the tropics of Cancer and Capricorn, the parallels at a latitude of 23.5° on either side of the equator. But this delineation of the tropics is too rigid, because some regions with clear tropical characteristics are found at latitudes of more than 23.5° while, on the other hand, some clearly non-tropical areas are found much closer to the equator. Therefore, the tropical areas have been taken as coinciding with the 21°C (70°F) or 20°C (68°F) isotherms or as extending into these regions where the coolest month has a temperature of not less than 18°C (64°F) (10). The use of 18°C sea level isotherm has also been suggested, and delimited in this way, the tropics constitute a belt around the equator, varying in width from 40°–60° in latitude (13).

The tropical climates in which rubber is predominantly grown comprise the two major types – the equatorial monsoon and the dry and wet monsoon climates. The equatorial monsoon climate prevails over a large region between 10°S and 8°N latitude consisting of most of the Indonesian archipelago, Malaysia, southern part of Sri Lanka and some other islands. The main characteristics of this region are the existance of a mixture of land and sea surfaces, recepit of an annual total rainfall of over 2000 mm and absence of drought all of which provide a warm, humid and equable climate optimum for the growth of rubber. Dry and wet monsoon climate prevails in the Indian subcontinent, including the northern parts of Sri Lanka and coastal parts of Bangladesh, Burma, Thailand, Viet-Nam, the Philippine archipelago and Southeastern Indonesia. In these areas, the annual and diurnal ranges of temperature and the period of drought vary, depending on the location, altitude and latitude. These variations are reflected in the degree of success achievable in rubber cultivation.

The important elements of climate which influence rubber cultivation are rainfall, temperature, relative humidity and wind.

7.1.1 Rainfall

For optimum growth and yield, rubber plants require an evenly distributed rainfall of 2000–3000 mm in an year. In areas where rainfall is much less, it has been observed that the trees become stunted with crooked stems and lower branches. In general, growth of rubber is retarded in regions with a pronounced drought season. Excessive rainfall is also not desirable as it favours soil erosion and loss of nutrients through leaching in the lateral as well as vertical directions. It may also cause water-logging or high water table and attendant problems if drainage is not adequate. High rainfall may also cause loss of tapping days. Moreover, under high rainfall conditions, incidence of fungal diseases is also found to be very high (8). Rainfall also influences the temperature regime and relative humidity. Diurnal variations in rainfall pattern are also important. Sunny forenoons with evening rainfall are conducive to healthy growth and uninterrupted tapping of rubber.

The majority of the rubber growing areas in India are confined to a narrow belt on the western side of the Western Ghats which enjoys

the benefit of both southwest and northeast monsoons. Rain starts as premonsoon showers by the end of April which merge into the southwest monsoon from the middle of June to middle of August. Northeast monsoon is received from early October and extends up to the middle of November. Kanyakumari district in Tamil Nadu and part of Trivandrum district in Kerala, particularly the former, get more or less equal shares of both the monsoons and experience a climate much akin to that of equatorial monsoon. But towards the northern regions, the northeast monsoon turns out to be more and more scanty and undependable while the southwest monsoon becomes more intense (Fig 7.1). The pattern of distribution of rainfall is reflected in the average yield of rubber.

7.1.2 Temperature

Over 99 per cent of all energy in the earth's surface has its origin in radiation from the sun, ie insolation. The total amount of insolation is dependent on two factors, the duration and the intensity of radiation, both of which are influenced by season and latitude. The combined effects of duration and intensity of insolation result in hotter summer and occurrence of a winter season in higher latitude, as compared with places near the equator. Most of the physical and chemical processes in plants are strongly affected by the temperature conditions. According to the van't Hoff law, dry matter production doubles for every rise in temperature of about 10°C. However, this relation may not be valid for some highland crops like pyrethrum, coffee or potato the yields of which are inversely correlated with temperature (12).

A warm tropical temperature of about 21°–35°C without wide variations is found suitable for the growth of rubber. Desert areas and elevated areas are not suitable for rubber cultivation because of temperature limitations. The mean temperature recorded in the major rubber growing tract is 27°C, the maximum being 38°C and the minimum 20°C. In some non-traditional areas in India where rubber is being cultivated, temperature is found to go down to 10°C or even lower for very short duration during winter. Eventhough no marked adverse effect on rubber plants has been noticed in these areas, no detailed and systematic study has been carried out to elucidate the role of low temperature on the growth and yield of rubber in these areas.

7.1.3 Relative humidity

It is a measure of the water vapour content of air. Relative humidity values show a clear maximum near the equator where high rates of evapo–transpiration, large amounts of advected water vapour and frequent precipitation keep the air humid at all seasons. Seasonal variations of relative humidity are small near the equator and increased differences are observed with latitude. Local factors like elevation and nearness to sea or lakes also influence relative humidity.

High humidity of the air has some beneficial effects on plant growth, because many plants can absorb moisture directly from the air and the rate of photosynthesis generally increases with humidity (3). However, the combination of high temperatures and high humidities that prevail in the tropical low lands creates highly favourable conditions for the proliferation and growth of numerous microorganisms which cause diseases. Weeds and parasites which can do great damage to crops, also develop more vigorously and more rapidly under these conditions. Very often the quality of the crop is also adversely affected.

A humid atmosphere throughout the year without much variation is found to be ideal for successful cultivation of rubber. The relative humidity varies from about 70 per cent during January to 95 per cent during August in most of the rubber growing regions in India. At elevations of 500 m, the maximum relative humidity is around 80 per cent. When relative humidity is higher, evapo-transpiration is lower. Higher rates of evapo-transpiration result in lower soil moisture regimes, lower leaching losses and lower turgor pressure of cells. Diurnal variation in relative humidity is also marked. Since the turgor pressure of the laticiferous system influences the yield of latex, relative humidity indirectly influences yield. The inter-relationships among relative humidity, evapo-transpiration, turgor pressure and yield of latex have been considered in selecting the early hours of morning for tapping to get maximum yield.

7.1.4 Wind

Winds and storms adversely affect rubber cultivation. The damage caused varies with the age of the tree and the nature of the wind. Young trees exposed to strong seasonal winds for prolonged

periods become stunted in growth. The leaves become lacerated, crinkled and get dried up particularly on the margins and along the lacerations. The dried up portions are subsequently blown off resulting in a sparse foliage. Wind affects older trees through uprooting, trunk snap and branch break. Shallow soil or high water table usually results in uprooting. Trunk snap and branch break are the consequences of unduly heavy development of the canopy. Rate of girthing on tapping and configuration of branches, both clonal characteristics, influence susceptibility to trunk snap and branch break. Faulty and unbalanced nutrition is another pre-disposing factor causing wind damage.

7.2 Physiographic features

The important physiographic features which influence the growth of rubber are elevation from mean sea level, slope and rockiness.

7.2.1 Elevation

In the tropics, the uniformity of temperature in different places within the same latitude is interrupted by the major factor elevation. Temperature always goes down with elevation, but the rate of decrease, the lapse rate, is far from uniform. It not only varies with cloudiness, and therefore, in many areas with seasons and between day and night, but also depends on the prevailing topography of the highlands. Under cloudy conditions when the effects of radiation are greatly reduced, the lapse rate tends to become similar to that of the free atmosphere which is usually around 5°C/1000 m (13).

Mountains and high lands receive more rainfall than near-by low lands, at least on their windward sides. This is the result of orographic lifting, a process which increases rainfall in all climates. In the tropics, however, the increase stops at a level of about 1000–1500 m, and above this elevation precipitation decreases with height.

Growth of rubber has been found to be satisfactory up to 450 m above mean sea level. At higher elevation, temperature becomes unfavourable for its growth. At low temperature, the rate of biochemical and physiological processes generally decreases. At very low temperature, desiccation or death of tissues may result from

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Growth of rubber has been found to be satisfactory up to 450 m above mean sea level. At higher elevation, temperature becomes unfavourable for its growth. At low temperature, the rate of biochemical and physiological processes generally decreases. At very low temperature, desiccation or death of tissues may result from

freeze injury. In an experiment conducted at West Java Experiment Station to compare the performance of *Hevea* at two locations 515m and 250 m above sea level, it was found that there was considerable retardation of growth at high elevations (5). The plants at lower elevation reached tappability by the end of fifth year while the plants at higher elevation came into tapping at the end of the seventh year only. Experiments indicated that the immaturity period was increased by six months for every 100 m rise in altitude, ie about 1°F drop in the environmental temperature. Bark thickness was also considerably lesser at high elevation. High yielding clones at lower elevations were not high yielders when planted at high elevation. In Sri Lanka, at high elevations high incidence of *Oidium*, retarded growth and poor bark renewal were also observed (4). Similar observations have also been made in India.

Most of the rubber plantations in Kerala are found in the midland region which has elevations varying from a few metres in the west to about 450 m in the east. Eventhough the performance of rubber is comparatively poor under higher elevations, several cases of successful establishment of economic units can be noticed in some of these areas such as Wynad in Kerala where distributed rainfall and good soil conditions are obtained.

7.2.2 Slope

Slope of the terrain determines the extent of infiltration and run off of water as well as the liability to soil erosion. A flat land is favourable for proper infiltration of water and prevention of run off and soil erosion. However, flat lands, particularly if low-lying or in the valley portion of hills, may be liable to water-logging or high water table during the rainy season, and the problem of impeded drainage may occur. A gently undulating topography or a slope in the range of 5°–15° may be considered ideal, particularly in areas where the intensity of rainfall is high.

The rubber growing regions in India are mainly hilly terrain, sometimes with steep slopes. Eventhough a slope of up to 15° is considered ideal, rubber cultivation has been successfully carried out in many areas in Kerala where the slope is up to 45° or more but where effective soil conservation methods including establishment

of creeping legume covers have been carried out from the very beginning of rubber cultivation.

7.2.3 Rockiness

Rockiness refers to the rocky outcrops in an area. These outcrops limit the soil volume available for exploitation by the roots. Even if 50 per cent of the area is occupied by outcrops, it does not become a serious limiting factor, provided in the remaining areas adequate soil depth is available for planting. Presence of surface or subterranian boulders is also not a problem so long as they do not seriously interfere with the planting operations.

7.3 Physico-chemical properties of soil

Soil productivity is a complex of physical and chemical properties of the soil which provide plants with a favourable environment for growth resulting in better crops and higher yields. These properties should be such as to provide proper anchorage of the plant and supply of adequate quantity of air, water and nutrients.

7.3.1 Physical characteristics

The important physical properties of soil which affect growth of rubber are depth, drainage, texture and structure. In general, physical properties have to be considered much more important, as these are not easily amenable to manipulations while many of the undesirable chemical properties can be corrected by the application of fertilizers and soil amendments.

7.3.1.1 Depth of soil

Soil selected for rubber cultivation should have a minimum depth of 100 cm without any intervening hard pan or impenetrable layer. Water table should also be well below 100 cm so that at least 100 cm of soil with good aeration, essential for root penetration is obtained. Good soil depth helps the plant to tide over the drought season more efficiently as moisture stored in lower depths will become available to the plant during the drought period. Yield of rubber is found to be

very much reduced in shallow soil as compared with soils having adequate depth (5). Shallow soil or soil with high water table does not ensure proper anchorage of the tree which therefore becomes susceptible to wind damage by uprooting.

7.3.1.2 Drainage of soil

Well drained soils are found to be essential for optimum growth and yield of rubber plants. In marshy areas, owing to poor physical properties and water-logged condition, growth of rubber is always found to be very poor. Soil drainage is affected by topography, intensity and duration of rainfall, soil physical characteristics and ground cover condition. Addition of fertilizers will not make any difference in yield, if proper drainage of the soil is not ensured.

In rubber plantation on level land, drainage is facilitated by digging open trenches. In hilly areas, the ravines and depressions which form natural water ways are generally utilised with the adoption of proper methods for reducing stream velocity. Drainage of excess water considerably improves the physical structure of water-logged soils. Water table is lowered resulting in better aeration of soil. As a result, roots get more oxygen. Tap roots penetrate deeper into the soil and lateral roots spread into deeper strata. Drainage thus ensures better anchorage because of the formation of well-developed root system. Absorption of water and nutrients, dependent on proper aeration of soil, is also improved. The activity of beneficial soil micro-flora is also increased. It has been found that yield of rubber is increased by deepening the drains in poorly drained areas (5).

7.3.1.3 Texture

Texture is one of the important properties affecting the water and nutrient holding capacity of soil. This is a measure of the relative proportions of different size fractions in soil. These fractions are graded into two classes based on size of particles. Particles above 2 mm diameter are called larger separates and those below 2 mm are called fine earth which includes sand, silt and clay. The diameter, number of particles in a gram of soil and surface area of the different soil separates are given in Table 7.1 (6).

Table 7.1 **Some features of soil separates**

Soil separate	*Diameter (mm)	Number of particles (No./g)	Surface area (cm^2/g)
Coarse sand	2.00–0.20	720	23
Fine sand	0.20–0.02	46,000	91
Silt	0.02–0.002	57,76,000	4,154
Clay	below 0.002	90,26,08,53,000	80,00,000

*International system

The rate and extent of the many physico-chemical reactions in the soil are governed by the texture of soil because it determines the total surface area in which the reactions can occur. Sand particles are larger in size and hence expose less surface compared to that axposed by an equal weight of silt or clay particles. The chief function of sand particles is to serve as a frame work around which the active part of the soil is associated. Sand increases the space between particles, thus facilitating movement of air and drainage water. Sandy soils are termed as hungry soils because of their inability to retain plant nutrients. These soils are unsuitable for rubber cultivation as their water holding capacity and nutrient status are very poor. They can be improved to a certain extent by the addition of organic matter. Silt has more surface area and is more active than sand. Silt particles are smooth and have little tendency to adhere together. Medium silty soils possess good structure and constitute some of the most fertile soils. Clay fraction is composed of mineral particles and it exposes more surface area and hence plays an important role in the physicochemical properties of soil. Clay acts as a store house for both water and nutrients. A soil is termed 'clay' if it contains 40 per cent or more clay, and 'sand' if it contains more than 70 per cent sand. A 'loam' has a more or less even distribution of sand, silt and clay. Rubber is found to grow on soils of varied texture but soils of medium texture are best suited for rubber cultivation as

these soils will have average water holding and percolating capacities. A somewhat finer textured sub-soil can be useful in preventing leaching of nutrients and in retaining moisture at a suitable depth.

7.3.1.4 Structure

Structure refers to the arrangement, size and stability of soil aggregates or peds. In rubber cultivation, a soil with good structure is essential as it influences pore space and controls movement of air and water. If water from high rainfall is to percolate through the soil without running off the surface, a high proportion of interconnected larger pores or macropores of about 0.5 mm in size is necessary. Except in very coarse sandy soils, which are unsuitable for rubber cultivation, larger pore spaces can exist only if the individual soil particles are aggregated into crumbs. Such aggregates also have capillary or micropores of size down to 0.003 mm within them which hold water available to plants. An optimum proportion of micro and macropores is, therefore, necessary to provide proper infiltration, drainage and aeration of soil as well as to increase its water holding capacity. A granular or crumb structure provides these conditions.

In the tropics, maintenance of granular or crumb structure is difficult as the granules or crumbs on the surface breaks down owing to the impact of falling rain drops. The fine materials thus formed clogs the larger pores forming a surface skin largely impermeable to water.

Structure is one of the soil properties which can be improved by management practices. In rubber plantations, maintenance of a good granular or crumb structure can be achieved by growing a protective leguminous cover crop. Organic matter added to the soil also aids in aggregate formation.

7.3.2 Chemical properties

The important chemical properties of soil are pH, organic matter content and fertility status. Eventhough the pH of the soil is not easily alterable, the organic matter content and fertility status can be improved by proper management of the soil which include growing

of leguminous cover crop, application of manures and fertilizers and adoption of soil and water conservation methods.

7.3.2.1 pH

The optimal pH of soil for rubber lies in the range pH 4.0 to pH 6.5 but the crop will tolerate pH in the range 3.8–8.0 (5). Young seedlings tend to be more sensitive to low pH than mature trees. Soil pH above 8.0 causes growth retardation but most of the soils in the humid tropics are acidic in reaction. Micronutrient deficiencies are less common in rubber growing soils.

7.3.2.2 Organic matter

Organic matter consists of materials derived from living organisms of both plant and animal origin. These, after decomposition, attain a more or less stable form called humus which is dark coloured, amorphous and colloidal in nature. Humus is very similar to clay in physico-chemical properties. It carries on its surface negative electric charges which attract and hold ions like potassium, calcium and magnesium. Humus acts as a cementing material and assists greatly in granulating clay particles to form stable crumbs. It facilitates movement of water in the soil and improves aeration. The capacity of the soil to retain moisture and nutrients is also increased by addition of organic matter. The organic acids produced during the decomposition of organic matter increase the availability of phosphorus and micronutrients to plants.

In the tropics, because of the high temperature and good aeration of the soil, the organic matter content is reduced rapidly. However, in rubber growing soils, a fair amount of organic matter is usually preserved as a result of the maintenance of a leguminous ground cover, recycling of leaves, absence of ploughing or other tillage operations and a relatively cool environment.

7.3.2.3 Fertility status

Nutrient needs of the rubber are less than those of other plantation crops like coffee, cocoa or oil palm. Rubber can, therefore, be grown

on soils poor in nutrient content but of good physical properties. If the physical properties are good, an extensive root system develops thus ensuring proper anchorage and absorption of water and nutrients. Any deficiency in the fertility can be made good by adequate manuring and management practices like growing a leguminous ground cover. Sometimes, an inherent high content of magnesium and calcium in the soil may pose some problems, particularly in the tapping stage, but these can be overcome by proper selection of clones for planting and by manipulation of manurial schedule.

7.4 Rubber growing soils in India

Rubber cultivation in India is confined to laterite and lateritic types of soil, red soils, forest soils and alluvial soils (7). An idea of the distribution of these soils in the important rubber growing regions can be obtained from Fig. 7.2 and Fig. 7.3 (9, 11). It can be seen that majority of rubber growing areas come under laterite and lateritic types of soil.

7.4.1 Laterite and lateritic types of soil

Laterite soils are formed under conditions of abundant rainfall and high temperature of the tropics and is characterised by the presence of a hard laterite horizon in the profile. Their subsurface soils are commonly red or yellow in colour due to the accumulation of free iron oxides. Lateritic soils have an underdeveloped laterite horizon and some weatherable minerals.

Laterite soils found in higher elevations are high in organic matter content but poor in calcium and magnesium and generally deficient in phosphorus and potassium. However, these soils have high fertility status compared to those found in planes due to the better systems of management adopted in the cultivation of plantation crops. Laterite soils found in the rubber growing tracts are loams of some kind. High amount of iron and aluminium oxides present in these soils makes phosphorus unavailable to plants by the phenomenon of phosphorus fixation. The presence of these oxides and the kaolinitic nature of the clay, however, impart good physical properties to these soils. Thus, though the soils are poor in plant nutrient content

the physical condition of the soil is well suited for rubber cultivation. These soils are friable and have good aggregate stability which facilitate good aeration and free drainage. These soils are acidic in reaction, the pH range being 4.5–6.0.

7.4.2 Red soils

These soils are derived from granite, gneiss and other allied rocks of micaceous type. They are less weathered when compared to laterite soils and the texture varies from loam to silty clay loam or clay loam. The cellular concretions of iron, characteristic of the laterite soils, are absent in red soils. These soils are therefore not laterite but may be termed red earths or red loams. These soils are acidic in reaction (pH 5.0 – 6.5), deficient in organic matter and low in all the major plant nutrients but more fertile than laterite soils. Typical red soils are found in Kanyakumari district and part of Trivandrum district where rainfall is less intense. The physical properties of these soils are also well suited for cultivation of rubber.

7.4.3 Alluvial soils

Alluvial soils are the youngest geological formations laid down by materials brought from rivers and the regions through which the rivers pass. They are found in banks of rivers, valleys and in deltas. As alluvial soils are transported soils, they are not related to the underlying rocks in genesis. These soils are acidic in reaction and generally well supplied with organic matter, nitrogen and potash. Magnesium content of the soil is also found to be relatively higher. Only the alluvium found along the banks of rivers and valleys are generally brought under rubber and hence rubber cultivated area under this type of soil is limited.

7.4.4 Forest soils

Forest soils are generally characterised by a surface layer which is dark brown in colour due to the presence of organic matter. Like alluvial soils these are also young. Soil development is more advanced than alluvial soils but less than that of laterite soils. They slowly undergo laterisation on clearing and planting with rubber. These

soils are acidic (pH 5.0–6.5) and rich in total nitrogen but poor in bases due to intense leaching. Available phosphorus status is also low.

7.5 Rubber growing regions in India

Rubber cultivation in India is at present confined to the west coast region of the country extending from Kanyakumari district of Tamil Nadu in the south to Coorg district of Karnataka in the north. Apart from the regions coming under the main rubber tract, there are limited areas in Andaman and Nicobar Islands.

The rubber plantations are situated in the midland regions in a narrow belt of approximately 400 km in length. The climatic conditions prevailing in the northern and southern regions of this belt vary considerably. Physico-chemical conditions of the soil are also different from south to north. Based on the variations in the climatic and soil conditions, the rubber growing tract was classified into eight regions (9). Fig. 7.3 illustrates the rubber growing regions in Kerala and Tamil Nadu. An updated and modified version of the original classification is given below.

7.5.1 Kanyakumari region

Rainfall in this region is moderate and more or less evenly distributed. The annual rainfall is about 1900 mm which does not exceed 350 mm in any month. Both southwest and northeast monsoons are equally important for this region. Temperature variations are not marked. Laterite, lateritic and red soils are encountered in this region. These soils are generally deep, less weathered and comparatively more fertile. The available magnesium content of the soils in this region is relatively high. Strong winds are prevalent on the exposed situations. This region has only occasional, very mild incidence of abnormal leaf fall of rubber which is considered to be the most damaging disease prevalent in most of the rubber growing areas of the country. However, the incidence of powdery mildew disease is severe here.

7.5.2 Quilon and Trivandrum region

The annual rainfall ranges from about 2000-3300 mm. Southwest monsoon is stronger but not so intense as in Kottayam, Idukki, Ernakulam and Trichur region. June and July are the wettest months and abnormal leaf fall disease is present in this region owing to intense rainfall. January and February are normally dry months. The temperature fluctuations are of minor nature and the soil conditions are more favourable for rubber cultivation than in high rainfall areas. Laterite, lateritic and red soils are encountered in this region also. The soils are acidic and comparatively rich in plant nutrients. Laterisation is not as intense as in high rainfall regions. Pink, powdery mildew and phytophthora diseases are prevalent.

7.5.3 Kottayam, Idukki, Alleppey, Ernakulam and Trichur (part) region

This region is located in the centre of the rubber growing tract and rubber cultivation is concentrated here. From Trichur district, only Mukundapuram taluk is included in this region. Annual rainfall ranges from 3000-4500 mm. Southwest monsoon is more intense in this region beginning in May with a peak period during June-July. Northeast monsoon is comparatively weak and ends by about November. Premonsoon showers are usually received during March and the diurnal variations in temperature are not much. Laterite is the major soil type encountered in this region. Soils are acidic in reaction and comparatively poor in available plant nutrient status. The climatic conditions prevailing in this area are highly conducive to incidence of phytophthora diseases and, therefore, adoption of extensive control measures is necessary.

7.5.4 Palghat and Trichur (part) region

Distribution of rainfall is uneven and is the lowest when compared to other regions. Major portion of the rain is obtained during southwest monsoon. Wet and dry seasons are well pronounced. Drought period is long in this region, extending from four to five months. Incidence of abnormal leaf fall disease is mild. The presence of 'Palghat gap' influences the climate in this region. Summer temperature is comparatively high. Most of the areas experience strong dry wind which is a limiting factor for successful rubber cultivation.

The soils are slightly acidic and comparatively well supplied with nutrients particularly calcium and magnesium.

7.5.5 Malappuram, Kozhikode and Cannanore region

Compared to southern regions, rainfall in this area is intense and ranges from 3200 mm–3400 mm or more annually. Between 80 and 90 per cent of the rain is obtained during southwest monsoon. Rainfall is intense in June-July and conditions are more favourable for the incidence of abnormal leaf fall disease. Prolonged drought period of four to five months exists in these areas. Soils are highly leached, deficient in available plant nutrients and are acidic in reaction.

7.5.6 Karnataka region

This region is located in the northern most part of the rubber belt in India and is characterised by the longest summer season. Annual rainfall varies from 2100–2600 mm. Southwest monsoon contributes the major part of the rainfall, with July as the wettest month having nearly 1000 mm rainfall. Northeast monsoon is very weak. Conditions favourable to phytophthora and powdery mildew diseases are prevalent in this region. Soils are highly weathered, acidic and are poor in available nutrients except magnesium.

7.5.7 Andaman and Nicobar region

Climatic conditions prevailing in this area, especially in Nicobar Islands, are favourable for rubber cultivation. Rainfall is moderate and evenly distributed. No pronounced wet and dry seasons exist in this region. Both the monsoons are equally important. Temperature fluctuations are minimum but the soil conditions are much varied. Mild attack of phytophthora and powdery mildew diseases is noticed in this region. Soils are relatively young and are derived from a variety of sedimentary/metamorphic rocks like sandstone, calcareous sandstone, shale and limestone. These soils, which differ in their physico-chemical properties, can be seen in close proximity. The soils derived from shale have impeded drainage. Soils are acidic to slightly alkaline in reaction and deficient in 'available' phosphorus and rich in 'available' calcium and magnesium.

7.5.8 Regions with specific problems

7.5.8.1 High elevation areas

Rubber plantations at high elevations are mainly situated in Idukki district and Wynad area of Kozhikode and Cannanore districts in Kerala, in some parts of Coorg district of Karnataka and Nilgiris of Tamil Nadu. In such areas, the 'winter' temperature is very low with overhanging mist. Hence powdery mildew is severe in high elevation planting in some cases throughout the year. Growth of plants is poor compared to lower elevations. Bark regeneration is poor. Late dripping and incidence of brown bast are high.

7.5.8.2 Wind exposed areas

Rubber plantations exposed to the calamities of strong wind are found scattered all over the rubber growing tracts.

7.5.8.3 Areas with high water table

In the main tract such areas are encountered in river banks, in valleys in between hills and in some parts of Kuttanad in Kerala with reclaimed clayey soils.

7.6 Non-traditional areas

The growing demand for natural rubber makes it essential and imperative to extend the area under rubber in India. There is not much scope for increasing the extent in the traditional rubber growing tract in Kerala, Tamil Nadu and Karnataka. Therefore, attempts have been made to explore the possibility of cultivating rubber outside the traditional belt. Experimental planting have already been done in the Northeastern region, Konkan area of Maharashtra, Goa etc. Based on the experience in the pioneer plantings, commercial plantations have appeared in some of these areas.

7.6.1 The Northeastern region

The Northeastern region comprises the states/union territories of Arunachal Pradesh, Assam, Meghalaya, Tripura, Mizoram,

Manipur and Nagaland. This region lies between 22° and 29.5° North latitude. The Tropic of Cancer passes through Mizoram and Tripura while Arunachal Pradesh has the highest latitude. Eventhough the climatic conditions in the region are not ideal for rubber, experimental plantings in the area indicate that rubber can be successfully planted in some areas in the region. Because of climatic, physiographic and possibly other reasons, large scale cultivation of rubber, most of which in the public sector, has been done in the states of Tripura, Assam and Meghalaya. The agroclimatic conditions prevailing in the existing/potential rubber growing areas in Northeastern region differ from those of the main rubber growing tract.

7.6.1.1 Rainfall

In Fig 7.4 is given the mean monthly rainfall in the existing/potential rubber growing areas in Tripura, Assam and Meghalaya along with that in Kottayam (Kerala). Meghalaya has the highest annual rainfall followed by Kottayam, Tripura and Assam. The distribution of rainfall in Tripura is more even, as compared to that in the other two states in the region. The total rainfall in the wettest month is highest in Meghalaya followed by Kottayam, Triupra and Assam. The northeast monsoon is not prominent in the three states, unlike in Kottayam, and consequently drought season is longest in this region. Among the three states, Tripura has the shortest dry spell and Assam the longest.

7.6.1.2 Temperature

Unlike in Kerala, the three states have a winter season and among the three, Assam has the longest winter. The mean monthly minimum and maximum temperatures in the four places are given in Fig 7.5 and 7.6 respectively. The lowest minimum temperature is observed in January in all the four places. The minimum temperature during this month is around 10°C in all the Northeastern states while it is slightly over 20°C in Kottayam. The highest minimum temperature is around 24°C in all the four places, and is observed in August in Tripura and Meghalaya, July in Assam and May in Kottayam. The mean monthly maximum temperatures vary from 27°C–34°C in

Tripura, 24°C – 33°C in Meghalaya, 20°C – 29°C in Assam and 29°C – 34°C in Kottayam. The lowest mean maximum temperature is found during December in Tripura, January in Meghalaya and Assam and August in Kottayam. The highest maximum temperature is in March in Kottayam and Tripura, April in Meghalaya and September in Assam. The existence of a winter season does not appear to have any notable adverse effect on the growth of trees. Possibly, one of the reasons for this is that the day temperature, even during the coldest month, does not go down appreciably. Moreover, the lower temperature and shorter duration of night in this region reduce the loss of carbohydrates through respiration during night. However, detailed data are not available from the region for assessing seasonal variations in growth and yield.

7.6.1.3 Storms and hail storms

Occurrence of storms is almost an annual feature in Tripura. In wind exposed areas, this is likely to be a problem. Since the existing plantations are almost enveloped by forest vegetation which absorbs much of the impact of storms, the real magnitude of the problem may not be evident in these areas. Hail storms observed in this region cause injury to the foliage and bark of the tree.

7.6.1.4 Diseases and pests

Abnormal leaf fall diseases caused by *Phytophthora* spp is not reported from Tripura. However, the climatic factors, particularly in Assam and Meghalaya, are conducive to the incidence of abnormal leaf fall, shoot rot and bark rot diseases. Vertebrate pests such as deer, porcupine, wild boar, rodents etc are reported to cause damage to nursery and immature rubber plants in all plantations in the region.

7.6.1.5 Other factors

The tribal population in the region practises shifting cultivation ('Jhuming') which causes considerable soil erosion, particularly in the hilly terrain. By providing employment for these tribals in the rubber plantations, they can be induced to eschew their practice of shifting cultivation.

7.6.2 The Konkan area of Maharashtra

The Konkan area lies between 15° and 20° North latitude and comprises a narrow strip of land on the western side of the Western Ghats. It consists of three districts stretching from north to south, viz Ratnagiri, Kulaba and Thane. The total annual rainfall in the area is 2000–4000 mm which extends over a period of four to six months, the total as well as the period of precipitation showing a decreasing trend from south to north. The annual range of temperature is between 15°C and 35°C. Relative humidity varies from 60–90 per cent during most part of the year although during the period from December to March it may go down further. There is a drought period of at least six months. Most of the areas except those in the peak of the mountain ranges are within an elevation of about 450 m above MSL.

The indiscriminate felling of the forest trees in the area and the shifting cultivation practised have resulted in denudation of the vegetative cover and erosion of soil. The parent material from which the soil in the area is derived is predominantly basalt which is rich in calcium and magnesium. The presence of flakes of parent materials in the surface soils of eroded area is the result of the 'onion type' weathering characteristic of basalt. Where much soil erosion has taken place, the surface soil is near neutral to slightly alkaline in reaction because of the basic nature of the parent material. Where soil depth is more, the surface soil may be acidic. In general, the agroclimatic conditions are more favourable in the southern part of Konkan as compared with the northern part.

Observations in the pioneer plantings in the Konkan area indicate the possibility of establishing economically viable rubber plantations in the area. The extensive drought period is a problem, particularly in the early years of planting. With the exploitation of sources of irrigation water in dams, streams etc and with the adoption of improvised or special techniques of irrigation, it may be possible to overcome this problem. Indications are that, after canopy closes, the impact of drought is less severe. Eventhough the period of immaturity may be more and the average yield less than those in the traditional areas, there are other redeeming circumstances and ancillary benefits which appear to make rubber cultivation in this area a worthwhile proposition.

Since rubber cultivation is labour intensive, it can provide gainful employment to the local population who could thus be induced to abandon shifting cultivation so harmful to the agricultural potentiality of the area. Labour is also comparatively cheap in this part of the country. Being a crop adaptable to a variety of soil conditions, rubber can be cultivated in the marginal soils available in the area. Moreover, its cultivation in association with the leguminous ground cover, considerably improves the physico-chemical properties of the soil. The price of rubber in the nearby market is invariably higher than that prevailing in the traditional areas. Timber which would become available at the time of replanting would also fetch a very high price because of its high local demand for fuel and for making packing cases. Thus, the agroclimatic, physiographic and socioeconomic factors would suggest that rubber would be a suitable crop for the Konkan area.

7.7 Agroecological requirements of guayule rubber

The ever increasing demand for rubber, the limitation of *Hevea* cultivation to the tropics and the high price and dwindling stock of petroleum, the non-renewable feedstock of synthetic rubber, have contributed to a revival of interest in the guayule shrub, *Parthenium argentatum* which grows wild in some semi-arid regions of North America. Eventhough the normal yield of guayule rubber is about 500 kg/ha, the recent report that spraying the plant with bioregulators-mixtures of low cost chemicals - about three weeks before harvest can produce two to six times the 'normal' yield of rubber in young plants(2) has given a further impetus to guayule cultivation. Research work has shown that deresinated guayule rubber, protected by antioxidants, is equal in every respect to *Hevea* rubber. Commercially valuable by - products such as bagasse (wood fibre) resins and wax are also obtained. The possibility, that during periods of low rubber prices, the crop can be left unharvested without losing its rubber makes it a living and growing stockpile. It has a unique 'bimodal' reproductive system. In one mode, the female flowers do not have to be fertilized to set seeds, and this 'apomictic' reproduction ensures that once a good variety is found, it can be propagated indefinitely by seeds without genetic change (14). Its adaptability to marginal semi-arid regions on the fringes of conventional agriculture is an added attraction. The various aspects of guayule rubber production, including the

agroclimatic requirements of the crop, have been discussed in a recent report (1).

7.7.1 Climate

In its native habitat, annual rainfall can be less than 230 mm, but early researchers concluded that 280–640 mm annually is needed for commercial rubber production. About 410 – 460 mm was recommended for production on a long rotation (four - eight years). The guayule plant can survive arid conditions, but if rainfall is less than about 360 mm, supplemental irrigation is needed to give a worthwhile yield of rubber in a reasonable time. When annual moisture exceeds about 650 mm, excessive vegetative growth, rather than rubber formation, may occur. The highest yields for cultivated guayule have been obtained with irrigation. Irrigation can force growth, shorten the production cycle and extend guayule production into areas where rainfall is unreliable. To meet guayule's peculiar need for stress periods that cause it to produce rubber, both irrigation and rainfall must be unevenly distributed year round. Definite dry seasons appear necessary and, of course, with irrigation these can be induced at will in arid regions.

In its native habitat, guayule withstands temperatures between -18° and 49°C. Heat appears not to affect this desert-adapted plant but at temperatures below 16°C growth rate slows and below 4°C it becomes semidormant. Wild guayule bushes have survived temperatures well below freezing, but in plantations the plants, especially young seedlings, are frost-sensitive. For survival guayule planted in frost prone areas requires careful tending. A frost of -7°C can injure tender plants but those previously induced into dormancy ("hardened off") by exposure to gradually decreasing temperatures or by reduced irrigation are not harmed by much lower temperatures.

7.7.2 Soil

For successful cultivation of guayule, the moisture holding characteristics of soil are most important. Early researchers stressed the need for well drained soils and concluded that sandy loam was the best. In compacted and poorly drained soils, the growth of the plant

is not good. Guayule appears to need little fertilizer, will grow well in moderately fertile soils, and is not a serious soil depleting crop. While fertiliser improves vegetative growth, it does not necessarily increase the amount of rubber produced. The optimum fertilizer for maximum rubber production is yet to be determined. Guayule does not appear to be very salt tolerant. Because of the high evaporation, salt build up could cause problems if the plant is grown under irrigation in arid regions.

7.7.3 Adaptability of guayule to agroecological conditions

The semi-arid or arid areas in north western India, particularly those not now used for conventional agriculture, appear to be suitable for guayule cultivation.

Guayule's water requirements are not so well understood as to predict its yield in a given location. It was shown that, under dry land conditions, guayule roots are able to penetrate porous soils (if devoid of thick strata of gravel and coarse sand) to depths of 2.4–3.0 m during the first growing season, and to a depth of 4–5 m during the second season. The extensive fibrous roots may also spread liaterally up to 3 m. These root characteristics may partly explain its resistance to drought. Eventhough the essential need for moisture stress is known, the minimum period of stress required is not established. Similarly, rainfall exceeding 650 mm is not considered desirable. But it is also not clear whether a rainfall higher than this but confined to three or four months, particularly in areas with limited soil depth, would interfere with rubber production. Thus, the possibility of growing this crop on an experimental basis in areas in India where the above agroclimatic conditions prevail is worth exploration.

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8 NURSERY ESTABLISHMENT AND FIELD PLANTING

Chapter 8

NURSERY ESTABLISHMENT AND FIELD PLANTING

8.1 Nursery establishment

Nurseries are required to raise stock seedlings for the purpose of budding or to produce seedlings to be transplanted as seedling stumps. The practice of raising nursery has several advantages over that of direct sowing of seeds in main fields. Maintenance of seedlings in the main field for about one year can be eliminated by raising nurseries. In a nursery, young plants can be looked after more efficiently and economically for uniform and vigorous growth. Nursery also provides better opportunity for selection of the most vigorous plants after rejecting the weaklings. Depending on the type of planting materials to be produced, ground nurseries or polybag nurseries may be raised. Ground nursery is for raising budded stumps, seedling stumps, stumped buddings and soil cores while polybag nursery is for the production of polybag plants. The method of establishment may vary according to the type of nursery. The requirements of area under different types of nurseries for raising 100 ha of plantation are given in the Appendix II.

8.1.1 Ground nursery

8.1.1.1 Selection of site

The site selected for the establishment of nursery should provide ideal conditions for the rapid growth of young rubber plants. It should be easy to supervise and least expensive to maintain. Availability of a perennial source of water is an important pre-requisite. A well drained flat piece of land is ideal because in such sites all nursery operations will be easy and cheap. Undulating lands are also suited, provided soil conservation measures are adopted. Terraces are

needed where the slope is in excess of one in fifty. Slope should be uniform, preferably in one direction, in order to facilitate surface drainage. Water-logged areas should be avoided. Water table should be sufficiently low to allow good tap root development. Beds may be prepared sufficiently away from the surrounding vegetation to avoid shading. Easy accessibility is another important factor to be considered. This is especially true for the nurseries made for raising advanced planting materials. It will be convenient if the nursery is laid out near the clearing to be planted, provided such nursery is not in a remote part of the estate where supervision and upkeep may be difficult.

For ground nurseries, loamy soils are the most suitable. Extremely sandy soils are unsuitable because leaching removes plant nutrients at a rapid rate. On the other hand, heavy soils demand greater care involving higher expenditure in management. A subsoil with a hard pan should be avoided because it prevents good drainage. Heavily cropped lands require extra care as nutrient status of the soils in such areas is likely to be considerably low.

8.1.1.2 Preparation of germination and nursery beds

Specially prepared beds are used for germinating the seeds. Level beds of 90 cm width and convenient length with 5 cm thick surface layer of river sand are generally made for germination. The surface of these beds should be raised 10 – 15 cm above the soil surface to avoid water-logging. Shade is provided to prevent exposure to strong sun. Since the period of viability of rubber seeds is very short, they are put in germination beds as soon as obtained. Seeds are planted in a single layer, touching one another and pressed lightly into the bed. Beds are kept in a moist condition by evenly sprinkling water during early morning and late evening. Covering the beds with thin coir matting or gunny bags is also necessary. Germination starts within six to seven days after sowing. The beds are inspected daily and all the seeds which show emergence of radicle are removed and planted in the seedling nursery or in the main field. Seeds which do not germinate in two to three weeks may be discarded.

In all types of ground nurseries the germinated seeds are planted in the seedling nursery beds. The beds may be either sunken or

raised, the former separated by bunds and the latter by drains. For the preparation of a seedling nursery, the soil is dug up to a depth of 60 – 75 cm. All stumps and stones should be removed and the soils worked till a fine tilth is obtained. Before nursery beds are formed, 25 kg of compost or well rotted cattle manure and 3.5 kg of powdered rock phosphate (20–24 per cent P_2O_5) are to be incorporated for every 100 m^2 of nursery bed. For nurseries in newly cleared forest areas, addition of compost or cattle manure may not be necessary during the year of opening. In areas which are repeatedly used for raising nursery, application of rock phosphate is necessary only once in three years. Beds should be 90 – 120 cm wide and of convenient length with pathways laid in between to facilitate manuring, weeding and watering.

8.1.1.3 Nursery planting

The sprouted seeds should be planted when the young root is less than 2 cm in length and before the young shoots start developing. Delay in transplanting increases the chances of damage to the tender roots. Germinated seeds should be carefully handled. Seeds picked from germination beds are usually carried in containers with water to prevent any damage during handling. Spacing varies according to the type of planting material to be raised in the nursery. Common spacing adopted for seedling stumps is 30 cm x 30 cm. The spacings for budded stumps are 30 cm x 30 cm or staggered pairs of rows 60 cm apart and 23 cm between plants. The spacing recommended for budwood nursery and stumped budding is 60 cm x 90 cm or 60 cm x 120 cm and for mini stumps and soil core buddings 30 cm x 90 cm or 60 cm x60 cm. Wider spacing is usually adopted in between rows. A long cord, coir rope or wire with planting distances marked on it is used. The rows are marked with row markers. The cord is held tight on the row marker and germinated seeds are planted at each mark along the line.

In the budwood nursery, budded stumps are planted at the required spacing, adopting the method described for planting in seedling nursery. Alternatively, seeds can be planted at the required spacing and budded *in situ*. Later, they are cut back and the scion allowed to develop.

8.1.1.4 Nursery for seedlings and budded stumps

Efficient management of nursery aims at the most rapid and economic production of healthy planting materials. In India, seed fall is usually during July - September and hence the period available for nursery is about ten months. A high percentage of non-buddable seedlings at the end of ten months causes unnecessary expenditure and wastage of space. Therefore, a concerted effort is required to produce the maximum number of buddable seedlings from a nursery. From the results of several field trials conducted, optimum cultural practices of agronomic importance have been identified (1). Only healthy and vigorous seedlings are to be retained in the nursery for getting the full benefit of inputs like fertilizers, water and pesticides. For this a careful thinning out of unhealthy and weak seedlings is necessary. The ideal time for thinning out would be three or four weeks after the first fertilizer application when the weak stunted plants can be easily distinguished.

In nurseries, generally hand weeding is practised in India. Two rounds of weeding are done just before the application of fertilizers. It is estimated that for each round of weeding about 100 labourers are required per ha. The results of field trials indicate that the first manual weeding in nurseries could be replaced by chemicals. Diuron and Prometryne at the rate of 2–3 kg/ha gave very good control of weed growth, the effect lasting for more than three months (4).

Mulching the seedling nursery is a recommended practice. Natural materials such as undergrowths from forests and grass cuttings are commonly used after drying. Experiments conducted showed that the vigour of the seedlings was not affected by the type of mulching materials used (5). Field trials indicated that *Salvinia* sp, 'African payal', a noxious and menacing weed in the waterways of Kerala, could also be used as mulch material in seedling nursery. Mulching was found to be very effective in retaining soil moisture in the beds during summer months. The mean percentage of available soil moisture in April, at 15 cm depth, was 88.6 in the mulched beds. The unmulched beds retained only 32.8 per cent available soil moisture which was insufficient for the proper growth of plants (1). More than one round of mulching is being practised by many. Field experiments on this subject indicated that one round of mulching

prior to hot weather in December was adequate (5). Experiments conducted in five different regions to study the effect of nitrogen, phosphorus, potassium and magnesium on Tjir 1 seedlings in nurseries showed that the optimum fertilizer requirements could be fixed as 500, 250 and 100 kg/ha of N, P_2O_5 and K_2O respectively (1). Application of magnesium at the rate of 37.5 kg/ha was also found to give a higher percentage of buddable seedlings in areas where soil was deficient in magnesium (1). Field experiments showed that ammonium sulphate, urea and ammonium sulphate nitrate were equally efficient for seedling nurseries (7). When considering the unit cost, urea would be the cheapest source of nitrogen. But urea and commercial magnesium sulphate are not compatible in a fertilizer mixture. Hence these fertilizers should be applied separately or mixed immediately before use. Different sources of phosphorus like superphosphate, ammonium phosphate sulphate (16 : 20 : 0), basic slag and bone meal had similar responses. Based on unit cost and residual effect, rock phosphate is recommended for use in nurseries. Lack of response of seedlings in nursery to micronutrients was reported (6). Manuring may be carried out by ascertaining the specific requirements of individual nurseries after soil analysis. If this is not possible, the genera, fertilizer recommendation given in chapter 10 may be followed.

Rubber nurseries have to be irrigated during the dry period from December to March. An even supply of water during the growing season results in uniform growth of plants. An overhead sprinkler irrigation system is ideal for bigger nurseries. The quantity of water needed varies with the soil, climate and age of the nursery plants. Daily watering is always preferable during the initial periods. But later, frequency can be once in two or three days.

8.1.1.5 Budwood nursery

Buds start sprouting in about three to four weeks after planting the budded stumps or in about two weeks after cutting back if budding is done *in situ*. False shoots developing from the root stock are to be pruned regularly. Side shoots are not allowed to grow. Supplies should be made as soon as casualities occur. If a few budded stumps are planted in polybags along with budwood nursery planting, those could be used for the immediate replacement of early casualities.

Manuring is to be carried out as described in Chapter 10. Other agronomic practices such as watering, mulching and weeding are similar to those for seedling nursery management. When the budwood nursery plants are one year old, about 1 m of usable budwood can be obtained. The budwood is cut when at least 1 m of brown bark has developed. The immature green portion at the top should be discarded. About a week before the budwood is cut, the leaves in the brown portion shoud be removed to a point about 1 m below the terminal bud, leaving the leaf stalks in position. The budwood may be sawn off about 15 cm at the base, taking care to leave a few dormant buds to develop into bud shoots for the subsequent season. Budwood for use on the same day should be cut in the morning, and for transport to distant places, in the afternoon.

8.1.1.6 Nursery for stumped budding

The method of establishment and maintenance of nurseries for raising stumped buddings are the same as those of budwood nurseries. However, for stumped buddings, green budding at four to five months stage is preferable. Intense care is given to the plants so that they attain a girth of 10–11 cm at the collar within a period of about 18 months after cut back.

Soil moisture level is to be kept sufficiently high so that there is continuous growth. During dry weather, watering is essential. Mulching the plant bases prior to the commencement of hot weather will also help in conserving soil moisture. Regular manuring is recommended once in two months with 10 : 10 : 4 : 1.5 NPKMg mixture, starting from one month after cutting back. To start with, 25 g per plant would be sufficient which can be gradually increased to 50 g. Frequent rounds of weeding are essential to prevent competition for water and nutrients by weeds. Prophylactic spraying against shoot rot, leaf spot diseases and pest attacks is highly essential for unhindered growth. Stumped buddings, under optimum conditions, would attain sufficent growth for transplanting within 18 months. About five weeks before transplanting 'tailing' is done. A trench of about 60 cm depth is opened on one side, very close to the plants, and the tap root is severed at a length of 45 – 60 cm. The trench is then partially filled. In order to induce sprouting of dormant buds, pollarding of the

m° mh after cuttina back-

bud shoot at a height of about 2.4 m and just below a whorl of dormant buds is done about 10 – 14 days before planting. The cut ends are treated with suitable wound dressing compounds and the stumps are white-washed. In a week's time the dormant buds start breaking out. The stumps are ready for extraction when the buds just emerge. Transplanting at a stage when the buds are much longer than 0.5 cm would entail considerable damage to the buds. On the other hand, transplanting before bud emergence results in greater failures. The lateral roots are to be pruned at 10-15 cm before planting. Mini stumps, under optimum management, will develop brown bark up to 60 cm within a period of five to six months after cutting back. At this stage, they are ready for transplanting. About 10 days before extraction, the plant is pollarded at the brown bark region just below a whorl of dormant buds and white–washed. Just before pulling out, the tap root is severed and laterals trimmed (Fig 8.1).

8.1.2 Nursery for polybag plants

There are two methods for raising polybag plants. The earlier practice was to raise stock seedlings in polybags and green bud them (Fig 8.2). Recently, it has been found that planting of green budded stumps in polybags is more advantageous since this practice gives an opportunity for the selection of vigorous plants and avoids the loss of bags through poor seedling growth and budding failures. Moreover, it has been observed that treatment of roots with indole butyric acid (IBA) a rooting hormone, results in better growth of plants (3). Either small plants with two to three whorls of leaf (Fig 8.3) or larger plants with six to seven whorls (Fig 8.4) can be raised.

Polythene bags of lay flat dimension 55-60 cm length and 25-30 cm width and 400 gauge thickness, which can hold about 8–10 kg soil, are generally used for raising plants up to two to three whorl stage. If the plants are to be retained till the six to seven whorl stage, bags should be of 65 cm x 35 cm size, 500 gauge thickness and should hold about 23 kg soil. Black polythene bags are preferred. Sufficient number of holes to facilitate drainage should be punched on the lower half of the bags.

The soil medium used for raising the plants should have good moisture and nutrient holding capacity which promotes root development. This also helps in minimising damage while transporting

and planting. It has been found that heavy clay-loam soil having good structure and friability is best suited for filling the polybags. Only top soil collected after removing the surface vegetation and leaf litter are used for the purpose. After collection, the soil is partially dried if it is too moist, pieces of stones and roots removed, larger clods of soil broken to small pieces and then it is used to fill the bags firmly, leaving about 2 cm at the top. Powdered rock phosphate at the rate of 25 g for small bags and 75 g for larger bags is then incorporated into the top soil.

The filled bags are placed in trenches of about 20 cm depth, and the soil removed form these trenches is put around the bags to hold them in position and to keep up the soil in moist condition. Placing the bags too deep may cause difficulty in lifting at the time of planting. The soil in the bags is allowed to settle and green budded stumps are platned.

The scion is allowed to develop two to three whorls of leaves in the case of smaller bags (four to five months) and six to seven whorls in the case of larger ones (eight to nine months). Regular plant protection operations against pest and disease attack are to be adopted. Monthly manuring with 10 : 10 : 4 : 1.5 NPKMg mixture is to be done. During the first month 10 g per plant is to be applied which can be gradually increased to 30 g per plant in four months' time. Sufficient moisture must be available for ensuring maximum growth and hence regular watering is essential. Weeding is to be done regularly.

8.2 Field planting

The rubber plantations in India are mostly on slopy and undulating lands. Flat lands are easy for working, but the extent of such areas available for planting rubber is limited. On hilly lands adequate soil conservation measures are necessary. In India, June–July is the best season for planting, and therefore all preplanting operations should be completed well in advance. The land to be brought under rubber plantation should be cleared of the vegetation present. These operations are more elaborate and difficult while planting in jungle lands, as compared to replanting. In jungle, clearing operations should begin sufficiently early to avoid any delay in the time of planting. Large trees of economic value are removed first, followed by felling

and removing of smaller trees and slashing of undergrowths. The slashed vegetation should be left for about a month for drying. Uprooting of stumps, if expensive, may be avoided. However, big stumps which interfere with planting lines or terracing are to be removed. A light burn, after drying of the vegetation, may be done. It has been found that light burning ensures easy planting operations, helps to have closer supervision and slows down regeneration of weeds. However, excessive clearing and burning may cause destruction of humus, adversely affecting the structure and fertility of soil. Because of the high cost of firewood in the country, most of the timber including small branches, are usually removed before burning. After a light burn, it is easier to introduce legume ground cover which will over grow the natural cover regenerating from the undergrowth.

In replantings, the old stand of rubber is felled as close to the ground as possible and the usable timber removed. The stumps may be left in the field and allowed to rot. The residues consisting of small twigs and leaves are burned or collected and stacked along the contour. In some cases, lining and digging pits may be done before felling. Cutting terraces in advance may not be advisable as considerable damage is likely to be caused to the terraces when trees are felled. Tree poisoning using sodium arsenite or 2, 4, 5–T is adopted in some countries, but this system is not practised in India since rubber wood is very costly.

8.2.1 Roads, buildings and fences

A well planned net work of roads and foot paths is necessary to facilitate easy transport of inputs to the various fields and latex to the factory and for efficient supervision of field operations. A minimum length of 25 km road may be required for a plantation of 1000 ha. It is preferable to trace the roads before the commencement of lining so that sufficient strip of land could be reserved. The construction of roads and formation of foot paths may be taken up immediately or can be taken up later.

The requirement of buildings may vary considerably. Sufficient provision should be made for estate office, stores, processing factories, residential accommodation etc. The sites for these buildings may be

suitably located and reserved so that their construction could be taken up as and when resources are available.

The plantation should be well protected by proper fencing for keeping off the grazing cattle and for preventing pilferage of the produce. Barbed wire fences with five or six strands fixed on teak, stone or concrete posts are commonly used.

8.2.2 Lining

Lining is based on the planting system and the spacing to be adopted. Rubber is planted adopting square, triangular, quincunx, rectangular, avenue or hedge planting systems. Of these, the first three offer well balanced growth of the aerial portions and roots of plants. However, these systems of planting can be done economically only in the case of level areas. The rectangular system, most widely used, can be adopted in level and slopy areas. In this system, trees along the rows become closer and rows are wide apart as in avenue planting. Because of this, strips to be weeded in between plants get reduced and the distances to be walked for tapping become shorter. The shading of inter-rows is delayed and therefore ground covers persist longer. However, avenue planting is more susceptible to wind damage because of the widely exposed inter–rows. Hedge planting is an extreme form of avenue planting in which the rows are so far apart that the branches of trees do not meet overhead to form a closed canopy. The wider rows increase the risk of wind damage and the growth is less uniform than in avenue planting. The lack of shade increases the danger of invasion of the inter-rows by noxious weeds like lalang grass or *Eupatorium*. Hedge planting is not common now and it can be justified only when intercropping is desired.

It is important to ensure that adequate space is provided for each rubber plant so that there is good exposure to sun light for the development of aerial portions, and sufficient volume of soil for roots to spread. Adoption of wider spacing may involve heavy expenditure in upkeep. On the other hand, in the case of closer planting, the vegetative growth suffers, bark development becomes poor and disease incidence increases. Therefore, it is of utmost importance to adopt optimum planting density.

The yield per ha may be higher when the density is high, but yield per tree will be high when the stand is less. When rubber prices are high or when family labour is employed for tapping, higher yield per ha resulting from higher density may be more profitable. On the other hand, when labour costs are high, in relation to the price of rubber, it is desirable to have higher output per tree. Therefore, a compromise between the two seems to be necessary to decide the final stand in a rubber area.

In the case of seedlings, because of the genetic variability, several plants will be low yielders and these have to be thinned out. Therefore, a higher initial stand than that for budgrafts is usually recommended for seedlings. The planting density recommended is 420 – 445 plants per ha in the case of buddings or plants proposed to be field budded and 445 – 520 plant points per ha in the case of seedlings. The common spacings adopted to give such a stand per ha are:

(i) For buddings

In hilly areas	–	6.7 m x 3.4 m	– 445plants/ha
In flat areas Square	–	4.9 m x 4.9 m	– 420 plants/ha
Triangular	–	4.9 m x 4.9 m	– 470 plants/ha

(ii) For seedlings

In hilly areas	–	6.1 m x 3.0 m	– 539 plants/ha
In flat lands	–	4.6 m x 4.6 m	– 479 plants/ha

Appendix III gives the number of trees per ha at different spacings when square and rectangular planting systems are followed:

8.2.2.1 Rectangular or square planting

This system can be adopted on flat or slightly undulating areas. In the case of rectangular planting, the lines should be oriented east-west to intercept maximum sunlight. A compass, a number of marking pegs and two ropes made of galvanised wire are required for lining.

One of the ropes can be used for the base line and the other for the guide lines. The planting distances should be marked on ropes with coloured rags.

The first step is to fix a base line in the clearing. Longest straight boundary running north to south would be the most convenient base line. One guide peg may be fixed at the beginning of the proposed base line at one end, say, the southern end, and the compass kept over this guide peg No. 1 (corner peg). A shot is taken due north and the guide peg No. 2 put at the extreme end of the lining rope. Planting points are then pegged at the marks along this base line using smaller pegs (Fig 8.5). Again, with the compass over the corner peg, another shot is taken east or west, depending upon the shape of the clearing, and another guide peg and smaller pegs are put (Fig 8.6). The process is repeated at the other end where guide peg No. 2 has been fixed. Thus, the three sides of the square or rectangle are formed by the north-south base line (Fig 8.7). Advances are made from the base to the open end of the square or rectangle with the lining rope held at the north and south ends by two men who stop at each peg on the guide lines while others put pegs along the ropes at the rag marks (Fig 8.8).

8.2.2.2 Quincunx planting

In this system also, the base line is aligned in the same way as in the case of square planting. The guide lines are put by diagonal lining at an angle of 60 or 120 degrees to the base line (Fig8.9).Alternatively, an extra half planting distance can be marked beyond the last tree point on the rope. In the second and subsequent alternate rows, this marker is brought against the guide peg, and smaller pegs are placed in the normal way against the coloured rags on the ropes (Fig 8.10). The guide pegs in these alternate rows are removed after the lining is completed, since they do not correspond to planting points.

8.2.2.3 Contour lining

This system is the most suited for undulating and hilly lands in which the planting points are marked on lines passing through points of same elevation. A line of average slope, down the hill side, is

selected dividing the land conveniently. Guide pegs are driven in along this guide line to mark the contour intervals. For this purpose, the surface interval, equivalent to the desired horizontal interval, is calculated and used as contour intervals. Alternatively, the horizontal interval itself can be measured by holding the tape level, and pegs put down this line of average slope. Once the guide lines are aligned and marked, it is possible to commence marking of the planting points using a road tracer or other suitable instrument. Contour lines are aligned right and left of the guide line with pegs to indicate planting points. Where the gradient increases, contours will converge, and where the slope is less steep, they will open out. It is, therefore, necessary to stop a contour line where the contours come too close, and to start intermediate contours when the rows become too wide. A rule of thumb would be that the minimum distance between two lines should not be less than two thirds and the maximum not more than one and one third of the proposed distance.

For smaller areas a useful tool would be a triangular or rhomboid wooden frame with the points of its legs at the required planting distance (Fig 8.11) and fixed with a spirit level or plumb line to determine the correct level. The levelling triangle is placed with one leg against the guide peg and when the instrument is correctly levelled, a peg is driven in where the second leg meets the ground. Subsequent points are marked using the preceding point as the guide, taking care to alternate the legs of the wooden frame to minimise any possible error.

8.2.3 Pitting and refilling

Pitting is necessary to provide favourable conditions for the early establishment and growth of the young plant. Size of the pits depends upon the type of planting material used and the nature of soil, eg, the standard size of the pit recommended is 75 x 75 x 75 cm. But alterations from this standard size may be made when stumped buddings or germinated seeds are to be planted. Stumped buddings would need wider and deeper pits while germinated seeds or polybag plants smaller ones. Similarly, when the soil is hard, the pit has to be enlarged. For economy, in better types of soil, pits are sometimes dug wider at the top and tapering to the bottom, or the depth reduced to about 60 cm with a central crow-bar ('alavango') hole 15 cm or more

in depth for the tap root. Pitting can be commenced as soon as the work of clearing is sufficiently advanced. When digging the pit, the top soil should be placed on one side and subsoil on the other. It is important that filling should be completed some time before planting to give the soil sufficient time to settle. Filling should be done with the top soil as far as possible. Sufficient surface soil has to be collected from the surroundings, stones and roots removed, and used for filling. When manure is to be applied, it should be thoroughly mixed with the top 20 cm of the soil in the pit. The pit should be filled for about 5 cm above ground level. A peg may be placed in the centre of the pit to locate the position later. In replantings, particularly of larger areas, lining and pitting can be undertaken during September - December period preceding the year of planting for economy and for proper planning and organisation.

8.2.4 Terracing

On hilly and undulating lands, cutting of terraces on the contours is recommended as a means of conserving moisture and preventing soil erosion (Fig 8.12). Continuous terraces along the planting rows are initially expensive, but are well worth the expenditure in the long run, as these form the best method of protection whenever the risk of soil erosion is apparent. It also serves as foot path.

For making the contour terraces, the soil on the hill side is cut from a distance of about 60–75 cm in front of the planting row and thrown back in such a way that the terrace so formed will have a width of 1.25–1.50 m and an inward drop of 20 – 30 cm. The angle of the slope to the back of the terrace depends much on the type of the soil. For example, steeper slope is necessary in light soil than in clay or gravelly soil. The soil, cut and removed, is used to extend the front of the terrace and to provide it with a small bund on the outer edge. Steps of uncut earth should be left out at intervals along the terrace line to check lateral flow of excess rain water along the terrace. For reasons of economy, planting on hill sides may be done on square platforms of side about 1.25 m (honeycomb terrace). These individual tree platforms could be joined together later to make complete and continuous terraces or connected with narrow outer ledges of about 60 cm width to facilitate movement of workers and supervisory staff from tree to tree.

8.2.5 Provision of drainage

Good drainage enhances soil aeration and stimulates beneficial microbial activity and proper establishment of ground covers, all leading to soil conditions conducive to better growth of rubber. Proper drainage also promotes development of a more extensive root system which brings about better absorption of moisture and nutrients. Provision of proper drainage facilities is important especially on low-lands. Natural waterways available in the area may be cleared, dressed or deepened to form a satisfactory drainage system. If no outlet drain exists, one has to be provided. Depending on the drainage problem, main drains are dug at intervals of 100 – 200 m. These main drains lead to the outlet drain. If necessary, side drains or contour drains at the required intervals are dug subsequently in such a way that they meet the outlet drains at right angles. The drains should not be cut at full depth in the beginning itself, but deepened gradually.

8.2.6 Silt pits and 'edakayyalas'

In order to reduce the hazards due to soil erosion, silt pitting may be practised on very steep areas. Trenches are dug at intervals along the contours depending on the lie of the land. The water and soil particles washed off from portions above are collected in these trenches. The soil from the pits should be thrown below the pit to make earth bunds. Construction of level contour terraces with stone-pitched retaining walls ('edakayyalas') is another effective method of soil and water conservation. These terraces check the movement of run off water. The washed off soil would be deposited on the upper sides of the terraces while water would filter through the terraces. The distance between terraces should be adjusted according to the slope of the land. Periodical repairs may be needed for the 'edakay-yalas' and silt pits till the leguminous cover is well established.

8.2.7 Planting

The success of planting depends on the prevailing weather conditions, quality of the planting materials used and the care with which the planting is done. It is essential that the planting should be carried out during favourable weather. It is not desirable to plant when

heavy rains are received, because the soil in the filled pits becomes slushy, a condition which leads to high rates of casuality. In the major rubber growing areas in India, continuous wet weather can be expected during June–July and hence this period is considered to be the ideal one for rubber planting. It is desirable to assess the most favourable time for planting from rainfall records of previous years. Different planting practices are adopted in rubber cultivation.

8.2.7.1 Seed-at-stake

In seed-at-stake planting, three or four germinated seeds are planted in the centre of the refilled pits. After establishment of the seedlings, the weak plants are removed. The plant bases are always kept clean of weeds. During the first year, the seed-at-stake plantings are manured with 10 : 10 : 4 : 1.5 NPKMg mixture at the rate of 225 g per plant point in a single dose, six weeks after planting germinated seeds. Seedlings other than approved high yielding polyclonal are field budded in the month of April subsequent to planting when the plants attain the required size. If the conditions are not very favourable, plants attain buddable size only during September-October. Field budded plants are cut back *in situ* and the bud allowed to grow.

8.2.7.2 Seedlings and budded stumps

Both seedlings as well as budded stumps should be planted in the main field as early as possible after pulling them out from the nursery. About 5 cm of the surface soil is first removed from an adequate area at the plant point to accommodate the whorl of lateral roots attached to the stump. Using an 'alavango' or a pointed stick, a planting cavity is made to a depth equal to the length of the pruned tap root (Fig 8.13). The stumps are then carefully inserted in the cavity sufficiently deep in such a way that the whorl of lateral roots are properly accommodated in the area dug around the cavity for the purpose. Special care should also be taken to ensure that the tip of the root is in actual contact with the soil at the bottom of the cavity. This is important because the planted stumps re-establish by the development of roots from the tip as well as from the sides of the tap root. The presence of air gap in the planting cavity will result in failure of the stump. Therefore, it is important to put sufficient loose soil in

the cavity around the tap root by pushing the 'alavango' or the hard pointed stick into the edge of the planting hole as deep as the tap root or more in a slanting manner, and then pulling it towards the stump which is firmly held in position (Fig 8.14). The process is repeated on all sides.

Under favourable weather conditions, the buds usually sprout in three to four weeks after planting. Sprouting may be delayed up to several months if the budded stock seedlings are left in the nurseries for a period longer than one month before they are cut back and transplanted as budded stumps. This delay is due to the overgrowth of callus. An unduly long snag may also cause delay in bud sprouting as well as formation of too many stock shoots.

8.2.7.3 Stumped buddings

In India, the use of stumped buddings is not very popular at present. The planting holes for stumped buddings are refilled and allowed to settle as in the case of planting budded stumps. Just before planting, a hole is dug 15–25 cm shallower than the length of tap root of the stumped buddings to be planted. A small cavity is made in the centre of this hole to a depth of 15–25 cm, depending upon the length of tap root by means of a sharp wooden stick or 'alavango'. The end of the tap root of the stumped budding is firmly wedged into this hole. The soil is filled into the planting hole and pressed firmly around the base of the plant to ensure firm anchorage. The plant base is mulched thickly.

The success of stumped buddings depends much on the receipt of adequate rain after planting. It is reported that a prolonged dry period of more than 10 days can cause considerable loss, and under such conditions watering at the rate of 10–15 l per plant, once in four or five days, has been recommended. All shoots which develop towards the top of the stem are allowed to grow until the plant is well established. Afterwards the number is reduced to three well spaced shoots. If die back is noticed soon after planting, the stem has to be cut back to healthy tissues and suitable wound dressing compounds applied. Mini stumps are planted in the same way as budded stumps. However, preplanting operations such as pollarding, severing and

white–washing are essential requirements. Plant bases are to be mulched immediately after planting.

8.2.7.4 Polybag plants

In the case of polybag plants, the top storey of leaves should be fully mature at the time of planting. Just before removing the plants from polybag nursery, all the plants are watered well. The soil around the bag is removed and the bags are taken out of the trench. Dressing of the lateral roots and tap root, if grown out of the bags, may be necessary. Then they are carried to the planting points. A planting hole bigger than the size of the bag is made. The bottom of the bag is completely cut and then the bag along with the plant is inserted into the planting hole. A vertical cut is made at the bottom of the plastic sleeve, taking care not to damage the lateral roots. Then the cut is continued as the hole is gradually filled so that the cylinder of soil is unbroken. When the hole is partially filled, the bag is slit along its length and carefully pulled away. The soil is finally firmed around the plants.

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9 FIELD UPKEEP

Chapter 9

FIELD UPKEEP

Field upkeep comprises various operations like establishment of leguminous ground covers, intercropping, weeding, vacancy filling, pruning, mulching, induction of branching and thinning. All these operations aim at reducing the immaturity period and obtaining an optimum stand of healthy and vigorous plants at the minimum cost.

9.1 Legume ground covers

In earlier years, clean weeding was adopted to avoid competition of weeds with rubber for moisture and nutrients. This practice was slowly replaced by the establishment of suitable cover crops. An ideal cover crop for rubber plantations should be:

(i) A perennial creeper or twiner with very fast growing habit;

(ii) Capable of withstanding frequent slashing;

(iii) Able to smother weeds;

(iv) Tolerant to shade;

(v) Of maximum nitrogen fixing capacity;

(vi) Tolerant to pests and diseases;

(vii) Unpalatable to cattle; and

(viii) Having the least competition with rubber for nutrients and moisture.

Some of these qualities are seen in certain leguminous plants which are widely used as cover crops for rubber. These plants have the capacity to fix atmospheric nitrogen in their root nodules in association with a group of bacteria belonging to the genus *Rhizobium*. In India, rubber is being cultivated mostly on hilly areas which receive high rainfall. Topography and torrential rains can cause severe soil erosion if the surface of the land is left unprotected. Leguminous covers prevent the beating action of rain and effectively stop run off of water thus minimising soil erosion. They will also help increase soil moisture. Cover crops trail on the weeds and suppress their growth thereby reducing expenditure on weeding. Legume covers return to the soil a large amount of litter. This plant litter is subjected to biological degradation by numerous soil microorganisms, and mineralisation takes place. This activity raises the organic matter content of soil. The humus, formed as a result of microbial degradation, serves as a storehouse of nutrients and slowly releases them into soil. It also improves soil aggregation and water holding capacity.

Leguminous cover crops enhance the growth as well as yield of rubber. The cost of cultivation is also low if cover crop is properly maintained. In Malaysia, the budded rubber plants under leguminous cover are reported to attain tappable girth in 61 months whereas those with grass cover take 68 months. In the seedling area it was found that trees under legume took only 56 months to come into tapping while those under grass and *Mikania* weed reached tapping stage in 59 and 67 months respectively (4).

Nitrogen is one of the essential macronutrients needed for plant growth. To meet the nitrogen demand by plants, nitrogenous fertilizers are incorporated in soil at a very high cost.

In an experiment carried out in Malaysia, over a period of 13 years of tapping, rubber trees with grass cover needed extra application of at least 737 kg of nitrogen for the yield to be comparable to that of the trees previously under legume cover. This much nitrogen is fixed by the root nodule bacteria and its residual effect could be seen up to seven or eight years of tapping.

9.1.1 Different species of legume covers

9.1.1.1 *Pueraria phaseoloides* (Fig 9.1)

This is commonly known as 'tropical kudzu' and used in grasslands for fodder purpose. It is included in the Papilionaceae subfamily of family Leguminosae. It has a shallow root system. Leaves are trifoliate, broad and pubescent. Flowers are pink in colour and they occur in long racemes. Pods are round and measuring 6–8 cm in length. This is the most vigorous twiner-cum-creeper and when well established, it forms a dense thick cover. It assumes dominance over common weeds during the early years when there is no overhead shade. It can be easily established by seeds and cuttings. The seed rate is 3.0–4.5 kg/ha. Flowering takes place during January–February. This species produces seeds at the rate of 30–40 kg/ha. *Pueraria* is extensively grown in most of the rubber plantations in India.

9.1.1.2 *Calopogonium mucunoides* (Fig 9.2)

This is a twiner-cum-creeper, introduced from tropical America, belonging to the sub-family Papilionaceae. It has profuse shallow roots and has the most rapid initial growth. The leaves are trifoliate and smaller than those of *Pueraria phaseoloides*. The brownish pubescence on leaves and tender shoots is much pronounced. Flowers are very small and pale blue in colour. Pods measure 3–5 cm in length and are full of brown pubescent hairs. It forms a complete cover over the ground within a short period, but it is less hardy than the other creeping legumes. Though it is suitable for poor soils, it does not have either shade tolerance or drought resistance. During summer months, this cover crop dries up after profuse seeding and the plants come up again mainly from the seeds during the following monsoon season. The seed rate of this plant is 3.0–4.5 kg/ha.

9.1.1.3 *Centrosema pubescens* (Fig 9.3)

It is a shade-tolerant legume from tropical America, having both climbing and creeping habit. This is also another member of the sub-family Papilionaceae. It makes rather slow growth in the early stage, eventually forming an excellent cover. The roots are deeply

penetrating. Leaves are dark green and narrow. Flowers are large and pink in colour. Pods are flat and long and attain a length of 10–12 cm. Seeds contain a toxic principle which is lethal to nodule bacteria. Seed rate is 5.5 kg/ha.

9.1.1.4 *Mimosa invisa* var *inermis* (Fig 9.4)

This is a thorn-less plant belonging to the sub-family Mimosoideae of family Leguminosae. It has neither climbing nor creeping habit and it is unsuitable as a fodder crop. Its thick prostrate growth forms a good cover and keeps weeds in check. It is suitable for areas of marginal rainfall with long dry spells because it dries out during the dry season and regenerates with the onset of wet weather. As this cover crop crosses with thorny species and produces thorny plants in due course, it is not very popular. When the old growth dries out in summer, it is considered a fire risk.

9.1.1.5 *Calopogonium caeruleum* (Fig 9.5)

This is a native of tropical America and is widely cultivated in citrus orchards in Philippines and rubber plantations in Malaysia. The trifoliate leaves are leathery, dark green in colour and without hairs. Flowers are small and blue in colour. Pods are flat, measuring 5–7 cm in length. It is reported to withstand shade and drought. Fruit set is not observed in Kerala and therefore propagation through cutting has to be resorted to. It fixes two to three times more nitrogen than *Pueraria phaseoloides* (9).

9.1.1.6 *Mucuna bracteata* (Fig 9.6)

It is a very fast growing legume with deep roots commonly found in the northeastern region of India. It forms a thick cover which suppresses all weeds. The dried leaves form a mulch of 6-10 cm thickness. The trifoliate leaves are very big and dark green in colour. It flowers during January–February. Flowers are violet in colour and arranged in racemes. Fruit set is not observed in Kerala. Stem cuttings can be used for propagation, but the percentage of success is not high.

9.1.1.7 Mixed cover

Some of the desirable characters of cover crops for rubber plantations are rapid initial growth for early covering of ground, dense vigorous growth to suppress weeds and continued growth for as long as possible during the period when overhead shade increases. None of the cover crops commonly used has all these attributes. Hence it is desirable to establish a mixed cover. A mixture of *Calopogonium, Pueraria* and *Centrosema* seeds in the ratio of 5:1:4 is used for sowing in Malaysia. In this mixed cover, *Calopogonium* grows much rapidly and covers the ground quickly during the first year itself. Then *Pueraria* and *Centrosema* start dominating. Dense and vigorous growth of *Pueraria* suppresses weeds. But it starts fading out when the canopy closes. Subsequently, *Centrosema* continues to grow under shaded condition while the former two cover crops fail to thrive. Thus, complete benefits of cover crops starting from the first year of planting could be obtained if mixed cover crop is established in rubber plantations.

9.1.2 Establishment of cover crops

Cover crops are generally established from seeds. However, *Pueraria* and *Calopogonium caeruleum* can also be propagated by stem cuttings. Establishment of mixed cover crop is also recommended.

9.1.2.1 Preparation of cover crop beds

Seeds or cuttings of cover crops are planted on raised beds prepared in clean weeded areas in between rubber rows. About 420 beds of 1.0 x 1.2 m / ha are prepared immediately after premonsoon rains. For better results, it is preferable to raise them immediately after cleaning the area for planting and in the case of replanting, one year ahead of planting, if possible, or after felling the old stand of rubber. This will help in reducing the cost of weeding as it covers the area even from the very beginning of rubber growth.

9.1.2.2 Pre-treatment of seeds

Seeds of cover crops have a very hard seed coat which delays germination and reduces its percentage. These, therefore, require pre-sowing treatment to ensure uniformity and higher percentage of germination. This also helps in reducing the toxic compounds present in the seed coat, which inhibit the nodule forming bacteria. Generally any one of the three pre-sowing treatments is recommended.

(i) Acid treatment

In this method, seeds are treated with concentrated sulphuric acid to form a thin film for a specified period. It is 10 min for *Pueraria* seeds and 20–30 min for *Calopogonium* seeds. The seeds are put in a glass or other acid resistant containers and stirred after adding sufficient concentrated sulphuric acid. The seeds thus treated should be placed in a large container having cool water and washed well to remove the acid completely. It is advisable to avoid acid treatment of *Centrosema* as the seeds are adversely affected by the acid.

(ii) Hot water treatment

This is a popular and simple treatment for cover crop seeds. Though popular, percentage of germination may not be as high as in acid treatment. Hot water treatment is carried out by pouring water at 60–80°C over the seeds in a container till all the seeds are submerged and keeping them as such for four to six hours before sowing.

(iii) Abrasion treatment

It is a very successful dry treatment of cover crop seeds. The aim is to abrade, scratch or scarify the seed coats in order to assist moisture absorption from the soil. This treatment could be achieved by rotating the seeds in a drum lined with sand paper and operated by an electric motor at 75 rev/min for 24 h. If the quantity of the seeds to be treated is less, abrasion treatment is carried out by mixing the seeds with sand (one to two times the quantity of seeds) and then pounding them in mortar. After the abrasion treatment, seeds may be soaked in water overnight before sowing.

9.1.2.3 Sowing of cover crop seeds

The pre-treated and soaked cover crop seeds are mixed with an equal quantity of rock phosphate and sown in beds after the pre-monsoon showers. In places where drought is a limiting factor in the establishment of cover crops, the germinated seeds can be sown during January or February in coconut husks filled with soil and the plants allowed to grow under shade till the pre-monsoon showers are received. These are then planted on patches prepared in the field.

9.1.2.4 Planting of cover crop cuttings

This method of propagation is practised for *Pueraria* and *Calopogonium caeruleum*. Fresh vines, 60–100 cm in length, are collected during June-July when frequent rains are available and planted in beds. The success of establishment will be more if rooted cuttings are used for planting.

9.1.3 After-care

In the initial stages, weeding may be carried out in the cover crop patches. Cattle grazing and removal of the vines for fodder should also be prevented for ensuring proper growth and spread of ground cover. In the case of severe crop damage by insects, appropriate plant protection measures are to be carried out. Manuring of cover crops is carried out as described in Chapter 10. Under the normal practice of cover crop establishment they grow very rapidly and cover the ground within the year of establishment itself. Twining of cover crop vines on young rubber should be prevented and the plant bases also should be kept free of cover crop growth for three to four years to prevent competition with young rubber.

9.2 Biological fixation of atmospheric nitrogen

Nitrogen is a vital element in the nutrition of plants and it is continuously depleted from the soil through leaching, uptake by crop and denitrification. Some bacteria play an important role in making up this loss and in maintaining the nitrogen balance by returning nitrogen to the soil by the processes of biological fixation of the atmospheric nitrogen. Biological nitrogen fixation is brought out by free

living bacteria or blue green algae which make use of nitrogen by non-symbiotic means or by symbiotic association. The legume-*Rhizobium* symbiosis is the major source of biological nitrogen fixation in nature. This is effectively utilised for rubber cultivation by growing leguminous cover crops in association with rubber during the early years. Bacteria belonging to the genus *Rhizobium* form nodules in the roots of leguminous plants. They infect root hairs of the legumes and stimulate the root tissues to produce characteristic nodules inside which they proliferate. The nodules of the common cover crops used at present are round in shape, varying in size from a pin head to a berry of pepper. The shape of the nodule is determined by the species of the leguminous plant. The nodules of *Calopogonium* spp have white bands while the nodules of *Centrosema* spp have raised pin head like structures. The nodules of *Pueraria* are often smooth. Nodules can be classified into effective, moderately effective and ineffective on the basis of their nitrogen fixing capacity which can be distinguished from their position and colour. The effective nodules are generally pink in colour owing to the presence of leghaemoglobin, and the ineffective ones are pale in colour.

9.2.1 Rhizobium

Rhizobium is a symbiotic, aerobic and gram negative nitrogen fixing bacterium of rod shape, measuring 0.5μ–0.9μ width, 1.2μ–3.0μ length, motile when young and commonly changing to bacteroid form. The genus *Rhizobium* is classified into six different groups based on host range and physiological activities. The *Rhizobium* forming nodules in the roots of cover crops is not named up to species level owing to their promiscous nature with respect to nodulation in different groups of leguminous plants.

9.2.1.1 Nodulation and nitrogen fixation

When the leguminous cover crops start establishing, they excrete an organic compound which stimulates the multiplication of *Rhizobium*. The chemical nature of the excretion is still unknown, but the substances may be growth factors or the energy substrate necessary for initiation of infection. Infection occurs through amyloid spots at the tips of the young root hairs. As soon as bacteria enter the root hair,

an infection thread is formed which grows towards the base and nodule formation results. As the plants mature, nodules become brown, bacteroids disappear and the nitrogen is released to the plant.

Atmospheric nitrogen is fixed in the form of amino acids, proteins and other intermediary products inside the nodule tissues. Major part of this fixed nitrogen is stored in the nodule tissue. When the plants start flowering, all the nitrogen fixed is translocated to the shoot portions. A small quantity of this nitrogen also goes to the soil as exudate. Some species of *Rhizobium* are antagonistic to the pathogenic fungi that infect leguminous plants.

9.2.1.2 Bacterisation of cover crop seeds

Bacterisation is the process of inoculating either seeds or soil with the bacteria for the improvement of the crop (1). In leguminous seed, inoculation with *Rhizobium* spp is widely practised for effective nodulation and maximum nitrogen fixation. Successful legume seed inoculation can be beneficial in soils in which the specific *Rhizobium* is absent or sparse or where local *Rhizobium* is ineffective or sub-maximal in their nitrogen fixing capacity. Inoculation of specific strains of *Rhizobium* makes the host quickly independent of soil nitrogen and most likely results in increased yield and better quality of herbage or crop.

Even if the introduced *Rhizobium* is later displaced by an emerging naturalised population, the use of inoculum is likely to favour early nodulation and nitrogen fixation. The *Rhizobium* population in acid soils is comparatively low and ineffective. As the rubber growing soils are acidic in nature, cover crop seed inoculation may result in better nodulation and faster growth rate of cover crops. Inoculation of cover crop seeds can be effectively carried out by pelletization with calcium carbonate or rock phosphate using gum-arabic as adhesive. Calcium carbonate is preferred because it will enhance the pH of the soil around the seed temporarily and favour early nodulation with the inoculated bacteria.

9.2.2 Non-symbiotic nitrogen fixation

Microbes, which can fix atmospheric nitrogen independently in soils, are known as non-symbionts and the process as non-symbiotic nitrogen fixation. Both aerobic and anaerobic micro-organisms fix nitrogen, depending upon the soil condition and crop cultivation practices. In rubber fields, only the aerobic bacteria can carry out their functions and influence the growth of rubber. *Azotobacter* and *Beijerinckia* are the two major groups of aerobic nitrogen fixing bacteria. Among these two, *Beijerinckia* sp is acid tolerant and can survive in acid soils of rubber plantations. They are present in some of the rubber soils of India. When inoculated, they survive for a long time and congregate in the rhizosphere region of rubber. Besides fixing atmospheric nitrogen, these groups of bacteria synthesise auxins and enzymes which influence the growth of higher plants. Their antagonism to major plant pathogens reduces the population of pathogenic microorganisms.

9.3 Mycorrhiza

Some of the soil fungi living in mutual relationship with roots of higher plants form mycorrhizae. The fungi are mostly found on the roots in the form of mycelial strands and they belong to Ascomycetes and Basidomycetes. Mycorrhizae are divided into two groups, ectotrophic and endotrophic. In ectotrophic mycorrhiza, the fungus forms a lateral root like structure, similar to root hair, composed of mycelial strands which fill the intercellular space of the host plant. The strands serve as root hair and help in the absorption of nutrients from the soil. In the case of endotrophic mycorrhiza, the fungal hyphae penetrate the cortical cells of plant roots and a direct connection is established between plant tissues and soil. The endotrophic forms of mycorrhiza are more commonly found than the ectotrophic ones and both cannot be grown in pure culture. The presence of endomycorrhiza formed by the pythiaceous fungi, *Endogone* sp, was established in the roots of rubber and *Pueraria.* But its role in the growth of rubber is yet to be studied. However, in the cover crops which were inoculated with this fungus, early and better nodulation was observed.

9.4 Plant association and competition

In rubber plantations, the plant association consists of the main crop, the ground cover and the intercrops, if any. The ground cover may be regeneration of natural covers, introduced leguminous creeping covers or a combination of both. The natural covers or ground covers may be vigorous in the earlier years, may strongly compete with the rubber for moisture, plant nutrients, light etc and may dominate the plant association. In spite of the possible competition, it is desirable to establish the leguminous cover because of several beneficial effects. The competition could be minimised by maintaining the immediate vicinity of the rubber plants free of weeds and ground covers. It is recommended that a circle of about 2 m diameter around each plant in square or rectangular plantings and the planting lines to a width of 2 m in the case of contour plantings may be kept free of weeds as well as cover crops. With the spread of the root system of rubber plants, they will have to share the moisture and nutrients with the ground covers in the inter-rows.

If the leguminous ground covers are properly controlled and all cultural operations are carried out in time, the rubber trees will dominate the plant association by the second or third year. The ground cover starts dying off from the fifth year since they cannot thrive under the increasing shade of the rubber trees. During this process, considerable amount of nutrients are released to the main crop.

It has been observed that intercrops may dominate the association and retard the growth of rubber, if the choice of the crop or the time of its establishment is not judicious. Varieties of tapioca having spreading growth habit has been found to affect the growth of rubber adversely. Similarly, planting of banana with profuse suckering and tall growth habits along with rubber has also retarded the growth of rubber plants (8). Therefore, choice of intercrop which may not dominate the rubber plants, is important. In any case, intercrop should be sufficiently away from rubber to avoid competition.

9.4.1 Intercropping

Raising of annual food or cash crops along with rubber during the initial years is practised in many smallholdings in India, as it

fetches some return during the immaturity period. Intercropping also reduces cost of weeding. Many smallholders raise intercrops during initial years and then attempt to establish cover crops. This results in poor establishment of the leguminous ground covers since light becomes a limiting factor as canopy closes. The benefits that can be obtained by growing a legume cover are almost lost by indiscriminate intercropping. Moreover, raising of intercrops after the roots of rubber have started spreading may result in damage to roots, as intercrops require adequate tillage. Tillage will also encourage soil erosion. However, on economic considerations, intercropping could be practised in smallholdings provided the crops selected neither deteriorate the soil nor stand in the way of establishing a leguminous cover. Intercropping is seldom practised in large estates owing to the high labour requirement, management problems and awareness of the beneficial effects of growing leguminous cover crops from the beginning itself. A survey on intercropping in India conducted during 1976 revealed that in the order of preference tapioca, paddy, ginger and 'nendran' variety of banana are the most popular intercrops grown by smallholders (5). The net return per hectare obtained from different crops is given in Table 9.1

Table 9.1

Intercrops: Cost of cultivation and net return

Intercrops	Cost of cultivation (Rs/ha)	Profit (Rs/ha)
Tapioca	1454	1421
Paddy	1561	96
Ginger	8023	7107
Banana	2439	1759

The main attraction of ginger is the highest net return. Cultivation of the crop, being labour intensive, can provide employment to

the family of the smallholder. Even though preparation of beds involves relatively deep tilling, the large quantity of mulch applied to the crop protects the soil, and the farm yard manure added to it improves its physical properties. Moreover, large quantities of inorganic fertilizers are also added. Thus ginger cultivation, with proper agronomic inputs, promotes the growth of rubber. It has been observed that the local market price of ginger is liable to wide fluctuations. Many small growers do not take up ginger intercropping owing to the uncertainty of market and the high investment required.

Field experiments conducted in India to study the economics and effects of growing intercrops like paddy, tapioca, banana and green gram showed that 'nendran' banana was the most suitable (8).

The greatest attraction of tapioca intercropping is that it is easy to cultivate and is in high demand as a food crop. The growth of rubber has been adversely affected by this crop because of competition for sunlight. Moreover, from the agronomic point of view, tapioca is an undesirable intercrop as it exhausts as well as erodes soil. It also attracts rodents which later damage the tap roots of rubber plants.

Paddy and green gram could prove to be profitable only if they are raised employing family labour. Moreover, tillage for paddy results in quick soil deterioration. Nevertheless, this being the staple food is preferred by many growers.

The net returns obtained from 'nendran' banana are quite attractive. This variety has good demand and hence an assured market. The capital investment required is not very high. It has been found that the girthing of rubber is higher during the initial years when intercropped with 'nendran' banana (8). This is so because, these plants exert a beneficial effect on the micro-climate by keeping the vicinity of rubber plants cool and humid and do not compete with rubber for light. The other advantages of this crop are: (i) Cover crops can be established successfully in the first year itself; (ii) Growth of weeds can be kept down thus reducing weeding cost and competition with main crop; (iii) Soil disturbance required for raising the crop is minimum and hence it does not increase soil erosion; (iv) Since large quantities of fertilizers are used for banana cultivation, soil is always left enriched; and (v) Large quantities of crop residues are added

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by way of sheaths and leaves which can be used as good mulching materials after harvest.

9.4.2 Weeds and weed control

The climatic conditions under which rubber is grown are favourable for the luxurient and rapid growth of weeds. Hence weeds are a serious problem in all rubber plantations. In India, there is a pronounced dry spell extending from three to five months in the rubber growing regions and hence the problem due to weed growth is less serious.

As soon as the land is cleared for planting, whether it is new planting or replanting, very vigorous growth of natural weed species dominates the area. *Eupatorium odoratum* is the most noxious weed under such conditions. The other weeds are *Imperata cylindrica*, *Mimosa pudica*, *Pennisetum polystygon*, *Borreria* spp and *Lantana aculeata*.

The competition by weeds for sunlight, water and nutrients results in suppressed growth of rubber plants. The competition for light will exist only in the initial one or two years, but competition for water and nutrients will continue through out the immaturity period. Blocking of drainage channels by weeds has also been experienced. Excessive weed growth along the rows may create difficulties in proper supervision. During summer months, particularly in areas with long dry spell, weeds may dry out and create serious fire hazards. They may also act as alternative hosts for insects and pathogenic fungi which may increase the incidence of pests and diseases. Thus it is necessary that efficient weed control measures are adopted in rubber plantations, particularly during the early years.

9.4.2.1 Manual weeding

Weed control in the planting strips or terraces as well as in the inter-rows is necessary for ensuring good growth of rubber plants and easy establishment of leguminous ground covers. It is recommended that the plant bases or the contour terraces may be kept free of weeds either by close slashing or by clean weeding. As clean weeding leads to soil deterioration, mulching with the slashed weeds would minimise its ill effects. Bushy plants growing in the inter-rows and

all weeds in the cover crop beds are controlled by four to six rounds of hand weeding for the first two to three years by which time the leguminous creepers establish well and keep down the weeds in the inter-rows. Therefore, during the third and fourth years of planting, it is enough to control the weeds in planting strips or terraces by less frequent weeding and restrict the weeding of inter-row area only to selective uprooting of noxious weeds, if any. After the fourth year, weed growth usually will not be a serious problem, because by that time in all well maintained plantations the rubber plants would have dominated in the plant association and their canopy closed, resulting in prevention of quick regeneration of weeds. Therefore, weeding operations in plantations from the fifth year onward is limited to weeding of planting strips or terraces, selective slashing of noxious weeds in inter-rows and close slashing of weeds which may grow vigorously in vacant patches. A schedule of weed control operations required in the case of plantations where rubber is grown in association with legume cover is furnished in Table 9.2

Table 9.2

Schedule of weed control operations under South Indian conditions

Year of planting	Operations recommended	Rounds per year
1st year	Overall manual weeding in inter-rows and planting strips	4
2nd year	Manual weeding on planting strips	5
	Overall weeding including uprooting of noxious weeds from inter-rows	4
3rd year	Manual weeding on planting strips	4
	Overall weeding in the inter-rows	2
4th year	Manual weeding on planting strips	4
	Overall weeding in inter-rows	2
5th year onwards	Overall weeding including weeding on the planting strips	2

9.4.2.2 Chemical weed control

Weeding is, at present, the most important labour intensive operation during the immature phase of rubber and therefore chemical weed control measures have been tried. The findings from the trials on weed control have helped in sorting out weedicides useful for control of weeds commonly found in the rubber plantations of this country. In the clean weeded planting strips or contour terraces, application of Cotoran, Diuron or Prometryne at 2 kg/ha or Simazine at 3 kg/ha in 750 l of water gives effective control of weeds which lasts for three months and it is possible to avoid one round of manual weeding (6). The weeds which regenerate in these strips can be controlled by spraying Tafapon or Dalapon or Dowpon at 5 kg/ha. After 10 days, another spraying may be given using a mixture of 1.5 l of Gramaxone and 1 kg of Fernoxone. These operations may have to be repeated every four or five months depending upon the rate of regeneration. For the control of weeds in planting strips, the cost of chemicals and spraying charges put together may work out to be slightly higher than that of manual weeding.

A few trials have been conducted for finding out the possibility of adopting chemical weeding of inter-rows. It was observed that *Imperata cylindrica* (lalang grass) can be effectively and economically controlled by repeated spraying with Tafapon at 10 kg/ha (7). Removal of this weed by manual means is labour intensive and cumbersome. Various species of grass and dicot weeds such as *Eupatorium* can be effectively controlled by mixing weedicides having different spectra of action. A combination of 4 l Ansar 529, 0.6 l Gramoxone and 1 kg Fernoxone in 670 l of water per ha is effective in controlling weeds of the inter-rows. Fernoxone can be replaced by Diuron (0.5 kg). However, it has been found that at least four or five rounds of spraying are necessary to give year round control and hence the cost is much higher than that of manual weeding. Moreover, these weedicides are harmful for the leguminous ground covers since they are not having any selective action.

9.4.2.3 Chemical versus manual weeding

Chemical weeding can replace hand weeding only to a limited extent in the rubber plantations in India. Before going into the scope

for chemical weed control, it is pertinent to examine the merits and demerits of hand weeding and chemical weed control.

Hand weeding can be employed for the control of all types of weeds occuring in rubber plantations irrespective of the stage of growth of rubber plants and without damaging the legume cover plants grown in association with rubber. On the other hand, the possibility of chemical weed control is limited, at present, to the planting strips or terraces because all the post-emergent weedicides currently available cannot be sprayed on inter-rows as they have no selectivity towards legume cover plants.

Chemical weed control in planting strips or terraces offers advantages over the manual weeding using spade ('mammotty') because the former eliminates damage to feeding roots and prevents development of basins around plants and exposure of the soil to the severity of climate, which may result in degradation of soil.

Hand weeding, being labour intensive, can provide profitable employment for more people. As unemployment and under employment are serious socio-economic problems confronting the country at present, the practice of manual weeding cannot be discouraged all on a sudden.

In chemical weed control, cost of chemicals constitutes a significant part of the cost of operations and therefore, when chemicals are available at reasonable prices, chemical weed control can be adopted with economic advantages also.

Thus, a programme involving a combination of hand weeding and weedicide applications can be profitably used for weed control at least in estates where economic considerations do not permit increase in labour force or in plantations where labour is scarce.

9.5 Vacancy filling

In a newly planted area, a small percentage of plants may not establish, and such early casualities should be filled up as soon as noticed. A few budded stumps polybagged along with field planting and maintained in nursery could be used for supplying. Some more plants may die off during the first year itself mostly during summer

months. The number of casualities may vary depending upon the quality of upkeep, planting techniques adopted and weather conditions soon after planting. It is necessary to fill up these vacancies during the planting season in the second year by the beginning of monsoon. Supplying during the third year of planting need be carried out only if it is warranted by special circumstances. In seed-at-stake plantings, all the two or three seedlings may be field budded during April-May and the vacant points assessed after five weeks. The vacancies should be filled up during the same season by using the field budded stumps pulled out from plants where more than one seedling have been successfully budded.

9.6 Pruning

Immediately after planting, sprouts may sart coming up from the stock and they should be removed by weekly inspection. Only the shoot developing from the bud is allowed to grow. The bud shoots are usually bright green in colour while those growing from the stock are usually dark coloured. Occasionally two shoots may sprout from the bud, but only one must be allowed to grow. It is not desirable to have branches up to about 2.5 m from the ground level and hence pruning of side shoots is done during initial years. For pruning, a sharp knife should be used. Top pruning of young budgrafts should be avoided since it results in the formation of a circlet of branches which makes the tree prone to wind damage. Branches arising above 2.5 m may be pruned judiciously wherever necessary to avoid lop-sided development of the canopy.

9.7 Propping

Clones like RRIM 600 have a tendency for severe bending during the initial years and for such clones it may be necessary to pull the tree into erect position by providing support. Wooden or bamboo props could be used for the purpose of propping. Alternatively, coir ropes could be tied at convenient height on the stem, trees pulled into erect position and the other end of the rope tied to pegs. It is desirable to provide such support from the three sides in a triangular manner. The bark of the trees must be protected with folds of sacking or other suitable materials to avoid damage to the tender rind.

9.8 Mulching

The immediate vicinity of the young rubber plants in the field should be kept clean weeded to prevent competition. By doing so there is a possibility of soil degradation around the plants due to the severe climatic conditions prevalent in most of the rubber growing regions. Providing a protective layer of mulch materials is, therefore, recommended as a cultural operation for young plants. Since the direct exposure of soil to sunlight is being prevented by mulch materials, the soil is kept cooler and more moist during summer months. This helps in the increase of bacterial population in soil, ensuring better availability of plant nutrients. Besides, the exposed plant bases are protected from the beating action of rain drops, thus helping in reducing soil erosion. The mulch materials also help in the control of weeds around the plant bases. Since organic materials are used for the purpose, the capacity of the soil to hold water and plant nutrients is improved. Commonly recommended mulching materials are dry leaves, grass cuttings and cover crop loppings. In young plantations, mulching should be undertaken after fertilizer application and just before the onset of summer. Usually, the month of November is the ideal time for mulching. However, in some areas, mulch can harbour slugs and snails that attack the terminal shoot of young rubber and hence suitable control measures may have to be adopted.

9.9 Induction of branches

For proper girthing, the rubber plants should produce branches from about 2.5–3.0 m from the ground level. In trees with high branching, the rate of girthing is less than that with low branching. This is because of the greater leaf area associated with low branching. Clones like RRIM 600 and GT 1 show a tendency to branch high and therefore induction of branching may be required. The principle behind this operation is to induce development of lateral buds. Well spaced branches in different directions ensure balanced canopy. Many methods have been tried in the past which were found to be unsatisfactory for commercial practice. The Rubber Research Institute of Malaysia has developed some techniques for branch induction like double-blade ring-cut device (2), leaf folding and leaf cap methods (3).

The double-blade ring-cut device consists of two 'V' shaped blades separated at a distance of 20 cm by two separators. By pushing the 'V' shaped blades and rotating them around the trunk complete ringing is done cutting the bark and just reaching the wood. The cuts are to be made within the regions of a flush of leaves so that a number of trunk shoots are produced below the lower ring cut as well as within the ring cuts. The usefulness of this device is limited to greenish brown or brown tissues and is not satisfactory on young green tissues. In young green tissues, the leaf folding or leaf cap method may be useful. In the leaf folding method the top whorl of leaves are folded down at the point of contact of the petiole with the lamina utilising only the upper few leaves to enclose the apical bud. The leaves are then tied with a rubber band and they are released after three to four weeks. For plants with terminal whorl of leaves at either leaflet or bud break stage, the leaf cap method is recommended. Three mature leaflets are taken to form a cap to enclose the apical bud and then tied with rubber band. The cap is removed three to four weeks later.

9.10 Thinning out

Considerable variations in growth of plants can be noticed even in well maintained plantations, especially in polyclonal seed plantings. It is, therefore, necessary to use a high initial density which gives scope for progressive removal of poorer plants from immaturity to first few years of tapping. In an experiment conducted in Malaysia, removal of 30 per cent of the trees gave an average increase of 17 per cent in per tree yield in the case of buddings and 20–25 per cent in clonal seed plantings. The advantages of thinning out are more uniformity, lower maintenance cost and realisation of a higher per tree yield with consequent lower tapping cost.

The initial planting density recommended for buddings is 420–445/ha and 445 – 520/ha in the case of polyclonal seeds. During the period of immaturity and early years of tapping, selective thinning out should be carried out so as to bring down the stand to 310/ha by the tenth year.

The programme of thinning should be progressive and judicious. By the third year, it will be easy to identify obviously worthless plants

like malformed and damaged ones which can be removed. In the case of budded plants, any false shoots which later develop into seedling trees should be removed. Subsequent rounds can be made at six-monthly intervals. It is important not to remove trees on the edge of a vacant patch unless they are quite useless. In hilly areas where contour system of planting has been adopted, it will be difficult to make even thinning since planting density varies owing to variations in slope. Where contours are close, the trees should be inspected in groups along adjacent contours and slightly higher proportion of trees may be removed where the stand is denser. A slightly lower proportion of the trees should be removed from the areas where slope is more gentle and contours are wider apart.

In areas where tapping has been started, the yield potential is taken as the criterion for thinning out. For seedling areas, the yield is to be assessed first by test-tapping or by collection of yield data of the individual trees before a tree is removed. But for budgrafts visual selection is sufficient since there is a close relation between growth and yield. The trees to be removed at mature stage can be put under intensive tapping and then killed by pruning branches progressively and finally removing the tree.

9.11 Maintenance of roads and fire-belt

Annual maintenance of roads may be attended to during lien periods of work. Just before the commencement of summer, fire-belts are made by cleaning a strip of about 3 m width all along the boundary of the plantation. Dry leaves falling on these fire-belts and on the estate roads are sweeped away at frequent intervals during the summer months.

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10 NUTRITIONAL REQUIREMENTS AND MANURIAL RECOMMENDATIONS

Chapter 10

NUTRITIONAL REQUIREMENTS AND MANURIAL RECOMMENDATIONS

10.1 Essential nutrients

Rubber, like other plants, requires all the essential nutrient elements in adequate quantities for satisfactory growth and yield. An element qualifies for the status of an essential nutrient when (i) its deficiency makes it impossible for the plant to complete the vegetative or reproductive stage of its life, (ii) the deficiency symptom of the element in question can be corrected or cured by supplying that element only, and (iii) the element is directly involved in the nutrition of the plant, quite apart from its possible effect in correcting some microbiological or chemical conditions in soil or solution culture.

Essential nutrients are classified into two groups, viz macronutrients and micronutrients. Macronutrients are required by the plant in relatively larger quantities in contrast to micronutrients which are needed only in small quantities. Macronutrients are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium and sulphur. Calcium, magnesium and sulphur are sometimes referred to as secondary nutrients. Micronutrients are iron, manganese, copper, zinc, molybdenum, boron and chlorine. Sodium, silicon, cobalt and vanadium have been found to be beneficial for some plants under certain conditions though these are not recognized as essential nutrients. These are called functional or metabolic elements.

Of the macronutrients, carbon, hydrogen and oxygen are supplied to the plant through air and water. Even though all the other macronutrients are also present in soil, the rate of supply of nutrients like nitrogen, phosphorus and potassium (NPK) from the soil is usually not adequate to meet the demand by the plants and therefore, these

nutrients have to be supplemented. Some of the rubber growing soils in India are deficient in magnesium, and this nutrient is also supplied as fertilizer. In India, deficiency of micronutrients is not normally encountered. However, zinc deficiency induced by excessive application of phosphatic fertilizers is at times noticed in nursery and young rubber in the field. In order to have a proper appreciation of the importance of nutrient elements to plants and the nature of the deficiency symptoms, it is necessary to have some idea about the role of nutrient elements in plants.

10.1.1 Role of important macronutrients

10.1.1.1 Nitrogen

It is a constituent of protein and thereby of protoplasm which is an essential part of each cell. Nitrogen is also an integral part of chlorophyll, the green colouring matter of plants, essential for photosynthesis. It goes into the structure of nucleic acids, enzymes, hormones etc which are of paramount importance in the physiology and biochemistry of the plant.

10.1.1.2 Phosphorus

Phosphorus is a constituent of nucleic acids, phytin, phospholipids, some important co-enzymes and high energy phosphate compounds, and is essential for functions such as photosynthesis, respiration and fatty acid synthesis. It is also important in the development of meristematic tissues.

10.1.1.3 Potassium

Although potassium is not a constituent of any stable compound in plants, and its exact role in metabolism is not clearly defined, there is hardly any physiological process in the plant where potassium is not involved. Thus, it has been attributed a role in photosynthesis, in the synthesis of carbohydrate, protein and fat, translocation of metabolites, promotion of meristematic activity and maintenance and regulation of water relations of plants.

10.1.1.4 Magnesium

Magnesium is a constituent of chlorophyll. It is required for the activation of many enzyme systems connected with carbohydrate metabolism. It also appears to play an important role in the transport of phosphate in plant. Magnesium is also essential for synthesis of oil.

10.1.1.5 Calcium

Calcium is a constituent of cell wall. It is required for the growth of root tips. Calcium is related to protein synthesis as it enhances the uptake of nitrate nitrogen and is associated with the activity of certain enzyme systems.

10.1.2 Nutrient deficiency

10.1.2.1 Causes

Deficiency of a nutrient element in the plant may result from the following causes:

(i) Inadequate quantity of the nutrient element in soil or other growth media.

(ii) Excess of one element in soil antagonistic to another element may induce deficiency of the latter in the plant. Thus in *Hevea*, potassium is antagonistic to magnesium and calcium and *vice versa*. Similarly, excessive application of phosphatic fertilizer has been found to induce zinc deficiency.

(iii) Abundant supply of an element like nitrogen may generate excessive vegetative growth which might result in the deficiency of say, potassium, when the supply of the latter from the soil may not be adequate to meet the additional demand generated by the extra growth.

(iv) Deficiency of one element may prevent the utilisation of another element which is not deficient, thus creating a

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(iv) Deficiency of one element may prevent the utilisation of another element which is not deficient, thus creating a

situation apparently similar to that of a multiple deficiency of both elements. Thus, a deficiency of potassium, phosphorus or magnesium may result in non-utilisation of nitrogen for protein synthesis. Here the deficiency of nitrogen is only apparent and not real and stands corrected once the deficiency of the other element is removed.

10.1.2.2 Symptoms

The deficiency symptoms of important nutrients (15) are summarised below:

(i) Nitrogen (Fig 10.1)

Deficiency of nitrogen results in stunted growth, reflected in reduced leaf size and number. The leaves initially become pale green in colour which later on turns yellowish. In young unbranched trees, the symptoms are first manifested in older leaves in the lower storeys, and only when the deficiency becomes very acute, they appear in upper or younger storeys. In old branched trees, as a result of retarded growth, the crown becomes small and the deficiency symptoms are seen mostly on leaves exposed to the sun, rather than on shade leaves. Nitrogen deficiency reduces girth and yield of the plant.

(ii) Phosphorus (Fig 10.2)

Visual symptoms of phosphorus deficiency in mature rubber are seldom manifested, and even in young rubber the symptoms are observed only in very rare cases. However, the deficiency is clearly detected in both the cases by leaf analysis. In young unbranched trees, the symptoms are usually first found in leaves in the middle and upper storeys, and considerable defoliation may occur. In old branched trees, deficiency could be detected on the basis of analysis of leaves exposed to full sunlight and not on shade leaves.

(iii) Potassium (Fig 10.3 and 10.4)

Yellowing of the margin and tip of leaf is the initial symptom, followed by marginal scorching. Marginal yellowing usually begins

as yellow mottlings which later develop into a continuous yellow band. This band later on becomes necrotic and the necrosis starts at or near the tip. In the case of unbranched young trees, the symptoms appear in the lower or older storey of leaves, and extend to the mid storeys in advanced stages of deficiency. In old branched trees, the symptoms appear on leaves exposed to sunlight, ie at the top of the canopy or on the sides where there is exposed open space. Most often, the foliage at the top of the canopy could be seen from the neighbouring hill as a distinct yellow patch surrounded by green foliage. The yellow colour may not be clearly visible from inside the plantation. Considerable reduction in leaf size is caused by potassium deficiency and this is very evident from deficient leaves in old trees. The leaf symptoms seldom appear before August.

(iv) Magnesium (Fig 10.5 and 10.6)

The main symptom is the development of golden yellow colouration, starting at the edges and extending down between the main lateral veins and spreading towards them, giving a herring bone appearance. In instances of severe deficiency, yellowing is often followed by interveinal and even marginal scorching of the leaf. When the deficiency is extremely severe, there may be considerable defoliation and marked reduction in tree girth and leaf size. In the young unbranched tree, the symptoms are usually seen in older or lower storey of leaves. In mature trees, the symptoms usually appear in leaves fully exposed to sunlight, ie in leaves of terminal whorl at the top of the canopy or even on leaves exposed to sunlight on lower branches, as in trees adjacent to a clearing or road. On mature trees, the symptoms are seldom seen before August.

(v) Calcium (Fig 10.7)

Unlike in the case of potassium and magnesium, there is no yellowing accompanying calcium deficiency. The first symptom is the development of tip or marginal scorch, usually white to slightly brownish. In young unbranched trees, symptoms usually appear on upper storey or younger leaves, and in severe cases die–back can occur. In old branched trees, deficiency has been observed on

leaves low down in the shade and not on leaves exposed to full sunlight.

(vi) Zinc (Fig 10.8)

Deficiency is usually manifested by young plants in the nursery or main field, as a result of heavy dressings of phosphatic fertilizers. The symptoms are usually transient, and disappear when the roots spread out into soil unaffected by the fertilizer treatment. The characteristic symptom is that the lamina becomes very much reduced in breadth relative to its length. Frequently, the laminae become twisted and the margins appear wavy or undulating. There is also a general yellowing of the leaf with the midrib and main veins remaining dark green in colour. In young unbranched trees the symptoms are found on top storeys. Death of apical meristem occurs under conditions of severe deficiency and side shoots may develop from axillary meristems. In old branched trees, deficiency may be detected on the basis of analysis of leaves exposed to full sunlight and not of those in the shade of the canopy.

10.2 Assessment of fertilizer requirements of rubber plants

For the efficient and economic use of fertilizer, it is necessary to assess its requirement for the rubber plants. The diagnostic methods available to the planter are the following:

10.21 Visual symptoms

Visual symptoms, usually expressed on the foliage, are clear indicators of nutrient deficiencies. But, by the time such symptoms are noticed on the plant, the deficiency would have progressed very much and the plant would have suffered a setback in terms of growth or yield. Therefore, this method of diagnosis loses much of its practical value as a routine method for assessing the fertilizer requirement of the plant.

10.2.2 Soil analysis

Soil testing aims at assessing the fertility status of the soil through quick chemical tests. These tests give information of the potential of the soil to supply nutrients to the plants. Soil analysis also helps in determining the type of fertilizers to be used and the method of application to be adopted. One of the serious limitations of routine soil testing is that, eventhough it gives some idea about the total quantity of 'available' nutrients in the soil, it fails to give adequate information on the rate at which these nutrients would become available to the plant. Routine soil testing also does not take into account the availability of organic forms of nutrients such as that of phosphorus. Moreover, application of nitrogenous and potassic fertilizers usually does not appreciably improve the fertility of the soil with respect to these nutrients eventhough they may be absorbed by the plant and stored in its tissues for future use. Thus, although soil analysis may reflect poor status of nitrogen and potassium in the soil, the plant may be well supplied with these nutrients, as a result of the influence of past manuring. Sometimes, the nutrients present in soil may not become available to the plant because of adverse physico-chemical or biological properties of the soil which may not be evident from routine soil testing. These limitations of soil testing could be overcome by the use of leaf analysis.

10.2.3 Leaf analysis

Analysis of leaf samples collected from the rubber plant, following the correct sampling technique, gives reliable information on the state of nutrition of the plant at the time of sampling. This information relates both to the adequacy of the content of each nutrient in leaf and the proper balance among the different nutrients. Sometimes, the inadequate content of a nutrient in the leaf may not be the result of lack of this nutrient in soil, but due to the presence of excessive quantity of another antagonistic nutrient or other special soil conditions which inhibit the uptake of the nutrient by the plant. Analysis of soil along with leaf will give definite clue to the antagonistic effect or adverse soil conditions such as acidity or alkalinity. From the discussions, it is clear that soil analysis or leaf analysis has limitations as a single diagnostic tool. They are, however, complementary to

each other. It may be concluded that for ascertaining the state of nutrition of the tree at the time of sampling, for assessing the nutrient supplying capacity of the soil, for understanding the interactions of nutrients in the soil and within the plant and for determining the type of fertilizers to be used and the method of application to be followed, analysis of both soil and leaf samples is necessary.

10.3 Discriminatory fertilizer usage

Manuring on the basis of soil/leaf analysis is usually referred to as discriminatory fertilizer usage. This method of fertilizer usage has come to stay as the most efficient and economic one for rubber and it offers many advantages over the general fertilizer recommendations using standard fertilizer mixtures.

10.3.1 Advantages

(i) Very often, adoption of the method results in saving of fertilizers. Field experiments have shown that response to NPK fertilizers even during the initial four years of immaturity is dependent on the fertility of soil (2, 13,14). For immature rubber, general recommendations advocate the use of 10:10:4:1.5 NPKMg fertilizer mixture during the initial four years. But, there are many areas, particularly in Malabar in Kerala, Kanyakumari district in Tamil Nadu, South Kanara district in Karnataka, Konkan area of Maharashtra and in Andaman and Nicobar Islands where the 'available' magnesium content of the soils is very high (9) and where there is no need to supply magnesium in the form of fertilizer. So, on the basis of soil analysis, magnesium ingredient in the fertilizer mixture could be dispensed with. Results of fertilizer experiments on immature rubber have demonstrated that, when scientific methods of cultivation are adopted, there is little chance of response to fertilizers, particularly nitrogenous and phosphatic ones, from the fifth year of planting (1,2,6,8,13,14). These results could be attributed to the large quantity of nitrogen fixed and other nutrients locked up by the leguminous cover crop (5,16), all of which ultimately becoming available to the rubber plants after three or four years when the cover crop starts dying out. Even during the period after commencement of tapping, especially during the initial few years, the response to fertilizers has been found to be little, erratic or inconsistent

and the results could be related to leaf nutrient status (7,8,14). These observations probably could be explained by the finding that 1400 kg of dry rubber obtained from 1 ha removes approximately 10 kg nitrogen (N), 5 kg phosphoric acid (P_2O_5) and 10 kg potash (K_2O) (3). Moreover, recycling of nutrients through leaf fall and availability of a large volume of soil, enriched by the growth and decay of a leguminous cover crop, for exploitation by the roots of the tree reduce the necessity for further input of fertilizers.

(ii) It ensures optimum growth or yield of rubber. Adequate supply of nutrients to the plants and maintenance of proper balance in the ratio of different nutrients are essential for optimum growth and yield. Leaf analysis alone can help in adopting a suitable fertilizer schedule for correcting any deficiency or imbalance in the nutrient status of the tree.

(iii) It avoids or corrects problems like wind damage, panel coagulation, panel overflow, late dripping and brown bast disease. Nitrogenous fertilizers are mainly responsible for the development of a good canopy. Sometimes, even when nitrogenous fertilizers are supplied in adequate quantities, its utilisation by the plant is prevented by the deficiency of other elements like potassium, phosphorus or magnesium. So, the development of canopy will become normal when the deficiency of phosphorus or potassium or magnesium is corrected. If, however, along with correction of the deficient element, further addition of nitrogen is made, development of canopy may become so heavy that the trunk and branches may not be able to support the canopy, thereby resulting in trunk snap or branch break during strong winds. Under a normal tapping system, the flow of latex after tapping continues for a period of 1.5–3.0 h. A shorter duration signifies an attenuated yield and a longer duration usually known as late dripping, heralds the onset of the physiological disease called brown bast characterised by absence of latex flow on tapping. The duration of latex flow depends on the colloidal stability of latex – the more stable the latex, the greater the duration of flow. The stability of latex is influenced by its mineral content, particularly magnesium. A high magnesium content in latex can result in premature coagulation of latex on the tapping cut (panel coagulation). Sometimes, the

coagulation takes place at discrete points on the tapping cut, leading to blockage of flow at certain points along the cut and consequent flow of latex over the panel (panel overflow). Instances of such disorders have been reported from estates and smallholdings in Malabar in Kerala and Kanyakumari district in Tamil Nadu (10). Sometimes, the manuring schedule adopted may be such that it favours the production of a highly stable latex. Under such conditions, late dripping is manifested by the trees and if this condition is allowed to continue, brown bast disease sets in (11). Thus, proper balance of nutrients, maintained or brought about through discriminatory fertilizer usage, can ward off or correct all the problems described above.

(iv) It improves the quality of the crop (produce) by preventing problems like pre-coagulation of field latex and instability of preserved latex. A very unstable latex may coagulate in the collecting bucket itself before it is coagulated in the factory through addition of acid. This instability may create difficulties in the preservation of field latex or in the manufacture and preservation of concentrated latex. The problem of instability of latex arises mostly because of the high magnesium content or the improper ratio of magnesium to phosphate in latex. A judicial manuring schedule on the basis of soil and leaf analysis will go a long way in avoiding or correcting such problems.

(v) It helps in making differential fertilizer recommendations to suit variations in clones, exploitation systems, soil conditions etc. Clones like PR 107 and RRIM 600, for instance, differ in their nutrient needs because of differences in growth rate or yield potential. For a clone like GI 1 containing high magnesium in latex, a higher dose of potassium becomes necessary to keep down the magnesium content in the latex at a desirable level. A lower dose of nitrogenous fertilizer is to be recommended for wind-susceptible clones like RRIM 501, RRIM 605 and RRIM 623. These differentiations are possible only on the basis of leaf analysis which is also indispensable for assessing the need for additional fertilizer for Ethrel–stimulated trees. In some parts of Palghat district in Kerala, Konkan area of Maharashtra and Andaman and Nicobar Islands, the soil has a neutral to alkaline reaction

and the contents of 'available' calcium and magnesium are high. Under such conditions, all fertilizers containing calcium are better avoided, and a higher dose of potassium than that recommended for other areas is warranted. In these areas, use of rock phosphate may not also be desirable, and soluble fertilizers like urea, ammonium phosphate or ammonium phosphate sulphate are preferable. These discriminations in terms of quality or quantity of fertilizers are possible only on the basis of soil and leaf analysis.

10.3.2 When to undertake soil and leaf analysis

10.3.2.1 In field plantings

(i) Before starting rubber cultivation in an area, particularly in a non-traditional tract, soil samples may be analysed to ascertain its fertility characteristics. On this basis, the fertilizer schedule to be adopted during the initial four years is determined. However, if at any stage during the first three years of immaturity the growth of plants is found to be unsatisfactory and some nutritional problems are suspected, leaf samples may be collected and analysed for ascertaining whether any change in the manuring schedule is necessary.

(ii) During the August-October period of the fourth year of the planting, soil and leaf samples may be analysed and fertilizer recommendation for the fifth year obtained.

(iii) Subsequently, leaf sample may be analysed every year for getting fertilizer recommendation for the following year. Soil samples need be analysed only once in three or four years.

(iv) If in a plantation, where soil/leaf analysis is not being regularly carried out and where problems like wind damage, panel coagulation or late-dripping arise, immediate steps may be taken to adopt discriminatory fertilizer usage.

10.3.2.2 In seedling and budwood nurseries

(i) Before the establishment of nursery, soil in the area may be analysed for assessing its nutrient status and determining the fertilizer schedule to be adopted initially.

(ii) Subsequently, in the case of seedling nursery, composite soil samples may be drawn every alternate year from the nursery beds, after removal of plants from the nursery, for determining the fertilizer schedule for the ensuing two years.

(iii) In the case of budwood nursery, analysis of soil for determining the fertilizer schedule needs be done only once in three or four years.

(iv) If the growth of the plants in the nursery is unsatisfactory, and nutrient deficiency or imbalance is suspected, leaf samples may be collected from the plants and analysed. Samples may be collected from the seedling nursery at the time of budding and from the budwood nursery eight months after cutting back. On the basis of leaf analysis fertilizer recommendations for the subsequent years are obtained.

10.3.3 Methods of collection of soil and leaf samples

10.3.3.1 For immature and mature rubber

While collecting soil and leaf samples from rubber plantations for the purpose of discriminatory fertilizer recommendations, it is necessary to take some precautions. The most important point to be kept in mind is that the samples collected should be truly representative of the area sampled. Moreover, after manuring, two to three months should elapse before samples are collected. If there is uniformity in the nature of the soil, lie of the land, manurial history, age of the rubber tree and growth of rubber and cover crop, two composite samples of soil from 0–30 and 30–60 cm depths and one composite leaf sample would suffice for an area upto 20 ha. But, if there are marked differences in the above factors, take separate samples for the different areas. It is also necessary to have separate leaf samples for each clone.

If soil and leaf samples are to be simultaneously collected, the suitable period would be between August and October. But, if soil sample alone is to be collected, the period between December and March would also be suitable. For collecting soil samples, select at random 5–20 spots (depending on the total area to be sampled) and dig 60 cm deep pits at these spots. In slopy areas, however, take care to locate more pits along the slopes where variations in soil

properties are likely to occur. As it is necessary to ascertain the effect of past manuring on the fertility of the soil, locate pits at the site of past manurial applications. Do not sample road margins, labour line sites, neighbourhoods of cattle shed or compost pile, areas recently fertilized, old bunds, marshy spots, vicinity of trees or stumps or other non-representative locations. After removing the surface litter and mulch, cut a thin vertical section of soil from the top to a depth of 30 cm using a sharp-edged tool such as chisel. Pool all the samples of 0–30 cm depth from the different pits and mix well. If the size of the composite sample is large, reduce by quartering. For this purpose, spread the well-mixed soil into a thin layered square on polythene sheet or brown paper. Divide the square into four equal squares and discard the soil in the diagonally opposite squares. Repeat this process until about 250–500 g of soil is obtained. Prepare composite sample from 30–60 cm depth also in a similar manner (Fig 10.9 – 10.12). Dry the samples in shade, pack them in clean cloth bags and never in manure contaminated gunny or alkathene bags. Label each sample giving details of block sampled, depth of sampling and date of collection, and put the label in the bag. Write the label with pencil or ball point pen and never in ink as ink will spread from the moisture in soil.

Leaf samples are collected during August – October. During this period leaves would be six to eight month old. Depending on the area to be sampled, select 10–30 trees at random (up to 5 ha select 10 trees, for 20 ha select 30 trees and between 5 and 20 ha select proportionate number of trees). In the case of branched immature trees and trees under tapping, collect four basal leaves from the terminal whorl of low branches in shade from each of the selected tree (Fig 10.13). Four basal leaves from 'spur leaves' (small off-shoots with only one whorl from the trunk or main branches– Fig 10.14) are also suitable for sampling mature rubber. Whorls with new flushes and leaves infected by *Oidium* and other leaf diseases are unsuitable for sampling. Leaves formed during the onset of southwest monsoon are also not mature enough for sampling. In the case of unbranched young trees with storeys, select plants without new flushes (without flushes Fig 10.15, with flushes Fig 10.16) and collect four basal leaves from the top most whorl (Fig 10.17). Detach the leaflet from the petiole using a sharp knife or blade. If 30 trees are selected, collect only the middle leaflet from each leaf

(Fig 10.18), if 15 trees, collect the two leaflets on either side (Fig 10.19) and if 10 trees, collect all the three leaflets so that about 120 leaflets would be available in one composite sample.

Bring the leaf samples to the analysing laboratory within 24 h. If this is not possible, dry the samples in the sun continuously for five days before despatch to the laboratory. Alternatively, press each leaflet on the upper side with a hot iron, adopting a single slow stroke at the cotton range (for electric iron) or at the heat used for pressing cotton fabrics with non-electric iron (4, 14).

10.3.3.2 For seedling and budwood nurseries

Follow the same basic principles, as described above, in collecting soil samples from nursery. In the case of seedling nursery, sample as many beds as possible for the preparation of composite soil sample. In the case of budwood nursery, locate the pits in the area where fertilizers have been applied.

For leaf sampling from nursery, the sampling technique to be adopted is the same as for unbranched trees. However, for effective comparision, it is better to collect separate composite leaf samples from plants showing poor as well as good growth.

10.3.3.3 For areas to be planted with rubber

Collect representative composite soil samples from two depths, following the same method as described above.

Despatch the samples of soil and leaf to the laboratory as quickly as possible. Along with the sample, send the case history of the area represented by each sample in the prescribed proforma (Appendix IV).

For testing of soil and tissue samples in the Mobile Soil and Tissue Testing Laboratory of the Rubber Research Institute of India, collect soil and leaf samples, following the same technique as described. However, in the case of leaf samples, bring them to the laboratory on the same day without detaching the petioles. The samples of soil and tissue should be accompained by filled up case history sheets.

10.3.4 Fertility standards for soil and leaf

Soil fertility standards and critical leaf nutrient levels, tentatively suggested, are given in Table 10.1.

Table 10.1

Soil fertility standards and critical leaf nutrient levels

Nutrient	Standard		
	Low	Medium	High
Soil			
Organic Carbon (%) used as a measure of availability of nitrogen	<0.75	0.75–1.50	>1.50
'Available' phosphorus (P) (mg/100 g soil)	<1.00	1.00–2.50	>2.50
'Available' potassium (K) (mg/100 g soil)	<5.00	5.00–12.50	>12.50
'Available' magnesium (Mg) (mg/100 g soil)	<1.00	1.00–2.50	>2.50
Leaf			
Nitrogen (N) %	<3.00	3.00–3.50	>3.50
Phosphorus (P) %	<0.20	0.20–0.25	>0.25
Potassium (K) %	<1.00	1.00–1.50	>1.50
Magnesium (Mg) %	<0.20	0.20–0.25	>0.25

The results of soil analysis are expressed on air dry basis. Organic carbon is determined by the Walkely and Black method. 'Available' phosphorus is extracted with Bray No. II reagent using a soil-extractant

ratio of 1 : 10 and a shaking time of 5 min in a reciprocating shaker. 'Available' potassium and magnesium are extracted with Morgan's reagent using a soil-extractant ratio of 1 : 5 and a shaking time of 5 min.

The leaf values given are for shade leaves collected during August-October and are expressed on dry matter basis. The values are not corrected for age on the basis of calcium content of the leaf. For low levels, a normal or higher dose of the nutrient, for medium levels a normal or half dose of the nutrient and for the high levels half dose or complete omission of the nutrients are recommended, after considering the actual values of the nutrient in the leaves, ratio of different nutrients, clonal characteristics, yield, age of the tree etc.

10.4 General fertilizer recommendations

Manuring of rubber plants at its various stages of growth viz nursery, immature and mature phases, should be on the basis of soil and/or leaf analysis, as already emphasised. If, however, this discriminatory approach is not possible for one reason or other, general recommendations given below may be followed:

10.4.1 Seedling nursery

The object of manuring seedling nursery is to produce from unit area the maximum number of vigorous and healthy seedlings suitable for transplanting or budding within the shortest period. The following manurial practices are recommended:

(i) Incorporate 2000 kg of compost or well rotted cattle manure and 350 kg of powdered Mussoorie rock phosphate analysing 20–24 per cent P_2O_5 for every effective ha, ie 25 kg compost and 3.5 kg of Mussoorie rock phosphate per 100 m^2 of the nursery bed as a basal dressing. If the nursery bed is opened in a newly cleared area, addition of compost or cattle manure may not be necessary during the year of opening, and application of Mussoorie rock phosphate alone is sufficient. Also, in cases where the same beds are used repeatedly, apply Mussoorie rock phosphate only once in three years.

(ii) Apply 2500 kg of 10 : 10 : 4 : 1.5 NPKMg mixture per effective ha, ie 25 kg/100 m^2 of the nursery bed six to eight weeks after planting

the germinated seeds in the nursery. Spread the fertilizers in a band of about 14 cm width about 8 cm away from the base of the plants, and gently fork in with a hand rake. Ensure that there is sufficient moisture in the soil at the time of application and that the fertilizers do not cause injury to the plants by coming into contact with their stem.

(iii) Apply 550 kg of urea per effective ha, ie 5.5 kg per 100 m^2 of the nursery bed six to eight weeks after the first application but before undertaking mulching, adopting the same method of application as above.

10.4.2 Budwood nursery

The aim of manuring budwood nurseries is to obtain the maximum quantity of budwood of good quality during a period of 10–12 months with an initial period of 12–18 months for the first crop of budwood. The following manurial practices are recommended:

(i) Incorporate 150 kg of powdered rock phosphate per ha, ie 1.5 kg/100 m^2 of the nursery bed as a basal dressing at the time of preparing the nursery bed.

(ii) Apply 250 g of 10 : 10 : 4 : 1.5 NPKMg mixture per plant in two split doses of 125 g each. Give the first dose two to three months after planting the budded stumps or cutting back, if budding is carried out *in situ* and the second dose eight to nine months after planting. Apply the fertilizers in a circular band or a linear band in between two rows of plants, avoiding the area covering 8 cm away from the base of the plant in either case.

(iii) Apply 125 g of 10 : 10 : 4 : 1.5 NPK Mg mixture per plant in one single dose two to three months after cutting back for the second and subsequent crops of budwood from the nursery, following the same method of application as above.

10.4.3 Immature rubber

The object of manuring rubber plants during the immature (pre-tapping) stage is to accelerate the growth with a view to reducing

the unproductive phase. The following manurial schedule is recommended:

(i) At the time of refilling the planting pits, mix 12 kg of compost or well rotted cattle manure and 175 g of Mussoorie rock phosphate with the surface 20–25 cm of the soil for providing good soil conditions required for the optimum development of the young rubber plant, particularly its root system. In newly cleared forest areas where the surface soil is rich in organic matter, it is enough to apply 175 g of rock phosphate.

(ii) Apply 10 : 10 : 4 : 1.5 NPKMg mixture as per the schedule given in Table 10.2 for the first four years.

Table 10.2

Schedule of manuring for the initial four years of immaturity

Year of planting	Age in months at manuring	Total annual dose of fertilizer mixture		Period of applications and number of split doses
		Quantity /plant (g)	Quantity /ha of 440-450 plants (kg)	
1st	3 – 5	225	100	Sep–Oct (2)
2nd	9 – 15	900	400	Apr-Oct (4)
3rd	21 – 27	1100	500	Apr-Oct (4)
4th	33 – 39	900	400	Apr-Oct (4)

During the September-October period of the first year, apply a total of 225 g of the mixture per plant, split into two equal doses, using an interval of one to two months between the two applications. From the second to the fourth year, apply the mixture during the period from

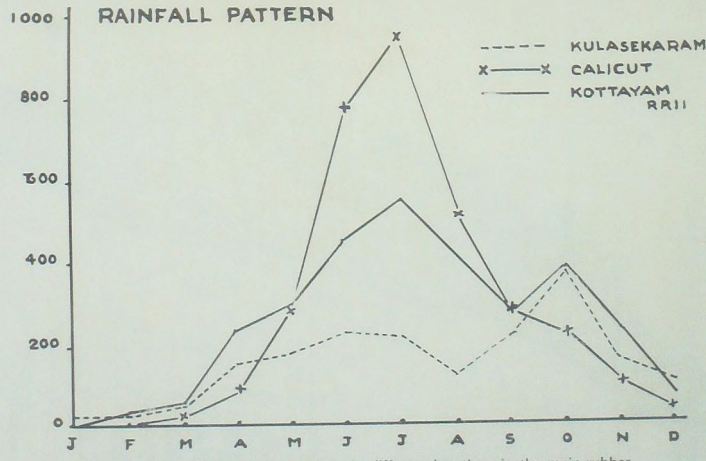


Fig 7.1 Rainfall distribution pattern in different locations in the main rubber growing tract (Kerala and Tamil Nadu)

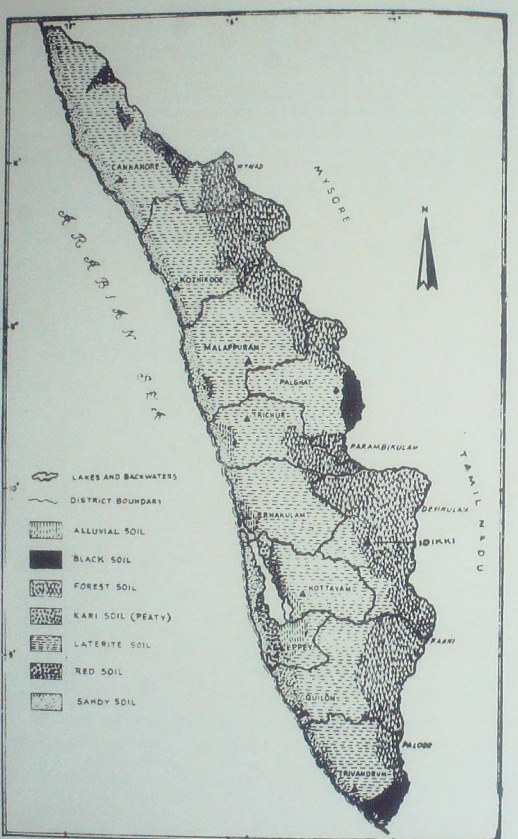


Fig 7.2 Soils of Kerala (Koshy and Thomas Varghese, 1972)

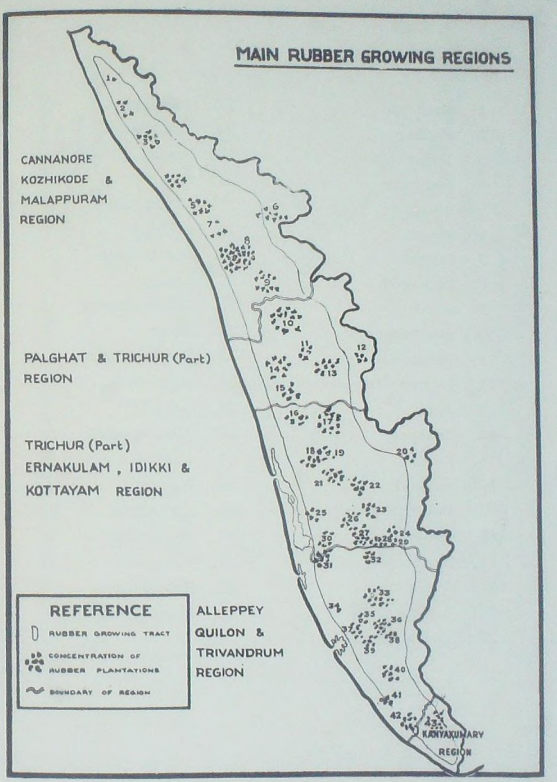


Fig 7.3 Main rubber growing regions (Kerala and Tamil Nadu)
Details of Locations overleaf

1. Kasaragod
2. Hosdrug
3. Taliparamba
4. Tellicherry
5. Badagara
6. Wynad
7. Quilandi
8. Kozhikode
9. Ernad
10. Perinthalmanna
11. Ottappalam
12. Chittoor
13. Alathur
14. Talappally
15. Trichur
16. Pudukad
17. Mukundapuram
18. Alwaye
19. Perumbavoor
20. Devikulam
21. Kunnathunad
22. Moovattupuzha
23. Thodupuzha
24. Erattupetta
25. Vaikom
26. Palai
27. Kanjirappally
28. Peermade
29. Mundakayam
30. Kottayam
31. Changanacherry
32. Ranny
33. Pathanamthitta
34. Mavelikkara
35. Adoor
36. Pathanapuram
37. Kunnathur
38. Punalur
39. Kottarakkara
40. Nedumangad
41. Trivandrum
42. Neyyattinkara
43. Kulasekharam

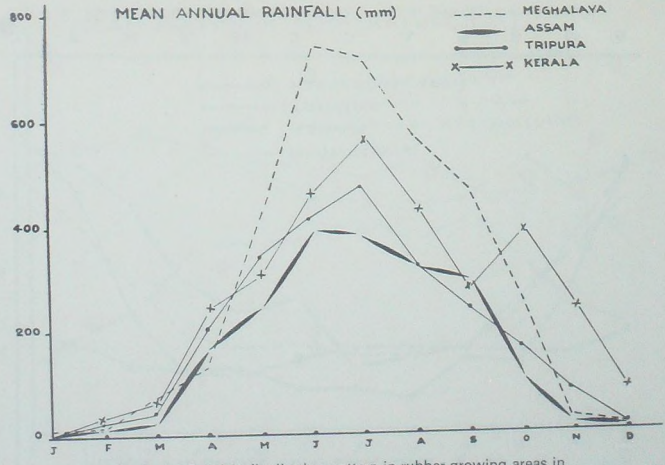


Fig 7.4 Rainfall distribution pattern in rubber growing areas in Kerala and three northeastern states

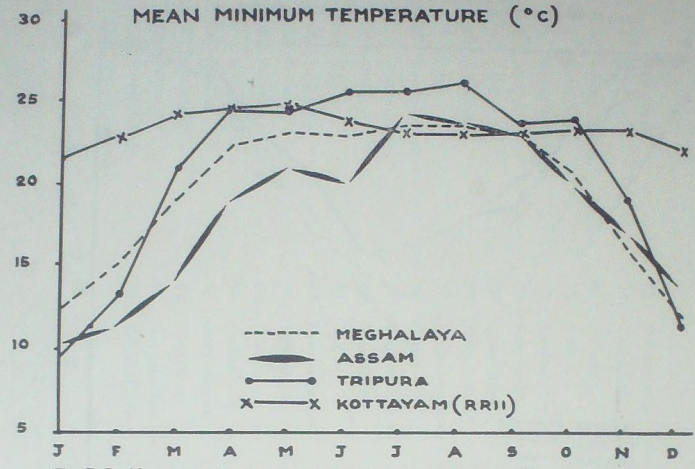


Fig 7.5 Mean monthly minimum temperatures in rubber growing areas in Kerala and three northeastern states

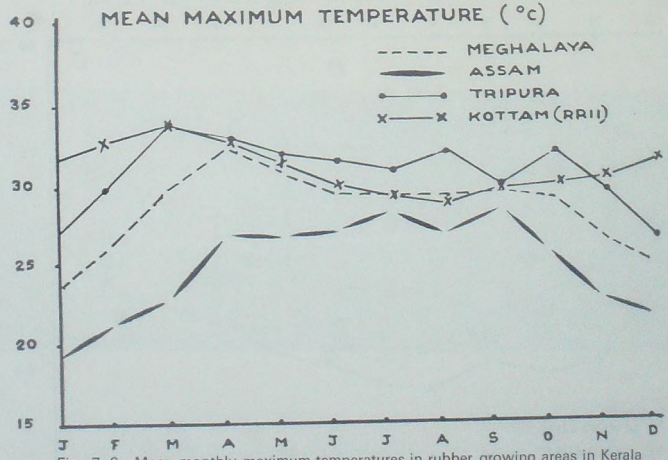


Fig 7.6 Mean monthly maximum temperatures in rubber growing areas in Kerala and three northeastern states

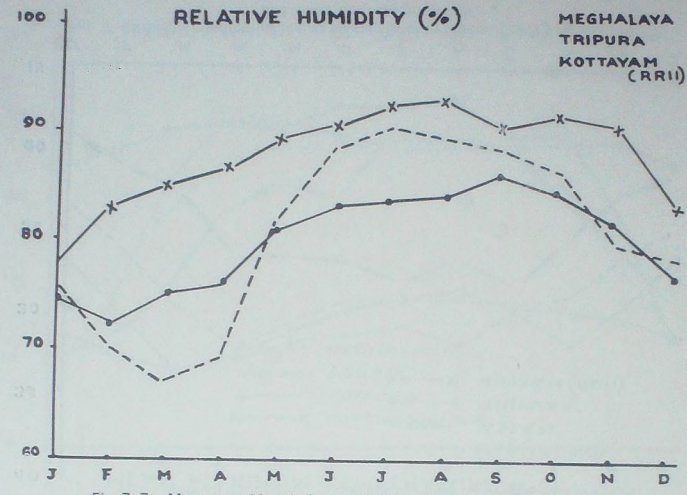


Fig 7.7 Mean monthly relative humidity in rubber growing areas in Kerala and two northeastern states



Fig 8.1 Ministump and stumped budding



Fig 8.2 Polybag nursery raising stock seedling



Fig 8.3 Polybag plants with three whorls of leaf



Fig 8.4 Polybag plants with six whorls of leaf

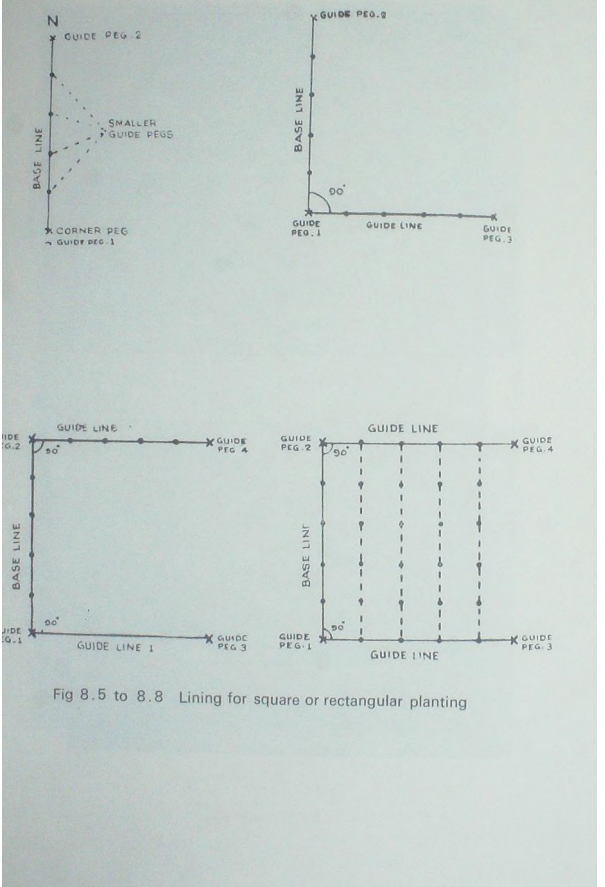
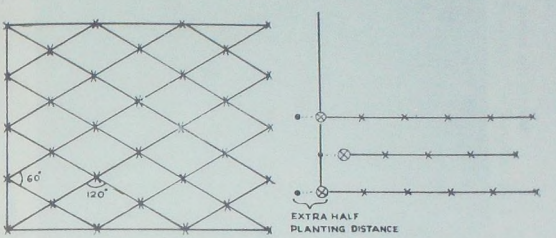


Fig 8.5 to 8.8 Lining for square or rectangular planting



Figs 8.9 to 8.10 Lining for quincunx system

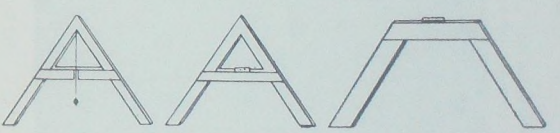


Fig 8.11 Levelling triangle and trapezium



Fig 8.12 Contour terraces



Fig 8.13 Planting — making a hole as deep as the length of tap root



Fig 8.14 Planting — compacting the soil around the stump



Fig 9.1 *Pueraria phaseoloides*



Fig 9.2 *Calopogonium mucunoides*



Fig 9.3 *Centrosema pubescens*



Fig 9.4 *Mimosa invisa* var *inermis*



Fig 9.5 *Calopogonium caeruleum*



Fig 9.6 *Mucuna bracteata*



Fig 10.1 Nitrogen deficiency: stages in the development of general yellowing (Tjir 1 seedling one year old) (Shorrocks, 1964)



Fig 10.2 Phosphorus deficiency: the under surface of six deficient leaflets showing development of bronzing (Tjir 1 seedling one year old) (Shorrocks, 1964)



Fig 10.3 Potassium deficiency: development of chlorosis and tip and marginal necrosis (unbranched tree) (Shorrocks, 1964)



Fig 10.4 Potassium deficiency: tip and marginal chlorosis (upper three leaves) and in severe cases more general chlorosis of the entire leaf except the leaf base (lower three leaves) (PB 86 mature tree) (Shorrocks, 1964)



Fig 10.5 Magnesium deficiency: stages in the development of herringbone pattern of interveinal chlorosis (PB 86 mature tree) (Shorrocks, 1964)



Fig 10.6 Magnesium deficiency: stages in the development of interveinal chlorosis not contiguous with leaf-margin (Tjir 1 seedling under one year) (Shorrocks, 1964)



Fig 10.7 Calcium deficiency: development of white papery marginal and tip scorch (PR 107 mature tree) (Shorrocks, 1964)



Fig 10.8 Zinc deficiency: reduced size, narrow shape and overall chlorosis (Shorrocks, 1964)

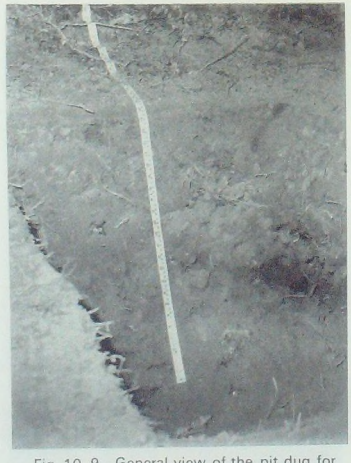


Fig 10.9 General view of the pit dug for soil collection



Fig 10.10 Collection of soil from 0–30 cm depth — first stage



Fig 10.11 Collection of soil from 0–30 cm depth — last stage

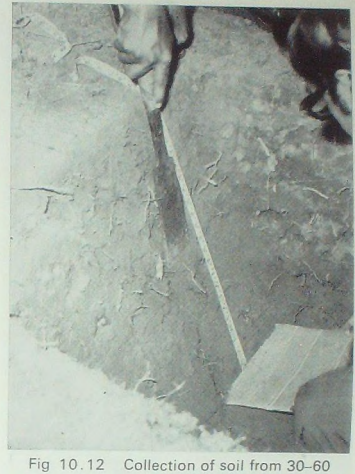


Fig 10.12 Collection of soil from 30–60 cm depth — first stage



Fig 10.13 Collection of shade leaf sample from mature tree
(arrows indicate terminal whorls suitable for sampling)



Fig 10.14 'Spur leaves' on a mature tree



Fig 10.15 Unbranched young plant without new flushes



Fig 10.16 Unbranched young plant with new flushes



Fig 10.17 Basal four leaves of the topmost whorl



Fig 10.18 Collecting middle leaflet from a single leaf



Fig 10.19 Collecting two leaflets from a single leaf

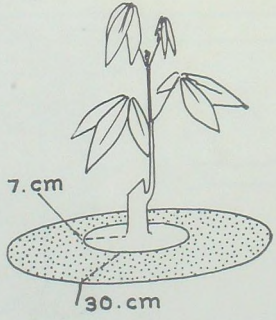


Fig 10.20 3 months

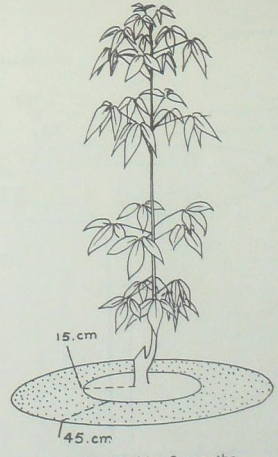


Fig 10.21 9 months

Method of application of fertilisers at different stages

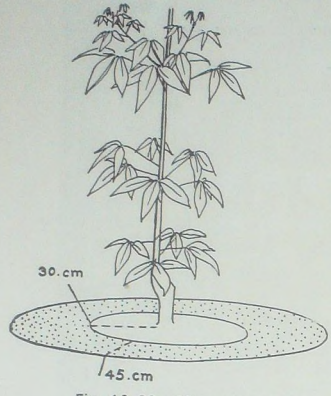


Fig. 10.22 15 months

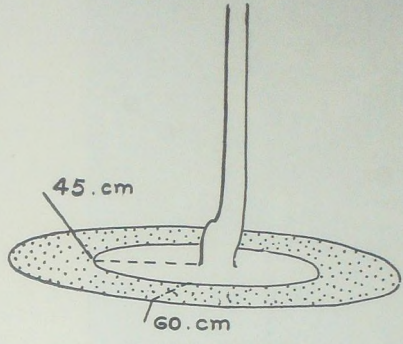


Fig. 10.23 21 months

Method of application of fertilisers at different ages

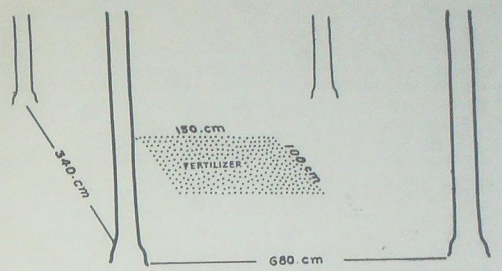


Fig 10.24 Method of application of fertilizers after 4 years—rectangular planting

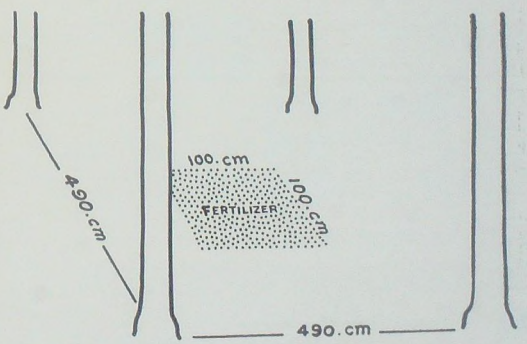


Fig 10.25 Method of application of fertilizers after 4 years—square planting

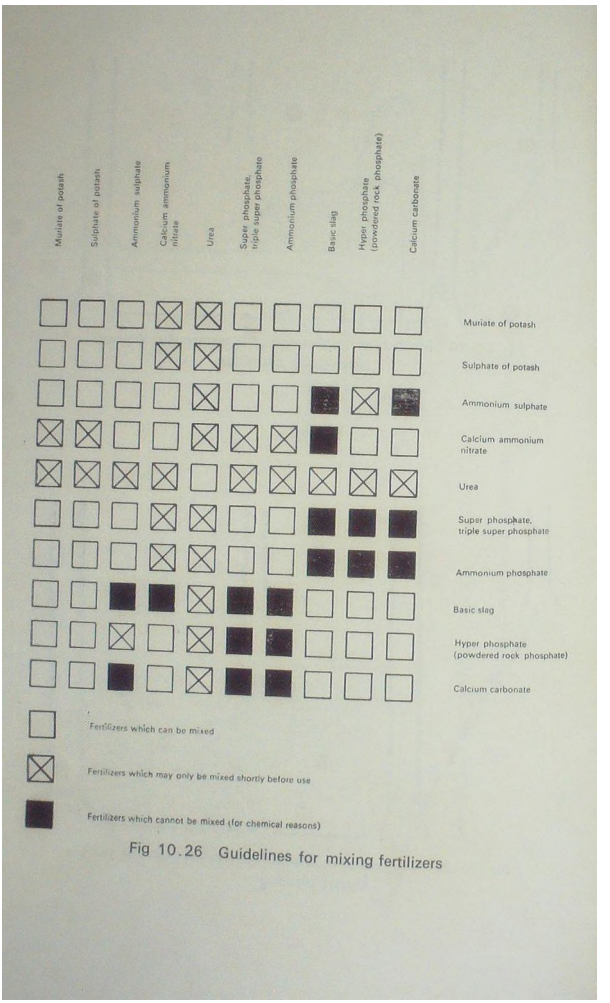


Fig 10.26 Guidelines for mixing fertilizers

April to October preferably in four equal doses with an interval of one to three months between applications, avoiding as far as possible the months of June and July with the heaviest rainfall when the possibility of losses of fertilizer through leaching is very high.

The method of application of fertilizers during the first few years of immaturity is very important as the plants will have only a limited root system. The basic principle to be followed is that the fertilizers are added to the area of soil where the concentration of active feeding roots is high. During the first year, distribute the fertilizer over a circular band of about 30 cm width around the young plant, leaving a radial distance of about 7 cm from the base of the plant all round. Follow the general guidelines given in Table 10.3 for determining the band width for the fertilizer and the distance from the base of the plant to be left unmanured (Fig 10.20–10.23).

Table 10.3

Method of application of fertilizer during the initial four years of immaturity

Year of planting	Age in months at manuring	Distance from the tree (in cm) to be left unmanured	Band width of fertilizer (in cm)
1st	3 – 5	7	30
2nd	9 – 15	15 – 30	45
3rd	21 – 27	45 – 60	60
4th	33 – 39	75 – 90	60

From the second year onwards, a range is given for the values of distance from the base of the plant, in view of the annual application being split into four doses. Fork the applied fertilizer into the top 5–8 cm of the soil. In areas where mulching is carried out, put the mulch over the fertilizer instead of forking.

(iii) Fertilizer requirements of rubber during the remaining period of immaturity depend to a great extent on the cultivation practices, such as mulching the plant bases during the initial years and the establishment and maintenance of leguminous ground covers like *Pueraria phaseoloides* in the area, as these practices, if properly carried out, will result in the improvement of soil conditions and availability of plant nutrients, particularly nitrogen. So there is a clear case for making separate fertilizer recommendations for areas with and without the above cultivation practices from the fifth year onwards. The following recommendations are made:

10.4.3.1 For areas where leguminous cover crops were established and maintained

Apply 300 kg of 10:10:10 NPK mixture per ha in two equal doses of 150 kg each during April-May and September–October. Instead of 300 kg of 10:10:10 NPK mixture, 250 kg of 12:12:12 mixture or 200 kg of 15:15:15 NPK complex or 175 kg of 17:17:17 NPK complex may be used. 12:12:12 NPK mixture and 17:17:17 NPK complex contain urea and, therefore, incorporate these into the soil to prevent loss of nitrogen as ammonia. Apply these two fertilizers in rectangular or square patches in between four trees and gently fork into the soil (Fig 10.24 and 10.25). In slopy areas where the cover crop has not completely died out or in level areas or where bench terracing is practised, it is enough to broadcast 10:10:10 NPK mixture and 15:15:15 NPK complex in between two rows of trees. However, in unprotected slopy areas, follow application in patches and incorporate all fertilizers into the soil.

10.4.3.2 For areas where no legume ground covers were established and maintained

Because of the absence of nitrogen fixation by the leguminous ground cover, the following recommendation is made: Apply 400 kg of 15 : 10 : 6 NPK mixture per ha, split into two equal doses of 200 kg each, during April-May and September-October. Since this mixture contains urea, apply it in patches and incorporate into the soil by forking.

10.4.4 Mature rubber under tapping

Apply 300 kg of 10 : 10 : 10 NPK mixture per ha (approximately 1 kg/tree) per year. Instead of 10 : 10 : 10 mixture, other mixtures and complexes already mentioned may also be used. It is desirable to split the total annual dose into two equal ones during April-May and September-October. If, however, only one dose is used, apply during April-May. In the method of appliction, follow the precautions and guidelines given under 10.4.3.1.

10.5 Foliar application of fertilizers

Under certain conditions such as when quick recovery from nutrient deficiency is desired, without considering cost, foliar application of fertilizers has been found to be more efficient than soil application. Urea low in biuret (less than 0.5 per cent) can be sprayed on to the foliage up to a concentration of 30 per cent. It can be incorporated into fungicide mixture for spraying purpose. A 2 per cent solution of ammonium phosphate sulphate (Factamfos) 16 : 20 : 0 has also been used for spraying immature rubber. For treating zinc deficiency, a 0.5 per cent solution of zinc sulphate may be used. The zinc sulphate used for foliar spraying should be of the fertilizer grade conforming to the specifications under the Fertilizer Control Order of the Government of India. Otherwise a 0.5 per cent zinc sulphate solution containing half the amount of lime may be used.

10.6 Manuring of cover crops

Manuring of leguminous ground cover with rock phosphate and muriate of potash has been found to be beneficial because of increased nitrogen fixation, dry matter production and turn over of nutrients (5). Hence, in areas where 'available' potassium is not deficient, application of 150 kg of powdered Mussoorie rock phosphate per ha is recommended in two split doses, the first, one month after sowing and the second, two months after the first application. In areas where the soil is deficient in 'available' potassium, application of a mixture of 150 kg of rock phosphate and 50 kg of muriate of potash per ha is recommended. In both cases, it is enough to broadcast the fertilizers on the strips where the cover crops are planted.

10.7 Fertilizers and fertilizer mixtures

10.7.1 Fertilizer mixtures used for rubber

The compositions of fertilizer mixtures used for rubber, viz 10 : 10 : 4 : 1.5 NPKMg, 15 : 10 : 6 NPK, 12 : 12 : 12 NPK and 10 : 10 :10 NPK are given in the Table 10.4.

10.7.2 Nutrient contents in straight and compound (complex) fertilizers

In Table 10.5 are given the percentages of nutrients in straight and compound fertilizers which are commonly used in India,

10.7.3 Mixing of fertilizers

In mixing straight fertilizers, the following general rules should be observed:

(i) Fertilizers containing ammonium cannot be mixed with basically reactive fertilizers (eg lime, basic slag, rock phosphate and calcium cyanamide) as losses of nitrogen may result through the escape of gaseous ammonia.

(ii) All the water soluble phosphatic fertilizers (superphosphate, triple superphosphate, ammonium phosphate) cannot be mixed with those fertilizers which contain free lime, because this reverts a portion of the soluble phosphate.

(iii) Various easily-soluble and hygroscopic fertilizers (nitrate fertilizers, urea, potash salts) tend greatly to cake or form lumps after mixing such fertilizers. Therefore, these should only be mixed with one another shortly before use.

(iv) The slightly acid superphosphate may liberate the acids from certain fertilizers (eg nitrates and chlorides) and this may damage packing materials and applicators. Fig 10.26 shows which fertilizers can and which cannot be mixed.

TABLE 10.4

***Ingredients (in kg) to be used for the preparation of fertilizer mixtures for rubber**

Sl. No.	Name of mixture	Ammonium sulphate	Ammonium sulphate nitrate	Urea	Mussoorie rock phosphate	Imported rock phosphate 29% (P_2O_5)	Muriate of potash	Commercial magnesium sulphate	Filler
1.	10 : 10 : 4 : 1.5 NPKMg								
	(a) Using ammonium sulphate	48.5	..	..	..	34.5	7.0	10.0	..
	(b) Using ammonium sulphate nitrate	..	39.0	..	46.0	..	7.0	5.0**	3.0
2.	15 : 10 : 6 NPK	..	..	33.0	46·0	..	10.0	..	11.0
3.	12 : 12 : 12 NPK	..	..	26.0	54.0	..	20.0	..	..
4.	10 : 10 : 10 NPK	48.5	..	..	..	34.5	17.0	..	..

* For composition of fertilizers used see Table 10.5

** The quantity of magnesium sulphate is reduced in view of the magnesium content of Mussoorie rock phosphate

TABLE 10.5

Percentage of nutrients in straight and compound (complex) fertilizers

Sl. No.	Name of fertilizer	Nitrogen (N)				Phosphoric acid (P_2O_5)			Total Potash K_2O	Total lime CaO	Total Magnesia MgO	Total Sulphur S	Moisture percentage by weight (Max)
		Ammonia NH_4-N	Nitrate NO_3-N	Amide NH_2-N	Total N	Water soluble	Citrate soluble	Total					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1.	Ammonium sulphate	20.60	..	..	20.6	..	..	..	..	..	..	23.7	1.0
2.	Ammonium sulphate nitrate	19.25	6.50 6.75	..	26.0	..	..	..	..	..	..	about 15	1.0
3.	Urea	..	..	46.0	46.0	..	..	..	..	..	..	..	1.0
4.	Calcium ammonium nitrate	12.50	12.50	..	25.0	..	..	..	..	10.20 ..	0.75	..	1.0
5.	Ammonium chloride	25.00	..	..	25.0	..	..	..	..	..	..	..	2.0
6.	Mussoorie rock phosphate	..	..	..	..	..	about 5	20–24	0.1–0.5	37–45	4–7	0.5–1.0	..
7.	Imported rock phosphate	..	..	..	..	..	4–7	29–36	< 0.1	44–51	0.1–0.3	0.1–0.4	..
8.	Single superphosphate (SSP)	..	..	..	..	16–20 (16)	..	16–20(16)	..	25–30	..	12	12.0
9.	Triple superphosphate (TSP)	..	..	..	..	42.5	..	46–48 (46)	..	17–20	..	1.3	12.0
10.	Dicalcium phosphate (DCP)	..	..	..	..	..	34.0	*	..	..	..	..	3.0
11.	Bonemeal (raw)	..	..	..	3.0	..	8.0	20	..	about 31	..	..	8.0
12.	Bonemeal (steamed)	..	..	..	..	..	16.0 (on dry basis)	22	..	about 33	..	..	7.0

13. Mnriate of p tas'i	..	..	..		..	..		58–60 (58)	..	..	..	0.5
14. Sulphate of potash	..	..	..			..	..	48–52 (48)	..	..	16–19	1.5
15. Potassium schoenite	..	..	..	..	..	..	..	23	..	10 (*Max*)	about 16	1.5
16. Commercial magnesium Sulphate (Epsom salt)	..	..	..	..	..	..	..	..	..	16	about 13	..
17. Diammonium phosphate (18 : 46 : 0)	18.00	..	..	18.0	41.0	*	46	..	..	..	..	1.0
18. Ammonium phosphate sulphate (16–20-0) Factamfos	16.00	..	..	16.0	19.5		20.0	..	..	..	15	1.0
19. Ammonium phosphate sulphate (20-20-0)	18.00	..	2.0	20.0	17.0	*	20	..	..	..	*	1.0
20. Ammonium phosphate sulphate (19.5-19.5-0)	19.50	..	..	19.5	17.5	*	19.5	..	..	..	*	1.0
21. Urea ammonium phosphate (28-28-0)	9.00	..	19.0	28.0	25.2	2.8	28.0	..	..	..	..	1.0
22. Urea ammonium phosphate (20-20-0)	6.40	..	13.6	20.0	18.0	2	20	..	..	..	..	1.0
23. Nitrophosphate (20-20-0) 'Suphala'	10.60	9.40	..	20.0	5.4	14.6	20.0	..	12.27	0.33	0.46	1.5
24. Nitrophosphate with potash (15-15-15) 'Suphala'	8.25	6.75	..	15.0	4.0	11.0	15	15	8.1	traces	1.70	1.5
25. NPK complex (17-17-17)	5.00	..	12.0 (*Max*)	17.0	15.3	1.7	17	17	*	*	..	1.0

Note:-For all fertilizers covered by the Fertilizer Control Order of the Government of India, the percentages of nutrients (NPK) given is the minimum stipulated in the order, unless otherwise specified, and the moisture is the maximum allowable. Whereasrange of nutrient percentages along with a figure in bracket is given, the latter relates to the minimum requried under FCO

* Data not available

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11 BIOCHEMISTRY AND PHYSIOLOGY OF LATEX PRODUCTION

Chapter 11

BIOCHEMISTRY AND PHYSIOLOGY OF LATEX PRODUCTION

Production of latex is confined to the latex vessels which exclusively occur in the phloem region. *Hevea* latex is a hydrosol in which the dispersed particles are strongly protected by a complex film made of protein, neutral lipid and phospholipid. Rubber is the principal water insoluble component of latex and it occurs as discrete particles. In embryonic latex vessels, apart from the prominent nucleus containing a single large nucleolus, normal cellular organelle such as mitochondria, proplastids, golgi bodies, endoplasmic reticula, lutoids and ribosomes are present. From a cytological point of view, latex can be considered as a specialised form of cytoplasm. What flows out on tapping is the fluid fraction of this cytoplasm. The yield of rubber from a tree, every time it is tapped, depends on the volume of latex collected and its rubber content (drc). While the drc of latex for a given system of tapping and environment is a clonal characteristic, representing the biosynthetic capacity, the volume of latex collected is influenced by the physiological characteristics and the environmental factors affecting them.

11.1 Composition of latex

11.1.1 Particulate composition

The dominant particulate phase of freshly collected latex is the rubber hydrocarbon (63). Particles of this make up 30–45 per cent of the whole volume and occur in size ranging from 0.02–3.00μ with the majority in the region of 0.10 (61). Rubber particles are usually spherical but sometimes oval or pear shaped (20). They are strongly protected in suspension by a film of adsorbed protein

and phospholipids (2). Next in abundance are the lutoid particles amounting to 10–20 per cent of the volume. The lutoids are sub-cellular membrane-bound bodies ranging in size from 2–5μ (61). The membrane encloses a fluid serum referred to as lutoid serum. The lutoid serum, also called B-serum, is a destabiliser of rubber hydrocarbon. In lutoids obtained from young latex vessels, a suspension of helical protein microfibrils is seen. Another type of particle present is called Frey-Wyssling particle which is spherical, usually larger in size than rubber and of yellow colour.

Separation of latex particles by ultra-centrifugation has paved the way for the rapid progress of knowledge on the complexity of latex. Latex may be divided into three main fractions by centrifuging, a white upper layer of rubber particles, a middle aqueous serum and the bottom fraction. The serum contains most of the soluble substances normally found in plant cells including amino acids, proteins, carbohydrates, organic acids, inorganic salts and nucleotidic materials (5). The bottom fraction consists mainly of lutoid particles and also includes varying amount of Frey-Wyssling particles, mitochondria and other particulate components of normal plant cell having a density greater than that of serum.

11.1.2 Chemical composition

The composition of latex collected by tapping is not similar to that of the latex inside the vessels. Depending upon the physiological variation in flow, the composition of latex collected after tapping and that inside the vessels may vary. Excluding rubber and water, the substances present in fresh latex are mainly carbohydrates, proteins, lipids and inorganic salts (12). Numerous other components are also present in small quantities.

11.1.2.1 Carbohydrates

Quebrachitol (methyl inositol) is the most concentrated single component in the serum phase, constituting about one per cent of the whole latex. The concentration of sucrose, glucose and fructose in latex is influenced by various factors such as planting material, tapping system and stimulation.

11.1.2.2 Proteins

The total protein content of fresh latex is approximately one per cent of which about 20 per cent is adsorbed on rubber particles, an equal quantity found in the bottom fraction and the remainder in the serum phase (12). The adsorbed proteins and phospholipids impart colloidal stability to the latex. Using starch gel electrophoresis, presence of 15 protein bands was demonstrated in the serum of fresh latex (28). Bottom fraction of latex was found to contain eight proteins. The isoelectric point of rubber particles in fresh latex varies from 4.0–4.6 and the variation has been ascribed to the presence of more than one protein on the rubber particle. The quantity of the adsorbed proteins on rubber particles is a clonal characteristic (18). The different proteins that have been studied in detail are alphaglobulin, Hevein, fibrillar proteins and basic proteins. Among these, alpha-globulin has the highest concentration in fresh latex serum (6,25). It is one of the proteins adsorbed on the surface of the rubber particles and is responsible for the colloidal stability of latex. Hevein is a major component of the bottom fraction of latex (1). Lutoid particles in young latex vessels contain a protein deposited in the form of bundles of microfibrils each having probably a double helical structure (12). This microfibrillar protein, which has a lower isoelectric point than Hevein, comprises about 40 per cent of the total protein of lutoid particles in young latex vessels but it is absent in older vessels. The major soluble basic protein of B–serum is Hevamine which remains in solution after dialysis (3, 63). The two closely related soluble basic proteins isolated from freeze-dried bottom fraction are Hevamine A and Hevamine B. The basic proteins of bottom fraction are of great interest because of their involvement in the mechanism of latex flow after tapping.

11.1.2.3 Lipids

Lipids of fresh latex consist of fats, waxes, sterols, sterol esters and phospholipids (12). These compounds are all water insoluble and concentrated in the rubber phase with small quantities in the bottom fraction and Frey-Wyssling. There is clonal variation in the total lipid content in latex.

11.1.2.4 Other constituents

Nineteen amino acids have been identified in latex (9). Nucleotides contained in latex are important as co-factors and are intermediates in biosynthetic processes. Total concentration of inorganic ions in fresh latex is 0.5 per cent, the main ions being those of potassium, magnesium, copper, iron, sodium, calcium and phosphate (12). Low molecular weight thiols, which are of importance in the redox potential of their environment, and enzymes normally present in cytoplasm are also found in latex (12).

11.2 Rubber biosynthesis

The first indication of the route of biosynthesis of rubber was obtained from its chemical analysis (17). Rubber is composed of isoprene units linked together to form a polymer. *Hevea* rubber differs from the majority of isoprenoid compounds in two respects. It has a high molecular weight which varies from a lakh to several millions (48) and the geometric configuration of double bonds is exclusively *cis* (19,23). Early investigations on the Mexican rubber plant, guayule (*Parthenium argentatum*), indicated that the precursor of rubber might be acetate (16). Later, it was confirmed that acetate forms the basic precursor of rubber biosynthesis in all rubber plants (7, 11, 15, 36). Using acetate, labelled with ^{14}C, it was further proved that latex,used as a medium can convert it to labelled rubber, indicating the presence of the entire enzyme system in latex for the conversion of acetate to rubber. The pool of acetyl coenzyme-A in latex should conceivably be generated from surcrose and it has been established that *Hevea* latex contains all the enzymes required for the metabolism of sucrose to pyruvate (10, 13).

11.2.1 Formation of hydroxy methyl glutaryl Co–A (HMG Co–A)

The enzymes required for the conversion of acetate and mevalonate to rubber have also been detected in latex (31). But the conversion of pyruvate to HMG Co-A in latex has not been established beyond doubt and the remarkably low rate of conversion of pyruvate to rubber *in vitro* confirms the need for further investigations. The conversion of pyruvate to acetyl Co-A in latex has never been proved and this is considered to be the unknown step in rubber biosynthesis (10). The

low ability of collected latex to convert sucrose or pyruvate into rubber *in vitro* does not, however, exclude the possibility that sucrose is the normal precursor under *in vivo* conditions, considering the fact that the biochemical and structural compositions of collected latex are different from those of latex inside latex vessels.

11.2.2 Formation of mevalonate from HMG Co-A

The discovery of mevalonic acid as an intermediary was a decisive step in the formulation of general pathways for the synthesis of isoprenoid compounds (65). Mevalonic acid is derived from HMG Co-A in a NADPH linked reduction which also occurs in *Hevea* latex (4). The activity of the enzyme HMG Co-A reductase in latex has been measured (31). This activity is surprisingly low and it has been suggested that the level of this enzyme may be a limiting factor in rubber biosynthesis.

11.2.3 Conversion of mevalonate to isopentenyl pyrophosphate (IPP)

Conversion of mevalonate to isopentenyl pyrophosphate requires two preparatory phosphorylations leading to 5–phospho and 5–pyrophospho mevalonic acid (4). The enzymes required for these conversions, mevalonate kinase and phosphomevalonate kinase respectively, have been detected in latex and their activity assayed (31). All the other enzymes required for the conversion of HMG Co-A to isopentenyl pyrophosphate have been detected in the serum fraction of latex (31).

11.2.4 Polymerisation of IPP to rubber

The mechanism of polymerisation of IPP has been elucidated in relation to terpene biosynthesis (30). Two processes are involved in this; the isomerization of IPP to dimethyl allyl pyrophosphate (DMAPP) by a shift of the double bond and the condensation of DMAPP with IPP to give a C-10 pyrophosphate. This C-10 molecule has allelic structure and it is able to repeat the condensation with a further molecule of IPP. This propagation step is repeated many hundreds of times in the formation of natural rubber to give a high molecular weight. The stereo-specificity of polymerase enzyme

in latex ensures a *cis* configuration for each double bond. Evidence has been provided for the incorporation of ^{14}C labelled IPP into rubber (26). The conversion of IPP into rubber in latex takes place on the surface of existing rubber particles which are essential for the *in vitro* formation of poly-isoprene. This would mean that the incorporation of IPP is predominantly a chain extension process on already existing rubber chains which carry allyl pyrophosphate end-groups (4). However, chain initiation can also be observed. It has been reported that the incorporation of IPP into rubber is strictly dependant on the addition of DMAPP when all soluble enzymes including IPP-isomerase are completely removed from the rubber particles (31). After this treatment, polymerase has been found to be still present on rubber particles, and in the presence of DMAPP, it would incorporate labelled IPP into rubber. Based on these results with latex system, a view has been held that both chain initiation and chain elongation can occur in latex, and that the failure to detect any chain initiation is attributable to contaminating enzymes. The IPP-isomerase activity (required for the formation of DMAPP) has not been detected in latex, but this could be due to the fact that the requirement for DMAPP would be extremely small, since each molecule of rubber contains several thousand isoprene units of which only one would be derived from DMAPP (2).

11.2.5 Site of rubber biosynthesis

A seemingly attractive hypothesis has been proposed for the biogenesis of natural polymers, involving a nucleotide template (33). No experimental evidence has so far been obtained to confirm this hypothesis. The site of polymerase activity is assumed to be at the interphase between serum and rubber particles (31). In this proposed system, the hydrophilic substrates, DMAPP and IPP, are converted into a lipophylic end product. It has been assumed that the growing hydrocarbon chain of rubber diffuses into the interior of the rubber droplet and that the hydrophilic pyrophosphate end group remains in the serum phase where it will interact with IPP, bound to the active site of polymerase enzyme. The possible pathway of rubber biosynthesis is given in Fig 11.1.

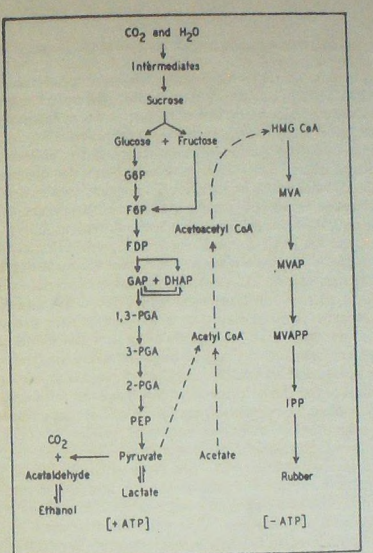


Fig 11.1 Pathway of rubber biosynthesis. [After Moir, G.F.J. (1969). J. Rubb. Res. Inst. Malaya 21(4) : 407]

G6P – glucose-6-phosphate
F6P – Fructose-6-phosphate
FDP – Fructose-1, 6-disphosphate
GAP – glyceraldehyde-3-phosphate
DHAP – dihydroxyacetone phosphate
1, 3-PGA – 1,3-diphosphoglyceric acid
3-PGA – 3-phosphoglyceric acid
2-PGA – 2-phosphoglyceric acid
PEP – phosphoenol pyruvate
ATP – adenosine triphosphate
acetyl-CoA – acetyl coenzyme A
a etoacetyl CoA – acetoacetyl coenzyme A
HMG-CoA – β-hydroxy-β-methyl-glutaryl coenzyme A
MVA – mevalonic acid
MVAP – mevalonic acid 5-phosphate
MVAPP – mevalonic acid 5-pyrophosphate
IPP – isopentenyl pyrophosphate

11.2.6 Inhibition of rubber biosynthesis by enzymes in lutoid serum

The non-rubber particles of latex including lutoids, which can be separated as bottom fraction by ultra-centrifugation,do not appear to be necessary for the formation of rubber from mevalonate (2). On the other hand, early work on rubber biosynthesis indicated the possibility that lutoid contents might exert a slight inhibitory effect on isoprene anabolism and this has already been demonstrated *in vitro* (11, 45). The decrease in the rate of incorporation was attributed to the presence of hydrolytic enzymes such as phosphatase, pyrophosphatase and ATPase which have been shown to be released when bottom fraction particles are disrupted (2). Addition of adinosine triphosphate (ATP) was shown to counteract the inhibitory effect of bottom fraction contents (2). Detailed studies on acid phosphatase in lutoids reveal that the co-factors such as ATP, Co-A and NADP and substrates such as phosphoenolpyruvate can be very easily destroyed by this enzyme (27). The possibility that the lutoid phosphatase, released from lutoids, might be responsible for the chain termination process in rubber synthesis by the removal of pyrophosphate ion from the end of the growing rubber chain has been examined (8). Leakage of phosphatase into serum, *in vivo*, might be conditioned by the peculiar physiological states or ageing of laticiferous cells. A number of *in vivo* factors might prevent the efficientaction of phosphatase liberated from lutoid. The pH of cytoplasmic serum itself is far from optimum for the acid phosphatase. In addition, the presence of inorganic phosphates in the latex serum might exert an inhibitory action on these enzymes. The magnesium present in latex serum is also considered to provide a protective role for ATP by the formation of ATP-Mg chelate (27). The significance of such enzymes, segregated in lutoid particles of latex, in regulating biosynthesis of rubber *in vivo* is still obscure.

11.3 Physiology of latex flow

11.3.1 Early studies on the mechanism of latex flow

Many studies have been carried out to elucidate the mechanism of latex flow. A mathematical exposition of the physics of latex flow was attempted (22). The first part of the flow curve followed an exponential law, ascribed to an elastic contraction of latex vessels

or a hydraulic gradient, and the second part followed the parabolic law of Poiseulle representing a capillary flow (22). The mechanism of latex flow, as conceived by the early investigators, can be summarised as follows: Latex vessels are filled with viscous latex under hydrostatic pressure. When the vessel is cut, the pressure at the location of the cut is released and viscous latex exudes. This expulsion of latex results in the displacement of latex along the length of the latex vessels owing to the strong forces of cohesion existing in the liquid phase. A fall in pressure in the latex vessels follows and consequently water from surrounding tissues enters the latex vessels owing to gradients in water potential. This dilution of latex, termed 'dilution reaction', makes the latex less viscous, resulting in an enhanced flow rate. It was assumed that, when the flow rate decreased due to fall in pressure, the adjoining cells might even remove water from the latex itself, thus increasing the latex concentration to the point of coagulation, so that the flow would stop completely.

Except for the mechanism of cessation of flow, the ideas entertained by the pioneer workers on the process of latex flow are still valid.

11.3.2 Modern concept of the physiology of latex flow

The discovery of the existence of an in-built flow restricting mechanism was a breakthrough in the conceptual development in latex flow physiology (14). It was observed that, when a tree is tapped at frequent intervals on the same day, a 'stepped' flow curve was obtained. A marked recovery of flow rate was observed at each tapping, indicating the removal of an impediment to flow, located very near the latex vessel ends. Further work indicated the presence of an inherent clotting mechanism within the latex vessels, responsible for the cessation of latex flow (57).

11.3.2.1 Colloidal nature of latex

In order to understand the modern concept of the mechanism of latex vessel plugging, a basic knowledge of the colloidal nature of rubber particles in latex is necessary. Natural rubber latex is a hydrosol strongly protected by proteins and the rubber particles in

latex occur as aggregates of molecules. The stability of rubber particles is due to the presence of net charge developed on the proteins, enveloping aggregates of rubber molecules. Since these proteins have an isoelectric point around 4.5 and since fresh latex has a pH around 7.0, the rubber particles have a net negative charge.

11.3.2.2 Role of lutoids in plugging

Besides rubber particles, latex contains another particle known as lutoid. The potential destabilising substances are segregated inside this particle. Lutoid particles are ruptured during latex flow, releasing the destabilising substances which in turn flocculate the rubber particles in the vicinity. Different stages of disintegration of lutoids have been identified and it was assumed that thermal, electrical, osmotic, mechanical and chemical factors might be involved in the process (58). Of these, thermal factor is unlikely to be of any consequence. Development of electrical potential following tapping has been demonstrated (29) and further studies on this aspect would be desirable. As the osmotic sensitivity of lutoids has been recognised, the role of osmotic changes during latex flow on the disruption of lutoids merits further attention. The greater degree of damage to lutoids in early flow fractions was attributed to osmotic shock following dilution of latex after tapping (35). The greater degree and number of damaged lutoids in early fractions could be expected if one assumes that the force of initial fast flow would sweep out the damaged particles. It was also recognised that shear stresses to lutoids during flow along latex vessels could also be important. By simulating pressure gradients in glass capillary tubes with internal diameter approximately that of latex vessels, breakage of lutoids, presumably due to shear stress has been demonstrated (62). It is pertinent to point out here that the latices freed from lutoids by ultracentrifugation fail to form plugs in capillaries even with great pressure gradient (66). Involvement of any biochemical factor in the disruption of lutoids is still to be proved. In this connection, studies on lutoid hydrolases (41) would be rewarding.

Direct evidence that the serum from lutoids (B-serum) has an extremely fast and complete flocculating action on aqueous suspensions of rubber particles has been obtained, and an electrostatic mechanism has been proposed (37, 44, 59). The divalent cations, Mg^{++} and

Ca^{++} present in B-serum in comparatively higher concentrations than in the latex serum as well as the B-serum proteins of high isoelectric point (and hence positive charge) have been implicated in the clotting action of B-serum (61).

The presence of phosphatase and other hydrolytic enzymes in B-serum has been extensively reported (5, 38, 40, 63) and it has been suggested that B-serum would lyse the protective envelope of rubber particles and that lutoids might be homologous to the lysosomes of animal cells. However, recent work indicates the predominant role of cationic proteins present in B-serum in the mechanism of flocculation of rubber particles. The B-serum activity is retained even after the removal of cations by dialysis. Recently, this activity has been ascribed to a particular protein zone isolated by starch gel electrophoresis (63).

The C-serum (latex serum obtained on high speed centrifugation) has an antagonising effect on B-serum. C-serum contains predominantly anionic proteins and hence has a net negative charge. B-serum and C-serum react with each other and the rapidity of flocculation process depends on the net effect of activities between the two sera (59).

11.3.2.3 Plugging index

Milford *et al* (34) proposed an index the plugging index – for measuring the extent of plugging and this index is now widely adopted.

$$\text{Plugging index} = \frac{(\text{vol in 5 min}) / 5 \times 100}{\text{total vol}}$$

However, as the volume yield on tapping is a function of both the initial rate of flow and extent of latex vessel plugging, plugging index alone would not indicate the yielding capacity of a tree.

Studies on the mechanism of latex vessel plugging have so far not shed much light on the reasons for clonal and seasonal variation in plugging index. Recent studies point to the possibility that clonal differences in plugging index may be related to variations in membrane

stability of lutoids and rubber particle stability. The lipid fraction of the membrane appears to influence the plugging process (49, 54).

Plugging index records greater values during drought in susceptible clones as compared to tolerant ones (47). The effect of soil moisture on plugging index has been demonstrated by irrigating the plants (50, 51). The plugging index was found to decrease on irrigation. Lengthening of the tapping cut also results in lower plugging index (60) and this effect was ascribed to the relationship between drainage area and plugging index (50, 51).

Plugging index can also be reduced by the application of yield stimulants (14). The action of yield stimulants on plugging index was considered to be mediated through the extension of drainage area (52, 53).

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Chapter 12

TAPPING

Tapping is the process of controlled wounding of the bark to extract latex from the tree. When the bark of a rubber tree is cut, latex, containing rubber particles, exudes. The present method of tapping was evolved through various stages.

12.1 History of tapping

12.1.1 Primitive incision method

In Brazil, the home of *Hevea*, primitive incision methods were practised for the extraction of latex. In this system, a series of cuts are slashed into the trees for a period of 100–150 days per year. With this kind of tapping, the cuts usually injured the cambium, and the trees often reacted by developing bumpy scars. For each tap, a new cut would be made and after a few years the stem part within the reach of the tapper would have become so uneven and bumpy by irregular secondary growth in the wounds that the trees would have to be abandoned.

12.1.2 Continuous excision method

The main principle of the present method of tapping is causing continuous excision of bark in a systematic manner. This concept of tapping was first proposed by Ridley (35). In this method, a sloping cut is made with a special knife and the same cut is regularly reopened by removing a thin shaving of bark at each tapping (Fig 12.1). This method takes into account the specific characteristics of the anatomy of bark and hence its superiority over the previous methods.

A skilled tapper can avoid injuring the cambium when this method is adopted. When a tree is tapped for the first time, only a small quantity of thick latex exudes. But with successive tappings, more and more latex with lower rubber content is obtained until a balance between the rubber content and the volume of latex exuded is established. The phenomenon of latex becoming gradually thinner has been termed the 'dilution reaction' (15).

Until 1900, the trees were given long periods of rest after about 25 successive cuts were made. Gradually many planters realised that the trees could stand longer tapping periods and longer cuts when the principle of Ridley's tapping method was adopted. The great demand for natural rubber at the beginning of the century motivated many planters to adopt tapping for longer periods and with increased length of cut. The full spiral and the herringbone systems originated at this time. But as the physiology of tapping and latex flow was not properly understood at that time, the trees were exploited in an unscientific manner with no relevance to the ability of the tree to replenish the lost latex before the next tapping. The conceptual development of the physiology of tapping owes much to the early experiments (15, 38, 39, 40).

12.2 Opening for tapping and tapping technique

12.2.1 Standard of tappability

The trees are brought under tapping only after they attain a certain girth. It is an established fact that the extraction of latex by tapping retards growth. As girth of the tree is one of the factors influencing the yield per tap, it is necessary that a satisfactory rate of growth should be maintained to obtain sustained yield for a number of years. The basic aim of a good exploitation system is to extract maximum latex with minimum retardation of growth. It has been established that growth of trees would be drastically affected by tapping before attaining the required girth. Moreover, this will not be economical as the yield per tree will be low. A standard of tappability has been fixed after considering this aspect. The standard is different for seedlings and buddings owing to the difference in the anatomy of the bark. In seedlings, the number of latex vessels as well as the bark thickness increases towards the base of the stem as these

have a conical trunk. Because of this the yield increases when the cut progresses towards the base of the stem. However, in buddings, which have a cylindrical trunk, such differences in the number of latex vessel rows or bark thickness are not significant at different heights. Therefore, opening of buddings can be made at higher levels than in seedlings.

Budded plants are regarded as tappable when they attain a girth of 50 cm at a height of 125 cm from the bud union. There is, however, no harm if the trees are opened at a higher level, ie 150 cm if the tappers can easily reach that height. In seedlings, on the other hand, the first opening for tapping is recommended at a height of 50 cm when the girth at that level is 55 cm. If opening at a higher level is preferred, the seedling trees can be opened at a height of 90 cm when the girth at that level is 50 cm. In a budded tree, subsequent panels are also opened at the same height, ie 125 cm. The height specified for opening subsequent panels on a seedling tree is 100 cm. The tapping panels are to be marked parallel to the contour terrace or planting line to facilitate easy and efficient tapping operations.

12.2.2 Marking

In a plantation, trees are opened for tapping when 50 per cent or more trees have attained tappable girth. To assess the percentage of tappable trees in an estate, separate 'girth wires' for seedlings and buddings can be used as shown in Fig 12.2. A piece of wire, 50 or 55 cm long, as the case may be, is fixed on a straight stick as long as the height at which the trees are to be measured. The stick is held against the tree with one end on the ground and the wire put around the tree. Where the free ends of the wire do not overlap, the trees have attained tappable girth. Such trees are to be marked for tapping. After deciding the position of the panel, a straight line is drawn on the right hand side. This line, the front channel, is then cleared and the opening height is marked on the line using a tape. Then by using a tape or a string the exact half circumference of the tree at the opening height is determined and marked. Another line, the back channel, is marked on the opposite side. With the aid of a template placed between these two lines at the appropriate height, the tapping cut and a few guide lines are marked (Fig 12.3). The template is made of a strip of flexible metal, preferably GI sheet,

16–18 cm width, for seedling and 20–23 cm for budding. Seperate templates are necessary for seedlings and buddings and should be made in such a way that when placed over the trunk the slope of the cut would be 25° for seedling and 30° for budding. The marks are made along its upper and lower edges and through the middle grooves. The tapping cut is made along the upper most mark while the marks below serve as guiding lines for subsequent tapping. The tapping cut is cleared and gradually deepened to the optimum depth with three or four subsequent tappings. It takes three or four such tappings to induce normal latex flow.

12.2.3 Tapping knives, spout, cup hangers and cup

The 'Michie Golledge' knife commonly used in India is well adapted for very efficient tapping and low rate of bark consumption. The 'Jebong' knife is also being used in certain estates. This is more suited for speedy and easier tapping and for tapping at higher levels. Slightly higher bark consumption per annum is observed when 'Jebong' knife is used. A third type of knife called 'Gouge' was also in use. (Fig 12.4).

A 'V' shaped metal piece made out of tin or GI sheet is used as spout. The spout is driven to the bark to guide the latex on tapping to the collection cup. Fixing of the spout should be done carefully to ensure that the cambium is not injured.

Different types of cup hangers are used on trees, as a means to place the collection cup. The commonly used cup hangers are made from GI wire and tied to the trees with the help of coir or spring. To avoid repeated replacement of spout and cup hanger, it is advisable to fix them about 25 cm below the tapping cut.

In India, coconut shell is mostly used as collection cup as it is cheap and readily available. Round bottomed aluminium or earthenware cups are used for this purpose in other countries.

The general practice is to remove the spout, cuphanger and the collection cup from the tree at the end of every tapping year and to refix them after a thorough cleaning, discarding the damaged and broken ones.

12.2.4 Tapping task

The number of trees allotted to a tapper for a day's tapping is called the tapping task. Task size is fixed on the basis of stand per ha and the topography of land. Normal tapping task in India varies from 250–400 trees. While increase in the task results in enhanced yield per tapper, it is important that the tapping should be over before 9 am. If tapping is delayed owing to larger task size, there is a possibility of a lower yield per ha. Task size is often reduced when double cut or other intensive systems are adopted.

12.2.5 Tapping rest

It is customary to give tapping rest for three to four weeks at the time of refoliation after wintering. This period synchronises with the period of lowest yield. Recent experiments have revealed that the drop in yield during this period is more due to the soil mositure stress prevailing during that period than to defoliation (45). No significant physiological damage is done even if the trees are tapped without any tapping rest. Therefore, it is recommended that no tapping rest need be given during wintering if the tapping during that period is economical.

The portion of bark tapped off during a year should be treated with a wound dressing compound during the period of wintering every year.

12.2.6 Bark consumption

A thin layer of bark is removed at the time of each tapping. This is to remove the plugs of coagulated latex formed at the cut end of the latex vessels. Removal of a thicker layer of bark than the required will not enhance the latex yield, but would result in unnecessary wastage of the good bark. But sub-optimal bark consumption may very often result in low productivity. Removal of an even thickness of bark shaving along the whole length of the tapping cut is also important. The recommended rates of bark consumption per year for alternate daily and third daily systems of tapping are as follows:

Alternate daily	: 20–23 cm
Third daily	: 16–18 cm

In a budded tree opened at 125 cm, it would take approximately 5–6 years to consume the bark in one panel. Thus within 20–24 years, the virgin bark panels and first renewed bark panels will be completely tapped. Trees are then subjected to intensive tapping for another five years. Thus the economic life cycle of a tree is around 30–35 years including the immaturity period. The practice of tapping second renewed bark is to be discouraged as the yield will be low and it would be economical to replant the area with high yielding materials.

12.2.7 Tapping on bark island

This happens when the third panel is opened above the first panel. Bark island is a small portion of bark of 15–20 cm width in between the present tapping cut and the previously tapped panel and of different age. When the tapping is in the bark island, yield decreases substantially. In seedling trees, formation of bark island takes place on panel C when the tapping cut reaches near the previous opening height on panel A. The ill effects of bark island can be minimised by the use of yield stimulants.

12.3 Symbols, notations and systems of tapping

There are different tapping systems. Variation in tapping system is brought about by altering the length of the cut, frequency of tapping or number of cuts. When various systems of tapping were employed in estates and research organisations, the necessity for a tapping notation to describe a tapping system was felt. Thus a notation was first introduced by Guest (18).

12.3.1 Symbols

A set of symbols was suggested to differentiate the type, number and length of tapping cut and the frequency of tapping.

12.3.1.1 Number, type and length of cut

These are expressed as follows:

S	—	Spiral cut
V	—	V cut
C	—	Circumference (where cut not specified)
S/1	—	One full spiral cut
S/2	—	One 1/2 spiral cut
S/3	—	One 1/3 spiral cut
2 S/2	—	Two 1/2 spiral cuts
V/2	—	One V cut (half circumference)
2 V/2	—	Two V cuts
C/1	—	One unspecified full circumference cut
C/2	—	One unspecified 1/2 circumference cut
2 C/2	—	Two unspecified 1/2 circumference cuts

12.3.1.2 Frequency of tapping

d	—	Days
w	—	Week
m	—	Months
y	—	Years
d/1	—	Daily
d/2	—	Alternate daily
d/3	—	Third daily
d/4	—	Fourth daily
2d/1	—	Twice daily
4w/6	—	Four weeks tapping and two weeks rest
9m/12	—	Nine months tapping and three months rest

12.3.1.3 Panels

A	—	Virgin bark
B	—	Virgin bark opposite side
C	—	Renewed bark on panel A
D	—	Renewed bark on panel B

12.3.2 Notations

12.3.2.1 Single cut system

S/2 d/2 — One 1/2 spiral cut tapped alternate–daily
S/2 d/3 — One 1/2 spiral cut tapped third-daily
S/3 d/2 — One 1/3 spiral cut tapped alternate-daily
S/1 d/4 — One full spiral cut tapped fourth–daily.

12.3.2.2 Double cut systems

2S/2 d/3 — Two 1/2 spiral cuts tapped third-daily
2S/2 d/4 — Two 1/2 spiral cuts tapped fourth-daily
2S/3 d/2 — Two 1/3 spiral cuts tapped alternate-daily

12.3.2.3 Change over systems

S/2 d/2 (2x2d/4)	Two 1/2 spiral cuts, tapping panels changed every alternate day
S/2 d/3 (2x3d/6)	Two 1/2 spiral cuts, tapping panels changed every third day

12.3.2.4 Relative intensity

Relative intensity is expressed as percentage of intensity of the standard system. The system chosen as standard is the alternate daily tapping on a half spiral cut which is considered as 100 per cent intensity (S/2, d/2, 100%). The relative intensity is calculated by multiplying the product of the numbers and fractions in the notation (ignoring the algebraic symbols) and then multiplying it by 400.

S/2 d/2	1/2 x 1/2 x 400	— 100%
S/2 d/3		— 67%
S/4 d/2		— 50%
2S/2 d/4		— 100%
2S/2 d/3		— 133%
S/2 d/2 6m/9		— 67%
S/2 d/2 (2 x 2d/4)		— 100%

Note: There is a proposal behind the International Rubber Research and Development Board to revise the above International Tapping Notation.

Yield increases with higher tapping intensities. Very high intensities, however, result in a large number of brown bast trees in course of time, resulting in loss of yield. When different tapping intensities are compared, it becomes evident that for unit of intensity the tapping efficiency decreases with increasing intensity (45). While the percentage tapping intensity serves the purpose of classifying different systems of tapping with respect to the absolute intensity, it has many limitations in quantifying the actual physiological strain on the tree.

The reaction of the tree to two different systems of tapping of the same intensity may vary. To cite an example, S/4 d/1 and S/2 d/2 have the same tapping intensity, but the daily system of tapping (S/4 d/1) would be more deleterious to the tree. Moreover, when yield stimulants are used with systems of lower intensity, the quantity of latex extraction may be more compared with a system of higher intensity with no stimulation. Therefore, the conventional calculation of intensity under such conditions has no relevance to the physiological strain on the tree. Puncture tapping with stimulation is an appropriate example to show that calculation of tapping intensity has no physiological meaning with such innovations.

12.3.3 Systems of tapping

12.3.3.1 Half circumference alternate daily system (S/2 d/2)

In this system, tapping cut extends around half the circumference of the tree and is tapped on alternate days. This is the most commonly used system for young bud materials. Nearly all clones seem to be able to stand continuous alternate daily tapping for many years with the exception of a few clones (eg GI 1, PB 28/59 etc) which show high incidence of brown bast, when tapped on this system.

12.3.3.2 Half circumference third-daily system (S/2 d/3)

A half circumference spiral cut is tapped once in three days. This system is used for those clones and seedling families which do not withstand half spiral alternate-daily system. In this system, the drc of the latex shows an increase of about two per cent as compared

12.3.2 Notations

12.3.2.1 Single cut system

S/2 d/2 — One 1/2 spiral cut tapped alternate–daily
S/2 d/3 — One 1/2 spiral cut tapped third-daily
S/3 d/2 — One 1/3 spiral cut tapped alternate-daily
S/1 d/4 — One full spiral cut tapped fourth–daily.

12.3.2.2 Double cut systems

2S/2 d/3 — Two 1/2 spiral cuts tapped third-daily
2S/2 d/4 — Two 1/2 spiral cuts tapped fourth-daily
2S/3 d/2 — Two 1/3 spiral cuts tapped alternate-daily

12.3.2.3 Change over systems

S/2 d/2 (2x2d/4) Two 1/2 spiral cuts, tapping panels changed every alternate day

S/2 d/3 (2x3d/6) Two 1/2 spiral cuts, tapping panels changed every third day

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S/2 d/2	1/2 x 1/2 x 400	— 100%
S/2 d/3		— 67%
S/4 d/2		— 50%
2S/2 d/4		— 100%
2S/2 d/3		— 133%
S/2 d/2 6m/9		— 67%
S/2 d/2 (2 x 2d/4)		— 100%

Note: There is a proposal behind the International Rubber Research and Development Board to revise the above International Tapping Notation.

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12.3.3.2 Half circumference third-daily system (S/2 d/3)

A half circumference spiral cut is tapped once in three days. This system is used for those clones and seedling families which do not withstand half spiral alternate-daily system. In this system, the drc of the latex shows an increase of about two per cent as compared

with the drc with S/2 d/2 and bark consumption per tap is higher than that of the S/2 d/2 system. The per ha yield is more under S/2 d/2 system while the per tapper yeild is more with S/2 d/3 system.

12.3.3.3 Full spiral fourth–daily system (S/1 d/4)

Under this system, a spiral cut extends around the full circumference of the tree, which is tapped on every fourth day. The main advantage of this system over the half spiral system is the reduction in the tapping cost and increased output per tapper. Because of the disadvantages of this system such as severe retardation of growth, increased scrap percentage and possible reduction in the task size, it is not recommended for young rubber.

12.3.3.4 Double cut fourth-daily system (2S/2 d/4)

This system consists of two half spiral cuts on opposite side of the tree preferably separated by a vertical distance of about a metre and both the cuts tapped once in four days. This double four system has the disadvantages of retarded growth, increased scrap percentage and reduced task size but has the advantage of lower tapping cost. Additional requirement of collection cups, cup hangers and spout is another disadvantage of the double cut fourth–daily system compared with the full spiral fourth-daily system.

12.3.3.5 Change over system

Panel changing systems were studied in different clones and it was found that such systems are more advantageous than S/2 d/2 system (26). In change over systems, two panels are opened simultaneously and tapping is done on alternate panels. S/2 d/2 (2x2d/4)and S/2 d/3 (2x3d/6) are examples of change over systems. Tapping panels are changed alternately every other day in the former system and every third day in the latter. Opening of two cuts on the opposite sides may, however, retard girthing.

12.3.3.6 Puncture tapping

Puncture tapping or micro tapping is basically an incision method of tapping, first reported (54) in 1906, and abandoned owing to bark

damages. This idea of microtapping has been revived recently after the introduction of the new yield stimulant Ethephon. Microtapping is done with a small needle on a vertical band of stimulated bark. (Fig 12.5). The length of the strip is usually limited to 60 cm and the number of punctures made may be four or five. A spout wider than the width of the band is fixed for collection of latex. The width of the stimulated band must be 2–4 cm and puncture tapping should be moved to an adjacent fresh stimulated band after every four or five weeks. The length of the needle used for puncture tapping must be adapted to the depth of the bark. Unlike in the conventional excision method of tapping, the possibility of avoiding the services of a skilled tapper and the possibility of increasing the task size are considered as the major advantages of puncture tapping over the excision method of tapping. Irregular bark surface and localised dead tissue surrounding each punctured hole are the two forms of bark damage generally observed with puncture tapping. Different types of puncture tapping experiments were conducted and it was observed that puncture tapping on immature trees one year before opening for conventional tapping could be promising. However, definite recommendation on puncture tapping for commercial adoption should await further studies on the physiological and economic aspects of this system.

12.3.3.7 Intensive tapping

After adopting less intensive commercial tapping system on the virgin and first renewed bark, adoption of intensive systems can be considered. Intensity of tapping can be increased, either by increasing the number and length of the tapping cut or by reducing the interval between two tappings. A double cut third-daily system with or without yield stimulation is generally considered to be a suitable intensive system. Double cut system in which the upper cut is tapped in the upward direction often results in very high yield. Upward tapping coupled with ethephon stimulation can give spectacular yield increase on a wide variety of *Hevea* cultivars.

12.3.3.8 Ladder tapping

Ladder tapping is a system of judicious exploitation of the virgin bark left untapped above panels A and B. This is distinct from

slaughter tapping in that no control is exercised with regard to bark consumption, intensity of tapping, slope and length of cut etc. A V/2 cut is marked at a height of 300 cm or at branching height of the tree. Back channels for the two ends of the V are marked, so that the tapping cut is restricted to be within these two back channels. This V–cut is tapped downwards, using a ladder that need not be shifted because of the shape of the tapping cut. Along with this V–cut, another half spiral cut can also be tapped on panel C or D. It is claimed that since the two tapping cuts are sufficiently well apart, they draw latex from different drainage areas. If a frequency of d/3 is adopted, this system of tapping can go on satisfactorily for six to eight years, ie three to four years on each of the two opposite panels prior to introduction of slaughter tapping. Many of the estates adopt this as a standard practice.

12.3.3.9 Slaughter tapping

Intensive tapping prior to replanting is the last stage in the tapping cycle and is called slaughter tapping. Tapping on the renewed bark at the lower levels may not be economic at this stage. Therefore, slaughter tapping is often done at higher levels, sometimes even on branches, with the help of ladders. As the objective of slaughter tapping is to extract as much latex as possible from the available bark, no consideration is given to the technique, intensity or standard of tapping. It may not be economical to use yield stimulants during slaughter tapping, because the response is not appreciable on account of the very high intensity of tapping adopted.

12.3.3.10 Tapping systems recommended

There is no tapping system which is best suited to all clones under all conditions. For most clones, half spiral alternate daily system is found suitable from the commencement of tapping. But half spiral third-daily system should be adopted in those clones which are highly susceptible to brown bast. Half spiral third-daily system is also recommended for seedling trees in the early years of tapping, as many among a seedling population could be highly susceptible to brown bast.

12.4 Certain factors influencing tapping efficiency

12.4.1 Depth of tapping

The highest number of latex vessels are situated close to the cambium. Therefore, to obtain optimum yields the tapping should be deep up to 1 mm from the cambium. Skilled tappers do this without injuring the cambium. Small tapping wounds caused occasionally on the tapping panel can be considered as a sign of good tapping. But a very clean panel without any such wounds may be due to shallow tapping. Appreciable yield increase can be obtained by deep tapping in such cases.

12.4.2 Time of tapping

The results of earlier experiments conducted to study the relation between time of tapping and yield were found inconsistent (8,9,10). However large scale studies conducted later indicate that yield decreases when trees are tapped after 7 am to a minimum of 84 per cent at 1 pm, followed by a small increase towards 4 pm (50). In another experiment, it was found that the extent of yield drop when trees were tapped at 9 am and 11 am as compared to tapping at 7 am was 4 per cent and 15 per cent respectively (14). It was also observed that 15–20 per cent reduction in yield occurred in trees tapped at 11 am instead of at 8 am (17). This drop in yield was entirely due to a lesser volume, as the drc at 11 am was slightly higher than that at 8 am. In another experiment, 14–19 per cent yield decrease was observed when tapped at 2 pm (27). The diurnal variation in yield and its relation to saturation deficit of air have also been studied and it was observed that yield was maximum and constant between 8 pm and 7 am and the yield decreased gradually to a minimum of 70 per cent of the maximum yield around 1 pm (28). The dry rubber content of latex at mid-day was found to be four points higher than that obtained during night. The diurnal variation in yield followed the variation in the saturation deficit of air and the correlation was inverse.

The decrease in yield during the course of day might be the result of increased transpiration and the lower turgor pressure of the laticiferous system (14). Indirect evidence (17) as well as direct

evidence (3,4) based on measurements of hydrostatic pressure in the phloem shows that diurnal fluctuation occurs in turgor pressure with a minimum in the afternoon. Diurnal yield fluctuations can be attributed to the variations in turgor pressure in the latex vessels. Significant correlation has been reported between transpiration and absolute saturation deficit of air (27). Based on these results, it can be assumed that the rate of transpiration controls the turgor pressure of the latex vessels, which in turn influences yield. Therefore, if tapping is carried out when atmospheric conditions facilitate a higher turgor pressure, a higher yield can be expected. The observed increase in the dry rubber content during mid-day as compared with night and early morning could be explained, on the basis of a lesser extent of dilution reaction after tapping (17). A high initial rate of flow during night and early morning would result in a higher volume of latex which more than compensates the effect of a slightly lower drc on yield (28).

12.4.3 Length of the tapping cut

Length of the tapping cut in relation to the circumference of the tree is an important factor determining yield. Tapping systems include full spiral cut (S/1), half spiral cut (S/2) and one third spiral cut (S/3). While the yield increases with increasing length of the tapping cut, the yield per unit length of tapping cut decreases (Table 12.1).

TABLE 12.1

Effect of length of cut on yield (yield per unit length as % of that of S/3 is given in brackets)

Clone	Yield (g / tap / tree) for different lenghts of cut		
	S/3	S/2	S/1
Tjir 1	33.54 (100)	41.40 (62.28)	59.36 (58.88)
LCB 1320	26.37 (100)	36.78 (92.98)	49.14 (62.11)

There is clonal difference in the rate of yield variation due to difference in length of the cut (16). Differential response of high and low yielders to shortening the cut is reported and it is assumed that the ratio of yield to different lengths of tapping cut is dependent upon the width of the drainage area (19). Since the drainage area varies with clones, the larger the drainage area, the lesser would be the effect of increasing the length of tapping cut on yield. In other words, high yielding trees respond less to increasing length of the tapping cut because such trees generally have larger drainage area. Further evidence of differential clonal reactions in yield response to the various lengths of tapping cut has been provided (25). It has been reported that differences in yield due to different lengths of tapping cut vary according to seasonal changes (45). Seasonal variation in yield is more pronounced in shorter cuts than in longer cuts. Recent advances in the knowledge of latex flow offer better explanations for these earlier observations. Clones with low plugging index show poor response to full spiral tapping while those with high plugging index respond well (23). Lengthening of the cut tends to lower the plugging index, resulting in enhanced yield (48). Therefore, a low response to the lengthening of the cut by a clone with low plugging index is expected. The seasonal variations in yield are mainly a function of varying plugging index. As the plugging index is already low with longer cuts, the seasonal fluctuation in yield is less in such systems of tapping as compared with shorter cuts. Lengthening of the cut would result in an extended drainage area (42,43). It can thus be concluded that in clones having larger drainage area and a lower plugging index, lengthening of the cut would have comparatively lesser influence on yield.

Another indirect effect on the length of cut on yield is mediated through its effect on the rate of girthing. Lengthening of the cut to full spiral has a depressing effect on the girth increment (11,13, 25,53). Lengthening of the cut is more deleterious for girth increment than a higher frequency for a given tapping intensity (13, 25).

12.4.4 Number of tapping cuts

Many early experiments were carried out to study the effect of number of tapping cuts on yield (14, 21, 22, 37, 39, 51). By operating two cuts, the area of latex extraction and regeneration

is extended and hence the yield is enhanced. The two cuts operate independently in a physiological sense as long as their drainage areas do not merge. The dry rubber content and the composition of the latex collected from upper and lower cuts may vary. If the two cuts are too close, the drainage areas may merge. The common systems of tapping with two cuts are 2S/2 d/3 (133 per cent intensity), 2S/3 d/2 (133 per cent intensity) and 2S/2 d/2 (200 per cent intensity). Based on the assumption that the two tapping panels are physiologically independent, it was reasoned that when a clone withstood a tapping intensity of S/3 d/2 (67 per cent intensity), it could be tapped 2S/3 d/2 (133 per cent intensity), provided a sufficient distance is left between the cuts (14). Double cut systems might affect the girthing and such systems are therefore considered unsuitable for young trees (11). The results of many experiments indicate that double cut systems would be profitable after D panel (24). The claim (49) that S/2 d/2 (2 x 2 d/4) tapping system was advantageous over other double cut systems of equal intentisy was later disputed (12). Later studies on the physiological aspects of double cut systems showed that opening of the upper cut might lower the plugging index of the lower cut, resulting in enhanced yield due to merging of the two drainage areas (41).

12.4.5 Frequency of tapping

Frequency of tapping is a factor which would influence the physiology of the tree as well as the yield from the tree. While a high frequency of tapping would affect the physiological balance between extraction of latex and its replenishment in the latex vessels, too low a frequency would result in reduced yield. The different frequencies of tapping are d/1, d/2, d/3 and d/4.

Different workers, using different planting materials and different systems of tapping, have obtained varying results. Nevertheless, some indications are obtained from these results. From results of large scale experiments, it was found that low frequency systems resulted in high yield per task per tapping (25). For a given length of tapping cut, a general inverse relationship between frequency of tapping and yield per tap was observed. In the case of certain clones, at least, the cumulative yields over three years in young trees were better with low frequency systems (25). The increased yield

obtained for low frequency system can be attributed to an increased level of late dripping recorded (25). How exactly a longer rest period between tappings, as in the case of d/3 system as compared with d/2 system, results in a lower plugging index is obscure.

Reducing the frequency of tapping at a constant length of the cut does not result in any appreciable difference in girth increment (24). It has been found that for a given length of the cut, reducing the frequency of tapping did not result in any significant increase in the rate of girthing (25). However, all periodic systems (with a period of tapping rest) gave better girth increment than the corresponding continuous system (36, 47). For a given length of tapping cut, rate of girthing is related to yield and not necessarily to tapping frequency (13).

Incidence of dry trees (brown bast) was related more to frequency of tapping than to the length of cut for a given tapping intensity (25,31,40,46). There are indications that, within the same tapping intensities (decided both by the length of cut and tapping frequency), there are no differences in the incidence of dry trees(1, 13, 29). A short cut has a smaller area of flow and by increasing the frequency of tapping, the balance between extraction of latex from unit area and the rate of regeneration is upset.

12.5 Brown bast

Despite many approaches that have been made into the cause and effect of 'brown bast' there is a long way to go before the complex sequence of events that culminate in the syndrome is understood. Various histological investigations have been carried out on the bark of the brown bast affected trees (31). Early investigators have related this phenomenon to the tree's reaction to wound healing (31, 34).

Brown bast is essentially a disorder of the latex vessels and the symptoms do not spread from virgin bark to regenerated bark or from one regenerated panel to another, indicating that continuity of the laticiferous vessel is necessary for its spread (29). It has been observed that it is possible to limit the area of bark where the brown

bast develops by isolating tapping panels with grooves on the bark up to tapping depth. The affected portion of the bark stops yielding latex.

Various forms of physiological disorders commonly considered as brown bast were grouped into five classes (7).

1. Abnormal colour of the cut, brown spots and cracks in the bark with eventual necrosis and stoppage of flow.
2. Partial dryness without brown colour or necrosis.
3. Woody burr formation resulting in deformation of the panel (Fig. 12.6).
4. Coagulation of latex on the tapping cut with no flow of latex.
5. Total dryness without brown colour or necrosis.

Usually, the actual onset of brown bast is preceded by an excessive dilution of the latex with late dripping. Whether this is a general rule for all the above classes of brown bast is doubtful. It has been noticed that certain trees go dry with no earlier late dripping. It is possible that certain contradictory results obtained by different workers may be due to the fact that they might have been dealing with different types of brown bast.

Probably, owing to the practical difficulties in studying the progressive stges of brown bast, most of the investigators have preferred to confine thier study to the effect of borwn bast. Schweizer (40) associated brown bast with lack of organic reserves, while Beaufils (2) considered mineral metabolism to be the causative factor. In support of his view, Schweizer induced conditions similar to brown bast by ring barking above the tapping cut followed by intensive tapping. This cannot be considered as direct evidence as the physiological exhaustion and the abnormal metabolism forced upon the tree with such treatments need not be the same as that which predisposes the tree to brown bast under normal conditions. Besides this, the results of later work stand against this contention as no evidence of starch depletion in the bark or lowered sugar content in latex during the onset of dryness could be obtained (5). The dry bark contained almost the same amount of total soluble sugars as that in the normal bark.

Efforts to correlate mineral content with brown bast incidence have not so far yielded any convincing results. However, a significant inverse correlation was obtained between the k_2O/CaO ratio in leaves and the percentage of brown bast (coagulation at the tapping cut) (2). Incidence of such conditions could be reduced by potash fertilizers. A higher Mg/P ratio was also recorded in latex in the susceptible clones (AVROS 308 and GI 1) compared with resistant clones (PR 107). It is assumed that the above mentioned disorder (coagulation at the tapping cut) is an extreme case of latex instability and that Mg content of latex could be a determining factor. It has also been observed that conditions similar to brown bast, induced by surgical treatments, resulted in very low flow rate of dilute latex containing damaged bottom fraction particles and it is suggested that such extreme rate of flocculation deep in the latex vessels may impede the flow, eventually inducing dryness (5). Role of divalent cation in promoting the destabilising effect of lutoids is also known (33). In the majority of cases of brown bast, however, a low drc of latex with late dripping, precedes the onset of dryness. Dilution of latex can cause osmotic shock to the lutoid particles causing it to swell and burst. But the mechanism by which a reduction in the rubber content is caused is far from clear. None of the above factors reported can be considered responsible for it.

It is reported that by drastic tapping, the phospholipids and potassium increase with a simultaneous reduction in the protein and calcium contents (40). A marked positive correlation between the stability of latex and potassium content has been obtained (30). A high content of potassium in the latex of brown bast affected trees is also reported. On the other hand, a high magnesium content of latex is reported to be associated with precoagulation tendency of latex at the tapping cut (2). So, theoreticaly it can be speculated that the reported brown bast conditions with high magnesium content and coagulation at the tapping cut may well be distinct from the conditions of brown bast reported to be associated with a high potassium content. Some clonal variations in the nature of brown bast symptoms are also reported (7). On the other hand, other reports do not indicate any relationship between brown bast incidence and soil type or soil and tree nutrient status (32).

The observations (7, 52) that incidence of brown bast is greater during and after wintering deserve further investigation. Fluctuation in the water relations as a consequence of excessive removal of latex has also been suggested to be the causative factor (46). An abnormally strong dilution reaction during latex flow was considdered to favour the development of brown bast (15). In intensively tapped trees initial flow rate and turgor pressure are found to be reduced before the onset of dryness (44). A view has been expressed that wound reaction might lead to a reduction in the permeability of the wall of the latex vessel resulting in a reduced availability of assimilates (1). In the same work a progressive decline in the cation concentration of latices of the trees subjected to intensive tapping to induce brown bast have been reported. Conversely, a higher concentration of cations in latices of intensively tapped trees was reported in a later study and it has been suggested that changes in the cation concentration might play a role in the observed deterioration of lutoids (29). With the aid of elctron microscope, evidence was provided for the flocculation of rubber particles around lutoid particles in such latices and a hypothesis was proposed that coagulation of rubber particles inside latex vessels due to decreased lutoid stability might be the causative factor for the onset of brown bast syndrome. It was assumed that the histological characteristics of brown bast affected bark, such as tyloses and stone cells, follow the development of disorders caused by damaged lutoids while features such as tissue necrosis and hyperplasia of the surrounding cells follow the death of the vessels. In these studies, phloem necrosis could not be detected and hence the earlier concept(6,20) that phloem necrosis or senescence could be the primary cause of this disorder was ruled out.

The usual recommendation of giving tapping rest for six months for brown bast affected trees does not always improve the situation. Usually, latex is found coagulated inside the vessels and giving rest to the trees does not remove this condition. It is, therefore, recommended to remove all the diseased tissues followed by continuous tapping off the remaining bark. If, however, the severity of the disorder is such that the whole panel has been affected, upward tapping of such trees can be considered.

The spectrum of veiws on the physiology of brown bast leaves behind the vital question how only a few trees in a plantation of

monoclonal budded material develop the brown bast symptoms. Much more work is needed to elucidate the different stages of physiological disorders which culminate in the brown bast syndrome.

12.6 Rainguarding

By fixing a polythene rainguard to the trunk of the tree above the tapping panel, tapping can be carried out during rainy season also. About 35–40 additional tappings per annum can be obtained by rainguarding the trees under the alternate-daily system. Rainguarding is recommended in areas where the annual yield is 700 kg/ha or more and where normally more than 25 tapping days are lost by rain. As the chances of panel diseases are high in rainguarded areas, systematic application of panel protectants is necessary at frequent intervals.

Gentle scraping to remove dry and flaked bark is carried out on a band of the bark 10-15 cm above and parallel to the tapping cut and extending 5 cm and 10 cm towards the back and front channels. A thin coating of a bitumen based adhesive is smeared on the scraped portion. Frilled polythene of 300 guage thickness and 45 cm width is then fixed where the adhesive has been applied. A strip of 2 cm wide 'kora' cloth is placed and stapled at four or five points, covering the upper edge of the frilled polythene. Then another coating of the adhesive is applied so as to make the rainguard leak-proof (Fig 12.7).

Some simple and new methods of rainguarding are under testing (Fig 12.8, 12.9). The principle is to fix a suitable channel above the tapping panel, so that the stem flow of water is diverted away from the panel thus keeping the tapping cut and the bark below in dry condition.

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13 YIELD STIMULATION

Chapter 13

YIELD STIMULATION

13.1 Early history

Since the introduction of *Hevea* cultivation on a large scale, many attempts were made to find a suitable method to increase the yield. Kamerun, a German chemist, reported in 1912 that periodic scraping of the outer corky bark layers could increase rubber yield (15). In the late 1920's some planters applied cow-dung on the bark below the tapping cut and claimed stimulating effect resulting in higher yield and good bark renewal. In the meantime, commercial preparations came into the market, consisting of a mixture of cattle manure and clay with other minor ingredients which included sulphate of iron and permanganate of potash. Later, it was thought that scraping could involve a wound reaction and that cow-dung was a source of auxins (5). This contention was confirmed in 1951 and it was found that all the effective mixtures contained plant hormones (10).

13.2 Use of vegetable oils and grease

The next development was the use of various oils as yield stimulants. Experiments using palm oil showed that it could stimulate yield when applied to scraped bark below the tapping cut (8). Studies conducted in Malaysia and Sri Lanka showed that light scraping and application of the oil gave increased yield (8). When palm oil and linseed oil were mixed, the response was higher. Use of coconut oil also increased yield in the first month and a gradual fall in response was observed after one month. It was also found that petrolatum grease could stimulate yield. As petrolatum grease contains no auxins, this finding did not support the earlier view that the effect of oil on latex yield was due to its auxin content.

13.3 Use of auxins and copper sulphate

A series of experiments were conducted in 1951 (6,17) to study the possibility of using certain chemicals as yield stimulants. IBA, NAA, 4–CPA, ∝–NOXA and β–NOXA in paraffin oil emulsion were tested for their effect on yield and bark renewal. It was found that 4–CPA, NAA and ∝–NOXA gave yield increases of 53, 27 and 23 per cent respectively. At this time it was reported that very large increase in yield was obtained by applying 2,4–D on scraped bark below the tapping cut (10). Among the 50 different preparations tested, 1 per cent 2,4–D was found to be the most effective. Injection of 2,4–D into the tree produced a good yield response but caused injury to the bark. During this time, the effect of 2,4,5–T was also tested and it was equally effective. Later, the long-term effects of 2,4–D 2,4,5–T and copper sulphate were studied (7). Copper sulphate was applied into the tree by injection. Though a high initial yield was obtained by copper sulphate, its effect on yield increase declined at each subsequent application.

The effect of yield stimulants was further analysed by De Jonge and found that the yield increase was dependent on various factors such as the nature and conditions of the bark, the intensity of tapping, environmental conditions and clonal characteristics (11). In 1954, a synergistic effect between 2,4–D or 2,4,5–T and copper sulphate was reported (12). Copper sulphate was not widely used because copper contamination affected the properties of rubber.

A study of a wider range of biologically active compounds was conducted in RRIM (1). Among the 89 compounds tested, only 23 showed significant activity. 2,4–dichloro 5–fluoro phenoxy acetic acid (2,4–Cl–5–F) was found to be superior to 2,4,5–T. However, the benefit of enhanced yield with 2,4–Cl–5–F was offset against its higher cost. Picloram was also an effective yield stimulant.

13.4 Role of ethylene

It was proposed that the action of 2,4–D and 2,4,5–T might mediate through the production of ethylene in the tissue. So ethylene oxide was tried to increase latex flow. But ethylene oxide was toxic to *Hevea*. Subsequently acetylene was found to be a good yield stimulant. But acetylene was not commercially used as it was

more difficult to apply. Search was then made for cheaper and effective chemical compounds that would release ethylene (2). This approach was more than justified with the discovery of ethephon, a very potent yield stimulant. This chemical on hydrolysis within the plant tissues, produces ethylene. National Chemical Laboratory, Pune, India has developed an indigenous process for the commercial production of ethephon. Another formulation in which ethylene gas is entrapped in molecular sieves has also been developed (13). The principle involves the use of dehydrated zeolite molecular sieve to adsorb the ethylene molecules into the honey combed cavities which are then trapped by mixing with oil or grease. The adsorbed ethylene could be displaced by the entry of water into these pores. This can be appliedas a paste.

13.5 Effects of stimulation

13.5.1 Effect on biochemical aspects of latex flow

It is now confirmed that the action of the auxin type of growth regulator such as 2,4–D and 2,4,5–T is mediated through the production of ethylene in plant tissues. Of the variety of chemicals capable of producing ethylene in plant tissue, 2–chloro ethyl phosphonic acid is found to be most effective in rubber. Once absorbed by the plant tissue, this chemical evolves ethylene by disintegration while 2,4–D or 2,4,5–T promotes the cellular production of ethylene in the tissue over a period. The drc generally decreases consequent to yield increase after stimulation. The duration of flow is prolonged resulting in late dripping. As the trees cannot regenerate the increased quantity of rubber, the drc goes down.

The enhanced yield has been related to increase in sucrose content andan enhanced invertase activity (23, 24). However, no statistically significant increase in the non-reducing sugars after stimulation has been obtained (20). It is seen that the contents of potash, phosphorus and copper in latex increase after application of yield stimulants and that the clones with a low concentration of these elements in latex give better response to stimulation.

Although it is now accepted that yield stimulating substances exert their influence by lowering the plugging index, the actual mechanism is not yet clear (16). The inhibition of flow-restricting process

itself may result in an enhanced flow rate (9). It is believed that the effect of ethylene is exerted through changes in the lutoid stability. There are indications that hormone stimuation might have certain stabilizing effect on lutoids (19). Our knowledge of the mechanism by which the membrane stability of lutoid is enhanced is still imperfect. An increase in anionic activity in latex C-serum after stimulation has been observed (25). This is considered to be a stabilising factor against flocculation. It has been established that the action of yield stimulant is mediated through an extension of the drainage area (18, 20).

13.5.2 Effect on girthing

Use of stimulation depresses girthing. This effect is more with ethephon than with 2,4,5–T. Moreover, growth is less affected when stimulation is on panel C. Stimulation generally increases the incidence of dry trees.

13.6 Factors affecting response to stimulation

In the last few years, a number of experiments have been conducted to study the response of different clones to stimulation (3,4,14). It has been established that there is clonal variation in response to stimulation. These variations in response among clones are mainly due to differences in plugging index. In general, greater relative response to yield stimulants is obtained from trees with high plugging index. Condition of bark, climate, tapping systems, concentration and frequency of application of stimulant etc also determine the extent of response. Seasonal changes in the effectiveness of ethephon, 2,4–D and NAA have been studied and it is reported that the fall in the effect of these stimulants during the period of refoliation, in spite of a lowering of plugging index, is due to a low initial rate of flow prevailing during that period (21).

13.7 Method of application of stimulants

13.7.1 Bark application

This method has been widely used because it is simple and the treated bark can be tapped within two months. The outer bark has



Fig 12.1 Tapping

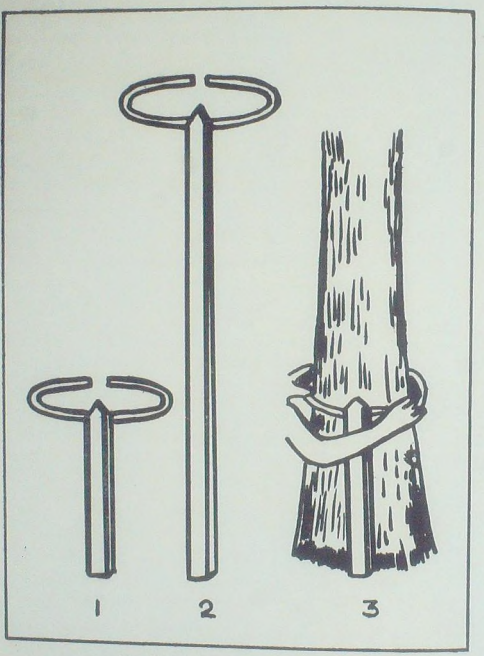


Fig 12.2 Measurement of girth



Fig 12.3 Marking for tapping

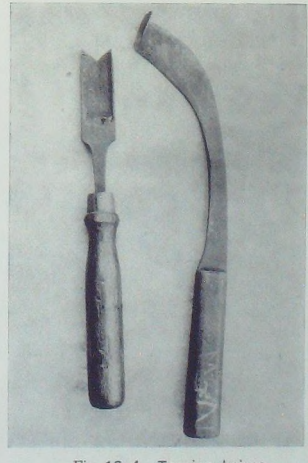


Fig 12.4 Tapping knives



Fig 12.5 Puncture tapping



Fig 12.6 A tree affected by brown bast



Fig 12.7 Conventional rainguard



F 12.8 Channel rainguard — jute hessain



Fig 12.9 Channel rainguard — polythene tube



Fig 13.1 Bark application of ethephon



Fig 13.2 Groove application of ethephon



Fig 13.3 Panel application of ethephon

to be lightly scraped before the application of stimulant. But over-scraping, resulting in latex bleeding, should be avoided. The stimulant can be applied with a brush below the tapping cut to a width of 5 cm on the scraped bark (Fig 13.1). Stimulation by this method gives quick response. Generally, the yield rises to a peak followed by a sharp decline.

13.7.2 Bore-hole technique

Application of stimulant by bore-hole technique is not popular because of the injury caused to the tree by this method.

13.7.3 Panel application

In this method, there is no necessity to mark the band or scrape the bark before application. The stimulant is applied to a 1.5–3.0 cm band immediately above the cut (Fig 13.2) at monthly or bi-monthly intervals. This method is suitable for areas where the renewed bark is not likely to be exploited in the future.

13.7.4 Groove application

In this method, the dried tree lace is removed and the stimulant is applied on the cut surface of the bark with a small brush (Fig 13.3). It is highly effective even with 0.5 g of the stimulant mixture per tree per application as opposed to 2 g/tree on bark application. More frequent applications would be necessry if this method is adopted.

13.7.5 Multiple band application

The Rubber Research Institute of India has developed a method to stimulate the bark of older trees up to the branches and extract latex from an extended drainage area through a single tapping cut (22). In this method, the stimulant is applied on horizontal patches having a length of one third of the circumference of the trunk of the tree at 25 cm intervals in a spiral fashion up to the major branches. Quantity of the stimulant required for this method depends on the number of bands.



Fig 13.2 Groove application of ethephon



Fig 13.3 Panel application of ethephon

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13.8 Methods of stimulation recommended by RRII

13.8.1 Trees suitable for yield stimulation

Use of ethephon is recommended for trees tapped on panel D (first renewed bark of the second panel). Trees tapped on panel C may also be stimulated once in an year.

13.8.2 Concentration of ethephon

The ready-to-use formulation of ethephon contains 10 per cent active ingredient. However, in experiments, no significant difference in effect could be obtained between 10 per cent and 5 per cent concentrations. Efforts are, therefore, being made to get a ready-to-use 5 per cent ethephon formulation. Until this becomes available, the 10 per cent formulations can be diluted by mixing with an equal amount of any suitable petroleum jelly.

13.8.3 Method of application

The method of application known as bark application is recommended for general use. Ethephon (ready-to-use formulation) should be applied with a brush below the tapping cut to a width of 5 cm after light scraping of the outer bark. In smallholdings where the owner himself taps the trees, groove method of application can be adopted.

13.8.4 Frequency of application

Only two or three annual applications are recommended. The application may be carried out in April, September and November.

13.8.5 Duration of continuous application

There is a declining trend in the response to continuous application of ethephon and it has been found that it may not be economical to stimulate trees which have been under stimulation for a period of four or five years. Accordingly, continuous application of ethephon is not recommended for periods of more than three years at a stretch.

13.8.6 Points to remember

Do not stimulate trees which have late-dripping.

Do not stimulate trees tapped daily.

Do not apply stimulant on rainy days.

Do not apply stimulant on the portion of the bark previously treated.

Next application should be done only after exhausting the previously treated bark.

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14 LEAF AND SHOOT DISEASES

Chapter 14

LEAF AND SHOOT DISEASES

A warm humid equable climate and a well distributed annual rainfall of 2000 mm are ideal for good growth and optimum yield of *Hevea*. The tree becomes susceptible to a number of diseases when it is grown under unfavourable climatic conditions. Most of the major rubber growing areas in India receive an annual rainfall ranging from 1500 – 4000 mm. About 70 per cent of the total rainfall is received during the southwest monsoon in the months of June, July and August. The northeast monsoon during October and November accounts for the remaining rainfall. However, the north-east monsoon is unreliable and scanty in most of the northern rubber growing regions. Drought conditions prevail in these areas for three to five months between December and April. These unfavourable climatic conditions adversely affect the growth and yield of rubber plants and also act as a predisposing factor for various diseases.

14.1 Leaf diseases

Leaf diseases form a limiting factor for rubber cultivation in some countries in the world including India. Even though there are a number of leaf diseases affecting rubber plants, abnormal leaf fall and powdery mildew are the important ones noticed. Other leaf diseases include corynespora leaf spot, bird's eye spot, secondary leaf fall, anthracnose and target leaf spot.

14.1.1 Abnormal leaf fall disease

14.1.1.1 History and occurrence

The abnormal leaf fall disease of rubber was recorded in India during 1910 from estates in Palapilly, in Trichur district, Kerala State

(25). The attention of growers was drawn to this disease when healthy seeds could not be obtained for planting because of pod rot which was followed by defoliation. In due course, the disease spread to all other rubber growing districts. At present, it is the most destructive disease of rubber in India. This disease was first investigated in India by McRae during the year 1914 (25). Subsequently, the disease was reported from Sri Lanka and Burma (28). In Java, Sumatra and Borneo, pod rot is prevalent but damage caused by leaf fall is not high. Pod rot and leaf fall caused by *Phytophthora* has also been recorded from Cambodia, Veit–Nam, Liberia, Ghana, Nigeria, Cameroon, Congo, Brazil, Peru, Nicaragua, Costa Rica and Venezuela. In Malaysia, serious abnormal leaf fall disease was reported during 1966 from Langkawi island and Kedah on the main land (18,19). This disease was also observed on the east coast of Malaysia in 1967, infecting plants during northeast monsoon. Incidence of pod rot and leaf fall due to *Phytophthora* attack has been reported from Thailand also (17). Even though this disease is recorded in several countries, severe incidence necessitating adoption of control measures every year is observed only in South India.

14.1.1.2 Factors influencing the disease

Rainfall is the most important factor influencing incidence of this disease. In several countries including Sri Lanka, Malaysia and Thailand, where pod rot and leaf fall due to *Phytophthora* attack are reported, the intensity of the disease does not warrant adoption of costly annual control operations. In these countries, the pathogen is present on rubber but severe defoliation is not caused because climatic factors are not conducive for its epiphytotic development. In India, Kanyakumari district does not experience severe incidence of this disease and therefore prophylactic spraying is not generally carried out. This is because the annual rain fall in this district is only slightly over 2000 mm which is fairly distributed (42). A continuous spell of rain of 250–350 mm for 7–10 days without intermittent hot sunshine will mark the commencement of leaf fall under Indian conditions. The minimum temperature under these conditions will be in the range of 22°–25°C and maximum 26°–30° C. The relative humidity goes up to 98 per cent. When such a rainfall pattern, low temperature and very high atmospheric humidity prevail continuously,

the disease spreads rapidly and assumes epiphytotic proportion. Under Indian conditions, leaf fall commences a week after the onset of the southwest monsoon. Normally, incidence of the disease is noticed by the second week of June and it reaches the peak by the middle of July. However, during the years when the monsoon is late, very heavy incidence is noticed during the middle of July and up to the middle of August. Incidence of the disease is also noticed during the month of May after the pre-monsoon showers.

14.1.1.3 Initial infection on pods

Initially, the green pods are affected resulting in pod rot. Water-soaked lesions, which are pale green in colour, are observed on the green pods. A few drops of latex ooze out from the lesion which coagulate and form dark spots on the infected pods (Fig 14.1). The fungal mycelia ramify inside the pericarp and also penetrate into the endosperm of the seed. The pericarp rots very soon and a white fluffy growth of the fungus appears on the surface of the fruits. The pathogen produces large crops of sporangia appearing as a thick white cheesy coating on the surface of the rotting pods under continued wet weather (Fig 14.2). Most of the infected fruits remain undehisced and attached to the branches. In some years, when severe disease incidence is noticed, all the fruits are destroyed making it difficult to obtain viable seeds.

14.1.1.4 Spread to leaves and twigs

Petioles are the main targets of infection, though lesions are observed on the stalk of leaflets, midrib and the lamina. On the petioles water-soaked lesions which are dark brown or in various shades of black colour appear with a drop of latex coagulated in the middle. During favourable weather for disease incidence, the affected leaves often fall off with the leaflets intact and while they are still green in colour. The infected leaves sometimes become yellowish red or light purple in colour before falling off. Lesions formed on the leaflets are also water-soaked and dull green in colour. In course of time, the colour of lesions changes from dull green to various shades of black (Fig 14.3). Sporangia of the fungus are formed on the lower surface of the affected portions of leaflets. Defoliation due to the

incidence of abnormal leaf fall disease is often sudden and is completed within a fortnight under favourable conditions. After defoliation, the pathogen invades leaf-bearing twigs and causes extensive die-back. Because of this, refoliation in severely affected plants becomes sparse and they present a denuded appearance till general refoliation occurs after subsequent wintering (Fig 14.4).

14.1.1.5 Causative organism

Several *Phytophthora* spp are reported to be causing pod rot, bark rot, patch canker and leaf fall disease of rubber in different countries. After investigating this disease for the first time in India, the pathogen was identified as *Phytophthora meadii* (25). In Sri Lanka, this disease is reported to be caused by *P. faberi* (28). *P. heveae* is observed to cause bark rot and pod rot disease of rubber in Malaysia (42). *P. palmivora* is reported to cause leaf fall and pod rot disease of rubber in Nicaragua (42). After detailed investigation, Tucker concluded that there was no valid difference between the different species reported to be causing abnormal leaf fall disease and he preferred *P. palmivora* as the causative organism (54). Later on, in Sri Lanka, it was reported that *P. palmivora* and *P. meadii* have been isolated from specimens infected by abnormal leaf fall disease (27, 47). In Malaysia, *P. botryosa* was reported to be causing leaf fall and pod rot disease of rubber. In India, *P. palmivora*, *P. meadii*, *P. nicotianae* var *parasitica* and *P. botryosa* were isolated from infected specimens (48, 51, 52).

Hyphae of the fungus are intercellular or intracellular and found in all tissues of the infected part including the xylem vessels. Sporangia are found externally emerging through the stomata of the host plant. The shape and size of sporangia vary according to the species. Each sporangium is borne at the tip of the stalk which is attached to the broader base. During favourable climatic conditions, the pathogen resorts to profuse asexual reporoduction by crops of sporangia which aid in the quick dispersal and rapid spread of the disease. The sporangia liberate reniform, biciliate zoospores which germinate to produce germ tubes which could establish fresh infections on the host. Sporangia may also germinate directly porducing germ tubes which could also cause fresh infections. It has been revealed that the

entry of the pathogen is only through the stomata in the case of abnormal leaf fall disease of rubber (50).

The pathogen also produces terminal or intercalary chlamydospores which are spherical in shape and hyaline. These spores are observed to germinate readily producing germ tubes. Sexual reproduction, involving antheridia and oogonia resulting in the formation of thick walled oospores, was noticed in culture as well as in infected plant parts under field conditions. Studies carried out in the Rubber Research Institute of India revealed that oospores of *Phytophthora* produced in culture or on infected plant parts, as well as those present in the soil could germinate and establish new colonies (23, 49). During off season, *Phytophthora* could be isolated from the soil collected from infected areas by using special media. It was also observed that healthy rubber pods blown down by strong pre-monsoon wind often become infected on the ground before the commencement of the actual season of disease incidence. All these indicate that the pathogen can over-summer in the soil with the help of thick walled oospores (23).

14.1.1.6 Alternative hosts, spread and over-summering

Phytophthora is observed to infect a very large number of host plants. *Areca catechu, Anacardium occidentale, Artocarpus integrifolia, Artocarpus incisa, Artocarpus hirsuta, Borassus flabellifer, Bougainvillia* sp, *Cocos nucifera, Colocasia* spp, *Citrus* spp, *Elettaria cardamomum, Jatropha curcas, Loranthus* spp, *Punica granatum, Piper nigrum, Spondias mangifera and Theobroma cacao* are a few economically important plants affected by this pathogen. When favourable climatic conditions prevail, the pathogen becomes active and the disease incidence commences by the arrival of the primary inoculum. Origin of primary inoculum could be from the thick walled oospores present in the infected and dried up materials of the previous season, any other alternative hosts or from the soil itself. In the case of *Hevea*, infection is first noticed on green pods on which an abundant quantity of inoculum is built up for further spread and intensification of the disease. Spread of the disease is acheived by water splash and rain water running down carrying the oospores and sporangia from the infected and rotting pods. Spread through the sporangia carried in small water particles blown by wind is also possible.

This was demonstrated by isolating the pathogen from sporangia contained in small water particles, collected on vaseline coated slides exposed in specially designed spore traps kept at varying distances of 60–120 m. Under field conditions, insects like cockroaches, ants, vinegar flies and beetles which were observed to visit infected pod carried viable sporangia on their body parts. Artificial inoculation, carried out using body washings of these insects under laboratory conditions, produced typical infection lesions on detached leaves and fruits. Live specimens of these insects when incubated with surface sterilised green pods in moist chambers also produced typical infections, indicating that these agencies could also be responsible for the spread of the disease (53).

14.1.1.7 Clonal susceptibility

In general, all high yielding clones and clonal seedlings are susceptible to abnormal leaf fall disease under Indian conditions. Clones like PB 86, RRIM 600, Tjir 1, Tjir 16 and PR 107 are all observed to be highly susceptible to the disease. But clones like RRII 105 GI 1, GT 1 and BD 10 are observed to retain more leaves than the susceptible clones with similar prophylactic spraying (41). However, without spraying, these clones are also observed to be affected severely. Reaction of seedling rubber to this disease is observed to vary and the leaf fall may not be severe and uniform as observed in the case of susceptible buddings. For screening planting materials for their susceptibility to this disease, artificial inoculation technique has been developed and is being used (29). The method of dipping the petioles in a spore suspension for a specific period and measuring the lesion size is also being adopted for this purpose (19).

14.1.1.8 Effect on growth and yield

Loss caused by this disease is reflected in several ways. On young immature rubber up to three years, leaf fall and shoot rot occur causing extensive die–back. In such cases, growth is retarded resulting in extended period of immaturity. In mature plantations extensive defoliation results in considerable loss of crop. Field trials indicate that, depending on the planting material and the intensity of disease incidence, loss of yield from 30 — 50 per cent

occurs due to this disease. Extensive die-back of leaf-bearing twigs also results in loss of vigour of the affected plants (41). Artificial defoliation of mature GI 1 plants by clipping off leaves also indicated yield drop of 30 per cent when defoliation was 75 per cent, even though die-back and other harmful effects of a parasitic disease were not involved in this case. This suggests that defoliation due to the disease may cause more yield loss.

14.1.1.9 Control measures

McRae, after investigating this disease in India, recommended removal of all infected and dried up twigs, fruits and fruit stalks of the previous season from the trees, to destroy the potential source of the primary inoculum. He also suggested deblossoming and defruiting to prevent primary pod infection and subsequent large scale multiplication of the inoculum (25). However, these methods were found uneconomic and ineffective and were abandoned by the planters long ago. In later years, investigations on the control of this disease was carried out by Ashplant, who recommended prophylactic spraying of rubber plants with 0.75 per cent Bordeaux mixture, and this method soon became very popular (12). Continuous and systematic investigations on abnormal leaf fall disease was commenced after the establishment of the Rubber Research Institute of India in 1955. Field experiments revealed that 1 per cent Bordeaux mixture was more effective for the control of this disease and this is being adopted extensively by rubber planters at present (Fig 14.5). When factors favourable for severe disease incidence prevail, 4500–5000 l of Bordeaux mixture per ha, depending upon the canopy spread of the mature plants, may be necessary for effective control. Bordeaux mixture, though very effective, has many disadvantages for covering large areas. The labour force required for this type of high volume spraying is large, and enormous quantity of water is necessary for the preparation of the mixture. The prophylactic spraying has to be carried out when the leaves are fully mature. Under tropical conditions, the maximum potency of copper fungicides persists only for four – six weeks. Therefore, spraying has to be completed as close to the monsoon as possible but before its onset. Hence the period available for sparying is very short. Bordeaux mixture spraying is a slow operation and an area of about 0.4 ha of mature rubber can be covered in a day

using one roker sprayer and employing 10–15 labourers. In larger areas it is difficult to complete it in time. Above all, the cost involved is also very high.

Field trials with copper oxychloride dispersed in agricultural spray oil sprayed through low volume applicators proved effective for the control of this disease. Low volume spraying using micron sprayers (Fig 14.6) from the ground or aerial application through helicopters (Fig 14.7) is also being recommended for the control of this disease (30). Using a micron sprayer and five to six labourers, an area of about 4–6 ha can be covered in a day. With a 14.12B helicopter, 200–250 ha can be completed in a day. Between these two, micron spraying is cheaper. Several formulations of copper oxychloride are available for rubber spraying. Oil based copper in a paste form containing 40 per cent metallic copper is being used for low voulme spraying of rubber. Oleocop and Fycol–8 are the two such products which have been marketed. Oil dispersible copper oxychloride in powder form containing 56 per cent metallic copper is also being used extensively for rubber spraying. This material is slightly cheaper and has got very long shelf life in contrast to oil based copper. Oil dispersible copper oxychloride 56 per cent has been marketed in the trade names Chlorocop and Fycop.

Copper oxychloride in paste form containing 40 per cent metallic copper which could be mixed with water for aerial spraying is being used in a very limited scale in areas where the rainfall is low and incidence of abnormal leaf fall disease is not very severe. Emulsicop and Fycol 8.E are two such fungicide formulations.

In the case of oil based copper, the required quantity of fungicide is taken in a drum, sufficient quantity of oil is added and the mixture stirred well. The fungicide-oil mixture is sieved through 60 mesh sieve before it is used for aerial or micron spraying. When oil dispersible copper oxychloride is used, the required quantity of oil is taken in a drum and the fungicide added to it continuously in small quantities while stirring the mixture vigorously. In this case also sieving should be done before the fungicide-oil mixture is used for spraying. Copper fungicides dispersed in spray oil will seriously scorch rubber plants if sprayed through ordinary high volume sprayers. Non-phytotoxic oils like IOC rubber spray oil and Rinki spray oil are being used for micron and aerial spraying.

For micron spraying, 6.2 l of oil based copper or 8 kg of oil dispersible copper oxychloride dispersed in 30–37 l of agricultural spray oil is recommended per ha. For aerial application, 6.2 l of oil based copper or 8 kg of oil dispersible copper oxychloride in 37–42 l of spray oil is recommended per ha (32). Thermal fogging using oil based copper fungicide is being experimented for the control of this disease.

Chemical control of this disease, though effective and practicable (Fig 14.8) is expensive and will have to be repeated every year. A permanent solution will be to evolve a clone resistant to this disease. For achieving this objective, a breeding programme was initiated by the Rubber Research Institute of India. From existing population in estates, a few plants showing tolerance to this disease were selected and clones were established. Such clones were again screened by artificial inoculation methods in the laboratory as well as under field conditions. Clones imported from other countries were also screened and those showing tolerance to this disease were selected. The clones thus selected were RRII 33, F 4542 and Fx 516. But the yield of these clones was found to be poor. These clones were therefore, used for crown budding on high yielding susceptible clones like RRIM 600, RRIM 628 and GT 1. Such experimental plantings were left unsprayed and it was observed that leaf retention during the past several years, even after the plants were brought under tapping was very good. The crown budded plants came into tapping about an year later than the control. Preliminary yield data indicate that RRIM 628 crown budded with all the three clones gave higher yield than the control. But in RRIM 600, the plants crown budded with RRII 33 and F 4542 gave higher yields than the control while in the case of plants crown budded with Fx 516, the yield was slightly lower than that of the control. In GT 1, lower yield was recorded in all the three cases of crown budding. The possible effect of the superimposed canopy on yield required further detailed investigation.

14.1.2 Powdery mildew

The powdery mildew disease of rubber is caused by *Oidium heveae*. This disease was first reported from Indonesia in 1918 and subsequently from Sri Lanka and Malaysia. During 1936, it was reported from India and it appears in different intensities in all

the rubber growing regions in the country. Its incidence is comparatively severe in Kanyakumari district. Congo, Cameroons, Uganda, Tanganyika and Sao Paulo are the other countries where the disease is prevalent. Powdery mildew disease infects rubber plants of all ages.

14.1.2.1 Factors influencing disease

The causal organism of this disease flourishes in dull, cool weather with intermittent showers. If the climatic conditions prevailing at the time of refoliation are favourable for the multiplication of the fungus and spread of the disease, incidence will be severe. Prevalence of overhanging mist, heavy dew formation during nights and cloudy days with a relative humidty of 75–80 per cent at the time of refoliation are the most favourable climatic conditions. Light showers during the refoliation period favour development and spread of the disease. But heavy rains and severe drought are unfavourable factors for the outbreak of the disease. Early–wintering plants usually escape the disease because the dry climate prevailing at that time does not favour disease incidence. Lack of sufficient inoculum in the beginning is also a factor aiding the escape of early-wintering trees from the disease. But when these two factors become favourable for the disease, the late-wintered trees are observed to suffer severe disease incidence. In Kanyakumari district, wintering is late in contrast to northern districts of Kerala, and this contributes to the severity of the disease there (43, 57). Mixed planting of different clones also influences the disease incidence and severity. In such plantations, wintering will not be uniform and the late wintering trees will be affected by this dsease severely. Plantations in higher elevations experience the disease throughout the year, because of the cool climate, frequent heavy dew formation during night and prevalance of thick mist. In such areas, control measures may have to be adopted throughout the year for ensuring healthy growth of rubber plants (14, 21).

14.1.2.2 Clonal susceptibility

The clone LCB 870 is reported to be resistant to powdery mildew in Sri Lanka. Under Indian conditions, PB 86, GI 1, GT 1. PR 107, PB 5/139 and RRII 105 are observed to be tolerant to this disease. Tjir 1, Tjir 16, BD 5, PB 5/51 and RRIM 605 are found to be highly susceptible to the disease.

14.1.2.3 Infection on mature rubber

Severe disease incidence is observed when the trees refoliate after wintering. The young leaves lose their shining appearance and the colour becomes dull. White or ash coloured powdery mass develops on the tender leaves, covering the lower and upper surface entirely or in patches or spots. The young infected leaflets shrivel from the point of infection to the top, turn purplish and then black, curl inwards and fall off, leaving the petioles still attached to the twigs which assumed a broomstick appearance. Infection is also noticed on petioles and tender shoots. Infected leaves remaining on the tree will have irregular dusty patches on the lamina (Fig 14.9). The leaf area with fungal growth later turns into brown scabby lesions. In the case of lesions occurring on the lower surface, corresponding area on the upper side will be pale in colour. The mature leaves become crinkled and distorted due to infection. On older leaves, the fungal colonies may sporulate heavily for several weeks, and the lesions attain a reddish brown scabby appearance. Later on, the tissues in the lesion become dried and even shot holes are found to develop (5, 44, 57). Inflorescence and young fruits are also affected by the disease, causing damage to flowers and shedding of tender fruits. When heavy incidence of this disease occurs, fruit set is reduced considerably causing scarcity of seeds for developing stock plants in the nursery.

14.1.2.4 Infection on nursery and immature plants

On nursery plants, the disease occurs from September – May on the new flushes. Shaded plants are severely affected. Immature plants in the field are also affected by the disease. In severe cases of infection, considerable defoliation and die-back of twigs are noticed. The disease is noticed every year during refoliation time. The new leaves produced during refoliation are infected. In severe cases, all the leaflets fall off leaving the petioles on the branches giving a broomstick appearance. Later on, the petioles also fall off. The plant refoliates, and the new leaves become infected again if climatic conditions are favourable, resulting in repeated rounds of refoliation and defoliation. This causes severe die–back of twigs.

14.1.2.5 Causative organism

The disease causing organism, *Oidium heveae* is an obligate parasite. Hyphae are branched, hyaline and septate. Mycelium is entirely superficial on the infected area to which it adheres by means of haustoria. Conidiophores arising from the mycelium are simple and erect. They bear a chain of 2–7 conidida. Mature conidia are elliptical to barrel shaped, vacuolate with round ends and measure 25–45μ x 12–25μ. So far sexual stage has not been observed. Conidia are dispersed through wind.

The fungus is found to survive the year round on the rubber tree itself. Wintering of rubber trees is not generally uniform and when the tender flushes appear on the trees, some of the unshed leaves with oidium lesions in the same plantation may serve as source of primary inoculum. The primary inoculum can be from a nearby nursery, from tender shoots produced during off-season, from leaves of pollarded trees or from self sown seedlings growing in the field. Alternative hosts like *Jatropha curcas, Manihot glaziovii, Bixa orellina* and *Loranthus* sp are also sources of primary inoculum (44).

14.1.2.6 Effect on growth and yield

Leaf fall caused by powdery mildew disease adversely affects the growth and yield of the tree. Repeated leaf fall results in die-back of twigs. Artificial defoliation by hand plucking showed that subsequent refoliation caused considerable reduction in yield, a loss of 11–34 per cent of annual production being recorded when 50 per cent of leaves were removed (43).

14.1.2.7 Control measures

Cultivation of clones resistant or tolerant to the disease saves the annual recurring expenses on plant protection operations and provides a permanent solution (26, 58). Dusting with sulphur gives effective control and this is the most common method followed in controlling the powdery mildew disease of rubber (Fig 14.10). Spraying in nurseries and young plants with wettable sulphur can be adopted with better results than dusting. The method, however

is not adopted for mature areas as spraying with wettable sulphur is expensive and impracticable.

Sulphur used for dusting should be dry, free flowing, free from lumps and should pass through 325 mesh. If the particle size is bigger, it will not reach the desired height. Sulphur mixed with talc in the proportion of 70:30 is as good as pure sulphur in controlling the disease. Pure sulphur or talc-mixed sulphur at the rate of 11–13 kg/ha/round is used. For effective control of the disease three to six rounds of dusting may be required at an interval of 4–10 days depending on the intensity of the disease. The first round of dusting will have to be done when about 10 per cent of the trees commence to refoliate. Dusting is carried out with the help of power dusters. The duster is carried along every fourth row of trees at a speed of about 3–4 km/h. With one duster, 14–18 ha can be covered in a day. The sulphur dusting may be carried out, starting by 4 am and continuing till 10 a m. During the period, the air will be still and the leaves wet dew enabling the dust to rise well and stick to the leaves (43). Calixin, a systemic fungicide, is also found to be effective in controlling the disease. This fungicide can be sprayed as 0.25 per cent solution. Thermal fogging using 3 per cent calixin-in-oil is found to be satisfactory for the control of this disease (11). In Malaysia, Phytar 560 at the rate of 35 l/ha, is used as aerial spray to induce early defoliation of the trees during the dry season so that the trees escape from the disease.

14.1.3 Corynespora leaf spot

This disease is widespread in all rubber growing tracts in India. It was reported for the first time in 1958 at the RRII experiment station (39). Later it was reported from Nigeria and Malaysia (3). The disease is a problem mainly in seedling and budwood nurseries. However, defoliation due to this disease has been observed in immature and mature rubber under field conditions recently.

14.1.3.1 Symptoms

Infection is noticed as minute spots on tender leaves as soon as they pass the bronze colour stage. These spots enlarge along with

the growth of the leaf. They are usually circular measuring 1–10 mm in diameter. Sometimes the lesions become irregular. Each spot has a brown centre surrounded by a dark brown ring. An yellowish halo surrounds the spot. On bigger spots concentric striations are seen on the lower side. The central part of the lesion may disintegrate or tear off, resulting in shot hole formation (Fig 14.11). When the infection is severe defoliation of the leaves may occur leading to die-back of the shoot. Infection is noticed on every storey of leaves. The disease incidence starts by the month of November, reaches the peak period of infection by March–April, and subsides by the onset of monsoon. The disease persists in the nursery all the year round on seedlings and budwood plants. The fungus can survive on alternative hosts also.

14.1.3.2 Causative organism

The pathogen involved in this disease is *Corynespora cassiicola* (Burk & Curt) Wei. The conidia of the pathogen are produced on both sides of the spot. They are obovate or cylindrical straight or slightly curved, often thick walled, multiseptate with 2–14 septa, tapering towards the apex, pale brown in colour and with prominent hilum. Size of the spores is highly variable and the range of length is from 40–120μ and breadth varies from 8-18μ. They are produced singly or in chains on the conidiophores. Conidiophores are brown in colour and septate and 55–300 x 6–10μ in size. A hyaline isthmus may often be noticed connecting the conidium to the conidiophore or another conidium (39).

14.1.3.3 Control measures

Providing light overhead shade in the nursery is very effective in reducing the intensity of the disease (1). When the area involved is small, shading with coconut leaves gives adequate control. Disease control using fungicides involves spraying the seedling with either Bordeaux mixture (one per cent) or Dithane M–45 (0.2 per cent). New flushes coming out every fortnight must be protected by spraying the fungicide. Bavistin (0.2 per cent), a systemic fungicide, is also found to be effective against leaf spot disease (35). In Malaysia, Benlate (0.15 per cent) is sprayed against the corynespora

disease(10). Glass house experiments indicated higher disease incidence in the presence of nitrogen (34).

14.1.4 Bird's eye spot

Bird's eye spot is noticed in nurseries during the hot months and it occurs in every rubber growing country though in many countries it is of minor importance. It was first reported from Sri Lanka by Petch in 1905 (24). The spot caused by the disease resembles the eye of a bird with white centre and brown margin and hence the name of the disease.

14.1.4.1 Symptoms

On tender leaves, the disease first appears as small dark brown spots about 0.2 mm in diameter. They give a water–soaked appearance in contrast to the shining red brown healthy leaflet. Generally, on very young leaves, the leaf margin or the whole leaf becomes blackened and shrivelled. The rapidly growing leaf becomes severely distorted. Normally, the lesions do not enlarge in size, but many spots may coalesce (Fig 14.12). The young unfolded leaves may fall down owing to severe infection exposing bare shoot tips. On leaves in the light green stage, minute yellow spots appear which later on develop a narrow dark reddish brown margin. Later on, the centre becomes white and papery. A large number of spores are formed on the lower surface of the spots. Shot hole formation is also noticed. On mature leaves the spots are small and dark brown with no pale centres. Dark elongated stripe-like lesions can be seen on the midribs, petioles and young shoot.

14.1.4.2 Causative organism

The pathogen *Drechslera heveae* (Petch) M.B. Ellis is responsible for the disease. The fungus produces conidia in abundance on the lower surface of the spots. They are brown in colour, many-celled, slightly curved and tapering towards both ends. They measure 0.1 mm in length and are borne on conidiophores (24).

14.1.4.3 Control measures

The control measures adopted in India are the same as those for *Corynespora cassiicola.* Copper fungicides have been effective against the disease in Sri Lanka, Congo and Liberia. In Malaysia, Ziram and Ferbam gave satisfactory control and Ferbam was accepted as the best one (4). Later experiments also proved that carbamate fungicides produced good results (7). Normally, weekly spraying will ensure adequate control of the disease.

14.1.5 Secondary leaf fall

Secondary leaf fall is caused by the fungus *Gloeosporium alborubrum* Petch *(Glomerella cingulata)* (Stonem) S & V.S. This is primarily a leaf-infecting fungus but it can attack any green part of the tree including the pods and is also the cause of die-back of green shoots. The disease has been reported from Malaysia, Sri Lanka, Java and Indo-China. In Malaysia, this pathogen, along with a few others, causes the most important disease complex called secondary leaf fall (SLF). The disease has been observed throughout South India in a mild form in the months of April, May, September and October. It is generally noticed after the receipt of the first showers and before the onset of the southwest monsoon or during the break between the southwest and northeast monsoons when new flushes are formed (40).

14.1.5.1 Factors affecting incidence

Weather plays an important role in the incidence of gloeosporium leaf disease. Damp condition favours infection and spread of the disease. High humidity is a pre-requisite for formation of acervuli. High incidence is observed on plants growing in gravelly and infertile soils. Lack of drainage also sometimes aggravates the disease. The spores are easily released and are carried by rain splash. Sexual spores are sometimes observed on old infected leaves. There is wide variation in the clonal susceptibility to the disease infection. RRIM 526, PB 86, AVROS 42 and PB 5/63 are reported to be highly susceptible while RRIM 605, RRIM 607, RRIM 614 and RRIM 501 are reported to be resistant. Tjir 1 is less susceptible.

14.1.5.2 Symptoms

The disease affects tender and immature leaves. Budwood plants and seedlings in nursery are severely affected. Leaves are susceptible during the first 10 days of expansion. If attacked during the early part of this period, the leaves rapidly wither and fall, but if infected at a later stage become highly spotted, crinkled and deformed and do not readily fall. A number of minute brown circular spots, having a narrow brown margin and yellow halo, are seen on the leaves. As the leaf ages, margins become thick and the spots raised above the leaf surface as conical projections and these are characteristic features of this disease (Fig 14.13). Appearance of tiny, cheesy spore masses all over the surface of leaves under damp conditions is also a characteristic symptom. Dark green mature leaves are not affected. Lesions are seen on green stem also. Die-back of shoots may be another symptom. The pathogen could be seen attacking young green pods before the onset of southwest monsoon, causing rotting of pods. Pericarp becomes dull green and covered by innumerable minute acervuli, pink in colour. Such fruits rot easily and they may shed or remain attached to stalks in a shrivelled condition. Intra-epidermal or subepidermal stomata are formed on the infected region. From this closely packed cylindrical conidiophores develop and rupture the epidermal layer. On these conidiophores, hyaline, oblong, one-celled conidia measuring 10–20μ x 3–5μ are produced. Though hyaline when single, in a mass they appear pink in colour. This is more so in budded plants. The disease is most severe during the first four years after planting. On mature plants, leaf fall is not severe.

14.1.5.3 Control measures

In India, Bordeaux mixture or copper oxychloride spraying is carried out as a prophylactic measure against abnormal leaf fall disease in April and as a result gloeosporium disease is also kept in check. In Malaysia, it is a major problem. Repeated application of prophylactic fungicide during the susceptible stage of the foliage is difficult and expensive. As a measure against SLF, manipulation of the time of natural wintering was attempted. Inducement of an earlier and complete wintering by spraying defoliants is recommended so that refoliation that follows is brought forward to coincide with the dry weather

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Weather plays an important role in the incidence of gloeosporium leaf disease. Damp condition favours infection and spread of the disease. High humidity is a pre-requisite for formation of acervuli. High incidence is observed on plants growing in gravelly and infertile soils. Lack of drainage also sometimes aggravates the disease. The spores are easily released and are carried by rain splash. Sexual spores are sometimes observed on old infected leaves. There is wide variation in the clonal susceptibility to the disease infection. RRIM 526, PB 86, AVROS 42 and PB 5/63 are reported to be highly susceptible while RRIM 605, RRIM 607, RRIM 614 and RRIM 501 are reported to be resistant. Tjir 1 is less susceptible.

14.1.5.2 Symptoms

The disease affects tender and immature leaves. Budwood plants and seedlings in nursery are severely affected. Leaves are susceptible during the first 10 days of expansion. If attacked during the early part of this period, the leaves rapidly wither and fall, but if infected at a later stage become highly spotted, crinkled and deformed and do not readily fall. A number of minute brown circular spots, having a narrow brown margin and yellow halo, are seen on the leaves. As the leaf ages, margins become thick and the spots raised above the leaf surface as conical projections and these are characteristic features of this disease (Fig 14.13). Appearance of tiny, cheesy spore masses all over the surface of leaves under damp conditions is also a characteristic symptom. Dark green mature leaves are not affected. Lesions are seen on green stem also. Die-back of shoots may be another symptom. The pathogen could be seen attacking young green pods before the onset of southwest monsoon, causing rotting of pods. Pericarp becomes dull green and covered by innumerable minute acervuli, pink in colour. Such fruits rot easily and they may shed or remain attached to stalks in a shrivelled condition. Intra-epidermal or subepidermal stomata are formed on the infected region. From this closely packed cylindrical conidiophores develop and rupture the epidermal layer. On these conidiophores, hyaline, oblong, one-celled conidia measuring 10–20μ x 3–5μ are produced. Though hyaline when single, in a mass they appear pink in colour. This is more so in budded plants. The disease is most severe during the first four years after planting. On mature plants, leaf fall is not severe.

14.1.5.3 Control measures

In India, Bordeaux mixture or copper oxychloride spraying is carried out as a prophylactic measure against abnormal leaf fall disease in April and as a result gloeosporium disease is also kept in check. In Malaysia, it is a major problem. Repeated application of prophylactic fungicide during the susceptible stage of the foliage is difficult and expensive. As a measure against SLF, manipulation of the time of natural wintering was attempted. Inducement of an earlier and complete wintering by spraying defoliants is recommended so that refoliation that follows is brought forward to coincide with the dry weather

when the pathogen is not active. Phytar 560 is found to be very effective and safe and is aerial sprayed before wintering at the rate of 35 l/ha (45).

14.1.6 Anthracnose

Secondary leaf spot, otherwise known as anthracnose, is reported from most of the rubber growing countries. The disease is observed in all parts of South India in nurseries, on young plants in the field and on old trees during April – October. It is, however, only of minor consequence (38).

14.1.6.1 Factors affecting incidence and control

The disease is prevalent on rubber under conditions not favourable for the growth of the plants. In newly planted areas the disease may be observed when soil around the plants becomes water-logged or when shoots grow or when formation of new roots is unduly delayed. In older plants, lack of adequate nutrition favours development of the disease. Sometimes the disease appears when bright sun intervenes after a long spell of rainy season. Obviously, leaves weakened by sun scorch are first invaded.

14.1.6.2 Symptoms

The disease is called 'anthracnose' because of the characteristic, limited lesions with necrosis and hyperplasia. The affected leaves are shed. Lesions of varying sizes and numbers are formed on the leaflet. They may be circular, semi-circular or irregular in shape, occurring generally along the margins and occasionally in the middle. The lesions are large having a diameter of 1–5 cm. Many of them may coalesce. Each spot is brown with a water-soaked dull green or yellowish margin. The central portion of the spot is light brown, papery and necrotic. A number of concentric striations are seen on both surfaces of the spot, more evident on the upper surface resembling typical target spots. This is because of the formation of a large number of acervuli in concentric patterns and of setae which can be seen as bristles. Under moist conditions, a large number of spores are produced from the acervuli and they appear pink. Leaves affected by anthracnose are unhealthy and yellowish in colour and fall off easily.

14.1.6.3 Causative organism

Secondary leaf spot is caused by the pathogen *Colletotrichum gloeosporoides* Penz the perfect stage of which is *Glomerella cingulata* (Stonem) S & V.S. The acervuli of the fungus are formed sub-epidermally. Conidia are hyaline, oblong, sometimes narrowed at the ends, one-celled, guttulate and 10–29μ x 3–5μ in size. They are borne on conidiophores which are short and closely packed. Blackish brown, septate setae, straight or sometimes curved at the tip and measuring 30–100μ in length and 3–5μ in breadth (at the base), are also produced.

14.1.6.4 Control measures

The best method of control is avoidance of adverse conditions. Flooding or water-logging should be prevented. Young plants should be protected from sun scorch. Adequate and balanced nutrition is also essential for ensuring freedom from the disease (38).

14.1.7 Thread blight

Thread blight, also known as target leaf spot, is a leaf disease of rubber caused by the pathogen *Pellicularia filamentosa* (Pat) Rogers. It is reported from Peru, Brazil and Amazon valley. The infection is prevalent during rainy season in crowded nurseries and in trees with dense foliage. The disease is common on Tjir 1 clonal seedlings and mature trees of Tjir 1 and BD 10.

14.1.7.1 Symptoms

The symptoms of this disease differ depending on the age of the leaves and environmental conditions. Tender leaves are easily damaged. Infected leaflets lose their natural colour and become whitish or brown, crinkled and shrivelled. The infection spreads to other leaflets. Fungal growth is noticed on the surface of leaves. The mycelium forms filmy growth with scattered minute buff-coloured masses (sclerotia). The leaflets are often held together by mycelia. Many of the leaflets are separated from their stalks and the mass of white disintegrating leaflets is suspended from the stem or older leaves

by strands of mycelia (Fig 14.14). Defoliation is also common. As a result, the older portion of the shoot becomes devoid of leaves. Whitish granular growth is noticed on the petioles and the stem and tender portions of the shoot get killed. On older leaves, white granular growth is noticed on the under surface (Basidial stage). In the beginning, the affected leaves remain green but they turn yellow prematurely. Sometimes, big lesions about 2 cm or more in diameter are observed on leaves. The spots are white and papery in texture with partly disintegrated central portion. Such lesions appear generally when the progress of infection is arrested by bright weather (36).

14.1.7.2 Control measures

This disease is not generally very important in India (36). Spraying Bordeaux mixture offers most satisfactory protection against the disease in India. Wider spacing to avoid overcrowding of seedlings in the nursery also keeps the disease in check. In South America, repeated spraying with Dithane Z–78 is practised. Dusting with a mixture of sulphur and fermate was reported to be effective.

14.1.8 South American leaf blight

Even though South America is the home of *Hevea* attempts made by Ford and Goodyear companies to cultivate rubber on an extensive scale in that country were unsuccessful and those ambitious programmes were almost abandoned after some years because of the incidence of the devastating disease of rubber, viz the South American leaf blight (SALB). From the original areas of infection the disease has spread to other regions in the tropical America. SALB has been reported from Trinidad, Panama and Costa Rica, Mexico, Guatemala and Honduras and Bahia State in Sao Paulo (2, 8). This disease is not prevalent in India. It has also not been reported from Malaysia and other South East Asian countries.

14.1.8.1 Influence of weather

The incidence and severity of infection of the disease are strongly influenced by the prevailing climatic conditions. Regions having high and well distributed rian fall with no pronounced dry season,

are observed to have severe disease incidence. Areas receiving moderate rainfall without a long dry season may have disease incidence intermediate in severity while regions with extended drought period for about four months and receiving varying intensities of rain fall may experience only low disease incidence.

14.1.8.2 Symptoms

Young rubber leaves, four to nine day old, are most susceptible to SALB. On young pendant leaves, dull velvety spots, olive to greyish green in colour, develop mostly on the lower surface during the primary stage of infection. The very young infected leaves blacken, shrivel and fall off. Repeated rounds of defoliation may take place resulting in severe die-back and even death of full grown trees. Symptoms of infection are also noticed on green stems, petioles, inflorescences, flowers and young fruits. The secondary stage of infection develops on leaves that have survived the primary infection. Infection on slightly older leaves produces irregularly outlined necrotic patches. Such leaves may not fall off but become severely distorted and assume a ragged appearance. As leaves become full grown, a number of spots, most of them with shot holes, will be noticed on the lamina.

14.1.8.3 Causative organism

The disease is caused by the fungus *Microcyclus ulei* (P. Henn) V. Arx *(Dothidella ulei)*. Usually two-celled and occasionally unicellular conidia are produced in abundance by the pathogen. Conidia are hyaline at first and greyish when mature, borne singly on conidiophores. Conidia on the surface of air-borne water droplets can spread the disease. Viability of conidia is only for a short duration. Around the margins of old lesions, especially on the upper surface, innumerable small spherical black bodies called ascocarps develop. These produce ascospores which are hyaline, uni-septate, constricted and ellipsoidal with the two cells unequal. Yet another type of spore bearing bodies, called pycnidia, are also produced by the fungus which liberate hyaline, dumb-bell shaped spores. Dispersal of the pathogen is mainly through conidia which are dry and carried in air currents. The ascospores produced during the secondary stage of infection can easily germinate and start an infection (9, 13).

14.1.8.4 Control measures

Control of SALB in mature rubber plantations using fungicides is considered costly as repeated fungicide applications may be necessary for achieving satisfactory results. In nurseries, disease control is reported to have been achieved by spraying copper fungicides or Dithane Z–78. Thermal fogging using fungicide in oil is also reported to be effective against the disease in S America. Controlling the disease by spraying fungicides in the young stage and later crown budding the rubber plants with a resistant clone to produce a disease-free canopy is reported to be the most practicable method of overcoming the disease incidence in countries where the disease is endemic (8, 9).

14.2 Shoot rot

Phytophthora spp which cause pod rot and abnormal leaf fall infect the tender green portions of nursery plants as well as immature and mature trees causing shoot rot. In India, this disease occurs during the southwest monsoon period. Infection is noticed from the last week of May to the end of August.

14.2.1 Symptoms

During the continuous heavy monsoon, the infected tender portions rot, assume black colour and dry up in due course. The earliest symptom of this disease is seen in the terminal portions, especially on the purple-coloured leaflets. Dark, sometimes water-soaked lesions appear either at the tip or along the margins of these leaflets. In the course of 24–48 h, the leaflets become limp and dark coloured and the rotting extends up the petiole. In a short time, more leaflets become involved. Infection spreads to the stem and progresses from the apex downwards. The affected portions of the stem are dark brown, shrunken and with a water-soaked appearance. The rotting of the shoots (Fig 14.15) may extend from 15–75cm in length, depending on the nature of growth and severity of disease. Generally, the rotting stops at the next lower storey of leaves. The diseased portion dries up and later a circlet of new branches arises from below the infected portion. In some cases, the lesions are

first formed on the main shoot itself as small elongated sunken dark spots. These enlarge rapidly and involve all the new growth. In young plants affected by shoot rot, the lower mature leaves are sometimes shed as a result of infection on the petioles, as in the case of abnormal leaf fall disease noticed on mature plants. The affected plants get stunted and about three to six months' growth is lost. In addition to the retardation of growth, low undesirable branches may also develop on the affected plants (6, 22, 37).

14.2.2 Control measures

The disease could be controlled by prophylactic spraying with a copper fungicide before the onset of monsoon. This operation must be repeated and all the new growth produced during the monsoon months sprayed and protected. Stickers/wetting agents like Sandovit, Triton AE, Tenac and Teepol can be used along with the copper fungicide to obtain better sticking of the fungicide on tender foliage (37).

14.3 Bordeaux mixture

14.3.1 Origin and history

The discovery of Bordeaux mixture was quite accidental when in 1882 Millardet observed that grape vines along the roadside at Medoc in the Gironde (France) were free from downy mildew disease while the vines in other areas had been completely defoliated. This was because of the custom of sprinkling the vines near the road with copper sulphate and lime to prevent pilferage. Next year, Millardet and David confirmed the efficacy of copper sulphate against grape downy mildew caused by *Plasmopara viticola*. Further field tests were carried out under the guidance of Millardet and Gayon who were professors at the University of Bordeaux. In 1885, they published the analytical data in detail and by 1887 great success was achieved in the control of the disease.

The mixture of copper sulphate and lime became very popular under the name 'Bouillie Bordelaise' (Bordeaux mixture). In 1885, it was tried against late blight of potato and in 1888 its efficacy in controlling the disease was established.

To start with, Bordeaux mixture was in the form of a paste to be applied with a brush. In 1887, Millardet and Gayon tested a series of formulae and found that the mixture with the lower concentrations of copper sulphate and lime was as effective as those with higher concentrations in the case of *Plasmopara viticola*. In the beginning, there was a tendency to use excessive proportions of copper sulphate to lime, but later the practice was to use equal amounts ie 4–4–40 (4 lb of copper sulphate, 4 lb of lime and 40 gal of water) and 5–5–50 (1 per cent). Bordeaux mixture still remains the most popular and the best fungicide (16).

The reaction between copper sulphate and lime is rather complex and even now the exact composition of the basic mixture is not well understood.

14.3.2 Preparation and use in rubber

Various proportions of the ingredients are being employed in the preparation of this fungicide for combating different diseases. Even on rubber, planters use different formulations. But the 1:1:100 (indicating the quantities of copper sulphate and lime in kg and water in l) mixture is observed to be the most efficient one. This is also called 1 per cent mixture. The solutions of copper sulphate and lime are mixed in different ways. But when the copper sulphate solution is poured into the lime solutions, the resulting fine gelatinous precipitate remains in suspension for a longer period. Hence this is considered to be the most satisfactory method of mixing.

In order to prepare 100 l of the mixture, 1 kg of copper sulphate is dissolved in 50 l of water kept in a copper, brass or wooden container To help in the quick preparation of the solution, copper sulphate is powdered and dissolved in water, or the chemical tied in a gunny bag and suspended overnight in water by means of a rod placed across the mouth of the vessel, so that by morning the solution would be ready for use. In another vessel 1 kg of fresh quicklime is placed and warm water sprinkled to slake it. When the slaking is complete, more water is added to make up the volume to 50 l. The lime solution is to be filtered to remove the undissolved foreign matter, hard lumps etc. The copper sulphate solution is poured into the lime solution, vigorously stirring the mixture during mixing. The resulting mixture

which consists of a blue gelatinous precipitate suspended in water is the Bordeaux mixture.

Properly prepared, the formulation should be fine in texture and gelatinous to touch. It should settle only very slowly. These characters determine the sticking property of the mixture and its fungicidal efficiency. Deep blue colour of the mixture is an indication that it is good. But a greenish blue colour denotes excess of unreacted copper sulphate and chalkly blue, excess of lime. A brown deposit of copper on the clean tip of a knife dipped into the mixture indicates the presence of unreacted copper sulphate and the need for additional lime. The mixture should be used on the day of preparation itself as its quality deteriorates on keeping. Though it is reported to have phytotoxic effects on some plants, no adverse effects have been observed on rubber even after continued use for severval years. As far as the present knowledge goes, it is by far the best protectant against abnormal leaf fall disease caused by *Phytophthora* spp on rubber. The mixture should not be allowed to fall on the tapping panel and contaminate the latex.

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15 STEM DISEASES

Chapter 15

STEM DISEASES

Various diseases like pink, black stripe, patch canker, mouldy rot dry rot and bark necrosis are reported for rubber from different countries. Among them, pink disease is the most serious, black stripe is of some consequence while the others except mouldy rot are of only very minor significance in India. Mouldy rot is seldom observed in the country.

15.1 Pink disease

15.1.1 History and occurrence

Pink disease caused by the fungus *Corticium salmonicolor* (Berk. & Br.) is prevalent in all rubber growing countries. It is noticed on rubber plants of all age groups, though the infection is observed to be more damaging for plants two to twelve year old. The intensity of infection also varies with different clones. The earliest record of pink disease was on coffee from Sri Lanka in 1870. On *Hevea* it was first recorded from Java in 1901 and in South India in 1908. At present, it is prevalent in all rubber growing areas in India. In Kanyakumari district, the incidence is sporadic and intensity is mild. In India, pink disease has been known to infect several other plants of economic importance like coffee, tea, cocoa, mango, *Artocarpus* spp cashew, orange, camphor, cinchona and *Eucalyptus* spp (15).

15.1.2 Influence of weather

In South India, incidence of the disease is noticed during the southwest monsoon period. Infection will be wide spread during June – September, and drying is noticed from September onwards.

By the commencement of dry season, the progress of the disease incidence is arrested even though the infection persists on the affected plants the subsequent favourable season if left untreated. Generally, weak southwest monsoon and absence of prolonged wet conditions are the main reasons for the mild disease incidence observed in Kanyakumari district (10).

15.1.3 Symptoms

The infection commences by the arrival of the primary inoculum in the form of spores of the pathogen or thin flakes of infected and dried up bark blown by wind. In young plants up to three years of age, infection is mainly observed on the main stem at different heights in the region of the brown bark. In older trees, infection could be mainly in the forking region or on the main stem or primary branches. Pink disease is sometimes noticed even at the base of young plants in the nurseries and on the tapping panel of mature trees.

During the initial stage of infection, superficial growth of cobweb like mycelia will be noticed on the bark surface. This mycelial growth is glistening white in colour when the infected bark surface is not wet, and under wet conditions, it cannot be detected from the ground. Mycelium is hyaline, thin walled and septate. Mycelial growth may extend to a distance of 30–90 cm both up and down from the point of infection all around the infected region, sometimes covering the entire portion. This stage of the disease is called 'cobweb stage' (Fig 15.1). The pathogen later penetrates the bark and grows inside the tissues. Because of the ramification of the pathogen inside the bark and wood region, extensive damage is caused to the internal tissues. By this time, exudation of latex is observed from the infected site, which coagulates and appears as black streaks on the bark surface below. This marks the second stage of the disease. The bark in the infected region rots and dries up in due course. Cracks are also noticed in the affected and dried up bark. Because of the extensive damage to the bark and internal tissues, which is sometimes all around the affected portion, the upward and downward translocation of water and food materials in the plant system is choked, resulting in initial yellowish discolouration of foliage and final drying up of the distal

enlaterpene-

portions of the affected region. In such cases, the dried up leaves, with deep brown colour, are seen still remaining on the dead branch which is a salient symptom of this disease. A number of sprouts arising from portions just below the infected region is yet another important symptom of this disease. Enlargement of the lenticels in the affected region could also be noticed at this stage. Ultimately, the infected and dried up bark cracks and falls off exposing the wood which also becomes blackish in colour.

When the infection is advancing, small cushion like structures called 'pustules' which are light pink in colour, are seen erupting in lines through cracks in the bark and through lenticels. These sterile pustules are seen all over the surface of the affected portion. This is called the 'pustular stage' of the disease. When such pustules are noticed, it is evident that infection has advanced considerably and extensive damage has already occuired. Later on, orange red pustules develop on the upper or lighted surface of the affected portion. These pustules consist of irregularly polygonal pseudoparenchymatous cells which develop into unicellular hyaline spores. These spores are called the 'necator spores' and this stage of the disease is described as 'necator stage.' The necator spores produced by the pathogen germinate readily forming one or more germ tubes and aid in the rapid spread of the disease. First record of asexual reproduction by the pathogen in culture, resembling the necator spores present in nature, has been recently reported(9). Another characteristic development in highly advanced stage is the formation of crusts on the lower surface of the affected branches or on the shaded side of the main stem. Cracks are often noticed on these crusts which are pink in colour. The name of the disease is derived from the pink crusts. On these crusts, the pathogen produces basidial spores which also aid in the spread of the disease. This is called the 'corticium stage' (Fig 15.2) of the disease(5,10,15).

When young plants are infected by pink disease,either on the main stem or on the forking region and if the infection is left untreated, the portions above the point of infection, very often the entire canopy of the plant dries up (Fig 15.3) and gets reduced to mere stump after the removal of the canopy. Such plants may sprout immediately but they have very little chance to come up because the neighbouring healthy plants may often grow fast and cover up

the infected plants. Hence the incidence of this disease on young plants results in considerable loss of stand. In mature plants, infection may cause drying up of a branch or two which may affect the yield though it may not result in complete loss of the plant.

15.1.4 Colonal susceptibility

Under South Indian conditions, high rate of pink disease infection is noticed in clones like Tjir 1, Tjir 16, BD 10, LCB 1320, PB 28/59 and RRIM 600. Clonal seedlings are also observed to be susceptible to pink disease. But clones like GI 1, PB 86, PR 107 and GT 1 are observed to be less susceptible (10). RRII 105 has only average susceptibility to this disease.

15.1.5 Control measures

Bordeaux mixture was recommended from the first decade of this century for the control of this disease in South India (4), Malaysia and later in Sri Lanka and Java. In earlier years, coal-tar or Bordeaux mixture was used in Indo-China but later, the emphasis was on oil-tar mixtures (5). In Malaysia, the use of asphalt-kerosene mixture, which was recommended for some years (6) was later found to be unsatisfactory (7) and hence Bordeaux mixture was recommended for spraying on affected young plants. Application of 0.5 per cent solution of Fylomac 90 was recommended for mature trees to avoid contamination of latex with copper. Recently, the Rubber Research Institute of Malaysia has recommended painting of the affected surface with Calixin 4 per cent in latex (14). In India, coal-tar was used in earlier years for the control of this disease and later Bordeaux mixture spraying was recommended. General prophylactic spraying of the main stem, forking regions and main branches during April–May did not control the disease. It was also observed that repeated rounds of Bordeaux mixture spraying was necessary to obtain satisfactory control of the disease. Later on, brushing of the affected surface with Bordeaux paste was recommended for the control of pink disease (10). This could be prepared by dissolving separetly 1 kg of copper sulphate in 5 l of water and 1 kg of quick lime slaked by sprinkling hot water over it and later making up the volume to 5 l and mixing these two. Even with this, repeated applications often become

necessary for the satisfactory control of the disease. Moreover, the use of copper fungicide is not favoured on mature trees owing to the risk of copper contamination of latex. To overcome these difficulties, the use of 0.2 per cent Thiride incorporated in a petroleum compound like Wax-rex treseal, Mahathotex Wax or Rubber kote is being recommended for the control of this disease at present (17). When the petroleum compound used for the incorporation of the fungicide is black in colour, it may be necessary to white-wash the treated surface to prevent the incidence of sun scorch.

In the treatment of pink disease, utmost importance has to be given for the detection of the disease in the early stages of infection. Weekly inspection of young rubber in the most susceptible age groups may have to be carried out during the period of infection. With some training, it is very easy to detect the affected plants when the bark surface is not wet. After detection of the disease, the affected plants may be treated (Fig 15.4). In the early stages of infection, Bordeaux paste may be applied upto 30 cm above and below the affected region. In advanced stages of infection, when exudation of latex is noticed, Bordeaux paste may be applied as above and when it dries up, the bark surface may be scraped to remove all infected and decayed bark and the fungicide applied again. When the bark all around the affected portion is damaged, the portion may be pruned off at least 30 cm below the infected region. It is advisable to spray Bordeaux mixture on the infected and dried up portions before pruning off the dried up part of the plant. For treatment of the disease with Thiride, only one application is recommended without scraping the lesion. However, whatever be the fungicide used, success depends much on early detection of the disease and prompt treatment at the initial stages.

15.2 Black stripe

Black stripe disease, also called black thread or bark rot, was reported from Sri Lanka as early as 1909 and later on from Burma, Malaysia, Java, India and other rubber growing countries of Asia, Africa and South America. The disease affects the tapping panel and it is noticed during rainy season.

15.2.1 Factors influencing disease

In India, during the rainy season inoculum for the spread of the disease is profuse but intensity of incidence is observed to be only very low. This is because most of the planters discontinue tapping during the southwest monsoon, thereby preventing the occurrence of fresh wounds necessary for the entry of the pathogen into the host tissue. In Malaysia and Sri Lanka this disease is very severe because of continued tapping during the rainy season also. In India, wherever tapping is continued with rain guards, the disease incidence is observed to be very high unless regular panel protection measures are adopted (12). High humidity (over 90 per cent), frequent wetting of the tapping panel and continuous tapping during rainy season are favourable factors for the spread of the fungus.

15.2.2 Symptoms

The first symptom of the disease is development of short, vertical, linear and shallow depressions in the newly tapped bark above the tapping cut. These lesions sometimes coalesce due to rotting bark. Infected bark later dries up and gets adpressed to the wood. When such lesions are scraped, black vertical lines, extending upwards into the renewed bark and downwards into the untapped bark, are observed (Fig 15.5). Discolouration of the tissue extends deep into the wood. The infected bark ultimately falls off exposing the discoloured wood. This causes uneven bark renewal making it difficult to tap the renewed bark. The disease causes reduction in yield. The lesions caused by black stripe disease are often confused with tapping wounds (4,12,15).

15.2.3 Causative organism

Phytophthora palmivora is the causal organism for this disease in India. *P. botryosa* is reported to cause this disease in Malaysia (2). *P. faberi* reported from Sri Lanka, is considered to be a synonym for *P. palmivora* (8). The fungus produces sporangia and oospores in the affected tissues. The organism causes abnormal leaf fall disease symptoms on petioles when inoculated under laboratory conditions.

15.2.4 Control measures

Prophylactic treatment using effective fungicides is the best method of control. Organo-mercurial fungicides like Aretan, Ceresan, Emisan and Agallol are the wettable formulations recommended. Ten grams of Aretan or Agallol–6 or Emisan, dissolved in 4 l of water, or 10 g of Ceresan or Agallol–3 dissolved in 2 l of water may be used. Any one of the above solutions should be applied on the tapping panel at weekly or fortnightly intervals if tapping is continued during the rainy season. Fungicide solution may be applied as a spray or brushed on the tapping cut and just above, after removing the tree lace. Application of a panel dressing compound on the renewed bark just before the onset of monsoon and during wintering protects it from rain water and also helps better and quick renewal of bark. The common panel dressing compounds are Rubber kote, Wax-rex treseal and Mahathotex wax (12).

15.3 Patch canker

This disease is noticed in rubber plants of all age groups. Infection may be at the collar region, the tap root, main laterals, main trunk, tapping panel or major branches and it is observed during the rainy season. The first report of this disease was from Sri Lanka during 1903 and subsequently it was reported from all other rubber growing countires.

15.3.1 Symptoms

Exudation of reddish or purplish coloured liquid is observed in earlier stages of infection. But this symptom may not be evident in most cases. However, exudation of latex from the point of infection is noticed in all cases and it dries up to form black streaks. Latex accumulates and coagulates under the bark at the infection sites forming a pad which produces foul odour. The formation of pad under the bark results in conspicuous bulges and sometimes causes cracking of the bark (Fig 15.5). When the affected region is examined after removing the infected bark and rubber pad, wounds are seen and the internal tissues show discolouration. The tissues are yellowish grey with brown border in the early stages, and in advanced stages, the tissues change into dirty red and these

purplish red with a well defined black border. Rotting and discolouration extend up to the cambium. The wood underneath also shows discolouration in advanced cases.

15.3.2 Causative organism

The disease is caused by either *Phytophthora palmivora* or *Pythium vexans*. *P. vexans* is associated only when canker is seen at collar and roots but at other regions *P. palmivora* causes the disease. On the infected bark *P. palmivora* produces sporangia under field conditions. Normally, these organisms infect rubber plants through small wounds and produce cankers. *P. palmivora* isolated from patch canker, causes typical symptoms of abnormal leaf fall disease when inoculated under controlled conditions in the laboratory (13,15).

15.3.3 Control measures

The affected portion should be thoroughly cleaned after removing infected and rotting bark and the rubber pad present in the lesion. The cleaned lesions should be treated with fungicide. A solution of Aretan, Emisan, Ceresan, Agallol–6 or Agallol–3 in concentrations mentioned under 15.2.4 is used to wash the lesion. When the fungicide dries up, a wound dressing compound like Rubber kote, Wax-rex treseal or Mahathotex wax may be applied to help quicker healing of the wound. In the case of immature plants and on portions other than tapping panel of mature plants, Bordeaux paste may be applied for control of the disease (13).

15.4 Mouldy rot

This is a panel disease usually observed during the rainy season and is caused by the fungus *Ceratocystis fimbriata*. Its occurrence is very rare in India but it is a serious problem in Malaysia and Sri Lanka.

15.4.1 Factors influencing disease

Continuous wet and cool climate is very conducive for the occurrence and spread of the disease. Usually, only the renewed

bark is affected and the fungus seldom infects the untapped bark. Tapping during rainy season favours the incidence and spread of the disease. During rainy season in India, tapping is usually discontinued. This is one of the reasons why this disease is not observed in a severe form in India. Rainguarding may help the organism to become more active.

15.4.2 Symptoms

The first symptom of this disease is the formation of depressed spots above the tapping cut on renewed bark. These spots coalesce to form an irregular sunken band running parallel to the cut. When climatic conditions are favourable, continuous fungal growth is noticed over the lesions causing greyish discolourations. The bark in the area rots and falls off in due course exposing the wood, giving an appearance similar to that resulting from bad tapping. The disease may spread rapidly involving large areas of renewed bark and causing extensive depressed wounds. Callus formation takes place around the wounds and the tapping panel becomes highly uneven making it difficult to tap the renewed bark (11,15,16).

15.4.3 Control measures

Organo-mercurial fungicides like Aretan, Emisan, Ceresan, Agallol–6 or Agallol–3 control this disase if applied at regular intervals (11).

15.5 Dry rot

This disease is also called collar rot or charcoal rot.

15.5.1 Symptoms

The initial symptom is copious exudation of latex from root, collar region, stem or branches where the infection occurs. As the infection progresses, the neighbouring brak is killed and fructifications of the fungus appear on the bark surface (Fig 15.7). These fruiting bodies are circular to irregular in shape, greyish white in colour and soft in the beginning. They enlarge and coalesce.

The fructifications also change their colour into olive grey and produce conidia. As these bodies age, they become black and brittle and produce perithecia ejecting ascospores. The fungus invades the wood which dries up. In due course, the plant breaks at the infected portion. In the infected wood, presence of black double lines can be observed.

15.5.2 Causative organism

The organism causing this disease is *Ustulina deusta (Ustulina zonata)*. This organism is a facultative parasite which can grow on dead and decaying wood and stumps observed in rubber plantations. It is a wound parasite and infection is observed to be more after heavy wind.

15.5.3 Control measures

The infected region must be disinfected by brushing with an organo-mercurial fungicide solution. Then the affected bark with fructification and infected and dried wood are removed. These portions must be again brushed with the fungicide solution. The treated portions must be protected with a wound dressing compound (15,18).

15.6 Bark necrosis

Bark necrosis is generally noticed on mature trees. Its etiology is not yet known.

15.6.1 Symptoms

The first sign of attack is a reduction in yield of latex in the affected trees. Purplish red to brown spots are seen on the lower portion of the tapping cut. The infection first spreads downwards in the bark of the tree, simultaneously spreading in other directions. The cambium is also affected. The wood and the renewing bark are however not affected. On scraping off the outer bark, the necrotic tissue is seen as purplish red to brown patches. Later these patches enlarge and coalesce. Exudation of latex is

also noticed. Subsequent invasion of borer beetles is also noticed. In severe cases, the tree succumbs to the disease. Certain trees on which the infection does not get to deeper layers of the bark recover by regenerating perfectly healthy tissue beneath the diseased bark.

15.6.2 Clonal susceptibility

The most susceptible clone is PB 5/51. Incidence up to 20 per cent is reported from Malaysia in this clone. Other clones prone to this disease are PB 28/59, PB 28/83, GT 1 and PR 107. In India, this disease was recently observed on a large scale in PB 28/59, causing drying up of even mature plants.

15.6.3 Control measures

In the early stages of attack, discontinuance of tapping and resting the tree for a period of six months encourage recovery and formation of new bark. Experiments conducted in Malaysia showed that application of 0.5 per cent Antimucin at weekly intervals for two months controlled the disease (3).

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16 ROOT DISEASES

Chapter 16

ROOT DISEASES

Rubber trees are prone to a variety of root diseases which can result in casuality and cause appreciable reduction of stand. Among the root diseases, brown root disease, white root disease and red root disease are the most important. The intensity of these diseases varies from country to country. Root diseases are a major problem in Malaysia, Sri Lanka and Congo but in India they are of minor consequence.

16.1 Brown root disease

Brown root disease is the only root disease of some significance reported for rubber in India. Though brown root disease is common in Malaysia, Sri Lanka and Congo, it is of still less importance than white and red root diseases in those countries. Higher incidence of the disease is found in sandy or light soils and in areas subject to inundation. The pathogen infects plants of all age groups.

16.1.1 Symptoms

The first visible symptom is partial or extensive discolouration of the foliage (9) accompanied by cessation of growth. Purplish or reddish yellow colour develops on the mature leaves. In course of time, the leaves dry up and may be shed or may remain attached to the tree. The twigs die–back and eventually the tree dies. The disease–affected trees may occur in patches or may be widely scattered.

The infection involves one or more of the lateral roots or the tap root or both. The affected root shows a thick encrustation of

soil and small stones firmly cemented to the root bark by mucilage produced by the fungal mycelium (Fig 16.1). When the soil is removed, tawny brown patches of fungal hyphae can be seen. If the disease happens to be in an advanced stage, the fungus may develop a black brittle covering over the brown masses. Hyphae penetrate the cortex and wood. If the encrusting mass is removed, the cortex appears brown and mottled with small white patches internally. The wood also shows brown discolouration and brown lines which are formed by aggregation of fungal hyphae that can be seen traversing the wood either across or lengthwise. In advanced stages, honeycombing of wood is noticed (8).

The spore-bearing structures of the fungus are very rarely met with. Resupinate fructification generally occurs in affected young plants. The sporophore of the fungus is bracket shaped. Large hard brackets are produced which are attached to the base of old infected trees or stumps. These are dark grey on the underside and brownish purple or black on the upper surface with prominent concentric growth rings and an yellowish margin. Innumerable minute pores are seen on the underside. Basidiospores are produced in profusion and are disseminated by wind (2).

Abortive sporophores of the fungus appear at the collar region of the plants above the ground level. These sterile fructifications are water-soaked and they vary in colour from tawny to purplish brown. They are irregular in shape covering the collar partially or all around. On uprooting the infected plant, the tap root is found invariably damaged. The bark at the lower portion of the tap root is completely rotten and it sloughs off easily exposing the wood tissue. Profuse formation of secondary lateral roots above the damaged portion of the tap root is observed in some of the affected plants (Fig 16.2).

16.1.2 Causative organism and spread of the disease

The disease is caused by the fungus *Phellinus noxius* (Corner) G.H. Cunn. This fungus is widespread throughout the tropics and attacks several perennial crop plants like bread fruit, coffee, tea, ceara-rubber, jack, cocoa, *Grevillea* sp and dadap. *Phellinus noxius* has recently been found to be an important stem pathogen

in Malaysia causing destructive die-back of mature trees (4). The fungus usually colonises the stumps of trees left in plantation. These may be of rubber or jungle trees and form an important source of infection. Actual underground root contact between infected materials and healthy rubber roots appears to be the chief method of spread. There is also some evidence that it might be possible for the mycelium to spread through the soil over short distance. Spores of the fungus are blown by wind and cause stump infection which helps in further spread of the disease.

16.1.3 Control measures

Control of the disease is effective when tackled in the initial stages of infection. The trees which show yellowing of leaves are to be given proper treatment. The soil around the tree base should be carefully opened up and the root system exposed. The roots should be traced very carefully upon to a length of 1 or 2 m. Portions of roots which have dried completely due to infection should be removed and destroyed. In the case of partially affected roots, the affected portions may be slightly scraped and given fungicidal treatment. Generally, Aretan (10 g in 4 l of water) is used for the treatment. Emisan (10 g in 4 l), Ceresan (10 g in 1.6 l) or Agallo (10 g in 2 l) can also be used for the purpose (8). When the fungicide dries, a petroleum compound like Mahathotex wax, Wax-rex treseal or Rubber kote is to be applied on the treated portion. This helps in quick bark regeneration. The tree base may be firmly refilled with soil and drenched with the fungicide solution. As a prophylactic measure, the bases of the trees around the infected ones are also to be drenched with fungicide solution.

Sometimes, by the time the discolouration of the foliage is noticed, the infection might have progressed so much that the treatment would not be effective. In such cases, the tree has to be removed with infected roots and destroyed along with any other rotting stump found in the immediate vicinity of the affected plant.

16.2 White root disease

Even though this disease is not prevalent in India, it poses the most serious problem in West Malaysia, Sri Lanka and Congo. It appears

in the stand a year after planting, reaching the peak period of infection in the fourth year. This alone is responsible for more tree losses than those caused by red root disease and brown root disease put together. *Rigidoporus lignosus* (Klotzsch) Imazeki is the pathogen involved in white root disease.

16.2.1 Symptoms

Yellowing of the foliage is the external symptom of the disease. The infection can be readily identified by the external rhizomorph system on the root. The rhizomorphs are firmly attached to the roots forming a net work as they advance. They are pure white in colour, but as they grow old, they assume a yellow or faint reddish brown colour depending on the colour of the soil. They vary in size and the thickest are seldom more than 4.5 mm thick. Sometimes they may unite to form a continuous sheet. The fungus rarely appears above soil level. If it does, the strands become subdivided into finer threads. Apart from these external rhizomorphs, the infected roots show no other distinguishing features. The infected wood remains hard and brown with a greyish tinge (2).

Infection generally occurs by direct contact of the roots of healthy trees with infected roots, stumps or surface timber on which the fungus has colonized. Strands of *R. lignosus* can traverse small distances through soil but die if separated from its base. New infection centres can arise at the time of felling for planting or replanting through the agency of wind or insect borne spores of the pathogen colonising healthy stumps and, subsequent to clearing, from spore infection of moribund stumps and surface timber.

Fructifications are bracket shaped, unstalked and formed in many tiers. They are orange yellow on the upper surface and orange red or brownish on the lower. The bracket generally appears at the collar region of diseased trees and on rotting stumps, particularly during wet weather.

16.2.2 Control measures

Recent recommendations in Malaysia for control of root disease aim at preventing infection from becoming established and spreading

from tree to tree in young stands. Diseased trees are detected by foliage symptoms and are treated, if possible, together with the neighbouring trees. The diseased roots are traced and removed as far as possible. Removal of the root portions which are not actually penetrated by the fungus is considered unnecessary as the advancing superficial mycelium is not able to sustain the disease. The remains of the infected roots and the source of infection present in the inter rows are left to the process of decaying which is accelerated by maintaining a good ground cover (3). In 1962 a break through in the treatment of disease was made when pentacholro nitro benzene (PCNB) was found effective (3, 11). In mature areas where treatment is not possible, isolation trenches are made. In Sri Lanka, Tillex was found effective against white root disease. Amendment of surface soil with sulphur while refilling the planting holes is also reported to reduce disease incidence (12). In Ivory Coast, *Tithonia diversifolia* used as a cover crop, is found to reduce the incidence of white root disease (11).

16.3 Red root disease

This disease causes considerable damage to young rubber from the third to the eighth year of planting in Malaysia. Red root disease is not reported from Sri Lanka and India. It is caused by the fungus *Ganoderma pseudoferreum* (Wakef) Over and Steinm.

16.3.1 Symptoms

External symptom of the disease is yellowing of the foliage, but it appears only after a lapse of years after infection. Those plants that look outwardly healthy may sometimes be completely infected. The slow rate of progress of the disease makes it very dangerous. The affected plant produces numerous adventitious roots from the unaffected root tissue.

In mature trees, the woody tissues of attacked roots degenerate into a soft spongy mass from which water can be squeezed by light pressing. This condition is not very obvious in young plants. The mycelium forming a red skin around the infected root is a typical character of the disease. This can be seen only when the soil is

washed away. When the strands are young, they are light red and when dry, the colour fades to a dirty white. The colour reappears on moistening. When older, the colour is deep claret and it remains unchanged on drying. When the roots are completely rotten, the colour of the rhizomorphs approaches blackish violet. Single separated rhizomorph is found only occasionally. The red skin is not formed on portions exposed to light. Discolouration is noticed on the wood. Brown or black lines are also found. Honeycombing of the wood is also seen. In the advanced stage, annual layers of the wood become so disintegrated that diseased roots resemble 'mummified' roots with an external red skin surrounding an aggregated mass of fungal tissue. Spread of red root disease is by root contact. Infection from spores may also occur. Fruit bodies are hard, woody brackets with dark-reddish brown and wrinkled upper surface. They are ashy white on the lower surface. The margins are creamy-white. Fructifications are generally rare and occur at the collar region of the affected plant. Mature ones bear viable spores in abundance (2).

16.3.2 Control measures

Formulations containing 10 per cent Drazoxolon or 10 per cent Tridemorph are recommended as protective dressings against red root disease in Malaysia (2, 11, 12). As in the case of other root diseases, pre-planting eradication of sources of inoculum is carried out, followed by measures to prevent spread in the stand. In case of infection, early detection and treatment of infected trees are recommended. Enhancement of antagonistic microflora by fumigation with methyl bromide or Vapam in combination with mulching, application of NPK fertilizers and drenching with Drazoxolon is reported to control red root disease to some extent (13).

16.4 Dry root rot

Dry root rot is generally found in old rubber areas and is reported from Malaysia, Sri Lanka, Java, Fiji and India. *Ustulina deusta* (Hoffm. exfr) Lind. is responsible for the disease. This is more important as a stem pathogen causing collar rot or charcoal rot. Besides rubber, many other perennial crops like tea, coffee and shade trees are susceptible to this disease. The characteristic symptom of the disease is the dry rot developing in the affected root. Profuse adventitious

root formation is also noticed. Double black lines can be seen in the bark as well as on the wood. They run irregularly in the rotting tissues forming circles surrounding dark coloured patches of diseased wood. The black lines are composed of aggregated fungal tissues which can retain their viability for a long time. There is no external mycelia on the infected root. Sometimes, fan-shaped, white patches of felt-like mycelia may be observed on the surface of the wood when bark is removed (10). The progress of the disease is slow. The fungus is largely confined to the medullary rays. The infected regions become soft and dry and finally the affected trees are blown over by wind. Fructifications are produced at the collar region. Spores, produced in profusion, are disseminated by wind. Insects also help in dissemination.

The commonest seat of infection is the collar of the tree. The accumulation of rubber as earth scrap at the base of the tree for a long time results in suffocation of the cortical layers beneath and thus the best condition for the attack of *Ustulina* is provided. So care should be taken to see that accumulation of the latex pads at the base of the trees is avoided. Fruit bodies should not be allowed to develop on unwanted stumps. Treatment for the disease is the same as that for brown root disease. Adequate manuring may be carried out to improve vigour. Unnecessary wounding of trees may also be avoided (7).

16.5 Stinking root rot

Stinking root rot was first recorded in Sri Lanka in 1907. It is reported from Malaysia also. Generally, it occurs in low lying areas especially after floods. The disease is so called since the attacked rubber roots and the surrounding soil have a foul smell. The foliage of the affected trees becomes thin and the branches gradually die-back. In very severe cases, the attacked trees shed their leaves rapidly. The progress of the disease is slow and it takes a long time to kill the tree. This disease is caused by *Shaerostilbe repens* B & Br. Unless the required conditions are available, this does not cause much damage. The affected roots can be easily distinguished from those infected by the other root disease pathogens by the black flattened radiating rhizomorphs which are usually found between the bark and

the wood. No external rhizomorphs are found. The edges of these rhizomorphs may be tinged with pinkish pustules which are the imperfect fructifications of this fungus. The rhizomorphs may be microscopic or may aggregate together to form large plates. When fresh and growing vigorously, these plates are greyish white with a reddish tinge at places. Later, they become deep red in colour and turn black with the death of the root. Even when the rhizomorphs have decayed, their former position is indicated by the presence of corresponding dark lines on the wood (10). The fungus produces both sexual and asexual spores. Sexual spores are borne on small, dark red, globular perithecia. Asexual stage, known as the 'stilbum' stage, consists of red or pinkish heads with red stalks. This stage arises from the submerged rhizomorphs in the cortical tissues of the diseased root. Perithecial stage follows conidial stage. The spores, readily disseminated by wind, cause infection. Spread by root contact rarely happens.

16.6 Poria root rot

Poria root disease of rubber was first reported in 1905 in Sri Lanka on the roots of a two year old rubber tree. Subsequently, the disease was reported from Malaysia, tropical America and India (6). It is one of the minor root diseases and is caused by the pathogen *Poria vincta* (Berk) Cooke, previously known as *Poria hypobrunnea* Petch. Yellow discolouration of leaves is the only external symptom of the disease. The affected root shows encrustation of soil and small stones as in the case of brown root disease though not to the same extend. Around the root, the fungus forms a complete skin, pale white in colour intermingled with brick red and black tinge. The wood also shows discolouration.

Basidiocarps, flat and plate like, are formed at the collar region of the affected tree closely adpressed to the substrate. They are brown when young becoming greyish brown later on. Spores, produced in profusion, cause fresh infection when disseminated by wind. The control of the disease in isolated cases is similar to that of brown root disease.

16.7 Black root disease

Black root disease is another minor root disease of *Hevea* caused by the fungus *Xylaria thwaitesii* (Cooke). The disease, first reported by Petch (5) from Sri Lanka in 1910, is found to be widespread in that country. The first recognizable external symptom is the appearance of clusters of fructifications which arise from the dead lateral roots especially at the collar region of the tree. The fungal colony advances in a fan-like pattern. The growing portion is white but it rapidly turns grey to black in colour. Later, a continuous, thin, smooth and black skin is seen around the root surface. Rarely, a slight encrustation of soil and small stones is found. Bark and wood become discoloured and the wood remains hard. Wetness in this region is a major characteristic feature. On infected tap root exudation of latex is pronounced. The absence of any marked foliar symptoms, even at the advanced stage of infection, is another feature of the disease. Reduction in refoliation vigour resulting in thin canopy is the only noticeable symptom. When the roots are rotted, the tree is often blown over by wind. The fructifications arise as white knob-like structures developing into erect clubs 2–6 cm in height and 0.5–2.0 cm in diameter. Each cluster may have 2–30 fructifications. Perithecia are produced from the lower parts of the fructification. The spread of the disease is generally by root contact. The role of spores in the spread is unknown.

Treatment with 10–15 per cent PCNB in a grease base (Fomac) along with destruction of source of inoculum is reported to be effective.

16.8 Armillaria root rot

A major root disease in West and Central Africa is Armillaria root rot. It is caused by the pathogen, *Armillaria mellea*. This disease has not so far been reported from Asia (2).

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17 NON-PARASITIC MALADIES

Chapter 17

NON-PARASITIC MALADIES

Non-parasitic maladies are those which are not caused by any pathogen. These include wind damage, sun scorch, lightning and fire damages, chemical toxicity, self pruning, fasciation and woody nodule formation.

17.1 Wind damage

Wind damage is a very serious problem of rubber plants. Some clones like Tjir 1, RRIM 501, RRIM 605 and RRIM 623 are inherently prone to wind damage. Clones like PB 86, PR 107, PB 5/51 and GT 1 are reported to be wind fast. Wind damage is observed in rubber plants of all age groups. The growth of young plants in exposed and wind-lashed areas becomes very much stunted. The leaves of plants in such locations are observed to be lacerated and crinkled and the crown becomes sparse and open. In older plantations, wind damage may be in the form of uprooting, trunk snap or branch break. Uprooting usually occurs in soils with shallow profile, high water table or a laterite hard pan. Branch snap is common in clones like PB 5/63, RRIM 605, RRIM 607 and Tjir 1. In this case, the branches are torn off in the region of crotch. Trunk snap is the most serious form of wind damage. Breakage can be at any point of the trunk. If the breakage occurs in the tapping panel region the tree is beyond repair. Clones susceptible to trunk snap are RRIM 501, RRIM 603, RRIM 605, RRIM 614 and RRIM 623.

Usually, tall trees with disproportionately heavy crown are affected by wind damage. The intensity is more near vacant patches within a stand and most during wet months. The trees which have been opened for tapping have a reduced rate of girthing which sometimes is not compensated by proportionate reduction in crown growth.

This condition which is more pronounced in some clones like RRIM 501 makes the trees more susceptible to wind damage. Trees with heavy main branches and those with branches arising at a narrow angle from the main stem are more susceptible to wind damage. Wind damage is high in elevated areas. Thus, tallness of trees, unbalanced branches, heavy canopy and extra weight due to water carried on the leaves after raining, coupled with the poorer girth increment on tapping, all add to the tree being top-heavy and having high turning movement around the trunk. The presence of gaps in ravines or vacant patches in the stand may bring about lateral imbalance.

Planting of quick growing trees on the borders to form a wind belt is one of the measures to mitigate the adverse effect of wind on young plants. Growing an intercrop like banana is also observed to reduce the damage to young plants due to strong wind. In the case of susceptible clones, application of balanced fertilizer on the basis of soil and leaf analysis is helpful in avoiding wind damage. Early selective pruning to remove heavy lateral branches thus reducing crown weight also helps in preventing wind damage.

17.2 Sun scorch

Rubber plants are highly susceptible to sun scorch. The damage due to sun scorch is more for young plants in nursery and field. In the field, when canopy closes, the plants are protected from exposure. In the case of young nursery seedlings, bark at the collar region gets scorched resulting in a girdling effect and the affected seedlings dry up subsequently. This is mainly due to heating up of the soil around the collar and it can be prevented by mulching the nursery beds with dry organic matter on the advent of hot dry weather.

In young clearings, bark at the collar region or above on the side facing south or southwest often gets damaged owing to sun scorch. In the affected cases, bark dries up and sometimes exudation of latex is observed. The dried bark becomes adpressed to the wood and depressions in the shape of spear-head is noticed (Fig 17.1). The affected bark is often colonised by secondary pathogens like *Diplodia*. In due course, the affected and killed bark cracks and falls off exposing the wood which becomes greyish or blackish in colour. Such plants,

if left untreated, dry up ultimately or break at the affected point. Application of black panel protection compounds, especially during the summer months, may also cause scorching of the bark if the treated plants are directly exposed to sun. To overcome this, treated portion may be white–washed.

Sun scorch incidence can be prevented by providing mulch for the young rubber planted in the field and also by providing suitable shade with bamboo baskets (tree guards) or plaited coconut leaf during the first year of planting. From second year onwards, young plants may be white-washed using lime up to the brown portions of the bark. White-washing may be carried out by the beginning of the dry weather, preferably in November-December itself. For white-washing, fresh quick lime is superior even though china clay can also be used. In the case of affected plants, the lesion may be scraped to remove all dried up bark and washed well with an organo-mercurial fungicide solution. When the fungicide dries up, a wound dressing compound may be applied, as a thin coating, to facilitate quick healing of the wound. Treated plants may also be white-washed.

17.3 Lightning damage

Rubber trees of different age groups are susceptible to lightning injury. The damage may be for a group of trees in lines or even in a scattered pattern. The extent of damage varies. The manifestation of visible symptom of distress is sudden. Seriously affected trees are completely killed and they dry up immediately. Partial damage to the main stem or to some branch may also occur. In the affected portion, exudation of latex is observed and bark gets separated from the wood. The damaged bark is colonised by borer beetles in larger numbers. A characteristic feature is that the cambium tissue is damaged first and as a result the cambium and the inner bark are coloured scarlet or dark violet. Tissue damage starts from the cambium, extending through the bark in an outward direction. Soon after lightning damage, incidence of patch canker also increases.

Immediately after lightning incidence, the damage caused to plants may be assessed by careful examination. Completely affected and killed plants may be removed. In the case of partially affected plants, the damaged bark may be scraped out and the wound washed

with an organo-mercurial fungicide. When the fungicide dries up, a wound dressing compound may be applied on the treated surface. If the affected plants are exposed to sun, it may be white-washed after the treatment.

17.4 Fire damage

Young rubber plantations with accumulated mulch due to the luxuriant growth of cover crop or mature plantations with accumulation of dired up leaves following wintering are highly prone to fire damage during the dry summer months. Fire may be from a neighbouring jungle, due to carelessness or by accident. The extent of damage varies from superficial burning of dead bark to deep injury and burning of the healthy bark. The lower leaves become scorched and dead. Exudation of latex from scorched bark portion is often noticed. Colonisation of damaged bark by borer beetles and high incidence of patch canker are also observed following fire damage. To prevent fire damage, all precautionary measures may be adopted. During summer period, fire belts may be taken and maintained. In affected areas, treatments to be adopted are similar to those for lightning damage.

17.5 Chemical toxicity

Rubber plants are susceptible to chemical injury caused by excess spray oil, old stock of copper fungicide, certain types of coal-tar, kerosene oil and some rainguard adhesives. Certain clones like GI 1 and LCB 1320 are found to be more susceptible to this. In the case of injury on leaves, they often turn yellowish and fall off. In some cases, tissues of the leaf lamina dry up in patches. These symptoms are noticed when phytotoxic oils or excess of diluent oil-fungicide mixtures are sprayed on trees. Phytotoxicity due to spray oil is seen on plants within four – six days after spraying. Oil based copper fungicides stocked for long periods also sometimes cause phytotoxicity symptoms on rubber plants. Certain types of coal-tars and mineral oils like kerosene are also phytotoxic to rubber plants. In nursery, physical contact of fertilizers with shoot portion of the plant causes injury to the tissue. Application of excessive quantity of chemical fertilizers to very young plants may cause scorching and defoliation. Instances are several where kerosene added to panel protection compounds for

dilution had caused severe phytotoxic symptoms on the bark. In such cases, profuse exudation of latex is noticed from the affected bark which later becomes deep grey to chocolate in colour and dries up in due course. Some rainguard adhesives also, at times, cause injury to the bark.

17.6 Self pruning

In young rubber plantations (5–10 years), self pruning of lower branches is noticed. This is more in areas with vigorously growing plants and where the stand per ha is higher than normal. Because of vigorous growth, the canopy closes early and complete shade prevails in such areas. Under the shaded conditions, the leaves on the lower branches turn yellow and fall off. The defoliated branches start drying up and fall off in due course. After initiation of the process of drying, borer beetle attack is sometimes noticed on such branches which show exudation of latex. Since the lower branches dry off owing to shade effect only, no treatment is required.

17.7 Fasciation

Certain deformities of growth resulting in flattened, curved and branched or unbranched shoot growth with many scale leaves and buds are occasionally noticed on rubber plants (Fig 17.2). The exact cause of such abnormal growth is not fully established. Very often, removal of the fasciated shoot results in normal growth.

17.8 Woody nodules

Woody nodules are sometimes noticed in the cortex of rubber plants. Nodules are found fully or partially embedded in the bark. A thin layer of bark covers the woody nodule. Nodules may be round, oval or irregular in shape and varying in size. These woody nodules are formed as a result of abnormal meristematic activity outside the normal cambial layer. Trees growing under unfavourable conditions, especially in areas with prolonged drought, are observed to produce woody nodules in the bark. By a gentle tap on the projected portion of the nodule above the bark surface with a tapping knife,

the woody nodules come out of the bark. They could also be extracted easily from the bark with a sharp knife. A thin layer of bark is generally found underneath the nodule, separating it from the wood. Exact reasons for the developments of such nodules are not known. Woody nodules, when observed, may be removed and the wound treated with a petroleum compound to facilitate quick healing.

18 PESTS IN RUBBER PLANTATIONS

Chapter 18

PESTS IN RUBBER PLANTATIONS

Pests of rubber are not many and their occurrence is sporadic and localised. However, there are a few pests which become serious at times and cause considerable damage. The cover crops raised in rubber plantations are also attacked by many pests. There are also pests which cause health hazards and inconveniences to personnel working and residing in rubber plantations.

Until recently, the concept of pest control was for eradicating them. But now it has been realised that eradication of pests is impossible and also harmful as it upsets the balance of nature, and pest resurgence occurs. This is due to the prolonged large scale use of pesticides with long residual action which destroy the pests as well as their natural enemies. Hence, the use of pesticides is to be minimised by taking advantage of natural controlling forces and managing the pest population to a level below the economic threshold. For this, different methods of control such as mechanical, cultural and biological are integrated with chemical control.

18.1 Pests of rubber

Pests of rubber can be classified into three major groups, viz insects, non–insect invertebrates and vertebrates.

18.1.1 Insects

Insects are organisms with three pairs of legs and they usually have a hard exoskeleton with head, thorax and abdomen.

18.1.1.1 Root grubs

Among the insect pests of rubber, root grubs are the most important. They are grubs of cockchafer beetles and are also known as white grubs. The beetles are stout and horney. The grubs are fleshy with wrinkled 'C' shaped body (Fig 18.1). The most common species found in rubber is *Holotrichia serrata* Burn. Other species noticed are *H. rufoflava* F, *H. fissa* Brenske, and *Anomala varians* Ol. The grubs feed on the tap root as well as lateral roots completely and also at times nibble at the bark at the collar region (Fig 18.2). Owing to this damage, the whole plant wilts and dries up. The attack could be recognised usually by the yellowing of leaves. In the morning, some plants could be seen to sway abnormally due to the feeding of grubs at collar region. Adult beetles do not damage rubber plants. Nearly 30–50 per cent plants are damaged in large nurseries adjoining reserve forests. In Malaysia, the pest is very serious in nurseries as well as main fields (2).

The white grubs have a one year life cycle. Adults emerge from the soil with the first rains in April-May between 7.30 am and 8.30 pm. Females are much larger than males. Adults are generally noticed to feed on leaves of *Acacia*, neem and tapioca. They mate and then get into soil around host plants and lay eggs singly at depths of about 8–10 cm enclosed in earthen cell. Adults live for about two months. The grubs emerge in 10–12 days and feed on humus and tender roots. Three larval instars occupy about 30, 35 and 102 days. The third instar grub does the maximum damage and measures about 48 mm. Pupation occurs in November-December in earthen cell. Pupal stage lasts for 12 days. Adults lie quiescent until the first summer rains. Emerging adults are highly attracted to light.

Adult beetles could be collected and killed with light traps using mercury vapour lamp or tube light. In Malaysia, black light traps have been found to be successful (10). Spraying DDT 0.4 per cent or Endosulfan 0.1 per cent on the host plants at the end of March and incorporating BHC 10 per cent dust at the rate of 100 kg/ ha in the soil of nursery beds at the time of preparing the bed are also effective. The pest is attacked by natural enemies like wasps, vertebrate predators and fungal and bacterial pathogens. But these are not very effective.

18.1.1.2 Gallery making caterpillar

Larvae of two species of moths feed on the bark of rubber trees, especially mature trees. They are the common *Aetherastis circulata* Meyr and the rare *Ptochoryctis rosaria* Meyr. They appear only during the dry period from October to April. With the advent of the rains they disappear. The caterpillars build galleries on the trunk with chewed bark, faeces and silk, and live within. They feed on the bark on all parts of the trunk and branches. At certain points where they feed deeper, latex oozes out. These points facilitate the penetration of pathogens causing diseases of the bark like canker and bark rot. The trees attacked by the caterpillars usually bear the disease symptoms. This pest has been noticed in Kanyakumari, Trivandrum, Quilon and Kottayam districts.

The adults lay eggs on the bark. The caterpillars emerge in three – four days. The larval period lasts for 25–30 days and the pupal period for seven days. The moths are white in colour with black dots on the fore-wing.

Spraying Sevin at 0.05 per cent concentration on the affected parts of the trees using high volume sprayers and repeating spraying when reinfestation is noticed are necessary for control. A wetting agent may be used for spraying.

18.1.1.3 Termites

Termites are insects that lead a subterranean life in soil and live in communities consisting of queen, males, standby reproductives, sterile workers and soldiers. The workers damage the rubber plants by feeding on the dead bark or any part partially or fully killed as a result of diseases, sun scorch etc. They also damage mulch, protection baskets, white-wash etc. Green parts of plants are not eaten by them, but stumps that are planted late are damaged. The common species found on rubber is *Odontotermes obesus*. In Malaysia, a species of termite, *Coptotermes curvignathus* attacks green wood of plants and causes considerable damage even in mature areas (7). The attacked trees snap back at the trunk region or are uprooted during strong wind.

Termites can live only at a particular temperature and humidity. Hence, the workers can move from one point to another only after building the earthen gallery. If the soil at the base of affected objects are poisoned termites could be controlled. The nuptial flight of termites occurs during the summer rains and new colonies are formed.

The soil at the base of affected objects may be drenched with Aldrin 0.05 per cent, just to wet the soil completey. In open condition, the concentration may be raised to 0.1 per cent to get year-round protection (4).

18.1.1.4 Scale insects and mealy bugs

These plant bugs feed on the sap of plants at the tender green growing parts (Fig 18.3). In severe cases, which are rare, the attacked parts may dry up, and die-back may also occur. The species of scale insects attacking rubber is *Saissetia nigra* and the mealy bug is *Ferrisiana virgata*. These insects secrete honey dew which spread on leaves and twigs. A black fungus *Capnodium* sp, called sooty mould, grows on them.

These bugs are controlled naturally by parasites, predators and the fungal pathogen *Hypocrelia reineckiana*. In severe cases of infestation, Malathion 0.05 per cent may be sprayed using a wetting agent.

18.1.1.5 Insects attacking rubber wood

Various species of powder post beetles damage rubber wood and commonly occurring ones are *Mynthea rugicollis, Heterobostrichus acqualis* and *Sinoxylon anale*. The attack of these beetles could not be prevented by coating any insecticide even in high concentration. Wood treatment methods had been developed in Malaysia (9). The simplest method of wood treatment is immersion of freshly sawn rubber wood in a preservative solution consisting of sodium pentachlorophenate (against fungi) gamma BHC, and borax (both against insects) in concentrations ranging from 1 per cent to 2 per cent by weight of the technical product, for 5 min or longer.

18.1.2 Non-insect invertebrates

Non-insects can be vertebrates or invertebrates. Unlike invertebrates, vertebrates have a back-bone and well developed endoskeleton.

18.1.2.1 Slugs and snails

These terrestrial molluscs cause two types of damage to rubber. In young plants of up to three years' growth, they feed on the terminal and axillary buds repeatedly and arrest the growth of plants (Fig 18.6). Die-back and fasciation may also occur in severely affected plants. In mature trees, they feed on latex from tapped trees and cross over the tapping cut or stay in collecting cup (Fig 18.4 and 18.5). In addition to loss of latex due to feeding, spillage and contamination of latex occur. The most common species of slugs and snails attacking rubber are *Mariaella dussumieri* Grey and *Cryptozona (Xestina) bistrialis* Beck and the frequently occurring slug is *Semperula maculata* (Templeton). These molluscs are nocturnal in habit. They shun light and during day time they lie under dried leaves and crevices in soil and rocks. They move about at dusk and during night. During day time, their presence could be recognised by the watch spring shaped faeces and glistening mucilaginous movement tracks. This pest has been noticed in all the rubber growing tracts of Kerala. *M. dussumieri* attacks rubber in Malaysia also (1).

Slugs and snails are hermaphrodites but mating is required to lay viable eggs. Each slug can lay up to 400 eggs. Eggs are leathery and pearly white in colour and under wet conditions, the young ones emerge in 7–10 days. The adults are unsegmented, worm shaped and with sole-like foot on which they glide. They have distinct head, bearing two pairs of club shaped tentacles, the posterior larger pair bearing a pair of eyes at the tip. Snails bear a spiral shell while slugs bear none or have only a rudimentary shell. Adults feed on tender leaves, flowers of weeds and cover crops. Only a small percentage of the total population attacks rubber in immature areas.

Slugs and snails can be controlled effectively by applying a band of the insecticide Temik 10 G on the surface of the soil at the

base of plants. They die owing to contact with the granules. This insecticide is effective under wet conditions also. Metaldehyde, a specific molluscicide, is lethal to slugs and snails as 2–5 per cent bait (3) or 0.1 per cent spray, but is not effective under wet conditions (6). Meta bait is prepared by mixing Metadex, cement, lime and wheat bran (rice bran) in the ratio 2 : 3 : 5 : 16 by weight and the mixture made into thick paste by adding water and made into small briquettes or pellets for broadcasting.

18.1.2.2 Mites

Mites suck the sap from leaves by feeding from the underside. Severely attacked leaves show minute white dots and such leaves dry and fall off in due course. Severe attack considerably debilitates the plants.

Mites can be controlled by dusting sulphur or spraying 0.5 per cent wettable sulphur. In severe cases, Kelthane 0.05 per cent may be sprayed. Dusting or spraying should be done on the underside of leaves.

18.1.3 Vertebrates

18.1.3.1 Rats

Burrowing rats and mole rats cause considerable damage to nursery plants and young plants in the field. The bandicoots feed on the plants up to the age of three years at the collar region and pull them down (Fig 18.7). The burrowing rats feed from the burrows on the tap root of plants up to collar region and the plants dry up. The common species of rats attacking rubber is *Rattus meltada* Grey and *Bandicota bengalensis* Bechstein.

Baiting with zinc phosphide is a good method of control. Since rat damage is more in rainy season, a paste of zinc phosphide can be made by mixing it with melted vaseline and used with bait food like tapioca and sweet potato. This formulation is not affected by wet condition and phosphine gas objectionable to rats is not evolved. Temik 10 G also can be used as bait poison. Mass baiting should



Fig 14.1 Pod infection — water soaked lesion



Fig 14.2 Pod infection — advanced stage

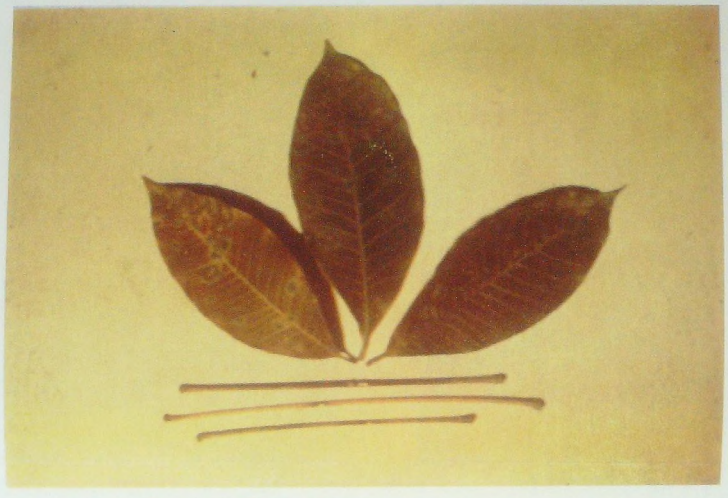


Fig 14.3 Infections on lamina and petiole



Fig 14.4 Defoliation due to abnormal leaf fall disease



Fig 14.5 Bordeaux mixture spraying



Fig 14.6 Micron spraying



Fig 14.7 Aerial spraying



Fig 14.8 Sprayed and unsprayed plants



Fig 14.9 Powdery mildew — symptoms



Fig 14.10 Sulphur dusting



Fig 14.11 Corynespora leaf spot

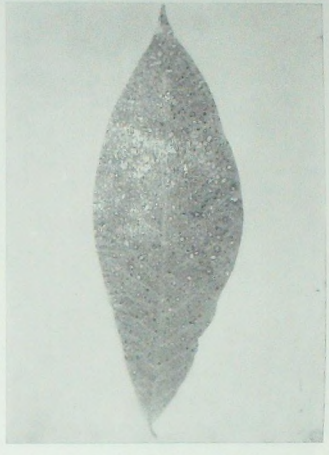


Fig 14.12 Bird's eye spot



Fig 14.13 Gloeosporium leaf disease



Fig 14.14 Thread blight



Fig 14.15 Shoot rot



Fig 15.1 Pink disease — cobweb stage



Fig 15.2 Pink disease — advanced stage



15.3 Pink disease — drying up of twigs



15.4 Pink disease — treated plant



Fig 15.5 Bark rot symptoms



Fig 15.6 Patch canker



Fig 15.7 Dry rot



Fig 16.1 Brown root disease — symptoms

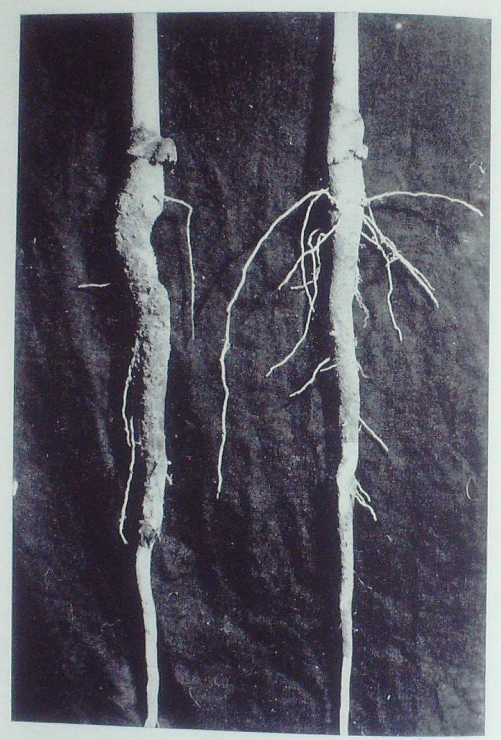


Fig 16.2 Symptoms of brown root disease on nursery plants



Fig 17.1 Sun scorch



Fig 17.2 Fasciation



Fig 18.1 Root grub of the species *H. serrata*

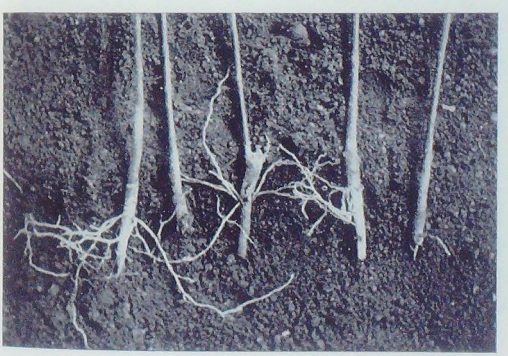


Fig 18.2 Roots of rubber seedlings damaged by root grubs



Fig 18.3 Scale insect

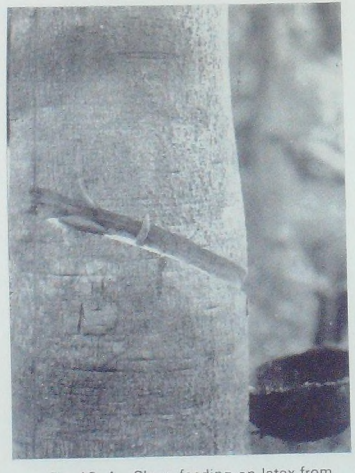


Fig 18.4 Slugs feeding on latex from tapping cut



Fig 18.5 Slugs feeding on latex from collection cup



Fig 18.6 Damage caused by snails on terminal shoots



Fig 18.7 Rubber plant damaged by bandicoot



Fig 18.8 Porcupine damage on bark of rubber tree

be practised in severely rat infested areas and baits should be supplied at points of fresh damage. Pre-baiting with tapioca alone may be done to avoid bait shyness. Burrowing rats can be trapped with country traps. Fumigation of burrows will be impracticable owing to thick growth of cover and weeds.

18.1.3.2 Porcupines

They feed on the bark of mature trees at the base causing ringing effect leading to drying of trees (Fig 18.8). Porcupines damage young plants by pushing out the soil at the collar regions after pulling out the plant and chewing the root. The common species found in India is *Hystrix indica* Kerr. Porcupines are much more intelligent than rats and hence baiting or trapping is very difficult. Killing them by shooting is the only practicable method of control. Porcupines like salt and baiting with poisons like zinc phosphide or Temik 10 G in salt meats can be tried. Arsenic-treated potato also may be used. Wire nets can be used to protect tree bases in porcupine infested areas.

18.1.3.3 Wild pigs, elephants, monkeys, deers etc

Wild pigs damage young rubber plants in nursery and main field by pushing out soil with their snout. Elephants also damage young rubber by trampling and pulling out and chewing the root. They rub their body on mature trees and damage the bark. The entry of both the animals can be prevented in severely affected areas by electric fences powered with 9–12 volt car batteries. Monkeys, bats, tree shrews, squirrels, deers, goats etc are known to damage rubber in Malaysia (8). In India also damage due to them is observed in certain locations.

18.2 Pests of cover crops

Various pests attack the cover crop *Pueraria phaseoloides* but only a few attack *Calopogonium mucunoides, Centrosema pubescens* and *Mimosa invisa.* The most important pests damaging the stem, leaves and inflorescence of *P. phaseoloides* are *Eucomatocera vittata, Pagria signata* and *Maruca testulalis* respectively.

The grubs of *E. vittata* bore into the stem and the portion above the attacked point dries up. The beetles of *P. signata* feed on the leaves and cause a number of small circular white patches which may turn to shot holes in due course. The caterpillars of *M. testulalis* web together the flowers in the inflorescence and feed on them and also bore into the pods. The attacked inflorescence and pods are thus destroyed, reducing seed production considerably.

Since flowers are pollinated by bees, a selective insecticide Endosulfan 0.5 per cent should be sprayed for the control of these pests.

18.3 Pests affecting personnel in rubber estates

Mosquitoes cause considerable health hazard and nuisance in rubber plantations. Stagnant water in pools and tanks should be treated with 0.2 per cent DDT or 0.5 per cent Lebaycid in cheap petroleum oils so as to cover the water surface. Gas escape outlets of septic tanks should be covered with nets to prevent emergence of mosquitoes. Treatments should not be carried out in the case of water resources used for domestic purposes.

Mooply beetle, *Lyprops corticollis* Frm, causes considerable nuisance in the dwellings in rubber plantations. They feed on partially dried leaves of rubber and they multiply in large numbers when large branches or trees snap down. Such falling branches and trees should be scouted regularly in the months of April–July and sprayed with 0.2 per cent DDT.

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19 PLANT PROTECTION EQUIPMENTS

Chapter 19

PLANT PROTECTION EQUIPMENTS

As rubber plants are ravaged by various diseases and pests, it is necessary to use many plant protection equipments for their control. Those used in rubber plantations include sprayers, dusters, fogging equipments and pressure injectors.

19.1 Sprayers

19.1.1 High volume sprayers

19.1.1.1 Rocker sprayer

This is a portable high volume sprayer usually developing pressure up to 36 kg/cm^2. There are two types, one with single discharge line and the other with two discharge lines. These sprayers are ideal for plantations, orchards and farms. In rubber plantations rocker sprayers are mainly used for spraying Bordeaux mixture. Double action rocker sprayers with bamboo extension lances are particularly useful for spraying mature trees. The effective coverage for rocker sprayers is only 0.4 ha/day; hence one sprayer can cover only 14–16 ha during one season. For effective spraying of mature trees, the worker has to climb all trees.

The sprayer has a suction pump, fixed on a wooden platform and connected to a long handle at one end and to a pressure chamber at the other end. A 2 m long suction hose is connected with the pump. Delivery hose at the required length is fixed at the base of the pressure chamber. A suitable lance with a duromist spray nozzle is attached to the delivery hose. In the case of sprayers

with two discharge lines, two suction pumps with two plungers working in opposite directions are fixed on the wooden platform. The handle and pressure chamber are fixed in the middle of the two pumps. The rocking movement of the handle back and forth builds up pressure in the pressure chamber which forces out the sucked spray liquid through the nozzle (2, 3).

19.1.1.2 Knap-sack sprayer

This is a compressed air sprayer which can be carried on the back or shoulder of the operator. It has a tank which contains the spray liquid and air. The container is made generally of galvanised iron, stainless steel, copper, brass or plastic and its capacity ranges from 2.5 – 18.0 l. It has a pump with a handle, pressure guage, air release valve, spray liquid filling port, air jet agitator, spray lance with nozzles and release and shut-off devices. In the case of pressure retaining knap-sack sprayers, the pump assembly is a separate unit.

The container is filled usually to three-fourths of its capacity and air is pumped by the hand pump. The pressure of compressed air forces the liquid through a nozzle from which it comes out in the form of a spray. The working pressure of this sprayer ranges from 9.0 –12.8 kg/cm^2. In the case of rubber, it is mostly used for the plant protection work in nurseries and on young plants (2,3).

19.1.1.3 DSP (double suction pump) sprayer

This sturdy sprayer is used for spraying Bordeaux mixture on mature trees. It is a hand operated sprayer. It consists of a suction pump, pressure chamber, pressure guage, suction hose and discharge lines. The discharge hoses can be connected to long bamboo lances with nozzles through which the spray liquid is forced out as fine spray. With a team of workers, about 0.4 ha of mature rubber can be covered in a day.

19.1.2 Low volume sprayers

In rubber plantations, these are used for spraying oil-based copper oxychloride dispersed in diluent spray oil. With this type

of sprayers, 30–37 l of fungicide-oil mixture in 1: 5 proportion or 35–43 l of fungicide-oil mixture in 1: 6 proportion can be sprayed per ha of mature rubber.

19.1.2.1 Mini micron sprayer

This is a mistifier type of power sprayer. In addition to the engine, the sprayer consists of a large impeller fan. The impeller is placed inside the body at its base. The body projects up like a tube to lead the air currents up. An atomiser is fitted in the centre of the tubular body at its top. The fungicide mixture is kept in a separate container. The container is connected with a pressure hose and a delivery hose. The top of the delivery hose is connected at the base of the atomiser. When the engine works, the atomiser turns at a speed of up to 25,000 rpm as a result of the air currents produced by the impeller. Owing to the pressure build up in the container, the fungicide mixture is forced up through the delivery hose, atomised into fine particles in the atomiser and forced up by the strong air blast to the surface to be sprayed. This sprayer is suitable for spraying plants having heights of 15–17 m. For still taller plants, micron sprayers can be used. About 4–5 ha of mature rubber can be sprayed with one mini micron sprayer per day. For operating this sprayer, four workers may have to be engaged. Since suitable small engines are not indigenously available, mini micron sprayers are not being manufactured in India now (7).

19.1.2.2 Micron sprayer

This is also a mistifier type of power sprayer working with a petrol engine. This type of sprayers have been developed to apply insecticides and fungicides on tall trees up to 27–32 m height. This sprayer has a pump which forces the spray material through an atomiser or a group of nozzles into the air stream produced by a fan. The air stream assists in breaking up the liquid into very fine droplets. The air stream also prevents the drops from combining and carries them far on to the object requiring treatment.

There are different types of micron sprayers like Duster-cum-sprayer and Micron 420. By engaging four workers one micron sprayer can cover 6–8 ha of mature rubber in a day (2, 3).

19.1.2.3 Aerial spraying

Spraying from the air on crops against pests, weeds and diseases has become popular now. Small, fixed-wing, single-engine air craft with 100–450 hp and helicopters are usually employed for this purpose. Such an air craft has a capacity of 200–1000 l with a delivery control valve fitted in the cockpit and a spray boom with low volume nozzles or other types of spraying attachments. The flow of the spray liquid into the delivery system is generally by the gravity method or sometimes under pressure.

Aerial spraying of rubber, with helicopters using oil-based copper fungicides dispersed in diluent spray oil, has now become an accepted practice. About 200–300 ha of mature rubber can be sprayed per day with one helicopter depending on the weather conditions. These helicopters are fitted with two tanks, each with a capacity of about 150 l, one on either side, which hold the spray mixture. The assembly utilizes the air blast of the cooling fan of the helicopter engine to atomise the mixture delivered at a pressure 2.8 kg/cm^2 from a centrifugal pump through various types of nozzles. These nozzles are arranged on the boom which is fitted just behind the engine. Normally, the boom length is 15 m and the swath width is 30 m. By increasing the length of the boom and number of nozzles, the swath width can be increased (4, 6).

19.2 Dusters

Insecticides and fungicides in powder form are applied evenly by means of dusters. Mainly two types are available, the hand operated and the power driven.

19.2.1 Hand operated duster

19.2.1.1 Plunger type duster

This is used specially for dusting plants in small areas without much waste of pesticides. Plunger dusters are made up of an air pump, a dust chamber and a discharge assembly consisting of a straight tube with nozzle or a deflector cap provided at the end of the dust chamber.

19.2.1.2 Crank type duster

This is also known as rotary duster and is used extensively in India for the application of pesticidal dusts on a field scale. One such machine can cover 1–2 ha/day. The equipment is available in two designs, one that can be mounted on the shoulder and the other which can rest on the belly. The duster is operated by means of a handle connected with gears which drive the fan at a high speed. The dust flows continuously so long as the handle is moved. The fan draws the dust from the dust chamber and discharges it into the delivery pipe from where it is blown out through one-row or two-row nozzles. The dust chamber has a capacity of about 3.5–4.0 kg and it is provided with a mechanical agitator connected with one of the gears and an adjustable feeding mechanism.

19.2.1.3 Knap-sack type duster

The knap-sack duster is designed for carrying on the back and is operated by means of a handle provided on the side of the dust chamber. The discharge from this type of duster is intermittent, since the dust comes out after each stroke of the handle. The air blast is developed by the bellows to which the handle is connected and it draws the dust from the dust chamber into the delivery pipe through which it is discharged outside. Knap-sack dusters are more suitable for spot application of dust.

19.2.2 Power-driven duster

A power-driven dusting machine comprises a hopper containing one or more agitators, a regulator for controlling the discharge of dust, a fan or blower producing an air blast for drawing in the dust from the hopper and blowing it out and a flexible discharge line. The hopper is provided with a mechanical type of agitator which prevents the caking of the dust and assures a constant and uniform feed to the fan. The dust regulating device can adjust the dust flow at any desired rate between 1–8 kg/min. Power dusters for trees have one out let connected with a long vertical pipe which directs the dust upwards to the tree tops. A power duster with one outlet can dust 12–16 ha/day, depending on the crop height and dosage.

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For dusting in rubber plantations, power dusters like Mistral II A B, Shaw duster-cum-sprayer and Aspee tree duster are being used (7).

19.3 Fogging Equipments

Fog generating equipments have been very recently introduced in rubber plantations for plant protection work. These convert insecticides or fungicides into fumes or fog. There are different equipments like Rat fumigation pump and Fogging equipments (2,3,5). Fogging equipments include Tart fogging equipment, Tiga fogging equipment, Microsal mechanical fog generator and Pulsfog. It is reported from Malaysia that 4.7 per cent oil-based Calixin, fogged thrice at 10–12 days intervals, controlled powdery mildew disease as effctively as four to five weekly rounds of sulphur dusting. A pre-monsoon fog of 21 per cent Copper-in-oil or 50 per cent oil-based Difolatan against *Phytophthora* leaf fall and pod rot proved to be more effective than the low volume spray of the standrad oil-based copper fungicide from the ground (1). Since weather conditions in India are different from those of Malaysia, field experiments on fogging are being conducted to assess the efficacy of this equipment for the control of abnormal leaf fall and powdery mildew diseases of rubber.

19.4 Pressure injectors

Pressure injectors are equipments used for injecting systemic insecticides, fungicides and nutrients into the conducting vessels of tree crops. The desirability of injecting fluids into trees for protection and treatment against plant diseases and pests and for correction of mineral deficiency had been recognised for some time. The equipment using air pressure is useful in injecting large volumes of relatively dilute solutions. The portable machine consists of a compressed air tank, made of brass, of 12 l capacity to hold the chemical solution, connected by hose to a hollow lag screw by means of a quick connect coupling to allow rapid set up of the equipment. For ensuring uniform translocation of the solution injected, the machine can be connected with three hoses. A pressure guage to read 10.5 kg/cm^2 is connected to the tank. Each injection unit consists of

pressure hose, pipe, nipple, quick connect coupling and lag screw provided with a shut off valve to control the flow of liquid through the unit. For injection, the solution is taken in the tank, shut off valves closed after expelling the air, and the tank pressurised up to 5.6 kg/cm^2 . Three holes, 5–8 cm deep, are bored on the trunk of the tree at about 1.5 m height at three equidistant points using an auger, the lag screws are screwed in slowly down to the minimum depth into the wood at which the screws could get a firm hold and then the supply hoses are coupled to the screws. The tank is held at a higher position above the injection holes and tied to the trunk. The valves are turned on. A chamber is created in the tree where the injected fluid comes in contact with the conducting system of the tree and is forced up owing to the air pressure. This equipment is being tested on rubber for the control of various diseases (8).

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20 COLLECTION AND PROCESSING OF THE CROP

Chapter 20

COLLECTION AND PROCESSING OF THE CROP: GENERAL CONSIDERATIONS

Seventy to eightyfive per cent of the crop harvested from rubber plantations is in the form of latex. The remaining portion is collected in coagulated forms which are collecitvely known as field coagulum rubbers or scrap rubbers. All forms of coagulated rubber collected from the field such as those removed from the collection cup (cup lump, shell scrap or cup scrap), tapping cut (lace scrap, curly scrap or panel scrap), trunk of the tree (dried rubber from the latex overflowed from the cut), those scraped and collected from the cup once in an year (black shell) and even those from the ground beneath the collection cup (earth scrap) are included under this category.

20.1 Micro-organisms in latex and their importance

Latex in the latex vessels of rubber tree is sterile, but as it comes out, it gets contaminated by bacteria and yeasts from tapping knife, tapping panel, spout and collection cups. About 20 per cent of the bacterial population in field latex is from the tapping cut, 20 per cent from the spout and 60 per cent from collection cups. Field latex, after routine collection, contains 10,000–10,00,000 bacteria and 10–100 yeasts per ml (6). The population may be slightly higher in stimulated trees. These organisms proliferate at the expense of the non-rubber constituents of latex, producing organic acids capable of coagulating latex. Increase in bacterial population to about a billion cells per ml of latex is sufficient to cause premature coagulation (pre-coagulation).

20.2 Short-term preservation

20.2.1 Pre-coagulation

Pre-coagulation is the coagulation of latex in collection cup, collecting utensils or bulking tank, before processing. Normally, this is due to the activity of micro-organisms present in latex, but it can also be caused by the peculiar chemical composition of latex. In normal latex, coagulation takes place after four to six hours of collection. But latex harvested under certain climatic conditions and that extracted from certain clones show a tendency for pre-coagulation. This is also observed in latex obtained from newly opened trees.

20.2.1.1 Influence of wintering

High magnesium content in latex tends to coagulate it. The increase in magnesium content in latex prior to wintering, therefore induces pre-coagulation. During wintering, leaves are shed and more sunlight reaches the latex, and this condition also gives rise to increased pre-coagulation (4).

20.2.1.2 Clonal susceptibility

High magnesium content in latex favours growth of bacteria and also accelerates chemical coagulation. Clones having high magnesium content in latex are GI 1. Tjir 1, Tjir 16, LCB 1320 and occasionally PB 86. Young trees, during the first two or three years after opening, also show high magnesium content in latex.

20.2.1.3. Rain water contamination

Rain water running down the trunk of the trees carries into the latex tannins and micro-organisms which induce pre-coagulation.

20.2.2 Anti-coagulants

Coagulation of latex, either during collection or during transportation, is an undesirable process and hence this has to be avoided

for ensuring proper processing. When pre-coagulation occurs in latex, processing it into high quality product (except solid block rubber) is difficult. For preventing pre-coagulation, several anti-coagulants are used. Sodium sulphite, ammonia and formalin are the popular anti-coagulants.

20.2.2.1 Choice of anti–coagulant

The main factor in the choice of anti-coagulant is the form into which latex is to be processed after collection. For producing sheet rubber, any of the popular anti-coagulants can be used. Sodium sulphite is generally effective in retarding pre-coagulation, but will not be very useful in cases where pre-coagulation tendency is very high. Ammonia is recommended as general purpose anti–coagulant in such cases. Ammonia can be safely used in latices which are to be processed into concentrated latex. In the production of pale latex crepe, this is likely to give slight discolouration. In processing into sheet also, use of excess ammonia creates problems during acid coagulation.

In the production of technically specified solid block rubbers the trend towards greater centralised processing has necessitated transport of latex over longer distances. Even though ammonia is found to be the most satisfactory and efficient preservative for field latex, the high levels of ammonia needed create problems at the coagulation and drying stages. So anti-coagulants which do not have these disadvantages have been developed. Two such anti-coagulant combinations are hydroxylamine-ammonia and boric acid-ammonia.

Formalin is not generally used in latices which are to be used in the production of pale latex crepe (PLC) or concentrated latex. In the case of PLC, it may create discolouration on the crepe while in the case of concentrated latex, it may react with ammonia which is used as preservative for concentrated latices. If this anti-coagulant is used in sheet rubber processing, there is no need for adding higher than normal dose of acid for coagulation purpose.

20.2.2.2 Sodium sulphite

This chemical is available commercially as a white powder. The powder is not stable under tropical conditions and it should be

stored in a cool place in air-tight containers. Stock solution is prepared by dissolving 50 g of the chemical in 1 l of water, which gives a 5 per cent solution. For 10 l of field latex 100 ml of this stock solution is adequate for giving anti-coagulant action. This provides a concentration of 0.05 per cent sodium sulphite on the volume of latex. Excessive use of sodium sulphite in latex retards drying of sheet rubber and gives rise to tackiness which is different from that observed on oxidised sheet rubber. Tackiness observed in such cases is due to the absorption of moisture by residual salts which remain on the surface of rubber sheets.

20.2.2.3 Ammonia

Ammonia is available in large cylinder, usually containing around 45–50 kg as liquified gas. Stock solution is prepared from this by dissolving 1 kg of the gas in 100 l of water, which gives a 1 per cent solution. Ammonia is also available in bottles as liquor ammonia which is usually a 20 per cent solution in water. From this a 1 per cent stock solution is prepared by taking 50 ml and diluting it to 1 l using good quality water. For use as an anti-coagulant, 0.01 per cent ammonia should be present on volume of latex. To 10 l of latex, 100 ml of 1 per cent stock solution should be added to get this concentration.

Ammonia evaporates on exposure to air from solutions and, therefore, it should be kept in tightly stoppered bottles. Unopened drums of ammonia solution should be stored in the coolest place available and immersed in cold water overnight before being opened. While ammonia bottles are opened, the stopper may be loosened slowly, allowing the gas pressure inside to get released step by step. If the stopper is pulled out carelessly, the whole liquid may come out forcefully and fall on the face of the person handling it. While opening the bottle, it should be kept in the left hand in an inclined position, keeping its mouth away from the operator. It is also advisable for the operator to keep his face away from the direction of opening. Similar precautions are to be observed while closing or opening ammonia cylinders. It is advisable for persons handling concentrated ammonia solution or ammonia gas to wear goggles. The concentrated solution is toxic and parts of the body coming into

contact with it should be profusely washed in running water immediately and further medical attention may be sought if irritation in the affected portion persists.

20.2.2.4 Formalin

Formalin is commercially available as an approximately 38 per cent solution of formaldehyde. The solution gets oxidised slowly to form an acid and so before use, it is advisable to neutralise any acid present in it by adding a little sodium carbonate or sodium sulphite. The neutralising point can be judged by using a litmus paper which turns blue in alkaline and red in acid solutions.

An approximately 1 per cent stock solution of formaldehyde can be prepared by adding 25 ml of formalin to 1 l of water. For providing good anticoagulant action, 0.02 per cent formalin has to be present on volume of latex. If 200 ml of the stock solution is added to 10 1 of field latex, the effective concentration on volume of latex is 0.02 per cent. For latices which show high tendency for pre-coagulation, a combination of formalin and sodium sulphite gives very good anti-coagulant action. In this case, the field latex to be treated should contain 0.02 per cent sodium sulphite and 0.02 per cent formaldehyde.

20.2.2.5 Hydroxylamine-ammonia system

Hydroxylamine is a bactericide, but does not preserve field latex. Ammonia is a bactericide and a strong alkali. Hydroxylamine salt is genreally used and its acidity is neutralised by use of ammonia. Best result with hydroxylamine neutral sulphate (HNS) is obtained when a level of 0.15 per cent of it on dry rubber content is employed in latex. For producing constant viscosity rubber also, the same level of hydroxylamine salt is used.

The combination of hydroxylamine neutral sulphate and ammonia has to be prepared as one stock solution. The stock solution should be prepared on the day prior to its use. The concentrations to be used in latices from different sources have been assessed by detailed studies (3) and are given in Table 20.1

Table 20.1

Recommended hydroxylamine-ammonia preservation system

Percentage weight of HNS on rubber content of latex	Percentage weight of ammonia on volume of latex	Duration of preservstion (h)	
		latex from estate	Latex from smallholding
0.15	0.03	11	5
0.15	0.05	11 – 19	5 – 11
0.15	0.07	19 – 30	11 – 20

20.2.2.6 Boric acid-ammonia system

Boric acid is at present used as a short-term preservative for field latex. It is, however, not as effective as ammonia. Its principal advantage is that, unlike ammonia, it does not discolour rubber even when used at higher levels. A combination of boric acid and ammonia is found to be useful for short-term preservation of latices used in the production of light coloured rubber. Combination of 0.4–0.5 per cent boric acid with 0.07 per cent ammonia (on latex volume) was found to give the same preservative efficiency as that provided by 0.17 per cent ammonia (3). The dosage of ammonia and boric acid varies depending on the source of latex and can be determined after necessary trials.

20.3 Collection and transportation of latex and field coagulum rubbers

20.3.1 Collection cups

Coconut shell, 'chiratta' (lower half), is the most popular type of collection cup used in rubber plantations in India. This is readily available at reasonable price in the traditional rubber growing areas. Porcelain, aluminium or glass cups are cleaner, but costlier. These

are, however, subject to pilferage. The shell cups are cleaned to remove fibres and other forms of dirt before use. In the course of an year, the shell picks up dirt and the rubber sticking to its sides gets oxidised. The original brownish colour of the shell changes, during this period, to black. It is preferable to replace the shell at this stage. The replacement becomes necessary every year and it is normally done during the resumption of tapping after the resting period. Dirty cups are a source of contamination leading to pre-coagulation in the field and fermentation and mould infection in the factory. Collection cup should not be thrown to the ground, as it may get contaminated with soil or other foreign particles. It is possible to keep the cup in the cup-hanger itself fixed to the tree. If this is not possible, as is the case when the bark near to the base of the tree is tapped, it should be kept inverted on wooden pegs driven to the ground close to each tree. Cup should not be kept in position until the tapping operation is completed, as otherwise the bark shavings may get into the cups and thereby into latex. Some of the high yielding clones produce large quantity of latex per tree per tap and the normal coconut shell is not large enough to hold latex from such trees. In such cases, it is customary to use more than one cup, one below the other. In some Malaysian estates, collection of latex from several tappings is done in ploythene bags fixed to the trees and containing small amount of coagulant to start with. The latex collected in such bags gets coagulated and the coagulum is removed periodically for processing, mostly into solid block rubber. The use of polythene bag for collection of crop has not so far been adopted in India.

20.3.2 Buckets or other containers for collection

Bucket or other suitable container made of galvanised iron is mostly used for collecting latex from the field. The container should be washed thoroughly after use. There is no difficulty in cleaning if this is done immediately after use. If the latex gets dried up inside the vessel, washing will be difficult. Unclean bucket may induce pre-coagulation. In estate practice, tappers use two types of containers for collection, a small bucket for taking latex from trees and a big bucket or other container for pouring such collections and transporting to the processing factory.

20.3.3 Collection of latex

Flow of latex usually ceases 1.5–3.0 h after tapping. In some high yielding clones, dripping continues even after this period, but the rate of flow is greatly diminished. Latex should be collected from the trees when the flow ceases or when the rate of flow is very slow. During rainy days, latex is sometimes collected earlier for preventing possible wash off or contamination of latex with rain water. Latex is transferred from collection cups to buckets by pouring followed by wiping with thumb and forefinger (Fig 20.1). Buckets containing latex collected from the field should not be kept exposed to sunlight.

20.3.4 Collection of field coagulum rubbers

Different forms of field coagulum rubbers like lace scrap, cup scrap and other lower grades may constitute 15 – 30 per cent of the total crop from rubber estate. Lace scrap should be removed from the tapping cut before tapping. The coagula removed from the collection cup and tapping cut are kept inside the basket carried by the tapper. The lace scrap pulled out from the tapping cut is more susceptible to oxidation as it remains exposed to atmosphere as a thin film. Moreover, because it remains attached to the bark, contamination by pro-oxidants present in bark (eg manganese) is also more. In high yielding clones, the quantity of coagulum in the collection cups is generally more. This phenomenon is observed in stimulated trees also and is due to late dripping noticed in both cases. Daily tapping as well as double-cut or full spiral tapping may also induce late dripping. The field coagulum rubbers should be sorted and stored separately. It is preferable to process them when fresh. Processing of wet coagulum ensures proper dirt removal and provides better colour to the processed rubber. When coagulum rubbers are to be stored, they should be dried in smoke house. Exposing scrap rubbers to sunlight or soaking them in water for long periods may accelerate degradation.

20.3.5 Transportation of latex

In small and medium size rubber estates in India, transportation of crop collected to processing factories is easily managed as the distance between any one field of the estate and the processing factory

is not much. Generally, the tappers deliver the latex to the processing factory direct by carrying it in buckets or other containers (Fig 20.2). Larger estates have collection centres in suitable locations in the field. Latex received in collection centres is transported to processing factories usually in tanks (Fig 20.4) or large churns made of aluminium or suitably coated mild steel in trucks, tractor or jeep trailors. A suitable overhead carrier fixed over the tanks can take the field coagulum rubbers also.

20.4 Pre-processing operation

20.4.1 Weighing

Latex received in the processing factory is weighed and the quantity of crop brought by each tapper is separately recorded.

20.4.2 Estimation of dry rubber content (drc)

Rubber and non-rubber content in latices vary according to season, soil and atmospheric conditions, clone, stimulation practices, tapping system etc. The quantity of rubber present in latex is calculated from its drc. This is defined as the quantity in g of rubber present in 100 g of latex. The drc of latex falls in the range of 30–40. Generally, a drc 35 is taken as an average figure for field latex. Corect determination of drc is important as in many estates, the wages paid to tappers are linked to the quantity of dry rubber brought by them. Besides, some estates and small plantations sell rubber in latex stage itself. Many methods have been developed for the determination of drc of field latex.

20.4.2.1 Standard laboratory method

About 10–15 g of a representative sample of the latex is accurately weighed by the difference method into a suitable glass, porcelain or aluminium container from a stoppered 50 ml Erlenmeyer flask. The latex is coagulated with sufficient quantity of acetic acid and heated over a steam bath until a clear serum is obtained. The coagulum is thoroughly washed, rolled to a thickness of 2 mm, and placed in a thermostatically controlled oven at about 70°C for 16 h. The dried

rubber obtained is cooled in a desiccator and weighed in an analytical balance. Several methods have been evolved for reducing the drying time. The most popular among them is the one using methylated spirit at the stage of coagulation of latex. Instead of using acetic acid, a mixture of 90–95 parts by weight of methylated spirit and 5–10 parts by weight of acetic acid is used for coagulation and the quantity of latex used for drc estimation is reduced to 3–4 g (1).

Another popular method used in the estimation of drc is the dipper method (1). In this, a dipper calibrated to deliver a definite quantity of latex is immersed slowly into the sample of given latex. This is then transferred to a dish, adequate quantity of 2 per cent acetic acid added and warmed over a steam bath until coagulation is complete and a clear serum is obtained. The coagulum is washed and rolled into a thickness of about 2 mm and dried in an oven at 70°C for about 16 h. The dry rubber obtained is cooled in a desiccator and weighed. There are several modifications to the dipper method for reducing the drying time.

20.4.2.2 Hydrometric method (metrolac method)

The most rapid and common method used in estates for drc estimations is the hydrometric method. In this method, two parts by weight of water are added to one part by weight of field latex. The diluted latex is filled in a cylindrical jar having a little more diameter than the metrolac. Excess latex and froth are removed by blowing through the surface. The metrolac is then immersed in latex, taking care to see that the graduated stem is just immersed in latex and that the reading gets stabilised (Fig 20.3). The reading on the stem is noted. Verification is done by repeating the process. The drc of latex is obtained by multiplying the reading by three.

Although this method is widely used in different estates, the values obtained using this method are not very accurate. Very often, the values will show variations in the range of 5–10 per cent. Investigations have been carried out to standardise the use of metrolac in drc esitmation (5, 7). Correlation has been established between metrolac drc and actual drc (5).

20.4.3 Sieving and bulking

Latex collected from the field is liable to contamination with bark shavings, dry leaves, small clots of rubber coagulum or extraneous impurities like sand particles. For removing these, it is sieved first through a 40 mesh and then a 60 mesh sieve. Sieves are usually made of monel metal, aluminium or stainless steel.

Latices received at the factory from different fields generally vary in their properties. So, for providing uniformity, it is necessary to bulk all the latices in a common tank called bulking tank. Bulking operation is also useful in removing sedimentable impurities in latex.

Latex collected from various fields or plantations differ in colour, viscosity, drc, susceptibility to enzymic action,molecular weight etc. This variability is due to differences in planting material, age of the tree, intensity of tapping, application of stimulants, soil and weather conditions etc. Hence for getting sheets of uniform quality, it is essential that the latices from different fields are blended together. This is done by mixing the latex uniformly in bulking tanks which may be of brick work or concrete, lined inside with glazed tiles. Aluminium tanks can also be used for this purpose. A tap fixed slightly above the bottom of the tank will be helpful to transfer the bulked and diluted latex without disturbing the sediments.

20.5 Maketable forms of natural rubber and machinery and utilities required for processing

The crop from rubber tree is highly susceptible to degradation on keeping. Latex or the different field coagulum rubbers are not generally used as such for the manufacture of rubber goods. So processing of the crop into forms that allow easy storage, transportation and utilisation by manufacturing industries is a necessity. Latex can be processed into any of the following forms:

(i) Ribbed smoked sheet or air dried sheet;

(ii) Pale latex crepe and sole crepe;

(iii) Solid block rubbers and different types of speciality rubbers; and

(iv) Preserved field latex or latex concentrate.

Field coagulum rubbers are processed into any of the following forms.

(i) Estate brown crepes; and

(ii) Solid block rubber

Details of the methods adopted for processing into the above marketable forms are described in subsequent chapters.

20.6 Choice of processing method

The prime objective of processing the crop from rubber plantation is to get maximum return from the produce. Therefore, the type of processing selected must be helpful to provide an assured return to the producer throughout the year. The various factors that are to be considered for selecting the most appropriate processing method are discussed below.

20.6.1 Present and potential demand and prices for the various marketable forms and their relative cost of production

Concentrated latex is at present the most attractive form of processed rubber from considerations of its price and cost of production. But, the requirement of this grade of rubber in India is only eight per cent of the total consumption. If more estates start this form of processing, the present price attractions to this grade might disappear, if there is no proportionate increase in demand. A few years ago, pale latex crepe was commanding an attractive premium, but today this grade gets hardly any premium.

20.6.2 Size of plantations and their production

For small plantations, it is preferable to adopt sheet rubber processing method. Even in such cases, it may be advantageous to sell latex as such to latex processing units if there are dependable

agencies for buying this. On an average, the cost of production of top quality ribbed smoked sheets amounts to Rs.1250/t. When the production of rubber in an estate is above 2t per day it is desirable to adopt modern processing methods which can process easily such large quanities of crop. Besides, the coagulum grades can also be processed to marketable forms using the same machinery.

20.6.3 Type of planting materials

The type of planting materials in an estate has to be considered while finalising the type of processing to be adopted. This is important especially in the production of concentrated latex or pale latex crepe. Latices derived from clones which are known to contain high magnesium can present problems during latex concentration operation. Similarly, latices from clones like PR 107, showing a tendency for discolouration are unsuitable for the production of good quality pale latex crepe while those from clones like PB 86 are eminently suited for the purpose.

20.6.4 Machinery, utilities and know-how

Before finalising the method of processing, one should also ascertain the availability of machinery, the time required for procuring them and also the problems connected with their operation and maintenance. Availability of know-how and utilities for the processing system selected also should be ensured. Some estates have established facilities for processing rubber into two or more different forms. This is advantageous in that the production of any particular form which is in good demand can be taken up and the overall return of the estate can be enhanced. The only point to be considered here is the capital cost to be incurred for setting up and maintaining such facilities.

20.7 Treatment and disposal of effluents

During the processing of the crop, large quantity of water (approximately 20 l/kg drc) is used for washing, cleaning and for dilution of latex. The serum obtained after coagulation and the water used for washing and cleaning during processing constitute the effluent which is generally discharged into public waterways. This effluent contains small quantity of rubber particles, varying

quantities of proteins, sugars, lipids, carotenoids and inorganic and organic salts. The presence of these materials increases the bio-chemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved and suspended solids and nitrogen content of the receiving waterways. BOD measures the quantity of oxygen utilised by a mixed population of micro-organisms in the aerobic oxidation. COD test, on the other hand, measures the quantity of oxygen required for chemical oxidation of organic matter in the sample to carbon dioxide and water. Thus, high BOD and COD of effluents tend to deplete dissolved oxygen in water and endanger aquatic life. A large population of bacteria is also present in the effluents discharged from the factories. The types of bacteria found in rubber effluent are coliform, *Streptococci* and *E. coli*. Most of the constituents of effluents can act as substrate for the growth of these micro-organisms, thus generating a high BOD and an objectionable odour. Therefore, indiscriminate discharge of effluents to natural streams and rivers is objectionable. Government of India have enacted Pollution Control Act in 1974 and most of the State Governments have already taken steps to implement the provisions of this Act. So all the rubber processing factories in the country are now legally compelled to build-up facilities to ensure that effluents let out to public waterways conform to specifications prescribed by the Water Pollution and Prevention Control Authorities. The specification parameters and their limits for the treated effluent are as shown below:

Parameters	Limit
pH	5.5–9.0
BOD	30
COD	250
Suspended solids	100
Phosphate	5
Ammoniacal nitrogen	50

All values except pH are expressed in mg/l.

20.7.1 Composition of rubber factory effluent

Physical, chemical and bacteriological properties of typical effluents from different types of rubber processing factories are given in Table 20.2 (2). The variations in pH of effluent from different

Table 20.2

The characteristics of different rubber factory effluents

Properties	*latex concentrate**	*Block rubber**	*RSS*	*Remiller*
Physical and chemical				
pH	4.2	6.3	4.9	6.2
Total solids	6040	1000	3750	480
Suspended solids	180	230	140	350
Settleable solids	100	160	50	210
COD	4590	1620	3300	900
BOD	2580	1140	2630	740
Ammoniacal nitrogen	395	55	10	15
Albuminoid nitrogen	85	20	100	10
Bacteriological Log count/ml at 27°C Log count/ml at 27°C	4.55	6.66	5.9	7.13
Presumptive count/100 ml ($\times 10^6$)				
Coliform	0.415	10.655	1.540	41.875
E. Coli	0.024	2.272	0.191	7.487
Streptococci	0.031	6.294	3.127	16.950

All values except pH are expressed as mg/l.

*The effluent from latex concentrate and block rubber factories were partially treated using ponding, pitting or filtering.

types of factories are mainly due to the difference in the quantity of acid used. The high content of total solids, mainly dissolved organic solids, is responsible for the high oxygen demand. Another important characteristic of rubber effluent is the significant level of nitrogen, mainly in the ammoniacal form derived from the preservative used. Therefore, the two potential pollutants in the effluent are organic carbon and ammoniacal nitrogen.

20.7.2 Effluent treatment

Many methods of effluent treatment have been described. These are divided into three basic types, viz physical, chemical and biological (3).

20.7.2.1 Physical and chemical treatments

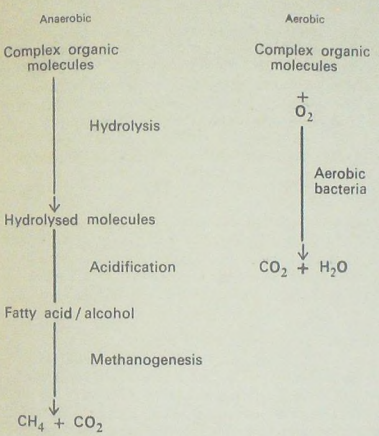
In physical methods, the impurities are separated from effluent without any chemical change. The important methods are filtration, sedimentation, and reverse osmosis. In filtration, the effluent is allowed to pass through a filter bed. In sedimentation, the force of gravity acts on particles heavier than water and causes them to settle whereas reverse osmosis is a membraneous process where concentration of dissolved substances tends to increase on one side of the membrane.

In chemical treatments, the impurities in effluents are separated by chemical means. The important processes are precipitation, flocculation, ion-exchange, oxidation and reduction reactions.

20.7.2.2 Biological treatments

In biological methods, the principle of break-down of organic matter by micro-organisms is made use of. When the effluent contains sufficient dissolved oxygen, complex organic compounds break down into simple compounds such as carbon dioxide and water by the action of aerobic bacteria and the process is described as aerobic. In the absence of dissolved oxygen, this reaction is brought about by anaerobic bacteria and the process is known as anaerobic. Two of the biological treatment systems which have

been evaluated on a large scale in rubber effluents are anaerobic/aerobic ponding system and oxidation ditch system. The former system is simple and economic but requires more land area compared to the latter. Therefore, the anaerobic/aerobic ponding system is more suited for rural areas and oxidation ditch system for urban areas. In ponding system both anaerobic and aerobic break downs occur whereas in the oxidation ditch system only aerobic degradation takes place as indicated below.



The success of methane (CH_4) formation depends mainly on the survival of methano–bacteria. The environmental requirements are pH 6.5–7.5, absence of dissolved oxygen and tolerable level of volatile acids and free ammonia which are known to be toxic to methano-bacteria. Aerobic break-down depends on adequate supply of oxygen. In aerobic pond, the supply of oxygen is obtained

from the photosynthetic activities of algal cells. The conditions required for the growth and survival of algal and bacterial cells are tolerable pH range, sunlight and adequate availability of carbon, nitrogen and phosphorus. In the oxidation ditch system, supply of oxygen is achieved by mechancial aeration.

The ponding system consists of a rubber trap, compositing pond, and anaerobic and aerobic ponds.

The function of the trap is to detain the rubber particles in the effluent. It also removes 60–70 per cent of the total solids thereby reducing its loading rate in the anaerobic pond. The rubber trap should have a holding capacity of at least 12 h retention with proper baffles to induce continuous up and down flow pattern. The length, width and height of each compartment of the trap are usually 1.8 m, 1.5 m and 1.8 m respectively. The total number of compartments is decided by the total quantity of effluent discharged per day.

The purpose of the compositing pond is to average out any fluctuations in pH, BOD loading etc of effluent before discharging into the anaerobic pond. The compositing pond should be designed for operation under anaerobic condition and its depth should be around 3 m. It should have a capacity to retain two days' effluent.

The operating depth of the anaerobic pond can vary from 1.8–3.0 m or more. If possible, anaerobic pond should be excavated as deep as possible to save land space. The pond design should be such that the length is more than twice the width. Further, at least two ponds in series are desirable. The capacity of the pond is decided depending upon the retention period required so that there should not be any overload in the aerobic pond. Excessive scum formation is not desirable, as this may lead to a reduction in effective treatment volumes as well as possible blockage of pipes.

The operating depth of the aerobic pond should not be more than 1 m. Again, the length should be more than twice the width.

It is preferable to have two or three ponds in series. The total capacity of these ponds depends upon the retention time required to reduce the BOD to the desired level. Scum, if any, formed on the surface should be removed to enable complete exposure of surface for penetration of sunlight. This would ensure higher photosynthetic activity of algae which are supplying most of the oxygen required for the breakdown of organic matter.

The rubber trap should be of brick work with cement plastering whereas all the others can be of earth work. The embankments of the ponds should have a slope of at least 30°—45° to prevent any sliding of earth. Turfing the embankments is preferred to the growth of other vegetation.

Optimum retention period in the anaerobic pond for reduction of BOD and removal of pollutants depends on the initial concentration of pollutants in the raw effluent.

The retention time required in the anaerobic and aerobic ponds for treatment of effluents from latex concentrate and block rubber factories can be calculated from the following:

Parameters	Latex concentrate	Block rubber
Optimum loading (P)	120 g BOD/m^3/day	150 g BOD/m^3/day
BOD removal constant (K)	0.061/day	0.017/day

$R = \frac{Li}{P}$ for anaerobic and $R = 1/K \ln Li/Le$ for aerobic treatment, where R is the retention period in days, Li is the BOD of the influent and Le the desired BOD of the final discharge in mg/l. For calculation purpose, Li for the aerobic treatment is assumed to be half that of the raw (untreated) effluent. Examples of retention periods required to reduce BOD of effluent from block rubber and latex concentrate factories to 30 ppm and 250 ppm are given in Tables 20.3 and 20.4.

Table 20.3

Retention period to reduce the BOD to 30 ppm (for discharge to public waterways)

Type of processing	Influent BOD	Retention period (days)	
		Anaerobic	Aerobic
Block rubber	1200	10	26
Latex concentrate	3500	29	67

Table 20.4

Retention periods to reduce BOD to 250 ppm (for land application)

Type of processing	Influent BOD	Retention period (days)	
		Anaerobic	Aerobic
Block rubber	1200	10	7
Latex concentrate	3500	29	32

A schematic layout for ponding system of treatment is shown in Fig 20.5.

The oxidation ditch system consists of a rubber trap, compositing pond, mixing tank, oxidation ditch, sedimentation tank and sludge ponds.

Details of rubber trap and compositing pond are already given. The mixing tank has baffles to mix sludge with effluent before discharging into the oxidation ditch. The oxidation ditch is elliptica in shape and is fitted with an aerator which oxygenates and circulates the effluent. Sedimentation tank is usually cylindrical at the top with

a conical bottom and having about 4–8 h retention capacity. The treated effluent from the oxidation ditch overflows into the sedimentation tank where the sludge settles at the conical bottom. The required quantity of sludge is recycled through mixing tank. The excess sludge is then pumped into the sludge pond where it gets dried up. The clarified supernatant effluent from the sedimentation tank is then allowed to discharge. The flow diagram for the oxidation ditch system is shown in Fig 20.6.

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Latex concentrate	3500	29	67

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21 RIBBED SHEETS

Chapter 21

RIBBED SHEETS

Raw rubber sheets are of various types like ribbed smoked sheets (RSS), air dried sheets (ADS) and sun dried sheets, depending on the method adopted for drying. The operations involved in making RSS and ADS include sieving, bulking and standardisation of latex, addition of chemicals, coagulation, sheeting, dripping and drying. Sieving and bulking operations have already been described in Chapter 20.

21.1 Standardisation of latex

The bulked latex is to be diluted to a standard drc of 12.5 per cent before it is coagulated. Dilution helps in settling denser and finer impurities at a faster rate and in obtaining a softer coagulum which can be easily sheeted. If the dilution is more than the standard value, the wet sheets become thin and porous and on drying, stretch to irregular shapes. The coagulum from undiluted latex is harder and it contains higher quantity of proteins which may appear as 'rust' when the sheet is finally dried. The quantity of water required for diluting the latex to 12.5 per cent drc can be calculated using the following equation:

$$\left.\begin{array}{l}\text{Volume of water to be added}\\ \text{to field latex}\end{array}\right\} = \left(\frac{D \times V}{12.5} - V\right) l$$

where 'D' is the drc of field latex and 'V' its volume in l.

While diluting latex, the buckets used for carrying it may be washed with minimum quantity of water and added to the latex through sieves. Water used for diluting the latex should be free from suspended and dissolved impurities. Table 21.1 gives the quantity of water to be added for diluting latices of different drc.

Table 21.1

Volume of water to be added to latex for pan coagulation (in l)

drc %	Volume of field latex (in l)									
	1	2	3	4	5	6	7	8	9	10
25	1.000	2.000	3.000	4.000	5.000	6.000	7.000	8.000	9.000	10.000
26	1.040	2.080	3.120	4.160	5.200	6.240	7.208	8.320	9.360	10.400
27	1.160	2.320	3.480	4.640	5.800	6.900	8.120	9.280	10.440	11.600
28	1.240	2.480	3.720	4.960	6.200	7.440	8.680	9.920	11.160	12.460
29	1.320	2.640	3.960	5.280	6.600	7.920	9.240	10.560	11.880	13.200
30	1.400	2.800	4.200	5.600	7.000	8.400	9.800	11.200	12.600	14.000
31	1.480	2.960	4.440	5.920	7.400	8.880	10.360	11.840	13.320	14.800
32	1.560	3.120	4.680	6.240	7.800	9.9360	10.920	12.480	14.040	15.600
33	1.600	3.200	4.800	6.400	8.000	9.600	11.200	12.800	14.400	16.000
34	1.720	3.440	5.160	6.880	8.600	10.320	12.040	13.760	15.480	17.200
35	1.800	3.600	5.400	7.200	9.200	10.800	12.600	14.600	16.200	18.000
36	1.880	3.760	5.640	7.520	9.400	11.280	13.160	15.040	16.920	18.800
37	1.960	3.920	5.880	7.840	9.800	11.760	13.720	15.680	17.640	19.600
38	2.040	4.080	6.120	8.160	10.200	12.240	14.280	16.320	18.360	20.040
39	2.120	4.240	6.360	8.480	10.600	12.720	14.84$_0$	16.960	19.080	21.200
40	2.200	4.400	6.600	8.800	11.000	13.200	15.400	17.600	19.800	22.000

eg: Consider a field latex of 36 per cent drc and let the volume of latex be 8 l. The volume of water to be added to the latex for dilution to 12.5 per cent drc will be 15.041

21.2 Addition of chemicals before coagulation

21.2.1 Sodium bisulphite

It is usually observed that the surface of latex coagulum from certain clones like RRIM 502, PB 5/37 and PR 107 is badly darkened. This phenomenon is called discolouration or surface darkening of the coagulum. Enzymes of the polyphenol oxidase type catalyse the oxidation of phenols and amino-phenols, naturally present in latex, by oxygen from the air to give orthoquinones. Orthoquinones react with naturally occuring amino-acids and proteins present in latex to give coloured products resembling melanin (4). Reduced melanin has brown colour and oxidised melanin black colour. Addition of sodium bisulphite to latex prevents this discolouration by preferential reaction with oxygen, getting itself converted into sodium bisulphate in the process. The quantity of this chemical to be used depends on the extent of darkening. Usually 1.2 g of sodium bisulphite are sufficient to treat the latex containing 1 kg dry rubber. Sodium bisulphite is to be added to the diluted latex as a 2 per cent solution and mixed uniformly by thorough stirring using a paddle. Since this chemical decomposes on storage, fresh solution is to be prepared every day. Use of excess quantity of sodium bisulphite may lead to low rate of drying of sheets since the excess chemical which remains on the surface of the coagulum gets converted into sodium bisulphate which is hygroscopic in nature. This may also lead to mould growth on the surface of the dried sheets.

21.2.2 Para-nitrophenol

Another chemical which is added to latex at this stage is para-nitrophenol (PNP) and it prevent mould growth on the surface of the dried sheets. The quantity of PNP required is 0.1 per cent on drc and it has to be added to latex as a 1 per cent solution (1). PNP is toxic and hence its frequent and prolonged contact with skin may be avoided.

Table 21.1

Volume of water to be added to latex for pan coagulation (in l)

drc %	Volume of field latex (in l)									
	1	2	3	4	5	6	7	8	9	10
25	1.000	2.000	3.000	4.000	5.000	6.000	7.000	8.000	9.000	10.000
26	1.040	2.080	3.120	4.160	5.200	6.240	7.208	8.320	9.360	10.400
27	1.160	2.320	3.480	4.640	5.800	6.900	8.120	9.280	10.440	11.600
28	1.240	2.480	3.720	4.960	6.200	7.440	8.680	9.920	11.160	12.460
29	1.320	2.640	3.960	5.280	6.600	7.920	9.240	10.560	11.880	13.200
30	1.400	2.800	4.200	5.600	7.000	8.400	9.800	11.200	12.600	14.000
31	1.480	2.960	4.440	5.920	7.400	8.880	10.360	11.840	13.320	14.800
32	1.560	3.120	4.680	6.240	7.800	9.9360	10.920	12.480	14.040	15.600
33	1.600	3.200	4.800	6.400	8.000	9.600	11.200	12.800	14.400	16.000
34	1.720	3.440	5.160	6.880	8.600	10.320	12.040	13.760	15.480	17.200
35	1.800	3.600	5.400	7.200	9.200	10.800	12.600	14.600	16.200	18.000
36	1.880	3.760	5.640	7.520	9.400	11.280	13.160	15.040	16.920	18.800
37	1.960	3.920	5.880	7.840	9.800	11.760	13.720	15.680	17.640	19.600
38	2.040	4.080	6.120	8.160	10.200	12.240	14.280	16.320	18.360	20.040
39	2.120	4.240	6.360	8.480	10.600	12.720	14.840	16.960	19.080	21.200
40	2.200	4.400	6.600	8.800	11.000	13.200	15.400	17.600	19.800	22.000

eg: Consider a field latex of 36 per cent drc and let the volume of latex be 8 l. The volume of water to be added to the latex for dilution to 12.5 per cent drc will be 15.041

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21.3 Coagulation

This operation consists of transferring the standardised latex into coagulation pans or tanks and adding suitable cogulating agent.

21.3.1 Coagulation pans and tanks

Latex, after the addition of the chemicals, is stirred well and allowed to remain undisturbed in the bulking tank for about 30–40 min. It is then transferred to coagulation pans or tanks without disturbing the sediments. Coagulation of the latex may be done in pans, troughs or tanks. Small growers generally use aluminium pans which are of 40 x 30 x 7 cm size. Four litres of diluted latex are taken in each pan so that the sheet prepared weighs approximately 500 g when dried. Troughs used for coagulation, mostly of aluminium, may be of 150 x 30 x 7.5 cm size. Usually 20–25 l of diluted latex are taken in the trough and coagulated. The coagulation tank commercially available is generally 300 cm long, 90 cm wide, 45 cm deep and made of aluminium or brick work/ concrete construction lined with porcelain tiles. In this case, a wooden frame at the top helps to insert the partition plates at 7.5 cm apart. Usually, coagulation tank is loaded in such a way that the level of latex-acid mixture reaches a height of about 37.5 cm.The slabs of coagulum obtained have a width of 32.5–35.0 cm which when sheeted give sheets of 35–37.5 cm width. The processing capacity of the tanks commercially available is in the range of 120–135 kg dry rubber. The size of the sheets when machined and dried is about 60.0 x 37.5 x 0.3 cm.

21.3.2 Methods of coagulation

Coagulation is the process of destabilisation of latex by some means with a view to recovering rubber from it. There are several methods of coagulation like coagulation by addition of chemicals, natural coagulation and assisted biological coagulation. In the chemical method, several coagulants like acids, metallic salts and alcohols are used. Among these, the popular coagulants are acetic and formic acids. In certain cases, sulphuric and phosphoric acids are also used. Dilute acetic and formic acids produce slow and

uniform coagulation and are easily removed by washing the coagulum during sheeting or are volatalised during drying. Also, these acids are less dangerous than others for handling. Formic acid is preferred as its action is quick and as it possesses light antiseptic properties. The action of acetic acid is slower and therefore it may lead to bubble formation in sheets due to bacterial action. Natural coagulation is a result of production of acid by micro-organisms at the expense of non-rubber constituents in latex. Unpreserved field latex coagulates within a few hours of collection but the coagulum is not sufficiently hard to allow processing until about 40 h. The resultant rubber is fast-curing and it has malodour and lower nitrogen content. Natural coagulation is not complete owing to insufficient production of acid from limited food sources available in latex. Complete coagulation could be accomplished by increasing the sugar level of latex. Sugar-containing materials like molasses, pine apple waste and coconut water were tried for this purpose and found to coagulate latex and this rubber is more or less similar to the acid coagulated rubber in technological properties. The process is called assisted biological coagulation (ABC). Variations in Mooney viscosity and PRI of rubber obtained using different coagulation methods (3) are given in Table21.2.

Table 21.2

Effect of methods of coagulation on Mooney viscosity (ML) and PRI of rubber

Method of coagulation	ML (1+4) 100° C	PRI
Acid	74	96
Natural	92	57
Assisted Biological	82	84

21.3.2.1 Acid coagulation

Coagulation of latex by the addition of acid is due to neutralisation of charge on the protective layer of proteins surrounding the rubber particles. The latex proteins which surround the rubber

particles and which carry the negative charge have an isoelectric point near 4.7 (2). Hence the pH has to be brought to this level for smooth coagulation. For the preparation of sheet rubber a pH of 4.6 is considered ideal. Dilution of acid is necessary for uniform coagulation of latex and for getting sheets free from air bubbles and stickiness. Acetic acid is to be diluted to 1 per cent and formic acid to 0.5 per cent before addition to the latex. Table 21.3 gives the quantity of acid required for preparing 1 kg dry rubber by different methods.

Table 21.3

Acid requirement for coagulation of 8 l of standard latex containing 1 kg dry rubber

Sheeting time	Acetic acid	Formic acid
Next day	6 ml diluted to 600 ml with water	3 ml diluted to 600 ml with water
Same day	8 ml diluted to 800 ml with water	4 ml diluted to 800 ml with water

The required quantity of diluted acid is added to latex and mixed thoroughly by stirring. The froth formed is then skimmed off by a glass plate or wooden piece. If the coagulation is done in tanks, the partition plates are inserted and the tank covered. If the pans are placed one above the other, they should be stacked in the same level (Fig 21.1) to avoid uneven thickness of the coagulum leading to non-uniform drying of sheets.

21.4 Sheeting and dripping

After draining out the serum, the coagulum is washed with water before sheeting. The sheeting rollers consist of a pair of plane rollers and another set of grooved ones. The rollers, usually made of cast iron, are of length 60 cm and diameter 15 cm. On the grooved rollers, grooves are cut at 3 mm intervals with 3 mm width

and depth and at 45° spirals. The design obtained by passing through the grooved rollers helps faster drying of the sheets due to increased surface area. It also helps in separating the dried sheets after they are packed in bundles. The nip of the rollers can be adjusted in such a way that the sheets will have a final thickness of 2.5–3.00 mm after three or four passes through the plane and one through the grooved rollers. For washing, provision is made for continuous flow of water through a line of holes drilled at the lower side of a pipe fitted over the rollers (Fig 21.2). On the surface of the grooved rollers, a mark is embossed for identification.

The sheeting battery consists of a set of three or four pairs of plane rollers and a pair of grooved ones (Fig 21.3). The nips of the plane rollers and grooved rollers are set in decreasing order so that after the final pass through the grooved rollers, the thickness of the coagulum is reduced to 2.5–3.0 mm. The rollers are driven by electric motor.

It is essential that, while sheeting, sufficient quantity of water falls over the coagulum to remove the serum residues and excess chemicals retained. If the serum residues are not washed out thoroughly fungal growth may occur on the sheets. It may also lead to low rate of drying of the sheets. In cases where para–nitrophenol has not been added to the latex to prevent mould growth, the washed sheets are dipped in a 0.1 per cent solution of PNP for about 10–15 min. Generally, 1 kg of PNP will be sufficient to treat 1000 kg dry rubber. The wet sheets are allowed to drip in shade for 1–2 h before they are transferred to smoke houses for producing RSS or te hot chambers for making air dried sheets.

21.5 Drying

Freshly machined and dripped sheets contain about 20 per cent moisture. For the preparation of RSS. these sheets are dried in smoke houses, while for the production of ADS, smokeless drying chambers are used.

21.5.1 Smoking and smoke houses

Drying the sheets in a smoke house has definite advantages. It is quicker than sun drying and does not cause oxidation by ultra-violet

radiation (5). Inside the smoke house there is only limited supply of air and it is mostly filled with smoke and carbon dioxide. Hence chances for oxidation of the rubber are very limited, provided the temperature is within limits. In a hot air drier, the chance for oxidation of the rubber is much more than that in a smoke house. Also, the creosotic substances present in smoke adhere to the surface of the sheets and prevent mould growth on smoked sheets. The requirements of a good smoke house are the following.

(i) The drying cost should be minimum.

(ii) Percentage of defective sheets should be as low as possible.

(iii) Loading and unloading of sheets should be easy and fast.

(iv) Labour required for operating the smoke house should be minimum.

(v) Drying time should be less and the temperature in various zones inside the smoke house should be controllable.

(vi) Continuous operation of the smoke house should be possible.

The smoke house consists of a chamber into which the sheets are loaded either on trolleys carrying reapers or on reapers fitted on a wooden frame work. Smoke is generated in the furnace which is usually outside the chamber and smoke and hot air from the furnace are directed into the chamber through flue. Air inlets and ventilators are provided at the bottom and top of the chamber respectively. These can be opened or closed for controlling temperature. Temperature can also be regulated by adjusting the rate of burning of the firewood or by opening or closing the air inlets at the furnace door. A damper is usually provided at the main flue outlet, as a safety measure to prevent fire entering the chamber if any one opens the furnace door. The building may be of brick work construction with a reinforced concrete frame. The smoke house should be provided with adequate drainage to facilitate removal of serum from the drying chamber. The roof and ceiling may be of asbestos sheets and the gap between the roof and ceiling at the top of the walls should be closed from all the four sides of the smoke house, so as to avoid heat

loss due to air current over the ceiling and to prevent condensed moisture from smoke dripping on sheets. Smoke houses are of two types, those in which the furnace is inside the drying chamber and those in which the furnace is outside the drying chamber.

21.5.1.1 Smoke houses with furnace inside the drying chamber

Smoke houses of the pit-fired type and trolley box type which are used in Sri Lanka come under this. In the pit-fired type, smoke is generated by firing wood in a central pit which is inside the smoke house. A thick-guage galvanised iron sheet, slightly larger in size than the mouth of the pit, is fixed at 25 cm above so as to spread the smoke. The sheets are hung inside the chamber and a minimum space of 180 cm between fire and the bottom of the sheet is given to avoid over-heating of the sheet near the pit. In the trolley box furnace type, smoke is generated in a fire trolley on wheels. The advantage of this type of smoke house over the pit-fired type is that the smoke house can be kept clean since operations like loading the fire wood and removing the ash can be done outside the smoke house.

21.5.1.2 Smoke houses with furnace outside the drying chamber

There are two types of smoke houses with external furnaces, the ground floor type and the tunnel type. In the ground floor type smoke house, the smoke from the furnace is directed to the centre of the smoking chamber. The sheets are hung on reapers fitted on a wooden frame work (Fig 21.4). Fresh sheets after dripping are put on reapers near the ground and on the next day they are taken from the lower reapers and hung on the upper ones. The usual drying time in this type of smoke house is four to five days. The disadvantages of this type of smoke house are that only batchwise operation is possible and more labour will be required, since the sheets are to be changed from the reapers every day.

RRIM tunnel type smoke house meets almost all requirements of an ideal smoke house. There are four types of RRIM tunnel type smoke houses designated as 1100, 2200, 3300 and 4400 corresponding to the nominal capacity in lb/day. The drying chamber

of the 1100 type smoke house has 8.0 m length, 2.5 m width and 3.0 m height. A light rail track is laid at the centre of the chamber and the trolleys are accommodated inside the chamber and each trolley carries one day's crop. The floor at the cooler end is sloped by 5 cm from the centre of the rails to the side drains and the side drains are sloped 5 cm in 3 m to give rapid elimination of the serum from the drying chamber. The roof and the ceiling are made of asbestos sheets and the gap between the roof and ceiling is closed. The furnace consists of a steel arch frame enclosed in a box type case with side walls of single brick work and top with reinforced concrete. The furnace arch slopes upwards from the furnace door to the flue outlets. The flue outlets open in the main chamber at various points at the centre line of the rail track over which the trolleys carrying the sheets move. Firewood is placed on fire bars arranged at the bottom of the furnace. On the furnace door, there are six ventilation holes of 5 cm diameter at 23.0 cm height from the floor and 8 saw cuts each 15 cm long and 23.0 cm away from the neighbouring two sides. The trolleys are made of M.S. angles and are of five tier construction. Each tier can accommodate 40 reapers. The reapers, having 34–35 mm diameter, are placed at a spacing of 75 mm. They are made of either wood or bamboo. Baffles are provided on the trucks at about 50 mm above the chasis of the truck to avoid drip water from the sheets falling into the flue outlets.

The trolley carrying wet sheets enters the chamber at its cooler end is gradually pushed towards the hotter end as the sheets get dried. The ventilators at the top should be kept open to allow the moist air to escape. The temperature of the smoke house is to be kept at 57° – 60°C by adjusting the flue outlets, furnace door apertures, roof ventilators and air inlets on the furnace door. Firewood used for smoking should be quite dry and depending on the nature of firewood used, 500–1000 g are required to dry wet sheets containing 1000 g dry rubber. The normal drying period is four days. It is better to provide a maximum-minimum thermometer in the smoke house to note variations in temperature. Alternatively, a thermometer with recording device kept outside the chamber can also be used. The capacity of the smoke house should be large enough to accommodate four days' complete crop.

21.5.2 Air drying and drying chambers

The sheets dried in a heated drying chamber are called air dried sheets (ADS). The chamber is heated by blowing air over a set of electric heaters or radiators to which steam is supplied from a a boiler. The temperature inside the drying chamber is controlled thermostatically in the range of 62°–65°C. The number of radiators/ electric heaters required depends on the capacity of the drying chamber. During the first two days of drying, the temperature has to be limited to 37° – 40°C as otherwise the sheets may have a darker shade. During the last two days, the temperature is raised to 62° – 65°C. If the design of the chamber is tunnel type, intended for continuous operation, then the temperature at the hot end of the tunnel is maintained at 62.5°C and that at the cooler end at 37.5°C.

21.6 Power and water requirements

Power and water requirements in sheet rubber processing units are comparatively low. In factories using hand driven rollers, there is no requirement of electric power. But water is needed for diluting latex, washing the coagula and for cleaning various utensils used for handling latex as well as the floor of the factory. Approximately 20–30 l of water are needed for producing 1 kg dry sheet rubber. In factories using sheeting batteries, electric power requirement depends on the size of battery. For smaller units 3 HP motors are found to be adequate. For bigger ones 5.0–7.5 HP motors are used. Water consumption is in the same rate as mentioned earlier.

21.7 Defects in sheet rubber

Defects of one type or other may appear on some of the sheets. These may be either of microbial origin or due to other reasons.

21.7.1 Defects of microbial origin

Sheet rubber produced under unhygenic conditions or stored in an improper way are liable to defects of microbial origin which include pin head bubbles, rust, discolouration and mould growth.

21.7.1.1 Pin head bubbles

Bubbles of bacterial origin in sheet rubber are like pin heads and in clusters all over the sheets. The presence of gas forming bacteria and acid coagulation above pH 4.8 which favour bacterial multiplication are responsible for this. Frequent washing of utensils used for handling latex with a dilute solution of formalin or lysol and addition of sodium sulphite into latex in the field help to check bacterial growth. Addition of sufficient acid to bring the pH of coagulation below 4.8 is also useful.

21.7.1.2 Discolouration

This is due to enzymic action on the non-rubber constitutents present in latex.

21.7.1.3 Rust

Rust is a brownish deposit or more usually a thin invisible film on rubber sheets. This film breaks and becomes visible when the sheet is stretched or scratched. It is caused by a large number of yeasts and bacteria. If the sheet examined is dark and heavily smoked, the colour of the broken film will be brown or rust coloured. Light-coloured sheets produce rust which is white or slightly yellow. This defect should not be confused with mould which is visible before the sample of rubber is stretched. Mould to a large extent can be removed by brushing, but rust remains quite firmly attached to the sheet.

21.7.1.4 Mould growth

Mould growth on sheets occurs when their moisture content is high. Usually, when the sheets are taken out from the smoke house, the moisture content is less than 0.5 per cent. Storing the sheets in humid atmosphere or on concrete floors causes the moisture content to increase and mould to grow on the sheets. If fresh coagula are not washed properly before they are fed into the smoke house, non-rubber constituents, which are present in serum, remain on the surface of the sheets, and these induce fungal growth.

Excessive use of sodium bisulphite results in the formation of hygroscopic sodium bisulphate on the surface of the sheets. This leads to increased moisture content and consequent mould growth on the sheet. Sheet rubber exposed to excess smoke produced by a slow burning fire is resistant to fungal attack because of the presence of small quantities of creosotes deposited on it during its exposure to smoke. However, this effect does not last for more than five to six days. During this period, the fungicidal effect of the constituents of smoke wears off and the rubber sheet becomes susceptible to fungal attack. A relative humidity above 75 per cent and air temperature of 37°–40°C are favourable for fungal growth. Water content of about 0.8 per cent is sufficient for mould growth. The fungi attacking rubber sheets belong to the genera *Aspergillus*, *Penicillium* and *Paecilomyces*. Addition of PNP to latex or soaking the sheeted coagulum in the solution of PNP prevents mould growth.

21.7.2 Defects due to other reasons

These may arise out of excessive use of certain chemicals, contamination with foreign matter or faulty conditions of drying.

21.7.2.1 Tackiness

The sheets when folded and released, should come to the original form and should not stick together. Tackiness on sheets may be due to any one of the reasons like use of excess sodium bisulphite or coagulant, too high temperature of drying or contamination of latex with copper or sheets with grease from the bearings of the sheeting machines.

21.7.2.2. Blisters

These are formed on sheet rubber as a result of higher temperature in the smoke house. Temperature in the first two compartments where the wet sheets are fed into the smoke house should be lower than that in the other compartments, that is, it should be in the range of 37°–40°C. The maximum temperature in the smoke house should not exceed 60°C. The thickness of the sheets should also be uniform to get sheets free from blisters. Blisters usually appear on the thicker parts of the sheets.

21.7.2.3 Reaper marks

A light dark colour along the centre of the sheets is called reaper mark. This is due to the deposits of small carbon particles on that part of the sheet. Reaper marks appear when the sides of the sheets are not turned over the reapers daily. Very thick smoke inside the smoke house enhances reaper mark. Dry firewood is to be used in the furance. The reapers are to be cleaned occasionally for getting sheets free from reaper mark.

21.7.2.4 Case hardening

The appearance of a white streak in the cut section of a dry sheet is known as case hardening. This is due to any one of the reasons such as rapid drying of the sheets in the early stages, excessive thickness of the sheets and insufficient dilution of the latex which gives a very hard coagulum. Under the above circumstances the surface film of the sheets may get dried at a faster rate, so that water inside does not escape, even if the temperature is increased or the sheets smoked for longer periods.

21.7.2.5 Tar drops

On the surface of the sheets sometimes black drops resembling tar may be seen. This is due to the falling of water drops which had absorbed dark coloured particles from the smoke. The water drops are formed by the condensation of moisture from the humid smoke on the ceiling. To avoid tar dripping, the space between the ceiling and the roof should be completely closed.

21.8 Inspection, sorting and grading

Sheets coming out from the smoke house on the fourth day are taken from the reapers and visually examined by holding them against clear light to see any speck or impurity remaining inside (Fig 21.5). They are sorted into different grades on the basis of colour, translucency, presence of mould, oxidised spots, blisters, bubbles, dirt, sand and other foreign matter, as per the international standards of quality and packing for natural rubber prepared by the

Rubber Manufacturers' Association, New York, as described in the Green Book. At present there are five grades of sheet rubbers and they are designated as RSS–1, RSS–2, RSS–3, RSS–4 and RSS–5 In India these grades are even now designated as RMA sheets.

21.9 Packing, baling, coating and marking

Ribbed smoked sheets are packed in rubber covered bales Fig (21.6). The maximum weight of each bale should be 113.6 kg for 0.16 m^3 outside measurements, as per the Green Book. Wrapping of bales may be done on all sides with the same or higher grade of rubber. This type of packing is known as bare back packing. When bare back packing is adopted, an outside coating is given with a suitable bale coating solution. This is prepared by admixing fine variety of talc, kaolin or whiting (calcium carbonate) with suitably prepared rubber solution. For the preparation of this solution, petroleum solvents like kerosene are taken and admixed with rubber in the ratio 1:1 and kept overnight. The swollen rubber is then made into a solution by addition of an equal quantity of the same solvent. This solution is stirred well and further diluted to double its volume. Any of the above mentioned powders is then added to this solution so as to get a 25 per cent (w/w) slurry of the powder in rubber solution. This solution may be used for coating of rubber sheets.

As per ISI specifications, raw rubber may be packed in 25 or 50 kg bales and packed in polyethylene sheets with an outside covering of jute, hessian or paper. Each bale of rubber has to be marked with grade of rubber, name of producer/estate, or trade mark and year of production.

The lay out of a typical RSS processing factory is given in Fig (21.7).

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22 CREPE RUBBERS

Chapter 22

CREPE RUBBERS

When coagulum from latex or any form of field coagulum or RSS cuttings after necessary preliminary treatments is passed through a set of creping machines, crinkly, lace-like rubber is obtained. This when dried, is called crepe rubber. Pale latex crepe and sole crepe are processed from field latex. The other forms of crepe rubbers are processed from field coagulum rubbers or RSS cuttings. Pale latex crepes are mainly used for the production of surgical and pharmaceutical articles, light-coloured and transparent goods, adhesives and tapes, derivatives like chlorinated rubber, cyclised rubber etc. Sole crepe is used for the production of translucent shoe soling material. The other forms of crepes are used for the manufacture of tyres, foot-wears, retreading materials etc.

Processes involved in the production of latex crepes include sieving, bulking and standardisation of latex, addition of chemicals, coagulation, creping of coagulum and drying.

22.1 Pale latex crepe and sole crepe

These are produced from field latex under strictly controlled conditions.

22.1.1 Choice of latex

Latex to be used for the production of pale latex crepe and sole crepe should be free from yellow pigments as far as possible. Also, the coagulum should have less tendency for discolouration and the rubber should be sufficiently hard to permit the addition of the required quantity of bleaching agent to get maximum whiteness. Thus the extent of yellow pigment in latex, tendency of the coagulum for

discolouration, viscosity of the rubber obtained etc are characters which determine the type of rubber tree from which latex has to be collected (3). Other factors like climatic conditions, tapping system followed, application of stimulants etc affect the above characteristics only to a limited extent. Yellow colouring matter in latex has been identified as carotenoid type of pigments. Latex from clones like RRIM 605 and RRIM 700 contains higher concentration of yellow pigments and has deep yellow colour whereas clones like PB 5/51, RRIM 501 and Tjir 1 give latex of only light yellow colour. White latex, which is more suitable for the production of pale latex crepe and sole crepe is obtained from colnes like PB 86 and RRIM 600. Normally, when yellow coloured latex is to be used for production of latex crepe, it should not exceed 20 per cent of the total quantity of latex required. Such latex is used in blends with white latex. Latex coagula from clones like PB 86, GI 1, Tjir 1, RRIM 501, RRIM 600 and RRIM 701 are less susceptible to discolouration due to enzymic action, whereas coagula from clones like PB 5/37 and PR 107 are badly darkened. Latex from clones which are highly susceptible to surface darkening is not usually used for producing latex crepes. The Mooney viscosity of rubber from different clones varies over a wide range of about 50–100. Harder rubber is more suitable for preparing latex crepes since more quantity of bleaching agent can be used in this case to get whiter crepes. Latex from clones like GI 1, RRIM 501, RRIM 701, RRIM 707 and PB 186 gives soft rubber which does not permit the use of sufficient quantity of bleaching agent to produce white crepe. Such latex, when used, should be blended with latices which give comparatively harder rubbers. Thus, proper selection of latex is an important factor in the production of good quality pale latex crepe and sole crepe.

22.1.2 Addition of anti-coagulants

Latex which shows tendency for pre-coagulation should be treated with anti-coagulants like sodium sulphite or ammonia. Formalin is not used as an anti-coagulant when latex is to be processed into pale crepe or sole crepe since it activates enzymic discolouration. Ammonia, if used, should be in concentration less than 0.03 per cent since excess quantity results in serious darkening of the coagulum. Sodium sulphite is the normal anti-coagulant used for

latex crepe production. The quantity used is about 0.05 per cent on latex by weight. A stock solution of this is prepared by dissolving 450 g of the chemical in 9 l of purified water. Hundred and eighty ml of this stock solution is sufficient to treat about 18 l of field latex.

22.1.3 Sieving and bulking

Latex reaching the factory should be sieved through 40 and 60 mesh sieves to remove suspended impurities. Latex from different fields are blended in bulking tanks, which may be of aluminium or brick work construction, lined inside with porcelain tiles. Volume of the tank should be sufficient to accommodate the total volume of latex, solutions of chemicals and water for diluting the latex. Depth of the tank should not be more than 125 cm so as to facilitate quicker settling of the denser impurities. If the width of the tank is more than 180 cm it may be difficult to mix the latex properly. Rectangular tanks should have a sloping floor so that the back is about 7.5 cm lower than the front and they should be fitted with a separate tap at the base to remove the sediments. The outlet for latex on the front side of the tank should be slightly above the bottom level. A mechanical stirrer of about 15 rpm may also be fitted on the tank.

22.1.4 Standardisation of latex

The dry rubber content of latex in the bulking tank is determined as per standard procedures, and the latex is diluted to a standard drc of 25. Water used for diluting latex should be free from suspended and dissolved impurities. It should have less than 150 ppm of dissolved solids, 20 ppm of suspended solids and 2 ppm of iron and should be free from copper and manganese. Since high calcium levels in water give rise to poor lamination of the sole crepe plies (4), calcium content in water should also be checked and maintained below 15 ppm.

22.1.5 Addition of chemicals

Sodium bisulphite or sodium metabisulphite is used to prevent enzymic darkening of the coagulum. The exact quantity of these chemicals to be used depends on the type of latex to be processed.

The usual dosage is 0.5 per cent on dry rubber content and is added to latex as a 5 per cent solution. Since sodium bisulphite on keeping decomposes gradually, fresh chemical has to be used to get better results. The solution is prepared on each day just before use.

22.1.6 Transfer to coagulation tanks

Latex, after dilution and addition of the chemicals, is stirred well and allowed to remain undisturbed for about 15–30 min to allow settling of the denser impurities. It is then transferred to the coagulation tanks without disturbing the sediments. The coagulation tanks may be of aluminium or brick work with glazed tiles inside. The usual size of the tank is 3.0x1.0x0.6 m. The tank is fitted with a wooden frame at the top which facilitates insertion of alunimium partition plates at intervals of 7.5 cm. The depth of latex loaded in the coagulation tank should be such that the width of the coagulum obtained is slightly lower than the width of the creping rollers. If the width of the rollers is 70 cm, the width of the coagulum may be around 60 cm.

22.1.7 Removal or destruction of yellow pigments

Removal or destruction of the yellow pigment is done by fractional coagulation or by bleaching or by a combination of the two methods, depending on the type of latex used, cost and availability of bleaching agent, extent of whiteness required etc.

22.1.7.1 Fractional coagulation

Fractional coagulation is the preferential coagulation of colouring materials present in latex along with a small portion of rubber. In certain cases, if latex after bulking and dilution is agitated thoroughly for about 20–30 min and then allowed to remain for some time, the yellow colouring materials present in latex separate out forming

a clot. This clot is removed by straining through a 60 mesh sieve. But usually, it is necessary to add a small quantity of coagulant to separate the fraction containing the yellow pigment. Acetic acid or oxalic acid can be used for the purpose. The quantity of coagulants required to effect fractional coagulation varies depending on the nature of latex, type of anti-coagulant used, weather conditions and storage time between tapping and processing. Acetic acid is preferred to formic acid since it is weaker than the latter. The quantity of acetic acid to be used varies between 0.625–1.100 ml/kg dry rubber if the anti-coagulant used is sodium sulphite. When ammonia is used as the anti-coagulant, higher quantities are required. The acid is to be diluted to 1 per cent before adding to the latex. In the case of oxalic acid, the quantity required is about 0.625 g/kg dry rubber and is added to latex as a 2 per cent solution. After adding acid, latex is thoroughly stirred and allowed to remain undisturbed for about 1–2 h. It is then sieved through 60 mesh sieve and the yellow fraction removed. The quantity removed in this fraction may come to about 10–15 per cent of the total dry rubber by weight. In cases where latex contains more yellow pigments, gelled rubber and non-rubber materials, the quantity of the first fraction is much higher. Thus, fractional coagulation has the disadvantage that the process is time consuming and is effective in converting only part of the crop into first quality crepe, the remaining being converted into lower grades.

22.1.7.2 Bleaching

In this process, a chemical, which preferentially reacts with the colouring material present in latex and destroys the colour, is used. Xylyl mercaptan which is available in the trade name RPA No. 3 is the most widely used bleaching agent for producing pale latex crepe and sole crepe. Xylyl mercaptan is insoluble in water and hence it is used as an emulsion. It is commercially available in two concentrations containing 35.5 per cent and 71 per cent of active ingredient. The remaining part consists of an emulsifying agent and an inert hydrocarbon. The commercially available form has to be diluted to 5 per cent before addition. Table 22.1 gives the quantity of ingredients required to prepare a 5 per cent emulsion of RPA No. 3.

Table 22.1

Quantity of ingredients required for the preparation of a 5 per cent emulsion of RPA No. 3

Ingredient	Quantity (ml) 1	2
Normal RPA No. 3	10.0	..
Concentrated RPA No. 3	..	5.0
Dupanol OS	1.0	1.0
Water	189.0	194.0
Total	200.0	200.0

The mixture has to be thoroughly stirred using a mechanical stirrer to get a good emulsion of RPA No. 3. Since Xylyl mercaptan reacts with rubber hydrocarbon, its use has to be restricted to the minimum required quantity which is fixed after trials. For latex containing lower concentration of colouring pigments, about 1500 ml of the 5 per cent emulsion is sufficient to treat latex containing 100 kg dry rubber. If the latex contains higher concentration of yellow pigments, about 2500 ml of the 5 per cent emulsion may be required to get good colour to the final crepe of about 100 kg. The latex has to be stirred well to get uniform distribution of the bleaching agent as otherwise white streaks are formed in the coagulum.

Better colour can be obtained if the bleaching agent is added after fractional coagulation. In this case, since the second fraction contains only lower concentration of the colouring materials, the quantity of bleaching agent required is much less. The bleaching method has the advantage that the complete latex can be converted into first quality crepe and that the process is quicker than the fractional coagulation method. But the higher cost of the bleaching agent and its harmful effect on rubber, when used in excess quantity, limit the application of this method to an extent.

22.1.8 Coagulation

Latex, after fractional coagulation and/or bleaching, is coagulated using formic or oxalic acid. The quantity of acid required for coagulation is variable. Normally, 3.3–4·4 ml of formic acid per kg dry rubber is sufficient to get clear serum after coagulation. The acid is to be diluted to 1 per cent before adding to the latex. Quantity of oxalic acid required per kg dry rubber varies between 5.6 and 7.5 g. It is added to latex as a 2 per cent aqueous solution. Latex is stirred well after adding the coagulant and the froth formed is removed. Partition plates are then inserted and the tank covered to prevent contamination by foreign materials. The coagulum obtained has to be milled in creping machines within a period of 24 h.

22.1.9 Creping machines and creping operation

Minimum essential set of creping machines for production of pale latex crepe consists of a coarse macerator, an intermediate, macerator and a set of smooth rollers. But, for economic reasons it is better to have a battery of machines consisting of two coarse macerators, one intermediate macerator and three sets of plane rollers (Fig 22.1 and 22.2). The size of the rollers depends on the width of the pale crepe to be produced. For producing sole crepe of 30 cm width, the finished pale crepe should be 40 cm wide to give allowance for shrinkage during drying and for edge cutting. In such a case, the width of the rollers should be 75 cm. For sole crepe of 50 cm width, the rollers should be of 95 cm width. The diameter of the roller is usually 35 cm. The rollers are made of either cast iron or an alloy of cast iron with nickel-chromium-molybdenum. Stainless steel or other types of steel which develop a high polish and shiny surface should not be used for making creping rollers. The rollers are to be provided with suitable roller bearings for smooth and efficient functioning. Individual drive to the mill is found to be more economical than back shaft drive. The speed ratio of the macerator may be 18/21 whereas that of the finishing rollers could vary from 19/31 to 17/32. Higher speed differential for the finishing rollers is necessary to get the close texture of thin pale crepe. The machines should not be allowed to run without rubber between the rollers, unless they are well separated. Wear of the rollers

makes a crepe thick at the centre and thin at the edges which may lead to poor lamination and uneven thickness of the final sole crepe. The life of the rollers depends on the nature of the material of the rollers and the care taken while operating them. Cast iron rollers need re-grooving after production of every 1000 t crepe. Groove recutting can be done only up to the stage when the diameter of the roller reaches about 25–28 cm. The machines shall be set in such a way that minimum number of passes is given to get the required thickness and cleanliness to the final crepe and the handling of the coagulum through each machine depends on the nature of the coagulum. The nip settings of the rollers are to be adjusted in such a way that the thickness of the final thin crepe obtained is about 0.95–1.00 mm. Sufficient quantity of pure water should be used while machining the coagulum to wash out the serum and other non-rubber materials. Details of the creping battery for sole crepe production (2) are given in Table 22.2.

Table 22 2

Details of creping battery for sole crepe production

Machine No.	Type of machine	Roll width (cm)	Gear ratio	No. of passes	No. of operators	Crepe thickness (mm)
1	Macerator 3.2x3.2 mm diamond	75	23/27	8	2	9.0–12.0
2	Macerator 3.2x3.2 mm diamond	75	23/27	6	1	4.0–6.0
3	Intermediate macerator 0.4x0.4 mm	75	19/31	2	1	1.0–2.0
4	Smooth roller	75	19/31	1	1	1.3–1.4
5	Smooth roller	75	19/31	1	1	1.1–1.2
6	Smooth roller	75	19/31	1	2	0.9–1.0

22.1.10 Crepe drying and drying chambers

The moisture content of the thin crepe, reaching the drying chamber, is in the range 7–12 per cent (5). This has to be reduced to less than 0.2 per cent before it is inspected and graded. Drying of the crepe is done either in air drying sheds or in heated drying chambers. The drying sheds are of two or three tier construction and crepes are hung on reapers of 3.8–5.0 cm diameter (Fig 22.3). The reapers are of wood or bamboo and are spaced 10 cm apart. The chamber should be provided with sufficient number of roof vents or exhaust fans and louvers to facilitate an upward air draught. The crepe at the bottom tier should be hung 1.2 m above the floor and all the tiers of the drying shed should be loaded simultaneously so that wet crepe is never hung over partially dry crepe. The drying time in such sheds depends on the atmospheric conditions and usually it takes about 7–10 days for drying the crepe. The drying capacity of this type of drying shed is about 5.6 kg/m^3.

In drying chamber, hot air at 33°C–35°C is circulated. The conventional heating equipment to provide warm air to the drying chamber consists of a boiler and a set of radiators. The boiler generates steam and it is passed through radiators over which air is blown. Air which gets heated, is trapped into the drying chamber. Usually, firewood is used as fuel for the boiler. In this case maintenance of a steady temperature within the chamber is dependent on the firing rate which is manually controlled. Inadequate and irregular firing can cause undue delay in drying the crepes and may affect the production and quality of the produce. Modern drying chambers have electrical heaters to supply warm air. The advantage of electrical heating is that the temperature inside the chamber can be controlled thermostatically. In a drier of 4100 kg dry rubber capacity, 16–22 numbers of finned air heaters of 1 kw rating are required. The blowers used in this should be capable of providing an air flow rate of about 0.67 m^3/sec. In such driers, it takes about four to six days to get the crepes dried.

22.1.11 Sole creping

The dried pale latex crepe is spooled off the hangers and kept on racks. These are then spread on the inspection table and any

speck of impurities, discoloured parts etc remaining on the surface of the crepe are removed and the crepe cut into the required length. Requisite number of pieces of pale crepe are placed on the building table. Each piece is lightly stretched, placed one above the other and pressed down with the palm or using a hand operated roller so as to avoid wrinkles. The weight of the built up unit should be about 20 per cent more than the weight of the finished standard size sole crepe to be made from it. This is then placed on the laminating table which is metal topped and heated by rapidly circulating hot water. The temperature of the table should be 45°C and each built up pad should be placed on the table for 1 min, turned over and again placed for another minute with the fresh surface. The built up pad is then taken to the laminator which consists of two heavy plane rolls for smooth sole crepe production and another set with the top roll grooved horizontally for corrugated sole crepe production. The speed of the laminator rolls should be dead even and should be in the range of 10–12 rpm. The warmed pad is passed through the laminator rolls, the nip of which has been adjusted properly, to get smooth sole crepe of exact thickness. For corrugated sole crepe, one pass through the smooth laminating rolls and another pass through the grooved one is necessary. If proper ply adhesion is obtained, it is difficult to split the plies apart. After lamination, the pads are covered and allowed to rest for about 24 h before they are cut using a guillotine type cutter. Each pad is cut into two pieces of 0.9 x 0.3 m size sole crepe. For wider crepe, the pad is cut into 1.0 x 0.5 m.

22.1.12 Defects in pale latex crepe and sole crepe

The grading of pale latex crepe and sole crepe is done by examining factors like colour, presence of streaks, strength of lamination, uniformity in thickness, presence of dirt and variation from the weights specified. Some of the common defects occurring in pale latex crepe and sole crepe are given below.

22.1.12.1 Fungal spots

Spots of black, blue, violet, red, yellow or green colour may be found on the surface of the crepes. This is due to the action of

various types of micro-organisms, on the non-rubber constituents present on the surface of the crepes, under moist conditions. Use of excess quantity of sodium bisulphite, storing the coagulum or macerated crepe for long period, excessive thickness of the crepe, coagulation of latex at higher drc, drying the crepes in badly ventilated air drying sheds etc delay the drying of crepes and help micro-organisms to act upon and develop coloured spots. Blanketing the crepe before it is quite dry, blanketing on wet rollers or contamination with sea or rain water may also cause development of coloured spots.

22.1.12.2 Brown discolouration

Brown discolouration of the crepe may be due to any one of the reasons like presence of iron in water, inadequate preservation of latex in the field and exposure of the rubber to direct sunlight during or after drying. Use of deteriorated sodium bisulphite may also give a dull brown colour to the crepe.

22.1.12.3 Gray or dark colour

This may be due to contamination with iron compounds, carbon particles or oil from the bearings of the rolls.

22.1.12.4 White spots

Thicker lumps of coagulum or adulteration with starch may give rise to white spots on the crepe.

22.1.12.5 White streaks

White streaks on the surface of the crepes are due to improper blending of the latex or improper dilution and mixing of sodium bisulphite and bleaching agent. Those portions in which the concentrations of these chemicals are more, are bleached to a greater extent compared with the other portions and they appear as white streaks.

22.1.12.6 Tackiness

Tackiness on the surface of the crepe is due to contamination with copper, mainly from the roller bearings, or due to direct exposure of the crepe to sunlight. Higher temperature in the heated drying chambers also causes tackiness.

22.1.12.7 Poor lamination strength

Worn out rollers make crepes thick at the middle and thin at the edges. Such crepes when laminated give poor lamination strength. Lower temperature of the lamination table, high calcium content in water used for pale crepe production etc may also lead to poor lamination of the sole crepe plies.

22.1.13 Grading

The thicknesses of the sole crepe specified by the consumers of sole crepe are 1.5 mm, 3.2 mm, 4.7 mm, 6.3 mm and 9.5 mm and the size of laminated piece is generally 90 x 30 cm. A variation of 0.4 mm in thickness from the specified value is allowed. Before marketing, the sole crepe is weighed and divided into light, exact and full categories. A variation in weight up to 98 g depending on thickness, on either side of the exact weight of the sole crepe of a given thickness is allowed. But in some cases, the tolerance is as low as 56 g on either side of the mean. At present, tests like colour index, iron content, ply adhesion, Mooney viscosity, Wallace plasticity, PRI and 50 per cent hardness are also conducted to examine the quality of the sole crepe. Grading of pale latex crepe is done as per the standards of quality and packing of natural rubber grades, presented in the 'Green Book'.

22 2 Field coagulum crepe rubbers

22.2.1 Types of field coagulum crepes

The crepes prepared from field coagulum materials fall into five types.

22.2.1.1 Estate brown crepes (EBC)

These are prepared from cup lumps and other grades of scrap. Tree bark scrap can also be used in their production after cleaning and removing the bark. Earth scrap and smoked scrap are not used for the production of estate brown crepes.

22.2.1.2 Thin brown crepes or remilled crepes

These grades are manufactured from wet slab, unsmoked sheets, lump and other high grade scrap. Tree bark scrap is used only after cleaning and separating the bark. Earth scrap and smoked scrap are not used.

22.2.1.3 Thick blanket crepes or ambers

Crepes of this category are manufactured from wet slabs, unsmoked sheets, lump or other high grade scraps. Pre-cleaned tree bark scrap is also used in this case, but use of earth scrap is not permitted.

22.2.1.4 Flat bark crepes

Crepes of this type are prepared from all types of field coagulum grade natural rubber including earth scrap.

22.2.1.5 Smoked blanket crepes

Another type of crepe, viz pure smoked blanket crepe is also available in the market. This is prepared exculsively from RSS cuttings. No other type of rubber is used for the production of smoked blanket crepe.

22.2.2 Processing procedure

22.2.2.1 Soaking

Depending on the type of crepe to be manufactured, suitable field coagula are selected. The raw materials are soaked in water

at least for one day. In certain cases, treatment is given to the field coagula with oxalic acid or phosphoric acid solution to improve properties like plasticity retention index. This treatment is given by soaking the materials in 0.50 per cent solution of oxalic acid or phosphoric acid for a few hours. It is reported that phosphoric acid treatment improves the PRI of raw rubber and aging properties of the vulcanisates to a considerable extent (6). Addition of detergent to soaking water to give a concentration of 0.1 per cent helps to remove the impurities at a faster rate. Care should be taken to see that the scrap is properly submerged in the soaking solution. For processing of very low quality field coagulum grades, the soaked material is to be passed through scrap washers to remove the foreign materials present on the scrap. This process helps to reduce the number of passes to be given through the creping machines and hence to increase the output.

22.2.2.2 Creping machines and creping operation

For the production of crepe rubber from field coagulum, the minimum set of machinery required consists of a macerator, creper and one finishing machine. Such a creping battery with three machines having roller size 60 × 30 cm can produce about 500 kg dry crepe rubber per shift of 8h (1). For higher output and for making fine textured crepe, additional crepers and smooth rollers are to be installed. The number of passes of the coagulum through various machines depends on the nature of the material to be processed. Normally, when no scrap washer is used, 10–15 passes through the macerator, five passes through the creper and two passes through the finishing rolls are given for the manufacture of the lower grade crepes. The nip setting of the smooth rollers is adjusted in such a way that the final crepe after passing through these will have a thickness of about 2–3 mm. Sufficient quantity of water should be passed over the crepes while they are being machined to remove the dirt and non-rubber constitutents.

22.2.2.3 Drying of crepes

The wet crepe obtained after machining is dried in air, shade or heated drying chambers. Inside the drying sheds, the crepes

are hung on reapers made of wood or bamboo up to a height of 2–3 m from the floor. The reapers are usually spaced at about 10 cm from centre to centre. The drying shed is provided with air inlets at the bottom and ventilators at the top which can be closed or opened. In air drying sheds, it takes about 7–10 days for drying the crepe during summer; but in rainy season, it may be more. In heated drying chambers, the drying temperature may be in the range 65°C–70°C and the period of drying may vary from a few hours to one day, depending on thickness of the crepe. The dried crepes are taken out from the drying shed, inspected and they are graded and packed (Fig 22.4).

22.2.3 Defects in crepe from field coagulum rubber

22.2.3.1 Mould growth

Mould growth on the surface of the crepes is mainly due to improper drying. The crepe should be dried within the minimum period possible, to reduce mould growth. In badly ventilated sheds or during rainy season, crepes take longer time for drying resulting in mould growth. The crepe should be washed thoroughly during machining to remove the non-rubber constituents. These materials, when present on the surface of the crepes, act as substractes for bacterial and fungal growth. Care should be taken to avoid stacking of the dried crepes in humid condition or on concerete floors.

22.2.3.2 Greenish and tacky streaks

This is caused by contamination with copper or brass from worn out bushes or bearings of the rollers.

22.2.3.3 Rust stains

Rust appears on the roller surfaces when they are at rest. The rollers are to be cleaned thoroughly before they are used again. If this is not done rust on the rollers gets incorporated in the crepes when they are milled.

22.2.3.4 Tackiness on the surface

This may be caused by exposure of the crepe to direct sunlight or by contamination with copper, brass or grease from the roller bearings. Tackiness may also be caused by high temperature in the drying chambers.

22.2.3.5 Uneven thickness

This is caused by the use of worn out rollers to process the crepes. Worn out rollers produce crepes thick at the middle and thin at the edges.

22.2.3.6 Presence of coloured spots.

Coloured spots of brick red, yellow, violet, green etc may appear on the surface of the crepes owing to infection by various types of micro-organisms. The presence of coloured spots will be more when the thickness of the crepe is high and the wet crepe is stored for longer periods before drying.

22.2.3.7 Discolouration

Discolouration on the surface of the crepes may be due to any one of the reasons like use of dirty water for dilution, rust on roller surfaces, over heating of the crepes in the heated drying chamber or contamination with grease from the bearings.

22.2.3.8 Dirt and sand particles on crepes

This is due to improper milling and washing of the crepes. Use of scrap washer and sufficient quantity of water for washing the crepe during machining can remove most of the sand and dirt on the surface of crepe.

22.2.4 Grading and packing of lower grade crepes

Crepes are graded by examining parameters like colour, dryness, strength and thickness. There are three grades of thick and thin

estate brown crepes, viz No. IX, No. 2X and No. 3X. These crepes must consist of dry and clean rubber with light brown, brown and dark brown colour respectively for the 1X, 2X and 3X. In no case, discolouration regardless of cause, specks, sand or other foreign matter, oil or other stains or any evidence of oxidation or heat is permitted. There are four grades of thin brown crepes or remilled crepes, viz No. 1, No.2, No.3 and No. 4. The grades for thick blanket crepes are No.2, No.3 and No.4. Flat bark crepes are marketed in two grades, viz standard flat bark and hard flat bark crepes.

The maximum weight of the crepe in each bale should be 101.60 kg/0.142 m^3 (224 lb/5 ft^3) outside measurements. The minimum weight of each bale should be 72.57 kg (160 lb) net except where lower weights are specified in the buyers' contract.

22.3 Water and power requirements for creping factories

Power requirement in crepe factories is fairly high. In olden days common drive systems were employed for a battery of crepers and macerators, through shafts and gear systems. Estates which were not having connected electric power were using oil engines for generating the driving force. Today all modern factories are using separate drive systems for the individual macerators and crepers. This is helpful in saving power as some of the machinery which are not needed during part of the operation period can be switched off without affecting work in the others. In a creping factory having six pairs of rollers the requirement of power is approximately 120 HP for driving the rollers alone. In some factories electric power is used for drying crepes. Mineral oil fired driers can also be used for drying crepes.

Water requirement in crepe factories processing field coagulum rubber is substantially higher than that for factories processing fresh latex coagulum. Approximately 40–50 l of water per kg is needed in the former case whereas for pale latex crepe around 30–40 l per kg is adequate.

The layout of a typical crepe rubber processing factory is given in Fig 22.5.

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23 PRESERVED FIELD LATEX AND LATEX CONCENTRATE

Chapter 23

PRESERVED FIELD LATEX AND LATEX CONCENTRATE

Natural rubber latex is a negatively charged colloidal dispersion of rubber particles in an aqueous serum. The presence of non-rubber constituents like proteins, carbohydrates etc in latex makes it a suitable medium for growth of micro-organisms. Because of the proliferation of micro-organisms, organic acids are produced and these decrease the stability of latex and eventually coagulate it. This is called spontaneous coagulation which takes place within a period of 6–12 h. Hence, if latex is to be kept for longer periods, bacterial activity should be suppressed. This is accomplished by the addition of preservatives. Preserved latex may be either field latex or concentrated latex.

Latex is used for the production of foam, carpet backings, dipped goods, rubber thread, adhesives etc.

23.1 Preservatives

Various chemicals are used as preservatives among which ammonia is of prime importance. Other chemicals used along with ammonia are known as secondary preservatives.

23.1.1 Attributes of a preservative

The primary requirement of any preservative is that it should preserve latex against spontaneous coagulation and putrefaction. Preservatives should have the following essential attributes:

(i) It should destroy or inactivate micro-organisms;

(ii) It should contribute positively to the colloidal stability of latex, in particular by increasing the charge on the particles and the potential at the rubber-serum interface. This can be achieved by increasing the pH of NR latex and hence the preservative should preferably be an alkali; and

(iii) It should de-activate or remove traces of metal ions present in latex.

In addition, an ideal preservative must have a number of other secondary properties also. It should not be harmful to people, should not have adverse reaction on rubber or containers of latex and should be cheap, readily available and convenient to handle.

23.1.2 Pre-eminence of ammonia as a preservative

Use of ammonia was first described in 1853 (8, 13). Now ammonia is the most widely used preservative for NR latex. In plantations, ammonia at a concentration of 0.7–1.0 per cent by weight of latex is added for preservation. This treatment preserves latex and maintains it in a stable colloidal condition almost indefinitely. Also, during storage, the higher fatty acid esters present in latex get hydrolysed into ammonium soaps which improve the mechanical stability of latex.

Ammonia fulfils all the three primary requirements of an ideal preservative and many desirable secondary properties. As a bactericide it is effective at concentrations above 0.35 per cent (Fig 23.1). For efficient preservation, the preservative should be added to the latex as soon as possible after collection.

Being an alkali, ammonia imparts an alkaline reaction to latex thereby enhancing the magnitude of negative charge on the particles and the potential at the rubber-serum interface, thus improving the stability. Some metal ions which tend to coagulate latex are inactivated by ammonia by forming insoluble compounds or complexes with them. Thus, magnesium is precipitated as magnesium ammonium phosphate, provided that enough phosphate ions are also present.

$$Mg^{++} + NH_3 + HPO_4^{--} \longrightarrow MgNH_4PO_4$$

This precipitate sediments as sludge together with any sand, dirt or other particles which may be present. Copper ions in latex are de-activated by ammonia by complex formation.

$$Cu^{++} + 4NH_3 \longrightarrow Cu(NH_3)_4^{++}$$

23.1.3 Low-ammonia preservative systems

The presence of high concentration of ammonia in preserved concentrated latex has been considered undesirable by the latex products manufacturing industry. Apart from handling difficulties, it presents problems in some manufacturing processes. Also, the high concentration of ammonia aggravates the inherent tendency of some serum constituents to get hydrolysed and decomposed into a variety of compounds including simple salts and soaps. This results in a progressive loss of zinc oxide stability of latex which is a property in industrial applications. Because of these disadvantages of ammonia, attempts have been made to find out alternative preservatives for natural rubber latex. The use of chemicals like tetrahydronaphthalene, alkyl mercury chlorides, arseneous oxide, acetaldehyde, nitrophenols and other organic nitrocompounds, morpholine and formaldehyde as secondary preservatives has been reviewed (11). Use of sodium pentachlorophenate as secondary preservative along with 0.2 per cent ammonia has also been reported (16). Ammonium pentachlorophenate, zinc dialkyl dithio-carbamate, aminophenols, EDTA and boric acid have also been used as preservatives (14). Use of 8–hydroxyquinoline and its various halogen and metal derivatives as secondary preservatives in low ammonia natural rubber latex concentrates has also been described (1). Evaluation of miscellaneous vulcanization accelerators as secondary preservatives was also carried out (2). Zinc oxide, which is known to be a good enzyme poison, has been tried for the inhibition of volatile acid formation in field

latex (17). RRII has introduced monomethylamine as an effective preservative for natural rubber latex concentrate (10). Among the various secondary preservatives described, only a few have become commercially popular. These are described in detail below:

23.1.3.1 Pentachlorophenol

Pentachlorophenol and its alkali metal salts are used as secondary preservatives in conjunction with ammonia. They are excellent bactericides. A typical combination is 0.2 per cent ammonia plus 0.2 per cent sodium pentachlorophenate (SPP), on the weight of the whole latex. Pentachlorophenol-preserved latices are having very high mechanical stability. It is likely that pentachlorophenate ions have a slight sequestering capacity for certain metal ions. This effect can be enhanced by the incorporation of additional sequestering agents. A typical combination could be 0.1 per cent ammonia, 0.1 per cent sodium pentachlorophenate and 0.1 per cent EDTA. The very high mechanical stability of pentachlorophenol preserved latex may cause gelling problems in the manufacture of latex foam. Other disadvantages of pentachlorophenol are that it is poisonous and it causes dermatitis with sensitive skins and causes discolouration of products prepared from it.

23.1.3.2 Zinc dialkyl dithiocarbamates (ZDC)

This was first introduced in 1948 by RRIM. A typical combination would comprise 0.2 per cent ammonia, 0.1–0.2 per cent zinc dimethyl dithiocarbamate and 0.2 per cent lauric acid. Addition of lauric acid is optional but without it the mechanical stability of latex would be very poor. Vulcanization behaviour is only slightly affected by the presence of dithiocarbamates. However, latices preserved in this way give deposits which tend to discolour badly on aging.

23.1.3.3 Boric acid

This was introduced by RRIM in 1956. A typical combination is 0.2 per cent ammonia plus 0.2 per cent boric acid plus 0.05 per cent lauric acid. Of the various low-ammonia preservation systems so far proposed, the one using boric acid as secondary preservative is

most promising and popular. Deposits from boric acid preserved latices are remarkably free from discolouration during aging. Moreover, boric acid improves the colour of the deposits. It is harmless, cheap, easily available and convenient to handle and has no effect in vulcanisation. It should be noted, however, that KOH number (a quality parameter) of boric acid preserved latex is abnormally high because of additional ammonium ions formed by the action of boric acid with ammonia.

23.1.3.4 Formaldehyde

As a bactericide, formaldehyde is more powerful than ammonia. An initial treatment of fresh latex with formaldehyde followed by ammoniation forms the basis of the Mc Gavack system of preservation (11). Fresh field latex is treated with 0.15–0.20 per cent formaldehyde as soon as possible after collection. The latex is then allowed to stand for 15–30 h during which period formaldehyde interacts with latex proteins and consequently the pH of latex falls slightly. Finally ammonia is added up to 2 per cent on the aqueous phase. Latex, preserved in this way, is reported to have enhanced stability and resistance to freezing.

23.2 Processing into preserved field latex

Although preserved field latex is not used as such in any manufacturing industry, there is good demand for this form of latex. It is the raw material for latex concentration units. Many such units buy preserved field latex from smallholders/estates. Also a large number of small scale units producing latex products, for economic reasons, buy preserved field latex and concentrate it by creaming.

For the preparation of preserved field latex, latex from the field is sieved and bulked and ammonia bubbled through it so as to get a concentration of 0.7–1.0 per cent on volume of latex. After ammoniation, latex is left undisturbed for about 15–20 min to allow separation of sedimentable impurities and reaction product (magnesium ammonium phosphate). It is then transferred to drums, sealed and marketed.

23.2.1 Handling of ammonia

Ammonia is available in two forms, as an aqueous solution containing about 25 per cent of ammonia and as pure liquified ammonia contained in high pressure cylinders. The former is more expensive, inconvenient to handle and its use dilutes latex. But purchase of ammonia solution is justifiable when the quantity of latex to be preserved is small. Equipments for adding ammonia gas to the latex, required at the collecting stations/factory, consist of a platform balance together with a cylinder of ammonia gas and pipe/hose connection. The process of adding ammonia to latex is simple. All that is necessary is to calculate the quantity required for the latex; the cylinder is then weighed and weights equal to the required quantity are removed. The cylinder valve is then opened slowly and the rate of flow of the gas is controlled in such a way that it is equal to the rate of absorption. Rate of absorption will be better if the gas is bubbled through the latex using a spreader. During and after addition of the gas the latex should be mixed to ensure uniformity. Although ammonia is a dangerous gas, very little risk is involved in its use provided normal precautions are taken. Being an alkali, concentrated solutions of ammonia are harmful to the skin. For normal maintenance work, a tank should be opened up and washed down with a fine spray of water which dissolves most of the gas present. It should then be left open to ventilate thoroughly and inspected before workers are sent down into it.

23.2.2 Dosage of preservatives

The efficiency of preservation depends both on the quantity of preservative added and the time lag between tapping and addition of preservative. As field latex contains more non-rubber constituents than concentrated latex, it requires a slightly higher dosage of the preservative. If the preservative is ammonia and if field latex is to be preserved only for a day or two, a concentration of 0.4–0.5 per cent on latex is sufficient. But if the latex is to be preserved for much longer periods, the minimum concentration shall be 1 per cent. If secondary preservatives are also used, the concentration of ammonia can be suitably reduced.

23.2.3 Sludge removal

It has already been mentioned that magnesium ions present in latex react with phosphate ions in presence of ammonia to form magnesium ammonium phosphate. Being insoluble, this gets precipitated and settled at the bottom of the tank. The phosphate ions required for this purpose are either already present in latex or are formed as a result of the hydrolysis of phospholipids. The ratio of magnesium to phosphate ions in latex is important in this connection. In latices from certain clones like GI 1, the proportion of magnesium is very high. Also, during wintering, the concentration of magnesium in latex increases. In such cases, the phosphate ions present in latex may not be sufficient for the complete removal of magnesium. As removal of magnesium is always advisable to get better stability for latex, additional phosphate ions are provided by adding calculated quantity of diammonium hydrogen orthophosphate solution to latex. Concentration of magnesium in latex is first estimated and a slightly more than the equivalent quantity of diammonium hydrogen orthophosphate solution is added. Latex is then stirred well and allowed to stand for a few hours or preferably overnight. Magnesium ammonium phosphate, being denser than latex, settles down at the bottom of the tank, along with sand, dirt and other heavier matter. This is called sludge. If the outlet pipe for the latex is fitted slightly above the bottom of the tank, latex can be removed without disturbing the sludge. Sludge can also be removed by providing a sludge tap at the bottom of the tank.

23.3 Preserved latex concentrate

The process of latex concentration involves the removal of a substantial quantity of serum from field latex, thus making latex richer in rubber content. Concentration of latex is necessary because of the following four reasons:

(i) Economy in transportation;

(ii) Preference for high drc by the consuming industry;

(iii) Better uniformity in quality; and

(iv) Higher degree of purity.

Various processes have been proposed for concentrating latex. Out of these, four have emerged as of special importance. These are evaporation, creaming, centrifuging and electro-decantation. Evaporation method involves the removal of water only. Hence the ratio of non-rubber constituents to rubber remains unaffected by this concentration process. The particle size distribution also is substantially unaffected. On the other hand, the other three processes involve the partial removal of non-rubber constituents and smaller rubber particles. Because of this, the range of particle size is reduced and a higher degree of purity is obtained.

23.3·1 Evaporation

This is the earliest process for the concentration of natural rubber latex. A typical process is illustrated diagramatically in Fig 23.2.

Latex is taken inside a horizontal double-walled cylindrical vessel which revolves on its own axis. Heating is done by circulating hot water through the annular space between the two walls. A hollow iron roller, with its axis parallel to that of the cylinder, rotates inside the latex along with the drum. It homogenises the latex, prevents scum formation, minimises frothing and provides a stirring effect. A current of cold air is drawn through the cylinder to remove water vapour. Latex should be stabilised with a fixed alkali and soap. Evaporation takes place from the bulk of the latex and from the thin film on the walls of the vessel and on the roller as they rotate.

A second process of evaporation is to spray hot latex into partially evacuated chamber. Rapid evaporation occurs as the latex leaves the nozzle. The operation may be repeated till the desired degree of concentration is attained. No frothing occurs during evaporation. The latex may be preserved with ammonia.

Now, a major part of the evaporated concentrate is produced using turbulent, film evaporators of the Luwa type which is more popularly used for the concentration of styrene–butadiene rubber (SBR) latices. The details of the Luwa thin-layer evaporator are illustrated in Fig 23.3.

Evaporation takes place from a thin film which is kept mechanically in continuous turbulent motion, thereby permitting rapid and uniform

concentration, at relatively low temperatures. The concentrator consists of two vertical cylindrical sections, one on top of the other, with the feed inlet between them. In the lower section evaporation takes place, whereas the upper section is concerned with the separation of water vapour. A central rotor with longitudinal blades which project radially from the shaft extends through both the sections and there is a clearance of 0.76–1.52 mm from the heated wall in the lower section. The separator section has longitudinal fins fixed to the inside wall. Latex enters the lower section and is picked up by the rotor blades and whirled against the heated wall. A thin turbulent layer of latex is maintained over the entire wall surface. Latex descends in a spiral path down the heated wall to the outlet at the bottom. Vapours ascend to the separator along the rotor shaft, thereby being removed from the evaporator. Any latex entrained in the separator flows back to the evaporator through the stationary fins. Latex is held in the evaporator wall for no longer than 20 sec and is therefore subjected to the very minimum of heat treatment.

23.3.2 Creaming

23.3.2.1 Principle of creaming

Rubber latex is a dispersion of very fine particles of rubber in serum. Like any other dispersion or suspension, the particles have an inherent tendency to sediment under the influence of gravity. Rubber particles, being lighter than serum, tend to cream up. The velocity of creaming, can be deduced approximately from Stokes's law which can be stated mathematically as follows:

$$V = \frac{2\,g(Ds-Dr)\,r^2}{9\eta} \quad \text{where}$$

V = Velocity with which the particles rise (cm/sec)

g = Gravitational force (cm/sec^2)

Ds = Density of serum (g/ml)

Dr = Density of rubber particle (g/ml)

r = Effective radius of the rubber particle (cm)

η = Viscosity of the serum (poise)

From the above expression, it is clear that the velocity of creaming is increased by increasing the particle size or the difference between the densities of the particles and serum or by decreasing the viscosity of the serum. No control over 'g' can be exercised when creaming is practised.

It was first discovered in 1925 by Traube that when certain gums are added to latex, the rubber particles or groups rise to the surface to form a cream, and on stirring, the rubber particles are re-dispersed throughout the liquid (18). Several explanations have been given for this behaviour. One theory is that the gum is adsorbed on to the surface of the rubber particles and this reduces the effective electric charge on the particles, resulting in the formation of reversible agglomeration of particles. But it is difficult to understand why anionic adsorbates such as alginates should reduce the charge carried by the particles. Another explanation proposes the formation of a loose net work between the molecules of the creaming agent adsorbed upon the surface of the particles and those dissolved in the serum. The Brownian movement is restricted by the 'anchoring' effect of such a network. But because the networks are not necessarily distributed homogeneously throughout the system, the Brownian movement is not restricted everywhere. The particles, in fact, move until they become entrapped in localised networks that are sufficiently strong to hold them. This is the way clusters are thought to be formed. These clusters are believed to grow by the continued entrapment of particles until the buoyancy of the clusters is sufficient to break them free from the network and carry them upwards. In the upper layers, the clusters may become more compact owing to the compressive effect of those rising from below, thereby causing expulsion of serum.

23.3.2.2 Creaming agents

A large number of vegetable gums and gelatinous materials as well as many synthetic substances have been tried as creaming agents. But on the basis of cost and efficiency, only a few have been found

to be satisfactory. These are sodium and ammonium alginates, tragon seed gum, locust bean gum, tamarind seed powder and methyl cellulose. As tamarind seed powder is readily available in India at a very cheap rate, it is the most widely used creaming agent in this country. The concentration of creaming agent frequently used is 0.2–0.3 per cent of dry material calculated on the water phase of latex. In actual practice, the optimum quantity is found to vary with each creaming agent, with the age of latex and with the drc of latex. Optimum quantity of creaming agent is that which produces a concentrate of highest drc, although it may not produce a serum layer that is entirely clear. If more than the optimum quantity is used, the induction period is prolonged and the rate of creaming is decreased. If less quantity is used, the rate of creaming is decreased and a low drc is obtained. In many cases, the optimum concentration has to be determined by trial and error.

All creaming agents have certain properties in common. Generally, they are hydrophilic colloids capable of swelling in water and holding large quantity of water in a loosely bound condition. They form viscous solution in water at low concentrations and, as an approximation, their creaming efficiency is proportional to the viscosity of their solutions.

23.3.2.3 Factors affecting efficiency of creaming

The important factors affecting efficiency of creaming are:

(i) Concentration of creaming agent: The optimum level should be employed;

(ii) Age of latex: Creaming is faster in the case of aged preserved latex than in the case of freshly preserved latex;

(iii) Temperature: Except in the case of methyl cellulose, a higher temperature improves the efficiency of the creaming agent;

(iv) Alkalinity of latex: Optimum pH is between 10.8 and 11.8;

(v) Stirring: Good agitation after the addition of the creaming agent reduces the induction period and generally improves the efficiency of creaming;

(vi) Soap: Small concentrations of fatty acid soaps in latex increase the efficiency. About 0.3–0.5 per cent concentration on latex is recommended; and

(vii) Viscosity: A high initial viscosity of latex retards creaming.

23.3.2.4 The creaming process

Latex is collected and ammoniated to 1 per cent and preferably kept for a few days for aging. The creaming agent solution at 3 per cent concentration is prepared by boiling the required quantity of the material with water. The preserved and de-sludged latex is taken in the creaming tank. Calculated quantity of the creaming agent solution, which has been sieved to remove uncooked materials, is then added. A 10 per cent solution of soap is added so as to make its concentration 0.3 per cent on latex. The latex is then thoroughly stirred for about 1 h. As the creaming agent solution is viscous, it does not readily mix with latex unless broken up by agitation. The complete dissolution of creaming agent and the thorough mixing of the solution in latex are very important. After stirring, latex is allowed to remain undisturbed till the desired level of creaming is obtained.

Although a minimum period of 48 h is usually required for satisfactory creaming, no fixed time can be set for all conditions. After the creaming agent is added, there is an 'induction period' of several hours before any creaming is visible. For the first 24–40 h, creaming is rather rapid and then it becomes slower. When the desired level of separation is obtained, the skim layer is drained off. The drc and ammonia content of the concentrate are checked and adjusted to standard levels. Several batches of cream are bulked together, packed and despatched.

23.3.2.5 Advantages and disadvantages of creaming

The advantages of creaming are the following:

(i) Requires only simple equipments;
(ii) Lower labour cost; and
(iii) Lower power consumption.

Disadvantages of the process are the following:

(i) Slowness;

(ii) Dependence of creaming efficiency on the quality of field latex; and

(iii) After-creaming (separation of serum from cream during storage).

23.3.3 Centrifuging

Although Biffin observed in 1898 that latex could be concentrated by centrifuging (3), no commercial development of the process took place until about 1923 when the process was apparently rediscovered by Utermark (20). The process was further developed by the Dunlop Rubber Company on a large scale in the Far East. Now this is the most widely used method for the concentration of latex. Over 90 per cent of the concentrated latex is produced by centrifuging.

23.3.3.1 Principle of centrifuging

The theory of centrifugal concentration of latex is basically the same as that of creaming. In centrifuging, centrifugal force replaces gravitational force which brings about separation of rubber particles in creaming. Latex is subjected to strong centrifugal force, several thousand times the gravitational force, in a bowl rotating at high speeds whereby the individual rubber particles tend to separate into a layer surrounding the axis of rotation leaving an outer serum layer having a comparatively low rubber content. Each layer is removed through annular spacings around the axis of rotation. By controlling the time to which latex is subjected to such forces and by controlling the conditions of operation, latex having an original drc of 30–38 per cent can be concentrated to drc of 60 or more. Usually, the speed of the machine is fixed, so that the variables for the purpose of control are: (i) the rate of passage of the latex through the machine and (ii) certain machanical adjustments on the machine. It should also be noted that with increasing temperatures upto 50°C an increasing proportion of the total rubber is obtained in the concentrate.

23.3.3.2 Centrifuging process

Several types of centrifuging machines are used for the concentration of latex. Of these, the most widely used type is the de Laval, (Fig 23.4) the details of which are illustrated in Fig 23.5. The rotating mass of latex is broken up into a number of thin conical shells within the bowl which rotates at speeds around 6000 rpm. The maximum distance which a particle has to traverse in order to pass from the skim to the cream is very small.

The degree of ammoniation of the latex prior to centrifuging depends upon the period which has elapsed since collection and ranges from 0.25 per cent, if centrifuging is immediate, to 0.8 per cent, if the period is two days or more. Only the minimum required quantity of ammonia should be added. Most of the ammonia that is added to the field latex goes in the skim which makes the coagulation of skim more difficult. Moreover, if the concentration of ammonia in latex is more, larger quantity escapes into the atmosphere causing discomfort to workers. Usually, latex is to be ammoniated and kept overnight before being centrifuged, thus giving time for the sludge to settle down. Latex is fed to the centrifuge from a constant head device so as to ensure a constant flow through the machine. It enters the bowl through a central feed tube and then passes through a distributor to the bottom of the bowl where it flows through a series of holes into the interior of the bowl. The cream centrifuges inwards towards the axis of rotation and then empties from the bowl through holes into a stationary gully. The skim flows outwards away from the axis of rotation and leaves the bowl through orifices which are formed by regulating screws. It passes out of the centrifuge through a second stationary gully. The parts of the machine which come into contact with latex should be constructed preferably out of stainless steel for avoiding contamination and preventing corrosion. The cream is separately collected in a bulking tank, its ammonia content estimated and made up to 0.7 per cent on latex and packed in drums.

23.3.3.3 Efficiency of the process

Efficiency of the centrifuging process is defined as that fraction of the total rubber entering the machine, which effluxes in the form of concentrate.

$$E = \frac{C \times c}{F \times f}$$

Where c = drc of cream

C = Weight of cream

f = drc of field latex

F = Weight of field latex

Usually an efficiency of 0.85–0.90 is attained in commercial units.

The following are the important factors which affect the efficiency of the process:

(i) Feed rate: A slow feed rate increases efficiency

(ii) Angular velocity of the machine: An increase in the speed of the centrifuge bowl causes an increase in efficiency

(iii) Length of the regulating screws: A shorter screw increases the drc of the cream, but reduces efficiency.

23.3.3.4 Skim latex and production of skim rubber

When field latex is centrifuged, in addition to the concentrate containing most of the rubber, an equal fraction in volume, containing a very small proportion of rubber, is also obtained. This is known as skim latex. As the normal efficiency of centrifuging process is only 85–90 per cent, about 10–15 per cent of the incoming rubber, goes in the skim. Hence on economic grounds, it is essential to recover the rubber in the skim latex.

(i) Composition of skim latex

The important factors governing the composition of skim latex produced are the type of centrifuge, drc of field latex, throughput and efficiency of operation. Normally, the rubber content of skim latex lies between 2.5 and 10 per cent. It contains about two-thirds of

the total serum from the field latex. The average size of its rubber particles is smaller than that of field latex since the larger particles separate more readily into the concentrate fraction. In addition to the water soluble substances in serum, latex contains proteins which are mainly distributed as adsorbed film on the surface of the rubber particles and as the particles are small, the protein content per unit weight of rubber is more in the case of skim latex. This not only renders coagulation more difficult, but also has a marked effect on the properties of the rubber. Skim also contains ammonia which adds to the cost and difficulty of acid coagulation. With increasing efficiency in concentration, the drc of the skim fraction decreases and the difficulty and cost of any recovery process increase.

(ii) Recovery of skim rubber

The usual method of recovery of skim rubber is by spontaneous coagulation or by acid coagulation. In the first method, the skim is de-ammoniated by bubbling air through it and then left in tanks for several days, during which time it gets coagulated. In the acid coagulation method, coagulation of skim is done in batches by the addition of sulphuric acid. In either case, the coagulum obtained is processed into crepe or sheet by conventional means, taking special care to give thorough washing. From very early days of the latex concentrate industry itself, skim rubber is known for its inferior properties. Although the total quantity of skim rubber is relatively small, its presence in consignments of other forms of rubber causes much trouble to manufacturers owing to its abnormal properties, particularly the tendency to scorch.

(iii) Improved skim rubber

Recently, several methods have been suggested for the preparation of higher grades from skim latex. Enzymic de-proteinisation of skim so to make the rubber subsequently recovered largely free from proteins has been suggested (12). In a typical process, trypsin, an enzyme digesting protein, is allowed to act on skim for 24 h in wax lined tanks. About 1 kg of trypsin is required for 10,000 kg of skim containing 6 per cent rubber. It is added as an 8 per cent slurry in water. After digestion, the skim is de-ammoniated to 0.1

per cent ammonia by agitation and aeration. It is then transferred to coagulation tank to which a small quantity of either sodium thiosulphate or sodium meta bisulphate has been added. The skim latex is coagulated by the addition of dilute formic acid. The coagulum is then processed into crepe. The principle of purification is that, under the influence of the enzyme, the proteins are hydrolysed into water soluble products and are thus removed from rubber.

In another process, the operation consists of spontaneous coagulation of the skim followed by subjecting the coagulum to alkaline hydrolysis and extraction. After clarification, the skim is allowed to stand further for two to three days when it coagulates spontaneously. The coagulum is crumbled and the crumbs are soaked for several hours in saturated calcium hydroxide solution and is then leached in 3 per cent caustic alkali solution for 20 h. During the process, the proteins and other nitrogenous substances are hydrolysed and made water soluble. Also, some enzymic degradation of proteins occurs during the spontaneous coagulation, rendering them alkali soluble. The product is a bright coloured sweet smelling rubber having properties like nitrogen and rubber hydrocarbon contents and cure rate comparable to those of pale crepe.

Another method of purifying skim rubber is by creaming the skim latex with tamarind seed powder (19). The optimum concentration of the creaming agent is between 0.5 and 0.7 per cent on latex. By this process, non-rubber constituents of skim rubber are reduced from 20 per cent to 4 per cent, nitrogen content reduced to less than 0.7 per cent and copper content to less than 8 ppm.

The main characteristics of skim rubber are outlined below:

1.	Colour	: Light
2.	Dirt content	: Very low
3.	Non-rubber content	: Up to 30 per cent
4.	Copper content	: 4–20 ppm
5.	Acetone extract	: 3–5 per cent
6.	Mill breakdown	: Normal
7.	Power consumption	: Slightly higher
8.	Mill shrinkage	: Less than for normal rubber
9.	Cure rate	: Fast, giving scorchy compounds

10.	Hardness of vulcanisate	: Higher
11.	Modulus	: Higher
12.	Resilience	: Lower
13.	Aging behaviour	: Variable

(iv) Use of skim rubber

The main application of skim rubber is in compounds requiring high hardness such as solings. The proportion of high styrene resins used in soling compounds may be reduced to a certain extent by using skim rubber.

23.3.3.5 Factory design

The important factors to be considered while designing a latex centrifuging plant are described below:

The plant shall preferably be located in a place which permits gravity flow of latex from one stage to the next. This will help to run the factory at a cheaper operating cost. When the factory is situated in level ground, flow of field latex from storage tanks is effected either by air pressure or by pumping. The factory floors should be in different levels. Field latex storage tanks are placed at the top most floor. These tanks should have sufficient capacity to hold at least two to three days' requirement of field latex. Just near the top level of these tanks there should be provision for parking tankers. The centrifuge machines are erected on the floor just below the field latex storage tanks. The field latex from each tank enters a header from which it is continuously flowing into the machines. There should be a chain block arrangement near the machines, which can move in two directions for lifting/replacing the bowls. Also facilities should be provided near the machines for washing the bowls. The concentrate storage tanks are placed on the floor next to the machine floor. The concentrate from the machines flows into a chute leading to these tanks. The skim which effluxes from the machine enters another chute leading to the skim collection tanks. The skim collection tanks should be situated a little away from the main factory floor so as to minimise the chances for bacterial contamination

of latex. From the storage tanks, the concentrate enters a header having a number of stop-cocks. The drums are filled by opening these stop-cocks. There should be facilities for weighing and marking of the filled drums.

Skim latex is coagulated in batches in shallow coagulation tanks, using dilute sulphuric acid which is stored in another tank. Creping machines are placed adjacent to the coagulation tanks. Suitable drying shed and packing shed/store are also necessary. The serum from the skim coagulation tank and the wash water from the creping unit flow into the effluent treatment plant, along with wash water from the main factory floor. The effluent treatment plant also should be situated a little away from the factory to minimise foul odour in the factory.

The factory building should have good ventilation. A reliable water supply also should be provided. The factory should be located at a central place in the estate and there should be roads leading to it from various parts of the estate. While designing the factory, the full crop of the estate should be estimated and a complete plan prepared.

The flow diagram of a typical latex centrifuging plant is given in Fig 23.6.

The latex and skim storage tanks are made of either mild steel or concrete. In either case, the inside of the tanks should be provided with a protective coating of an alkali-resistant material like wax or bituminous paint.

23.3.3.6 Water and power requirements

Power requirement in latex concentration is low. A latex centrifuge of the type described above can be worked using a 15 hp motor. In addition to this, electrical power is needed only in the operation of some stirrers which are used for blending or for de-ammoniation purpose. Some latex centrifuge factories also install crepe mills for processing the skim latex coagula. In such cases, the unit requires additional power.

Water requirement in latex concentrating factories is much less when compared to that for the other processes. Main requirement of water is in operations like cleaning of tanks and bowl. It is estimated that 7.5–15.0 l of water is needed for producing 1 kg dry rubber as latex concentrate.

23.3.4 Electro-decantation

The details of the process are illustrated in Fig 23.7.

Application of a potential difference between the two electrodes causes the negatively charged rubber particles to move towards the anode. They are intercepted by the semipermeable membrane and provided the potential gradient is not excessive, they deposit at the membrane in an essentially reversible condition. The particles tend to form loose agglomerates in the region of the membrane surface and these agglomerates cream rapidly. A layer of concentrate thus forms at the surface of the containing vessel. It is preferable to reverse the polarity of the electrodes periodically in order to prevent blockage of the semipermeable membrane and also the formation of irreversible deposits. Usually a direct current supply is given with a mechanical device for periodic reversal.

The power consumption is normally low, of the order of 45–153 watt hours per kg of 60 per cent concentrate. Temperature control of the bath is very important, because temperature tends to rise gradually as the process proceeds owing to the dissipation of electrical energy. Increasing temperature has the effect of increasing the electrical conductivity of the bath thereby causing unnecessary power consumption and promoting the formation of irreversible deposits on the membrane surface. Anionic surface active agents may be added to latex in small quantities, in order to increase the magnitude of the negative charge carried by the latex particle. The efficiency of the process is thereby improved. An important feature of the process is the very small rubber content of the skim. It rarely exceeds 1.5 per cent. The disadvantages of the process are its slowness and the unsuitability of its product for the production of foam.

23.3.5 Rccent developments in latex concentration

Some of the recent developments in the latex concentration field are outlined below.

23.3.5.1 Redispersible rubber

With the general escalation in transportation cost and labour wages, it has become necessary to reduce the water content of latex to the minimum possible level. Thus it is desirable to process latex into a form of dry rubber which can be later redispersed at the time of use to reform latex. A method for preparing such a redispersible latex has been proposed (4). According to this method, latex, treated with a glycoside, polyol, urea or their combinations with or without the addition of anionic surface active agent, is dried to three to five per cent moisture. The incoherent films or pastes thus obtained are redispersible in water, under high speed mechanical mixing. The principle is that the additives prevent dehydration of 'bound-water layer' surrounding each rubber particle during the final stages of drying. Redispersed latex is stable at ambient temperature and preliminary examination of its properties showed its similarity to the control latex. The storage behaviour of the redispersible rubber pastes varies with the quantity and type of the additive. Satisfactory redispersion of some pastes was achieved even after two months' storage in air tight containers at ambient temperature.

23.3.5.2 Continuous centrifuging

Although centrifuge is designed for continuous operation, accumulation of sludge and coagulum in the bowl necessitates stoppage of the machine every 3 h or so. Stoppage, replacing the bowl and restarting may take away 20–30 min.This naturally reduces the through-put. Attempts have been made to increase the running time of the machine. A new system called Hartex 103 has been proposed for latex concentrate production and this enables the centrifuges to run longer than 20 h continuously without loss of efficiency (5). The system involves new concepts for handling field latex, centrifuge operation and concentrate preservation. The basis of the process is stabilisation of field latex to a mechanical stability sufficiently high to

prevent build up of coagulum in the bowl. A new low-ammonia preservative system is used to allow the field latex to be aged several days before centrifuging which increases the stabiltiy. Thus the need for using a high quantity of ammonia for providing this level of stability in conventional system is avoided. A recent report shows that the running time of the machine could be increased from the normal 3 to 9 h (15). The main drawback of the proposed process is that it requires enhanced storage capacity for the field latex.

23.3.5.3 High drc latex concentrate

Some modifications in the centrifuging process can give concentrated latex of drc around 66 (7). Two methods are suggested. In the first, latex is initially passed through the centrifuge to obtain a drc of just over 50. This concentrate is then mixed with water and re-centrifuged with different settings to obtain a concentrate with 66 per cent or more rubber content. In the second method, latex is allowed to stand for 18 h after the addition of ammonium alginate. The creamed product with a drc of 50 is mixed with water, and centrifuged to obtain a concentrate with a drc of 66. High drc latices provide savings in transport and storage, dry faster, have low non-rubber content, pick up faster in dipping, need less thickening agents and have lower foam-rubber shrinkage. However, they have an additional production stage, they cost more to make and they are slightly more difficult to handle.

23.3.5.4 Freeze resistant latex concentrate

Latex concentrate undergoes colloidal de-stabilisation when it freezes below 0°C. On thawing, the latex has higher viscosity and lower mechanical stability. Persistent freezing results in complete coagulation of latex which on thawing becomes a gel. Therefore, in areas such as Eastern Europe and Russia, supply of natural rubber latex is either restricted or withheld during the winter months, because latex cannot be protected against frost. The problem becomes more acute when latex is transported not in tankers but in drums in which cooling is more as a result of the larger surface area exposed. It has been shown that the freeze-thaw stability of latex concetrate can be improved by the addition of certain surface active agents (6). Among the various substances found useful for this purpose are fatty

acid soaps like those of caproic, caprylic, capric and lauric acids and non-ionic stabilisers like nonaryl 930, phenolic compounds and salicylates. The effect of sodium salicylate along with a small quantity of laurate is outstanding. A general purpose freeze-thaw stable latex concentrate is based on this system. In high-ammonia latex, the concentrations of ammonium laurate and sodium salicylate are 0.025 per cent and 0.2 per cent respectively on volume of latex. Properties of latex, stabilised this way, are almost comparable to those of normal latex concentrate. However, use of non-ionic stabilisers makes the latex more resistant to acid coagulation.

The destabilisation of aqueous dispersions/emulsions by freezing is attributed to two factors.

(i) The crowding together of the particles by the advancing ice crystals.

(ii) The dehydration of the particles due to the removal of the bound water as ice.

The second is more significant in natural rubber latex. The additivies, conferring freeze-thaw stability, should therefore maintain a layer of unfrozen water around the particles, so that their colloidal stability is not destroyed. The fatty acid soaps and non-ionic stabilisers have strongly hydrated groups and would be expected to act in the above way and since they are adsorbed at the rubber particle surface, the effect is localised at the surface and particle hydration is more readily maintained. Phenolic compounds and salicylates are seen to have specific action on the stabilising protein chain, so that dehydration is either prevented or minimised.

23.4 ISI specifications for latex concentrates

As latex is a raw material for many consumer and industrial products, its quality should be controlled strictly. Natural rubber latex concentrate was being marketed to strict technical specifications even before the introduction of such a system to dry natural rubber. The reason is obvious. Whereas a buyer may attempt to assess the quality of a sample of dry rubber by visual inspection, it would be unwise to do so with latex. Visual inspection can neither reveal the rubber content which determines the price nor detect any tendency for instability. The Government of India have amended the Rubber

Rules 1955—[vide Rubber (Amendment) Rules, 1975] to make it obligatory to grade and market solid block rubber, preserved latex and latex concentrate produced in the country in conformity with such standards as are specified by the Indian Standards Institution from time to time. The use of the ISI Certification Mark is governed by the provisions of the Indian Standards Institution (Certification Marks) Act and the Rules and Regulations made thereunder. Presence of this mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard, through a well defined system of inspection, testing and quality control. The relevant portions of ISI specifications for preserved latex concentrate, as given in IS: 5430–1969, are reproduced below:

23.4.1 Types covered

This standard covers three types of concentrated natural rubber latices as follows:

Type HA (High Ammonia)—Centrifuged natural rubber latex preserved with ammonia only or by formaldehyde followed by ammonia with an alkalinity of at least 1.6 per cent on serum content.

Type MA (Medium Ammonia)—Centrifuged natural rubber latex preserved with ammonia and other preservatives as agreed to between the purchaser and the supplier with an alkalinity above 0.8 per cent but less than 1.6 per cent.

Type LA (Low Ammonia)—Centrifuged natural rubber latex preserved with ammonia and other preservatives as agreed to between the purchaser and the supplier with an alkalinity of not more than 0.8 per cent.

23.4.2 Specifications

(i) Colour: The colour for all types of latex when visually examined shall not be pronounced blue or grey.

(ii) Odour: For all types of latex, there shall not be any pronounced odour of putrefaction after neutralisation with boric acid.

(iii) Composition and physico-chemical properties: These shall conform to the requirements prescribed in Table 23.1.

(iv) Optional requirements: The limit for magnesium content when determined in accordance with the method prescribed in IS: 3708 (Part II)—1968, shall be as agreed to between the producer and the supplier.

Table 23.1

Requirements of composition and physico-chemical properties of preserved latex concentrate

Sl. No.	Characteristic	Requirements Type HA	Type MA	Type LA	Methods of test accroding to CL No. of IS: 3708 (Part I) 1966.
1.	drc *Min*	60.0	60.0	60.0	NRL: 1
2.	Total solids content, per cent by weight, *Min*	61.5	61.5	61.5	NRL: 2
+3.	Non-rubber solids, per cent by weight *Max*	2.0	2.0	2.0	
4.	Coagulum content, per cent by weight, *Max*	0.08	0.08	0.08	NRL: 3
5.	Sludge content, per cent by weight, *Max*	0.10	0.10	0.10	NRL: 5
6.	Alkalinity as ammonia per cent on water content	1.6 *Min*	above 0.8 but below 1.6	0.8 *Max*	NRL: 7
7.	KOH number *Max*	1.0	1.0	1.0	NRL: 8
8.	Mechanical stability, seconds, *Min*	475	475	475	NRL: 9
9.	Volatile fatty acid number, *Max*	0.15	0.15	0.15	NRL: 10
10.	Copper content, ppm on total solids, *Max*	8	8	8	NRL: 13
*11.	Iron content, ppm on total solids *Max*	8	8	8	NRL: 13
12.	Manganese content, ppm on total solids, *Max*	5	5	5	NRL: 14

+ Difference between total solids content and dry rubber content.
* In 1979, iron content has been removed from the specification.

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4.	Coagulum content, per cent by weight, *Max*	0.08	0.08	0.08	NRL: 3
5.	Sludge content, per cent by weight, *Max*	0.10	0.10	0.10	NRL: 5
6.	Alkalinity as ammonia per cent on water content	1.6 *Min*	above 0.8 but below 1.6	0.8 *Max*	NRL: 7
7.	KOH number *Max*	1.0	1.0	1.0	NRL: 8
8.	Mechanical stability, seconds, *Min*	475	475	475	NRL: 9
9.	Volatile fatty acid number, *Max*	0.15	0.15	0.15	NRL: 10
10.	Copper content, ppm on total solids, *Max*	8	8	8	NRL: 13
*11.	Iron content, ppm on total solids *Max*	8	8	8	NRL: 13
12.	Manganese content, ppm on total solids, *Max*	5	5	5	NRL: 14

+ Difference between total solids content and dry rubber content.
* In 1979, iron content has been removed from the specification.

The methods for testing the above characteristics of rubber latex are available in IS: 3708 (Part I) 1966 and Part (II) 1968. These can be had from the Indian Standards Institution, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi–110 001.

23.4.3 Packing and despatch

Shipment of latex is done either in drums or in tankers. Shipment in drums is the more common practice in India.

23.4.3.1 Shipment in tankers

This has the advantage of saving in cost of containers and freight. Also, it ensures large, uniform consignments of latex. But to operate the system, installations are needed at both the shipping and receiving ends and a destribution system must be organised in the receiving country. Special arrangements must be made with a shipping line to provide tanks which are suitably cleaned and surface coated for the transport of latex. Such an organization involves considerable capital expenditure which cannot be justified unless large volumes are handled.

23.4.3.2 Shipment in drums

The ISI has specified the code of packaging of natural rubber latex in drums. Relevant portions from this (IS: 5190–1969) are reproduced below:

Scope: This code prescribes the method of packing and marking of latex in clean, disinfected and painted drums.

Selection of drums: Light duty mild steel 200 l drums conforming to the sizes and dimensions given in IS: 1783–1961, free from rust and other contaminations may be used. Those used previously for other purposes may also be used, but they should be carefully cleaned, to make them free from traces of rust and other contaminations.

Filling procedure: Latex may be filled into the drums by gravity from bulk storage tanks, as per the following procedure.

Both bung holes should be kept open. An iron pipe, having lining of bituminous paint, should be passed through the bung hole and latex should be discharged through this pipe into the drum. The pipe should reach the bottom of the drum to prevent frothing of latex inside while filling. The drums should be filled to the capacity after the removal of the filler pipe leaving 25–40 mm height at the top. Then both bung holes should be tightly closed and sealed.

Painting outside: The drum should be painted outside for protection against weathering action.

Packing capacity: Each drum should contain 200±5 l of latex.

Marking: The drum should be marked with the following information:

(i) Name of the manufacturer or trade-mark, if any;

(ii) Type of the latex, whether centrifuged or creamed and whether LA, MA or HA;

(iii) Net and gross weights in kg and volume in l;

(iv) drc; and

(v) Date of packing.

The drums may also be marked with the ISI certification mark.

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24 TECHNICALLY SPECIFIED BLOCK RUBBER

Chapter 24

TECHNICALLY SPECIFIED BLOCK RUBBER

The conventional forms of dry natural rubber, viz ribbed smoked sheets and the different types of crepe are internationally recognised forms and are graded and marketed adopting the specifications detailed in the Green Book. The main drawbacks in the marketing of these forms are:

(i) Multiplicity of grades, posing problems to the consumer;

(ii) Non-avilability of technical information on quality of rubber; and

(iii) Poor presentation of rubber in large bareback bales prone to contamination.

Inspite of these drawbacks, production and marketing of natural rubber in conventional forms was on an even keel and there was little need for improvement in view of the monopolistic position of natural rubber. But during the second world war, when the Allies were cut off from their main sources of natural rubber supply, intensive research was carried out on the development of synthetic rubbers. This resulted in the production of synthetic rubbers on a large scale in the 1950s and 1960s. The advent of synthetic rubber and its steady and gradual encroachment into the traditional natural rubber markets posed a serious threat to natural rubber. Synthetic rubbers were marketed in compact, uniform and medium-sized bales, wrapped in low density ploythene to keep away dirt and with technical specifications. Moreover, since the synthetic rubber industry worked in close association with the manufacturing industry, it could produce rubber in a form most suitable for the consuming sector. As a result of competition from synthetic rubber, extensive research

and development work were carried out for processing natural rubber into a form comparable to that of synthetic rubbers. Consequently, during the last decade, new methods of processing and presentation were developed to market natural rubber in compact medium-sized blocks, wrapped in polythene and graded adopting technical standards. These are called technically specified block rubbers.

24.1 Origin of technical specification

To improve the presentation of natural rubber, the International Standards Organisation convened a meeting in New Delhi in 1964 and drew up draft standards for the technical grading and presentation of natural rubber. On the basis of this, Malaysia in 1965, launched the Standrad Malaysian Rubber Scheme. Subsequently, the other major rubber producing countries also launched schemes for presenting natural rubber with technical specifications. The Indian Standards Institution laid the standards for the specification of natural rubber in 1968. Thus, the system of grading natural rubber on the basis of technical parameters came into being.

24.2 Technical specification of conventional grades

The presentation of the conventional forms of natural rubber in technically specified block forms can be done especially when they are processed into the higher grades of RSS and crepe, the production of which requires standard processing operations like bulking and blending the materials to attain homogenity. But on the other hand, the presentation of lower grades of RSS and brown crepes in technically specified block forms poses serious problems in view of their marked variability in dirt and non-rubber content and raw rubber quality. This means that the presentation of the conventional forms of natural rubber in technically specified block forms is mainly suited for the rubber produced in estate sector where standard processing operations are practised. However, techniques were developed recently for presenting the low grade sheet rubbers produced by smallholders into technically specified block forms. Typical small holders' sheet rubber was subjected to surface cleaning with water by scrubbing the sheets using a brush. Larger dirt

particles on the sheets were clipped off and the sheets subjected to drip drying followed by infra-red drying at about 90°–100°C for 20–30 min. The dried sheets, after passing twice through a mixing mill, were then pressed into blocks and wrapped in polythene. The blocks were then graded adopting technical specifications and marketed.

24.3 New process rubbers and their advantages

The new process rubbers are marketed in different countries under specific names. In Malaysia they are marketed as Standrad Malaysian Rubber (SMR), in Indonesia as Standard Indonesian Rubber (SIR), in Thailand as Thai Tested Rubber (TTR) and in Sri Lanka as Sri Lanka Rubber (SLR). In India, the new process rubbers are marketed as Indian Standard Natural Rubber (ISNR). The scope for incorporation of technical innovations for the production of tailor cut products as a marketable feature of natural rubber has been widened by the development of new process rubbers. The production of new process rubbers takes only a much shorter time than that of conventional sheets and crepes and the product is easier to handle and store. These features together with the consistent and specified properties of these rubbers make them far more attractive to the consumers than conventional grades of natural rubber. In view of these attractions, at present new process rubbers fetch a premium price and it is likely that in the years to come conventional rubbers have to be marketed at a discount.

24.4 The production of new process rubbers

The production of new process rubbers involves a series of unit operations which may vary slightly depending upon whether field latex or field coagulum is used as the feed-stock. Where field latex is used as the feed-stock the processing operations involved are coagulation, dewatering, size reduction, drying, baling and classification. On the other hand the unit operations involved when the feed-stock is field coagulum, are pre-cleaning, blending, dewatering, dirt removal, size reduction, drying, baling and classification. A consideration of these unit operations suggests that size reduction is the key operation in the process and different methods

of processing are available, depending upon the means of size reduction employed. Among these processes, those which have received commercial acceptance are:

(i) Decan Grana process,
(ii) Hevea crumb process,
(iii) Granulation process,
(iv) Dynat process, and
(v) Extrusion drying process.

24.4.1 Decan Grana process

The Decan Grana process was originally developed by 'Promoci' a French group, to produce ribbed smoked sheets from latex coagulated at field drc (2). The process has since been modified to produce block rubber. The important feature of this process is the slicing of coagulum, prepared in cylindrical forms, using a band saw into continuous length of sheet and the sheets diced by rotating knives into granules. The granules are then dried on conveyor belt in a drier. The process can be used for operation with field coagula also if it is first converted into crepe. This process is in operation in Cambodia, Viet-Nam and in some of the African countries.

24.4.2 Hevea crumb process

This process was developed and patented by the Rubber Research Institute of Malaysia(5). The most important feature of this process is the use of small quantities of a non-compatible oil such as castor oil as crumbling agent which reduces the tendency of rubber crumbs to stick together. In this process, rubber, containing the crumbling agent, is passed through a series of crepers (crumbler) which gradually disintegrate the rubber into discrete particles called crumbs. These crumbs are then dried in driers, baled and classified. The aim in developing this process was to utilise the existing crepers for the production of new process rubbers. However, these crumblers, because of low input and excessive maintenance cost, were replaced by hammer mills.

24.4.3 Granulation process

Rubber granules are produced by cutting rubber using rotating knives cutting against fixed knives. The size of the granulated rubber is determined by a perforated screen at the base of the machine. Since the particles obtained have cut faces, dirt removal is less efficient and drying time is more. Granulaters require frequent sharpening of knives and adjustment of knife settings.

24.4.4 Dynat process

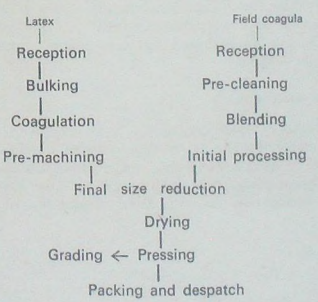
This process was developed and patented by M/s Guthrie Sendirian Berhad, Malaysia (7). In this process, rubber is granulated by using a Guthrier rotary cutter and in the case of field coagula, the rubber after granulation is passed through a pelletiser, a form of extrusion mincer. The later development of this process is the use of extruders in place of pelletisers.

24.4.5 Extrusion drying process

In this method, granulation and drying of rubber are done simultaneously in an extrusion process. The machine is a very compact and complex device requiring a high power input and capital investment. These machines have been installed by Firestone in Liberia and Goodyear in Indonesia.

24.5 Unit operations for the production of new process rubbers

Unit operations for processing latex and field coagula are shown below (6):–



24.5.1 Processing of latex

24.5.1.1 Preservation

For centralised processing, latex may have to be brought from long distances. Ammoniation of latex is necessary in such cases and usually the level of ammoniation is kept at 0.07–0.10 per cent on latex to ensure adequate preservation. But if the latex is to be processed into light-coloured rubber, the common preservative system used is ammonia/boric acid (0.03 and 0.20 per cent on latex respectively) whereas for constant viscosity (CV) or low viscosity (LV) rubber, it is hydroxylamine/ammonia (0.15 per cent hydroxylamine on dry rubber and at 0.03 per cent ammonia on latex) (1).

24.5.1.2 Reception and bulking

Latex, on arrival at the factory, is strained into the bulking tank using a 40 mesh sieve. Sodium bisulphite at the rate of 1 g/kg dry rubber is added as a 1 per cent solution to the bulking tank to prevent surface darkening of the coagulum. Latex is then thoroughly blended using paddle or mechanical stirrer.

24.5.1.3 Coagulation

Latex is then coagulated either in conventional aluminium tanks or coagulation troughs at field drc using either formic or acetic acid. Match flow technique of acid addition may be advantageous with large quantity of latex(3). In this technique, acid is continuously added to the latex in the correct proportion just at the point of discharge of latex to the coagulation tank. For small output, tank coagulation is the simplest and for large output, trough coagulation is more suitable.

24.5.1.4 Pre-machining

In the case of latex coagulated in conventional aluminium tanks, the individual slabs of coagula are cut into smaller pieces before feeding to an extruder or one or two passes are given through a creper before feeding to a hammer mill for final size reduction. With trough coagulation, the long thick coagulum requires one or

two passes through a creper before final size reduction. The present trend is to pass the coagula initially through a crusher and then through a heavy duty macerator and a creper before final size reduction using a hammer mill.

24.5.2 Processing of coagulum grades

24.5.2.1 Reception and storage

Coagulum grades such as cup lumps, tree lace, shell scrap and pre-coagulated lumps require reception, storage and pre-cutting for easy handling prior to precleaning, blending and final size reduction. Estate materials are reasonably clean whereas materials originating from small holdings are often unclean as these materials pass through several agencies before reaching the factory. Therefore, the requirements of machinery for processing vary with quality, quantity and size of the raw material. The best method of storing is to keep the material dry under shade (Fig 24.1).

24.5.2.2 Pre-cleaning

Field coagulum materials usually arriving at the factory from estate sources are fresh, clean and fairly discrete pieces or lumps. Large field coagula are normally sliced into smaller pieces manually or by mechanical means such as crusher or pre-breaker. Dry and dirty scrap requires soaking in water for about 24 h before pre-cleaning (Fig 24.2). Pre-cleaning can be effectively carried out by repeated passes through a macerator and a pre-cleaning hammer mill.

24.5.2.3 Blending

The blending of rubber from different sources can be achieved by adopting the following procedure:

(i) By evenly distributing the different lots of rubber on arrival at the factory into several receptacles.

(ii) By recycling a portion of the crumbs.

(iii) By multiple and overlapping passes of crepes through macerators.

A combination of the above methods has been found to be very effective and is now being followed.

24.5.2.4 Initial processing

Initial processing of the blended material is required mainly to impart a good shearing to the rubber particles, so that it can be dried easily by hot air convection drier. Shearing is done by creping the material by using crepers/macerators (Fig 24.3). The number of passes through crepers depends on the size and nature of the blended material.

24.5.2.5 Final size reduction

Final size reduction largely depends on the type of rubber produced. For mechano-chemical process (Hevea crumb), formerly crumblers were used. However owing to excessive maintenance and labour involvement, the crumblers were replaced by mechanical size reduction machines such as creper/hammer mill or extruder. After pre-cleaning operation, the blaknet formed is fed to the hammer mill through a conveyor system (Fig 24.4). For higher throughput and efficient dirt removal creper/hammer mill is superior to extruder. Extruder is particularly suitable with latex rubber.

The crumbs from the creper/hammer mill are received in a water tank (Fig 24.5) from where they are manually or mechanically loaded into the trolleys and fed to the drier (Fig 24.6). If the final size reduction is by extruder, the extruded rubber is directly fed to the trolley for drying.

24.5.2.6 Drying

Drying is done in oil fired or electrically heated driers. For light coloured latex rubbers, the temperature of drying is normally kept around 100°–105°C, for constant viscosity (CV) and low

viscosity (LV) grades, it is around 115°–120°C whereas for scrap rubber it is around 105°–110°C. The normal drying time is 4–5 h.

24.5.2.7 Baling, grading and packing

The dried crumbs are taken out (Fig 24.7) and cooled to about 60°C. Blocks weighing 25 or 331/3 kg, are normally prepared (Fig 24.8) by pressing dry crumbs in a hydraulic press of 30–50t capacity (Fig 24.9). Samples are then cut from a few representative bales (10 per cent) and tests necessary for technical specification are undertaken. Based on the test results, grading is done. Bales are then wrapped (Fig 24.10) in low density polythene film of thickness 0.05mm. The wrapped bales are packed in high density polythene or in pallets, stacked and marketed (Fig 24.11 and Fig 24.12).

24.6 Machinery used for new process rubbers

During early stages, the existing machinery were used for the production of new process rubbers. However, as the output of the new process rubbers increased several fold, the industry started using specific machines for various unit operations (4). The most important machinery now in common use for the production of new process rubbers are the following:

(i) Initial size reduction machines:

(a) Creper/macerator
(b) Pre-breaker

(ii) Pre–cleaning machines:

(a) Crepers/macerators
(b) Granulator/turbo mill
(c) Hammer mill

(iii) Final size reduction machines:

(a) Creper/hammer mill
(b) Extruder

(iv) Drier

(v) Baling press

24.6.1 Coagulum crusher

It consists of a pair of wavy-grooved heavy duty cast iron rolls rotating at even speed with low rpm and its principle of operation is similar to that of crepers. The coagulum block is fed into the nip between the rolls and crushed to form a continuous ribbon of coagula suitable for processing in the subsequent machinery. Modified groove patterns like triangular grooves and straight fluted grooves are also being used for improving the performance of the crusher. The throughput rate is around 1000kg/h.

24.6.2 Pre–breaker

Basically, it is similar to an extruder with twin scrolls made of high resistant alloy steel with a die plate drilled with 20–25 mm holes at the exit and a rotating knife assembly connected to the scrolls. The machine is capable of reducing the size of large lumps of field coagulum into pieces of less than 5 cm in a single pass through it. The throughput rate is about 1000kg/h.

24.6.3 Creper/Macerator

These machines consist of a pair of cast iron rolls, mounted on a rigid frame work and rotating in oppoiste directions towards the nip with a differential speed. The surface of the rolls is cut usually with various patterns of grooves in order to increase the grip on the feed material and to effect squeezing and shearing actions. With the liberal use of water at the roll nip, a large quantity of dirt is separated from the feed material. Thus, the main functions of the machine are to remove the dirt, to effect better shearing and to reduce the thickness of the crepe. A macerator is a heavy duty creper with deeper grooves usually diamond cut for handling lumpy material. The diameter and width of creper rolls vary from 25–30 cm and 65–75 cm, respectively.

24.6.4 Granulator/turbomill

These machines consist of a rotor fitted with three to five knives, a cutting chamber where two fixed knives are mounted horizontally and a screen fitted at the lower half of the cutting chamber. The

principle of this machine is to present the feed material at the clearance between the fixed and the rotating knives and thereby cut them into granules. The screen beneath the cutting chamber allows the pre-determined size of the material to pass through and the rest is returned to the system for further granulation. A turbo mill is a heavy duty granulator. These machines are driven by motors with hp varying from 10–40 and the speed of rotor ranges from 900–1500 rpm. These are mainly used for pre-cleaning of field coagula material.

24.6.5 Hammer mill

Hammer mill is basically similar to a granulator except that it has a set of hammers rotating horizontally in a solid chamber instead of sharp knives used in granulators. The hammers are made of hardened carbon steel. The hp of the motor is 50–70 and the speed of rotation of hammer is around 2000 rpm. The feed material is teared into small pieces, depending upon the screen size beneath the chamber. Hammer mills are used mainly for pre-cleaning of field coagula materials.

24.6.6 Creper–hammer mill

Creper-hammer mill is identical to hammer mill except that a pair of creper rolls is fitted above the hammer mill to regulate the feed and to reduce the electric peak load during processing. It has minimum clearance between the bottom of the creper rolls and tip of hammers. This combination is mainly used for the final size reduction of both latex and field coagula materials.

24.6.7 Extruder

In principle, it is essentially a domestic meat mincer with cutting knives working only from behind the die-plate drilled with extrusion holes. Extruders are mainly used for final size reduction of latex rubbers and to a limited extent of field coagula materials. Here, well sheared and uniform products are obtained from the machine but dirt removal is found to be less effiective.

24.6.8 Driers

Several types of driers are being used for drying new process rubbers. Most of them work with the basic principle of deep-bed drying through hot air circulation at elevated temperature. They vary in mechanical construction, nature of fuel and number of heating units, fans etc used. The main function of these driers is to dry the products obtained from the final size reduction unit within the shortest time at high temperature (100°–120°C) but without affecting the properties of the final dry rubber.

24.6.8.1 Types of driers

The various types of driers used can be classified as follows:

(i) Trolley in a batch or chamber drier with semi-continuous movement.

(ii) Trays, single or in multiple layers, with continuous or semi-continuous movement.

(iii) Apron drier with continuous movement within a chamber.

The heating systems employed in the above driers are either indirect fixed heat exchangers or direct fixed heaters using either a single unit for the entire drying or a series of units at different stages of drying.

24.6.8.2 Oil firing versus electrical heating

Kerala, which is the main rubber growing area in India, is also rich in hydro-electric power. In view of the escalating price of petroleum fuel, electrical heating system was developed for drying rubber in some of the block rubber factories in Kerala. A comparison of oil fired and electrically heated driers is given below:

Oil fired	Electrically heated
1. Compartmentalisation and independent control of temperature are difficult with oil fired system.	1. Compartmentalisation and independent control of temperature are possible.

2. There is chance for contamination of rubber resulting from incomplete combustion of oil which may affect quality in the case of ISNR-5 special and ISNR-5 type rubbers.	2. No contamination.
3. Control of temperature is more difficult.	3. Control of temperature is easy.
4. Oil storage tanks are required and special precautions are to be taken in the maintenance and operation of these tanks.	4. Not required.
5. The fuel cost may not depend on capacity utilisation.	5. The fuel cost is higher at lower capacity utilisation.
6. Economic, if stand-by generator is provided to overcome power interruption.	6. May work out costlier to provide stand-by generator.
7. Power factor correction may be required.	7. It may give a higher power factor for the total circuit.
8. Purchase, maintenance of stock etc needs additional work to stores.	8. No such additional work.
9. Fast initial start up.	9. Slow starting.
10. Thermal efficiency lower.	10. Thermal efficiency higher.

24.6.9. Baling press

Hydraulic presses with either manual or automatic time interval settings are being used for pressing new forms of rubber. Most hydraulic presses operate at 30–50 load rating and have top loading with hydraulic upstroke. Provisions of twin baling boxes are common and these facilitate loading and pressing of rubber to take

place simultaneously. The object of these presses is to make an even shaped and well compressed block of rubber.

24.7 Specifications for grading rubber

The important parameters included in the technical specifications of the International Standards Organisation (ISO) were contents of dirt, volatile matter, ash, nitrogen, copper and manganese. In line with the draft standards, Malaysia in 1966 introduced technical specifications for the new process rubbers produced under the title SMR specifications. In 1970, they revised the specifications with the substitution of Plasticity Retention Index (PRI) for copper and manganese. The specification parameters fixed for the various grades of block rubber are almost similar in various other countries.

In 1968, the ISI introduced technical specifications for three grades of dry natural rubber, Grade A, B and C in line with the draft standards introduced by ISO. Based on consumer preference and also taking into consideration the developments in other rubber producing countries, ISI, in 1974, revised the existing grades and introduced five new grades with trade mark, ISNR (Indian Standard Natural Rubber). The new grades are ISNR–5 Special, ISNR–5, ISNR–10, ISNR–20 and ISNR–50. Out of these grades, ISNR–5 Special and ISNR–5 are produced from latex and high quality coagulum grades, whereas the last three grades are produced from other field coagulum rubbers. The various specification parameters for each grade are given in Table 24.1

Table 24.1 **Specifications for ISNR**

Parameter	ISNR-5 Special	ISNR-5	ISNR-10	ISNR-20	ISNR-50
Dirt content %, *Max*	0.05	0.05	0.10	0.20	0.50
Volatile matter %, *Max*	1.00	1.00	1.00	1.00	1.00
Ash %, *Max*	0.60	0.60	0.75	1.00	1.50
Nitrogen %, *Max*	0.70	0.70	0.70	0.70	0.70
Po, *Min*	30.00	30.00	30.00	30.00	30.00
PRI, *Min*	80.00	60.00	50.00	40.00	30.00

24.8 Packing and despatch

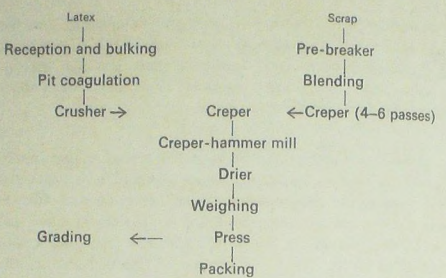
Countries like Malaysia and Indonesia are exporting their block rubber as 1 t pallet. Here each block weighing 33 1/3 kg, after affixing with a grade strip is put in low density polythene bag and packed in 1 t pallet crates. Each pallet contains 30 blocks. The rubber is then shipped to other countries.

Under Indian conditions, where rubber is almost entirely consumed internally, packing and despatch in pallets are found to be inconvenient. This is because the main transporting channel is either trucks or train where loading and unloading are found to be difficult if the rubber is in pallets. According to ISI specifications, each block should weigh 25 or 50 kg. However, in view of ease of handling, 25 kg blocks are at present produced in India. Each block is then wrapped in low density polythene film. The identification numbers such as lot number, bale number, grade etc are then marked on the film. Two such bales are then packed in high density square-woven ploythene bag marked with ISI certification for the particular grade. The rubber is then despatched to the consumer through truck or train.

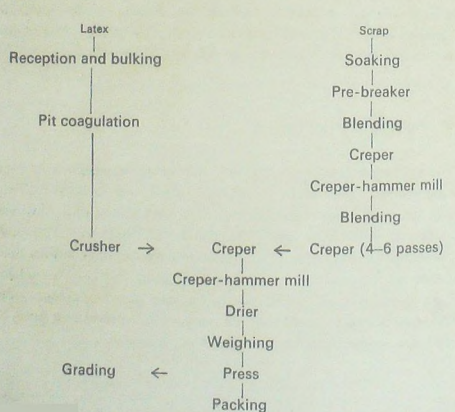
24.9 Factory designing

The processing of the crop from the rubber plantations as new process rubbers takes place in several stages and involves various closely connected unit operations. The unit operations, however vary slightly, depending upon the quality of material. The flow diagram showing the different unit operations using latex and/or field coagulum as the feed-stock are therefore given below. To ensure maximum operating efficiency of the factory, the equipments and machinery required to undertake the various unit operations have to be arranged in sequence as per the flow diagrams.

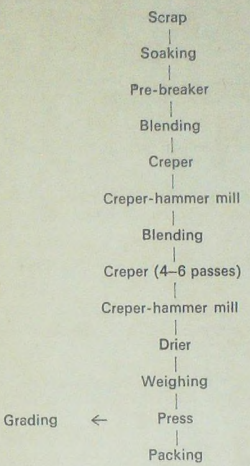
Flow diagram for an estate processing both latex and scrap



Flow diagram for centralised processing of smallholders' latex and scrap



Flow diagram for processing of smallholders' scrap



24.10 Power and water requirements

The total electrical power required in a factory depends on throughput of the factory and the type of fuel used for drying crumbs. When electrical energy is used for drying crumbs, the power requirement for this alone will be almost equal to that needed by all other machinery in the processing unit. When mineral oils are used for generating hot air, approximately 1 l is to be burned for drying 15 kg of rubber.

Water consumption in solid block rubber processing factories is comparable to that in sheet rubber processing factories. Here also, for processing fresh latex, lower quantity of water is enough when compared with that required for field coagula.

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Fig 20.1 Collection of latex in buckets



Fig 20.2 Transportation of latex by tapper



Fig 20.3 Determination of drc of latex using metrolac



Fig 20.4 Transporation of latex in tanks placed on trailer drawn by tractor

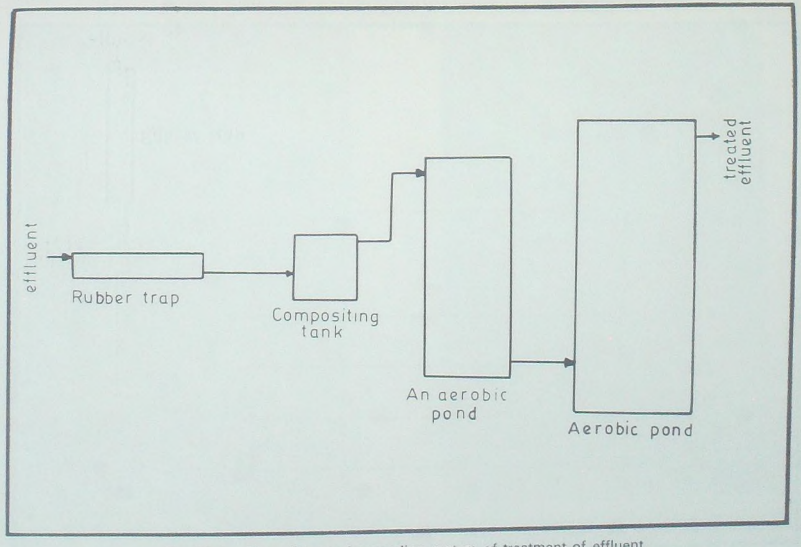


Fig 20.5 Flow diagram for ponding system of treatment of effluent

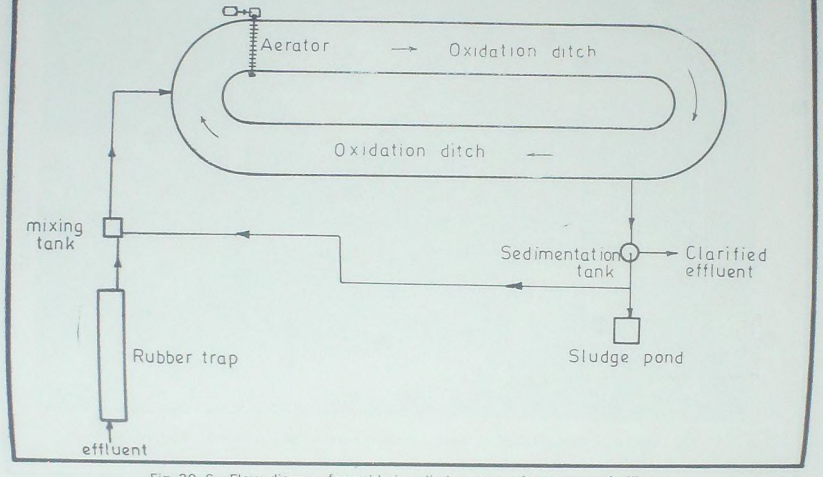


Fig 20.6 Flow diagram for oxidation ditch system of treatment of effluent



Fig 21.1 Latex coagulation in pans



Fig 21.2 Sheeting of latex coagulum using hand-operated rollers



Fig 21.3 Sheeting of latex coagulum using sheeting battery

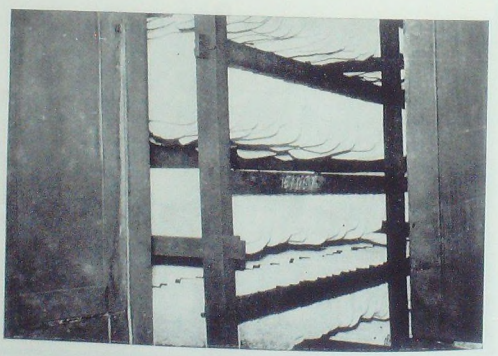


Fig 21.4 Sheets on reapers inside the smoke house



Fig 21.5 Grading of sheets



Fig 21.6 Packing of sheets

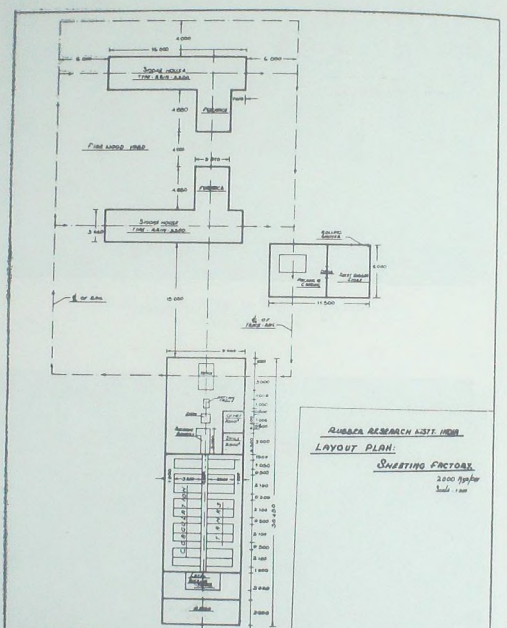


Fig 21.7 Flow diagram of a typical sheet rubber processing factory



Fig 22.1 Maceration of latex coagulum in a PLC factory



Fig. 22.2 Spooling of the laces from finishing rollers



Fig 22.3 Drying of crepes in drying sheds



Fig 22.4 Baling of lower grade crepes

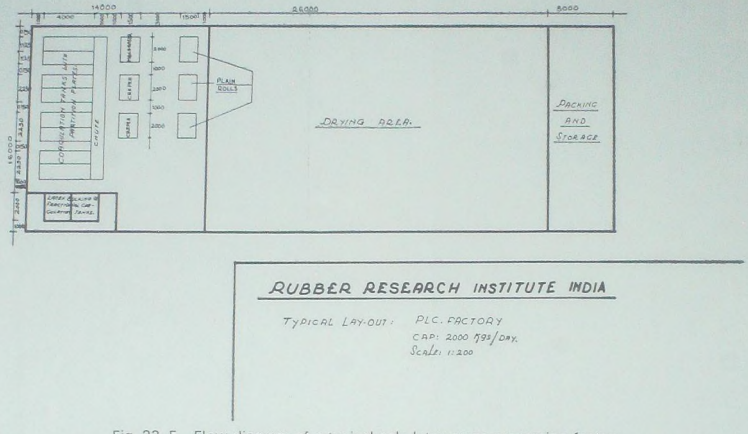


Fig 22.5 Flow diagram of a typical pale latex crepe processing factory

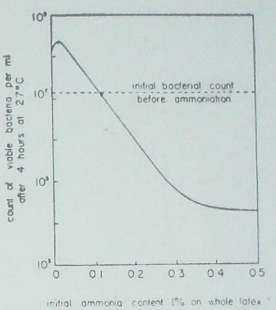
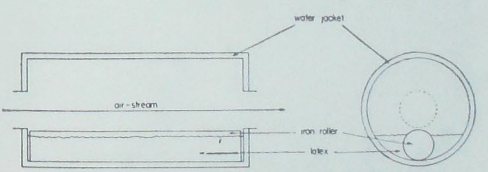
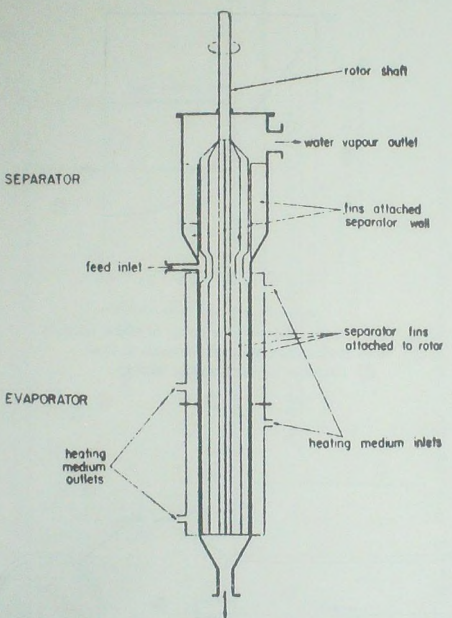


Fig. 23.1 Graph showing the count of viable bacteria with the concentration of ammonia in latex (Blackley: High polymer latices)



Typical apparatus for concentrating natural rubber latex by evaporation, as envisaged by B. Pat. 244,727

Fig 23.2 (Blackley: High polymer latices)

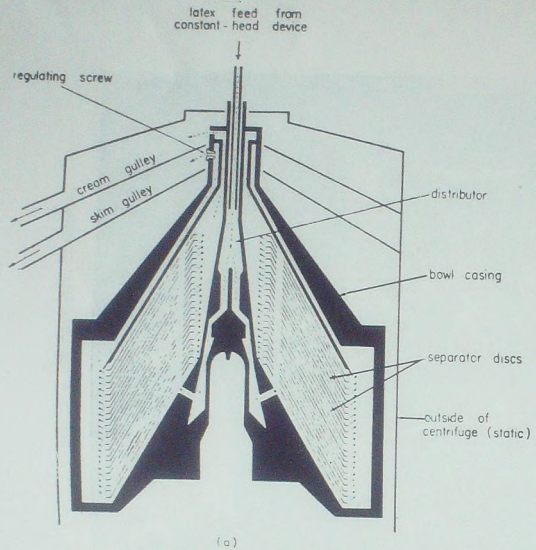


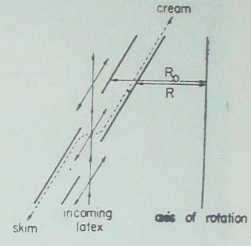
Luwa thin-layer evaporator

Fig 23.3 (Blackley: High polymer latices)



Fig 23.4 de Laval latex centrifuge





(a) Diagrammatic section through bowl of de Laval centrifuge, illustrating path of latex
(b) illustrating effect of separator discs

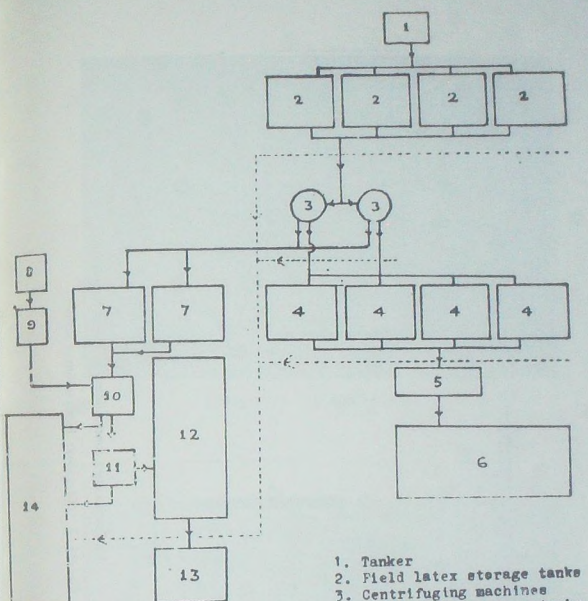
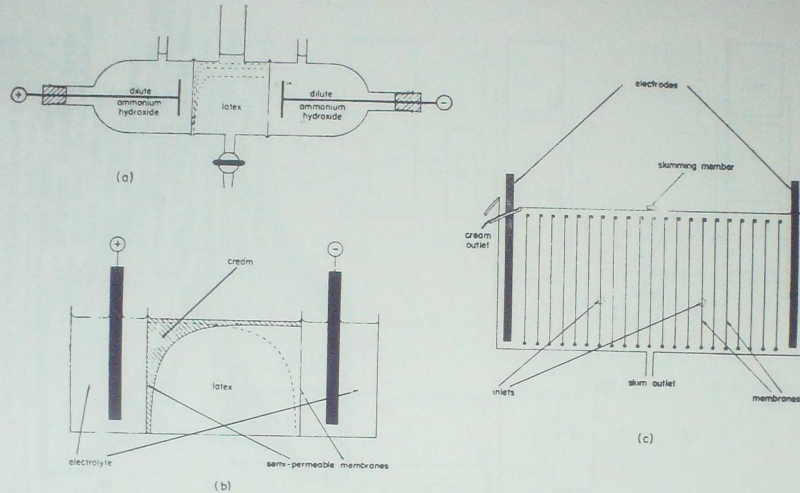


Fig 23.6 Flow diagram of a typical latex centrifuging plant

Fig 23.5 (Blackley: High polymer latices)



Illustrating latex concentration by electrodecantation

Fig 23.7 (Blackley: High polymer latices)



Fig 24.1 Storage of scrap

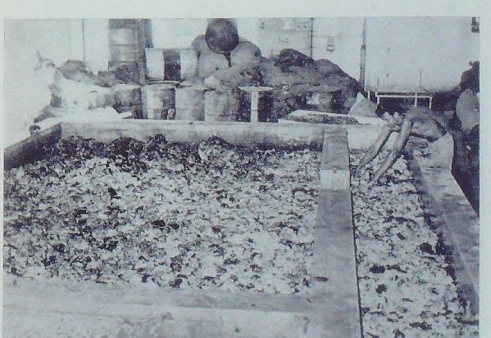


Fig 24.2 Soaking of scrap

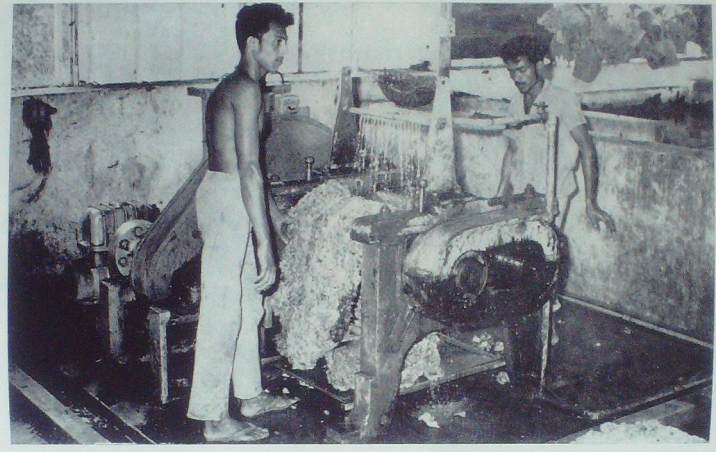


Fig 24.3 Pre-cleaning

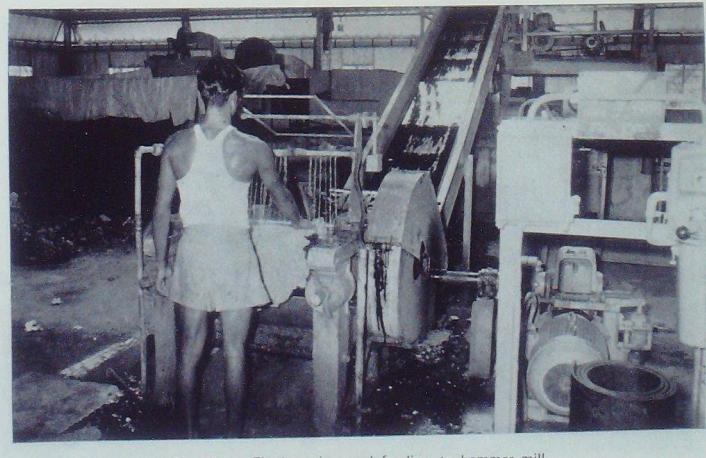


Fig 24.4 _Final creping_and feeding to hammer mill

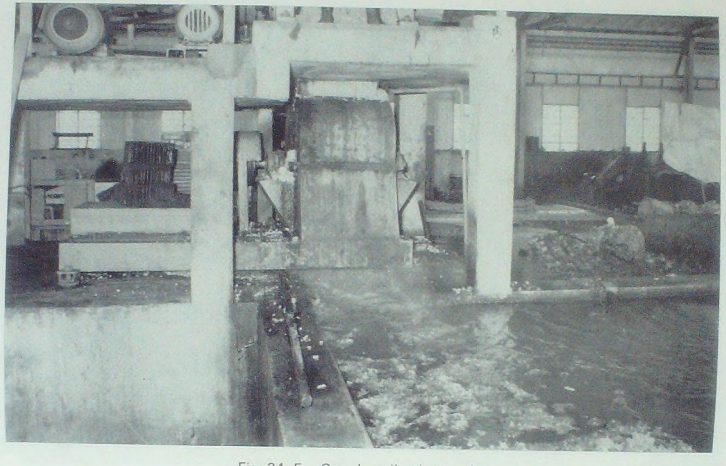


Fig 24.5 Crumb collection tank



Fig 24.6 Feeding to drier

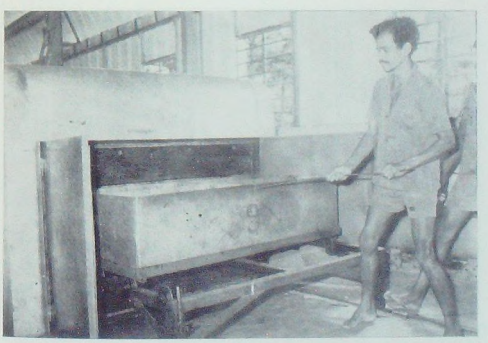


Fig 24.7 Taking out from drier

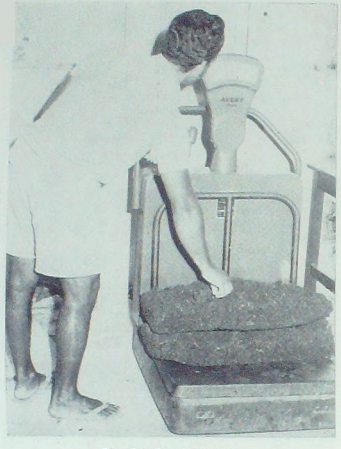


Fig 24.8 Weighing



Fig 24.9 Pressing



Fig 24.10 Wrapping



Fig 24.11 Stacking



Fig 24.12 Despatch

25 SPECIALITY RUBBERS

Chapter 25

SPECIALITY RUBBERS

The main objective of improving the processing technology of natural rubber is to make it more attractive and acceptable to the consuming industry. The development of technically specified block rubber meets this objective to a great extent. Further refinements in processing aim at production of speciality rubbers which can be used with techno-economic advantages in specific fields of application. Some of these speciality rubbers are also called tailor–cut natural rubber. Speciality rubbers are prepared by different methods such as blending of different grades of rubber, chemical modification of natural rubber and combination of rubber with different compounding ingredients in definite composition. Some of the important speciality rubbers are discussed in this chapter.

25.1 Superior processing (SP) rubbers

Superior processing rubber consists of an intimate blend of vulcanised and unvulcanised rubber prepared at the latex stage (2,4). In appearance, physical, mechanical and vulcanisate properties, SP rubber differs only slightly from those of normal rubber (29). The oustanding feature of this rubber is its reduced tendency to recover from deformation. This makes it an ideal material for calendered and extruded products. Moreover, compounds prepared from SP rubber show lower die swell, higher stock viscosity, easier handling, and greater resistance to collapse and water marking during open steam cure(6). SP rubber is compounded in a manner similar to ordinary grades of natural rubber. In some compounds, SP rubber has slightly increased tendency to scorch.

Various grades of superior processing rubbers are available, viz SP ribbed smoked sheet (SPRSS), SP air dried sheet (SPADS), SP crepe, SP brown crepe, processing Aid 80 (PA 80), and PA 57. The first four grades consist of 20 per cent vulcanised and 80 per cent unvulcanised rubber. PA 80 consists of 80 per cent vulcanised and 20 per cent unvulcanised rubber. PA 57, which is an oil extended version of PA 80, consists of 70 parts of PA 80 and 30 parts of a non-staining process oil (7). All the grades of SP and PA rubbers are prepared by blending vulcanised latex with unvulcanised latex in correct proportions and coagulating the blended latex.

25.1.1 Vulcanisation of latex

The vulcanisation of latex is a pre-requisite for the preparation of different forms of SP rubber. The first step in this process is the preparation of a stable dispersion of the chemicals. The recipe for the dispersion based on 100 parts dry rubber is as follows:

	Phr
Sulphur	2.00
Zinc oxide	0.75
Zinc diethyl dithiocarbamate (ZDC)	0.20
Mercaptobenzthiozole (MBT)	0.40
Dispersing agent	0.02
Water	4.85
Total	8.22

The field latex to be vulcanised is sieved through a 60 mesh sieve and ammoniated to 0.3 per cent (w/w) on latex. Dry rubbr content of latex is then determined and the correct quantity of the vulcanising dispersion is added to it. Latex is heated to 80°–85°C in 1 h by passing live steam and is maintained at this temperature for 2 h under gentle stirring. Completion of vulcanisation is tested

by coagulating a sample with 5 per cent (w/w) formic acid and noting the condition of the coagulum. If the coagulum is powdery and dispersible when rubbed between the fingers, the vulcanisation is complete. Even after complete vulcanisation, it is preferable to continue heating at 80°C for some more time to produce a well vulcanised latex. The vulcanised latex is then cooled and its total solid content is determined.

25.1.2 Different forms of SP rubber

25.1.2.1 SPRSS, SPADS and SP crepe

Vulcanised latex is diluted to 12.5 per cent total solids (ts) for the production of SPRSS and SPADS and to 20 per cent ts for the production of SP crepe (17). Field latex and vulcanised latex are mixed in the ratio 4:1, the ratio being based on the rubber content of field latex and ts content of vulcanised latex. This is then stirred and sieved (60 mesh) into coagulating tanks and coagulated with 2 per cent (w/w) formic acid. Subsequent processing procedure is similar to that of the normal grades of sheet and crepe (5, 35).

25.1.2.2 SP brown crepe

To make SP brown crepe, one part by weight of wet crumbs from 4:1 mixture of vulcanised and unvulcanised latex are mixed with three parts by weight of pre-processed wet scrap in power mills and processed as estate brown crepe.

25.1.2.3 PA 80 and PA 57

For the preparation of PA 80, vulcanised latex is first diluted to 20 per cent ts. This is then mixed with fresh field latex in the ratio of 4:1, the ratio being on ts of vulcanised latex and drc of field latex Blending time should be as short as possible. The blended latex is then sieved through a 60 mesh sieve into a coagulation tank. Latex is coagulated immediately with 5 per cent sulphuric acid. The serum is removed from the tank and replaced with clear water.

After soaking for 30 min, the coagulum is passed twice through lightly grooved creping rolls and the crumbs obtained are again soaked in water for 1 h. The crumbs are loaded in trays and dried in an air drying tunnel for 4–5 h at 70°C. PA 80 coagulum can also be processed using the machinery for producing solid block rubber. When PA 80 is blended with rubber in the ratio 1:3, the resultant material is equivalent in behaviour to other forms of SP rubbers.

PA 57 is the low viscosity version of PA 80 masterbatch. It consists of 70 parts by weight of PA 80 and 30 parts by weight of a non-staining process oil. The oil should be added in the form of stable emulsion to the correct blend of vulcanised and unvulcanised latex.

25.1.2.3 Testing of SP rubbers

For testing of SP rubbers, the samples are first compounded according to the recipe in which the base polymer contains 20 per cent vulcanised and 80 per cent unvulcanised rubber (SP 20 rubber). The recipe is as follows:

SP 20 rubber	—	100.0
HAF black	—	50.0
Zinc oxide	—	5.0
Stearic acid	—	4.0
Sulphur	—	2.5
Pine tar	—	3.0
CBS	—	0.6

The compound is extruded through a Macklowsmith extrusion plastimeter for determining its 'extrusion swell'. The specifications for the various grades of SP rubbers are as follows (35).

Grades	Extrusion swell	Acetone extract	Mooney viscosity ML (1 + 4) 100°C
SP	12.7 *(Max)*	—	—
PA 80	,,	—	80 *(Max)*
PA 57	,,	27.5—32.0	—

25.2 Constant viscosity and low viscosity (CV and LV) natural rubbers

Natural rubber undergoes hardening (as measured by Mooney Viscosity or Williams Plasticity) during processing and subsequent storage (34). The change in hardness is generally more when it is initially low and is greately influenced by the relative humidity of storage (1). Raw rubber of high hardness requires greater mastication time or the use of expensive peptisers to obtain a product of desirable hardness or viscosity. So this problem was investigated and it was observed that hardening reaction can be almost completely suppressed by adding chemicals like hydroxylamine or semicarbazide to latex prior to its conversion to dry rubber (33). It is considered that cross-linking reaction is the cause of this hardening and involves carbonyl groups which are distributed at random along the rubber molecule. Since 5'–5 dimethyl 1,3 cyclo hexane dione (Dimedone), an aldehyde specific reagent, also inhibits storage hardening it is assumed that the carbonyl groups are aldehydes. The minimum effective quantity of the reagent required per million molecular weights provides an indication of the number of aldehyde groups present in it and this figure ranges from 5–30 according to clonal type (7). Recently, it has been suggested that the postulated aldehyde groups are in fact epoxy or lactone-ring residues (9, 22).

When carbonyl reagents like hydroxylamine are added to latex a small quantity becomes chemically bound to the rubber and storage hardening is inhibited. The aldehyde groups are effectively blocked. Hydroxylamine, being monofunctional preserves the Mooney viscosity of the rubber at the level at which the treatment is given. Rubber so reacted retains its original viscosity for very long periods and such rubber is called CV rubber.

Hydroxylamine hydrochloride was recommended as the viscosity stabiliser for the production of constant viscosity natural rubber during early stages of its development. But now hydroxylamine neutral sulphate is more popular since it is equally effective and cheaper than the other hydroxylamine salt. The recommended dosage is 0.15 per cent by weight on rubber content. Since hydroxylamine darkens the rubber, semi carbazide is used in the production of light coloured rubbers. Commercially, CV rubber

After soaking for 30 min, the coagulum is passed twice through lightly grooved creping rolls and the crumbs obtained are again soaked in water for 1 h. The crumbs are loaded in trays and dried in an air drying tunnel for 4–5 h at 70°C. PA 80 coagulum can also be processed using the machinery for producing solid block rubber. When PA 80 is blended with rubber in the ratio 1:3, the resultant material is equivalent in behaviour to other forms of SP rubbers.

PA 57 is the low viscosity version of PA 80 masterbatch. It consists of 70 parts by weight of PA 80 and 30 parts by weight of a non-staining process oil. The oil should be added in the form of stable emulsion to the correct blend of vulcanised and unvulcanised latex.

25.1.2.3 Testing of SP rubbers

For testing of SP rubbers, the samples are first compounded according to the recipe in which the base polymer contains 20 per cent vulcanised and 80 per cent unvulcanised rubber (SP 20 rubber). The recipe is as follows:

SP 20 rubber	—	100.0
HAF black	—	50.0
Zinc oxide	—	5.0
Stearic acid	—	4.0
Sulphur	—	2.5
Pine tar	—	3.0
CBS	—	0.6

The compound is extruded through a Macklowsmith extrusion plastimeter for determining its 'extrusion swell'. The specifications for the various grades of SP rubbers are as follows (35).

Grades	Extrusion swell	Acetone extract	Mooney viscosity ML (1 + 4) 100°C
SP	12.7 *(Max)*	—	—
PA 80	,,	—	80 *(Max)*
PA 57	,,	27.5—32.0	—

25.2 Constant viscosity and low viscosity (CV and LV) natural rubbers

Natural rubber undergoes hardening (as measured by Mooney Viscosity or Williams Plasticity) during processing and subsequent storage (34). The change in hardness is generally more when it is initially low and is greately influenced by the relative humidity of storage (1). Raw rubber of high hardness requires greater mastication time or the use of expensive peptisers to obtain a product of desirable hardness or viscosity. So this problem was investigated and it was observed that hardening reaction can be almost completely suppressed by adding chemicals like hydroxylamine or semicarbazide to latex prior to its conversion to dry rubber (33). It is considered that cross-linking reaction is the cause of this hardening and involves carbonyl groups which are distributed at random along the rubber molecule. Since 5'–5 dimethyl 1,3 cyclo hexane dione (Dimedone), an aldehyde specific reagent, also inhibits storage hardening it is assumed that the carbonyl groups are aldehydes. The minimum effective quantity of the reagent required per million molecular weights provides an indication of the number of aldehyde groups present in it and this figure ranges from 5–30 according to clonal type (7). Recently, it has been suggested that the postulated aldehyde groups are in fact epoxy or lactone-ring residues (9, 22).

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is produced within the low range of 50–75 Mooney viscosity units which ensures premastication savings to the consumer.

Where viscosity levels are required in a still lower range, this can be achieved by the addition of a fixed quantity of an inert plasticiser, a non-staining naphthenic rubber process oil, to the viscosity stabilised rubber. This type of rubber is termed as LV rubber.

The range of Mooney viscosity of CV and LV rubbers is given in Table 25.1.

Table 25.1

Range of Mooney viscosity of CV and LV rubbers

CV rubbers		LV rubbers	
Grades	Mooney viscosity range	Grades	Mooney viscosity range
CV 50	45—55	LV 45	40—45
CV 55	50—60	LV	45—55
CV	55—65	LV 55	50—60
CV 65	60—70	LV 60	55—65
CV 70	65—75	LV 65	60—70

25.2.1 Processing of latex into CV and LV rubbers

25.2.1.1 Clonal variation in Mooney viscosity

Constant viscosity rubbers derived from different clones show wide variations in Mooney viscosity (36). It varies between 45 (RRIM 501) to 100 (AVROS 529). So in the production of CV and LV rubbers, different clonal latices are blended to get the desired viscosity for the rubber.

25.2.1.2 Processing into CV rubber

Properly blended, bulked and diluted latex is treated with the minimum quantity of ammonia as anti-coagulant (0.01–0.10 per cent on volume of latex). The use of formalin as anti-coagulant is avoided because of its reaction with hydroxylamine salts and sodium sulphite is also not recommended on account of its discolouring properties (13). The latex is then treated with 5 per cent aqueous solution of sodium metabisulphite (0.04 per cent by weight on rubber content) to prevent enzymic discolouration. Keeping the latex mixture well stirred, 10 per cent aqueous hydroxylamine neutral sulphate (0.15 per cent by weight on the rubber content) is added. Stirring the solution is continued for 3 min and the latex is then coagulated and processed into new process rubbers.

25.2.1.3 Processing into LV rubber

LV rubber contains four parts of a non-discolouring oil for hundred parts of rubber and this quantity of oil is too low to affect properties of rubber adversely. The oil is added to latex in the form of an emulsion. A stable oil emulsion can be prepared by stirring the components given in Table 25.2 at high speed for about 10 min; portion B being added to portion A. Before oil emulsion is added to latex, it is necessary to ensure that the latex is stable and has a pH of about 8 and that it is treated with adequate quantity of hydroxylamine neutral sulphate for viscosity stabilisation.

Table 25.2

Components for preparation of oil emulsion

Portion A	Naphthenic oil	100 parts by weight
	Oleic acid	1.5–2.0 parts by weight
Portion B	Water	30 parts by weight
	Ammonium hydroxide	0.1—0.2 ml

25.2.2 Testing of CV and LV nubbers

Accelerated storage hardening test (ASHT) is used for identifying CV rubbers. This involves the measurement of Wallace plasticity of the rubber before and after a short period of storage under conditions which accelerate the storage hardening reaction. Accelerated storage hardening is achieved by storing the rubber specimens over phosphorus pentoxide at atmospheric pressure and a temperature of 60°C for 24 h. The resultant increase in plasticity represents the accelerated storage hardening. Storgae hardening is inhibited if the increase in plasticity is below 8 units.

25.3 Oil extended natural rubber (OENR)

Use of mineral oils as a rubber processing aid is known for several years. Oil functions either as a plasticiser improving processability and filler incorporation or as an extender for cheapening the product. The factor which decides whether an oil functions as a plasticiser or as an extender is its concentration in the rubber product. Usually, when an oil is used in concentrations below 10 phr, it is referred to as a plasticiser or processing aid. Above this level, the oil functions as an extender for cheapening the product and the resultant mixture is referred to as oil extended rubber (26).

The concentration of the oil while functioning as an extender is in the range of 20–40 per cent although extended rubbers containing up to 50 per cent oil has been prepared, the latter product being almost a liquid (25). As a general practice the level of oil is limited to 40 per cent as concentrations beyond this adversely affect the physical properties of the vulcanisate.

25.3.1 Types of oil used

The different types of oils that are added to rubber either as plasticiser or as extender can be broadly classified as paraffinic naphthenic and aromatic. The criterion for this type of classification, is the numerical value of a factor known as the viscosity gravity constant (VGC). Oils with VGC below 0.8 are classified as paraffinic, those having values above 1.0 are referred to as aromatic and those

with values in between are naphthenic (7). Depending on the type of oil used, the final rubber develops certain specific properties which are given in Table 25.3

Table 25.3

Variation in properties of rubber with different oils

Nature of oil		Paraffinic	Naphthenic	Aromatic
Properties:				
(i)	Processability	Poor	Superior	Best
(ii)	Staining characteristics	Least	Light	High
(iii)	Aging characteristics	No effect	No marked effect	Poor

Hence depending on the end use, the oil type can be selected.

25.3.2 Processing methods

Oil extension of natural rubber can be carried out in the latex stage or in the dry stage. Each method has its own advantages and disadvantages. Extension at the latex stage is effected by adding an aqueous emulsion of the required quantity of the selected oil into the latex and co-precipitating the two. In the case of extension at the dry stage the process consists of incorporating the required quantity of the selected oil into rubber using an extruder type oilblender, a mill or an internal mixer. Various methods are adopted for the production of oil extended rubber.

25.3.2.1 Latex masterbatching

In this method, oil is added to latex as an aqueous emulsion and the mixture is coagulated using an acid (38). Mixing is carried out at an alkaline pH (8–8.5) for reasons of stability. The coagulum is then

processed in the usual manner. This method is now followed only for the production of PA 57. The disadvantages of this process are: (i) high cost of chemicals and (ii) increase in drying time. Difficulties are encountered when the extended coagulum is handled and dried in the conventional manner, which is due to the lowering of Mooney viscosity as a result of extension. Methods available to overcome this lowering of Mooney viscosity are:

(i) Introduction of cross links in rubber chains by treatment of latex with para phenylene diamine or similar bifunctional aldehyde reagents. But they have the disadvantage of prolonging the drying time and are also toxic and discolouring (3).

(ii) Use of prevulcanised latex as in PA 57.

25.3.2.2 Dry mixing

Dry mixing can be either by soaking or by extrusion method. In the soaking method, the hot crumbs emerging from the drier are mixed with the selected oil. Depending on the way of soaking and extending there are two processes, viz Kualakep and Socfin.

(i) Kualakep process

Here, the hot crumb and oil are mixed together in a Z blade mixer for 5–10 min followed by a soaking period when the crumbs absorb the excess oil (26). The time of soaking depends on the concentration of oil used. The extended rubber is finally blended in a two roll mill, baled and packed.

(ii) Socfin method

The essential difference in this method is that the wet crumbs are used in place of dry material. The mixture of crumb and oil is steamed for 10–20 min and dried at low temperatures in shallow beds.

In extrusion method, the major portion of OENR is produced by this method, using specially designed extruders. Weighed quantities of rubber are fed at regular intervals and the oil is metered in. The two are intimately mixed by the high shearing action of the screw.

25.3.3 Advantages and disadvantages of OENR

25.3.3.1 Advantages

(i) Eliminates pre-mastication

(ii) Improves resistance to crystallisation

(iii) Tyres from OENR/BR (poly butadiene rubber) blends are cooler running than those from OESBR (oil extended styrene-butadiene rubber)/BR blends.

(iv) Gives better skid resistance on icy roads

(v) Cheapens product

25.3.3.2 Disadvantages

(i) Shows slightly inferior vulcanisate properties

(ii) Exhibits cold flow

25.4 Tyre rubber

More than 65 per cent of the natural rubber produced in the world is being consumed by the tyre industry. Tyre industry uses mainly the lower RSS grades either directly or in combination with EBC. After the introduction of technically specified rubbers, it is observed that the tyre industry prefers generally the lower grades of such rubbers. This consumption pattern of the tyre industry reflects their basic requirement of a material which is available in large quantities at lower cost and which gives product of satisfactory technological performance. A sizeable portion of the technically specified rubber happens to be of higher quality derived from latex. These grades, though suitable for use in tyres, are highly priced to be attractive to the tyre industry. Hence attempts have been made in Malaysia to produce a blend of high quality latex grade rubber and field coagula so as to supply to the tyre industry a raw rubber most suitable for their use. These paved the way for the production of tyre rubber (14).

25.4.1 Processing

Tyre rubber is prepared from a blend of three types of raw materials and a plasticiser in the following proportion (15, 16):

Raw meterial	Weight (%)
Latex (as dry rubber)	30
Unsmoked sheet	30
Field coagulum	30
Plasticiser (mineral oil)	10

The method of blending involves the coagulation of a latex-oil mixture containing hydroxylamine neutral sulphate and wet crumbs, the crumbs being prepared from a blend of unsmoked sheet and field coagula. Subsequent processing of the latex-crumb coagulum gives a very uniform blend with minimum mechanical working.

The field coagulum is cleaned and made into a blanket. Dirt content of the blanket should be less than 0.12 per cent by weight. The unsmoked sheets are also milled into a blanket. The two blankets are then blended and crumbled with the aid of castor oil. The crumbs are then spread evenly in the coagulation trough. They are sprayed with 10 per cent formic acid solution and excess acid is recovered for further use. The required quantity of aromatic oil is emulsified and then mixed with the predetermined quantity of latex, containing hydroxylamine neutral sulphate at the rate of 2.0–2.5 kg/t of rubber. The pH of the latex-oil mixture is adjusted at 7.0–7.5 and poured into the coagulation trough. The mixture flows easily through the mass of crumbs before it coagulates. The coagulum is then processed and dried as if it were a whole latex coagulum.

25.4.2 Specification

Typical properties of tyre rubber are listed in Table 25.4.

Table 25.4

Properties of tyre rubber

Parameter	Typical values
Mooney viscosity ML (1+4) 100°C	55–65
PRI	81.00
Dirt content (% by weight)	0.04
Nitrogen content (% by weight)	0.38
Ash (% by weight)	0.33
Acetone extract (% by weight)	13.01
ΔP	4.00

25.4.3 Advantages

Apart from the economic advantages, tyre rubber has many desirable technological qualities. Tyre rubber, especially the one containing aromatic oil, has excellent resistance to low temperature crystallisation. Its low Mooney viscosity makes pre-mastication unnecessary. In compounds containing 10 phr plasticiser, the use of tyre rubber to replace pre-masticated natural rubber and oil could lead to improved vulcanisate properties such as strength, flex cracking resistance and lower heat generation (37).

25.5 Powdered natural rubber

During the last decade, there has been a trend in the rubber goods manufacturing industry towards the use of continuous process and automation at all stages of handling, mixing and processing This trend demands certain additional requirements for an ideal raw rubber. One such requirement is that it should be capable of being handled as a powder or a liquid. The possibility of producing products from powdered polymers has been demonstrated for many years

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by the thermoplastic sector and more recently in the use of certain synthetic rubbers. In the case of synthetic rubbers, mainly nitrile and special purpose powdered SBR are being used (24).

25.5.1 Production principle

Powdered natural rubber has been produced at least on an experimental basis both by Harrisons & Crossfield Ltd and by Guthrie Estates Ltd in Malaysia. Several methods have been proposed recently to make powdered natural or synthetic rubber. The methods include grinding of slab rubber into small particles, spray and flash drying and particle encapsulation. Most of these processes produce materials which are very surface tacky. They would all quickly stick together and form as inseparable mass if partitioning agents of the correct type and in the minimum required quantities are not used. Satisfactory partitioning agents include talc, other silicates, whitings, clay, carbon black, starch and various compatible thermo-plastic resins, depending on whether these materials can be tolerated in the recipe.

25.5.2 Advantages

The advantages of powdered rubber are (10, 20, 21, 39) :

(i) Much shorter mixing cycles than when using either conventional internal mixer or open milling techniques;

(ii) Less power consumption;

(iii) Less plant maintenance;

(iv) Less capital investment on plant;

(v) Better ultimate dispersion;

(vi) Increased output;

(vii) Possibility of direct feed to the extruders;

(viii) Elimination of bale cutting;

(ix) Elimination of pre–mastication and masterbatching; and

(x) Easier process control in the factory.

25.6 Thermoplastic natural rubber

Recently, a number of new polymeric materials such as styrene-butadeiene-styrene block co-polymers have emerged, with properties intermediate between conventional rubber and thermoplastics. Thermoplastic elastomer combines the physical properties of vulcanised rubbers with the easy processing characteristics of thermoplastics. In the case of thermoplastics, during product manufacture, steps like compounding and vulcanisation are not necessary.

25.6.1 Theoretical considerations

There are different types of thermoplastic elastomers. One is block copolymers of the general structure A–B–A where A represent a polymer segment which is glassy or crystalline at service temperature, but fluid at higher temperatures and B represents a polymer segment which is elastomeric at service temperaures. Choice of the segment type and the length and weight fractions of A and B are crucial in achieving the desired performance. The rubbery properties of conventional elastomers are mainly due to irreversible cross links formed among the long polymer chain during vulcanisation. The unique behaviour of thermoplastic elastomers, on the other hand, is attributed to the linear plastic-elastomer-plastic structure. Thus in S–B–S thermoplastic elastomer, rigid polystyrene end segments are joined by an elastomeric polybutadiene centre section. The polystyrene segments associate with each other to give long aggregates referred to as 'domains'. At normal service temperatures, these domains are hard and glass like and immobilise the ends of the rubbery polybutadiene segments. This end segment immobilisation in conjunction with chain entanglements creates a physical 'infinite net work' or physical cross links. At higher temperatures these polystyrene domains soften and may be disrupted by applied stress allowing the polymer to flow. This process is reversible and on cooling, the polystyrene domains again harden and the polymers regain their elastomeric properties.

25.6.2 Production of thermoplastic natural rubber (TPNR)

Though earlier attempts to produce thermoplastic elastomers were all on synthetic rubbers, recently attempts are being made to

modify natural rubber suitably so as to impart thermoplastic character to it. The important methods for the production of thermoplastic natural rubber are blending with polyolefines and grafting side chains of controlled size of a hard or crystalline polymer at regular intervals along the natural rubber molecule.

25.6.2.1 Blending with polyolefines

Mixing of natural rubber with polypropylene (PP) and/or polyethylene can be carried out in robust internal mixers having facility for steam heating (12). It is essential to raise the temperature of the mix above the melting point of polypropylene (165°C–175°C) early in the mixing cycle. To ensure this, steam is applied throughout the mixing cycle at about 3.85 kg/cm^2. Steam may not be necessary with large, high speed internal mixers. To maintain high mixing efficiency, the ram is held down under pneumatic pressure throughout the cycle. After dumping, the batch is immediately passed once through the nip of a cool mill to give a sheet of 4–8 mm thickness. This is then granulated or cut into strips for feeding into injection moulding machine or extruder. A mixing cycle which has been successful for a wide range of NR/PP/ carbon black combinations is as follows:

0 min – add carbon black, polypropylene natural rubber and dicumyl peroxide, in that order

5 min – add anti-oxidant

5½ min – dump

(i) Moulding behaviour

In the case of NR/PP blends, at high PP loadings, good samples with a fairly even semi-mat surface and with little distortion are readily obtained. As the PP level drops below 35 per cent, distortion increases. Small quantities of dicumyl peroxide is essential if good mouldings are to be achieved, especially at the lower PP levels. Physcial properties are also improved. But very high levels of peroxide impair the surface finish of mouldings and 0.6 PhNR of dicumyl peroxide has been found to be the optimum.

(ii) Anisotropy

Like other thermoplastic elastomers, TPNR also shows anisotropy and samples cut along the radial direction from mouldings show superior physical properties, except for elongation at break (EB). This aspect should be considered when moulds for particular applications are designed.

(iii) Changes at different temperatures and aging

NR/PP blends soften when heated but distortion does not occur below 150°C. At sub-zero temperatures they become considerably stiffer. The use of high moulding temperatures does not appear to be detrimental to the physcial properties. Recycling of wastes is thus possible. Aging performances is generally good. Particularly important is the resistance to ozone. No cracking is observed in the bent loop test, 72 h at 40°C and 20 per cent strain in 50 ppm ozone eventhough no anti-ozonant is used.

25.6.2.2 Thermoplastic graft copolymers of NR

Falk *et al* (19) have shown that 'comb' grafts of polyisoprene in which short side chains of polystyrene are attached at regular intervals along the rubber back-bone have thermoplastic properties. This was accomplished by metallating polyisoprene and anionically polymerising styrene from the active sites. But this type of grafting is not applicable for natural rubber either chemically or economically because of the poisoning effects of non-rubbers and the difficulties of having to work with solutions. However, it has been reported that short chains of the hard polymer, having highly reactive end groups, could be grafted to natural rubber simply by dry mixing(11).

25.6.3 Advantages, disadvantages and applications

The main advantages of TPNR are lower capital cost of processing machinery, lower labour requirements and better material utilisation since rejects can be recycled. It also provides possibility for production of good injection mouldings, with properties such as

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Falk *et al* (19) have shown that 'comb' grafts of polyisoprene in which short side chains of polystyrene are attached at regular intervals along the rubber back-bone have thermoplastic properties. This was accomplished by metallating polyisoprene and anionically polymerising styrene from the active sites. But this type of grafting is not applicable for natural rubber either chemically or economically because of the poisoning effects of non-rubbers and the difficulties of having to work with solutions. However, it has been reported that short chains of the hard polymer, having highly reactive end groups, could be grafted to natural rubber simply by dry mixing(11).

25.6.3 Advantages, disadvantages and applications

The main advantages of TPNR are lower capital cost of processing machinery, lower labour requirements and better material utilisation since rejects can be recycled. It also provides possibility for production of good injection mouldings, with properties such as

high flexural modulus, tensile strength, elongation at break and resistance to aging. Disadvantages include lower service performance than that of conventionally vulcanised rubber and higher material cost.

The main field of application of TPNR is in the production of vehicle body components. The chief characteristics of TPNR like good stiffness, elastic recovery, good weather resistance, paintability, low density and low material cost are taken advantage of in the above application. In footwear industry, the harder varieties of TPNR are useful in low cost components like ski-boots, skating boots and heel pieces. Softer varieties offer advantages over other materials for the direct moulding of soling to uppers.

25.7 Graft natural rubbers

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25.7.1. Method of production

A summary of the commercial method of producing Heveaplus MG is given below:

Methyl methacrylate monomer containing cumene hydroperoxide is emulsified and added to ammoniated field latex. The concentration of cumene hydroperoxide is 0.25 parts per 100 parts of rubber present in the latex. When a homogenous dispersion is obtained an equal amount of tetra ethylenepentamine as 10 per cent solution is stirred in. Stirring is then stopped and the reaction vessel is covered. The reaction is exothermic and within 2 h, there will be a rise in temperature between 5°–10°C. On the following day, a dispersion of an anti-oxidant (NONOX EXN) is added to the reacted latex. Coagulation is effected by running the modified latex into boiling water, containing 2 per cent formic acid for MG-49 and 10 per cent sulphuric acid for MG-30. The products are washed, milled into crepe and dried.

25.7.2 Properties of Heveaplus MG

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associated with ebonites and hard thermoplastic and thermosetting resins can be obtained. Another important property is its good resistance to flex cracking and dynamic fatigue. Heveaplus MG contains within its molecular structure both polar (poly methylmethacrylate) and non-polar (rubber hydrocarbon) components. This structure suggests that it should be a promising material for bending unlike surfaces, normally incompatible by virtue of their polar and non-polar characteristics.

25.7.3 Uses of Heveaplus MG

25.7.3.1 In adhesives

Adhesive applications involve both Heveaplus MG in solution and Heveaplus MG latex. It makes a very good adhesive for bonding rubber to PVC. Another use as an adhesive is in shoe industry where direct vulcanisation of rubber soling compounds to uppers of leather or plastics is involved. The adhesive property is also employed in the production of motor car mats, flooring, non-woven ribbed carpets etc. An important use of Heveaplus MG as an adhesive is in tyre cords and belting. Tyre cord adhesives are usually made up of a mixture comprising natural and synthetic latices (eg vinyl pyridine, styrene-butadiene terpolymer rubber) and resorcinol-formaldehyde resin. It has been shown that, at low temperature of vulcanisation, the terpolymer latex can successfully be replaced by Heveaplus MG latex which is very cheap. Other advantages are that the Heveaplus system with the graft copolymer bond possesses better dynamic properties than those of the terpolymer system. Another application of Heveaplus MG is its use as a binder for leather finishing where it not only proves adequate, but also improves the important property of 'rubfastness' of leather.

25.7.3.2 In other products

The main uses of Heveaplus MG are in impact resisting rigid articles. Its excellent mould flow qualities and good electrical properties are particularly advantageous. The low water absorption of Heveaplus MG, its freedom from bacterial degradation and its physical properties make it suitable as cutting boards for meat and

fish. It can also be used as an air impervious interliner for tubeless tyres and in pressureless tennis balls. It can be used in the manufacture of unbreakable electrical plugs, hard rollers, roller slates and wheels. A special type of washer has recently been developed from this for the air craft industry. MG–49 appears to be the most interesting extender for balata.

25.8 Latex stage compounds

The availability of complete unvulcanised custom compounds of natural rubber which require no further mixing except rewarming before final product fabrication is very attractive to the consuming industries, and latex stage compounds meet this requirement. The production of this type of rubber involves mixing of rubber and compounding ingredients in the latex stage, followed by coagulation, drying and packing into standard bales. The concept of latex stage compounding is not new. Till very recently, latex stage compounding was not popular because suppliers of rubber chemicals and rubber product manufacturers were in countries far away from rubber producing countries and technical problems associated with aging, shelf life and storage were not entirely solved. But many rubber producing countries have by now built up their own rubber consuming industries and a few of them are manufacturing compounding chemicals also. The developments in block rubber processing are also helpful in solving problems associated with the production of latex stage compounds.

25.8.1 Processing techniques

The major problems of latex stage compounding are the dispersion of additives in latex and loss of curatives or colour during washing in final stage. As severe mechanical action is necessary for mixing of various powder dispersions and emulsions, the stabilisation of latex is critical. Various operations involved in the production of latex stage compounds are discussed below (28).

25.8.1.1 Accelerator dispersions

Accelerators are to be calculated on dry rubber content. Similar type of accelerator system as used in rubber compounding

may be used. If sulphur is not included in latex stage, scorch problem can be avoided even when coagulated rubber is dried at 100°–110°C. In extreme cases, retarders like PVI (Santogard PVI) or benzoic acid may be used. Normally 50 per cent solid content dispersion is suitable for accelerator system.

25.8.1.2 Filler dispersion

Fillers may be incorporated as 50 per cent dispersions or slurries containing a single filler or a blend of fillers.

25.8.1.3 Fatty acid and oil emulsion

Fatty acids or oils are emulsified by high speed stirring in ammoniated water.

25.8.1.4 Mix preparation

Homogenous latex is slowly stirred, stabilizer is added and gradually other dispersions are added.

25.8.1.5 Coagulation

After mixing the ingredients, coagulation is done using method similar to that used in block rubber production. Fairly rapid coagulation is desirable which prevents sedimentation of powders. Normally, formic acid is used for coagulation.

25.8.1.6 Drying

Coagulum size is reduced as in block rubber process line. The wet crumb is sprayed with oil and dried in deep bed or other suitable drier at 100°–110°C and finally pressed in a suitable press to form a loose bale of rubber compound.

25.9 Deproteinised natural rubber (DPNR)

Latex contains about 2 per cent proteins by weight. Processing of latex by any of the usual methods does not eliminate this

material from the final product. Solid block rubber, for example, contains about 2.5 per cent proteins by weight and a normal 60 per cent commerical concentrated latex about 1 per cent. These proteins along with polyols and some of the inorganic salts contribute to absorption of water by rubber which has a number of consequences. It can affect the rate of vulcanisation and the efficiency of cross linking, thus giving rise to loss of processing safety and modulus variability. It can also adversely affect resilience creep and stress relaxation. The electrical properties are also impaired. For these reasons, the rubber plantation industry has been endeavouring to produce a commercial grade of rubber which gives a low protein, ash and acetone extract with low water absorbing property. Deproteinised natural rubber is a specially processed form of natural rubber meeting these requirements. When compounded with rubber-soluble vulcanising ingredients, DPNR gives a superior rubber vulcanisate with excellent dynamic properties, particularly suitable for use in engineering applications (40).

25.9.1 Production of DPNR

The practical problem encountered in the production of DPNR is the removal of non-rubbers by an inexpensive treatment which enables retention of maximum natural anti-oxidants for prevention of excessive oxidation during preparation, storage and processing. Enzyme deproteinisation of natural rubber latex is found to be a practical method in terms of cost and effectiveness.

The steps involved in the production of DPNR are treatment of field latex with a bioenzyme and dilution of the treated latex before acid coagulation. This enzyme changes proteins in latex into water soluble forms which are subsequently washed away during processing. A typical recipe comprising 2 phr potassium naphthenate and 0.3 phr 'superase' is allowed to react with latex over 24 h. In another method, 1 phr of 'vulcastab VL' and 1 phr of 'anilozyme P-10' (an enzyme formulation) are used and the reaction was found to be completed in 20 h at 50°C(30).

The preparation of light coloured DPNR and viscosity stabilised DPNR have been effected by the addition of 0.05 phr sodium metabisulphite and 0.15 phr of hydroxylamine neutral sulphate to the latex before enzymolysis.

25.9.2 Advantages of DPNR

The importance of this highly purified form of rubber is in engineering applications where conditions of high temperature performance, reduced creep and modulus precision are often required. When DPNR is used in conjunction with fully soluble EV (efficient vulcanisation) systems which use less sulphur and more accelerators useful improvements in modulus precision, creep, resilience and stress relaxation can be obtained. DPNR improves most dynamic properties and allied with soluble compounding, reduces creep still further. Rubber–soluble zinc soaps and DPNR both make some contribution in reducing compression set. The heat build up in tyre compounds can be reduced considerably by using DPNR.

25.9.3 Specifications

The specifications usually followed for DPNR are that nitrogen (N) and ash values should be below 0.15 per cent, the remaining ones being the same as those for ISNR–5.

25.10 Latex carbon black masterbatch

Masterbatching is one of the techniques used for obtaining a satisfactory dispersion of materials in the rubber matrix. Usually, a masterbatch contains an ingredient in a higher concentration than what is normally required in a mix for a particular product. The objective of masterbatching is to prepare a mix of rubber and the ingredient, which is well adapted for further dispersion by mastication and mixing. Masterbatches may be prepared both from dry rubber as well as from latex. The idea of adding carbon black or other compounding ingredients to latex to prepare latex masterbatch and to use this as a material for further processing was conceived as early as in 1922. The first commercial production of carbon black latex masterbatch dates back to 1934 (23). Masterbatches are produced both from natural and synthetic latices.

25.10.1 Types of latex black masterbatches

In the production of masterbatches, it is necessary that the period of contact between latex and the black slurry should be the

minimum(31). This is most essential for better and uniform dispersion as increased time of contact results in absorption of rubber particles into re-agglomerates which cannot be easily dispersed at the time of processing. There are three types of masterbatches, viz dispersant type, nondispersant type and banbury dried type.

25.10.1.1 Dispersant type

If the carbon black slurry is prepared with the aid of a dispersing agent, the resulting masterbatch is referred to as dispresant type. Carbon black is hydrophobic in nature, the more finely ground the black the more difficult to wet it. As the concentration of the black goes up, the difficulty in preparing the slurry also increases. Though carbon black can be slurried with water alone, the process is very much simplified in presence of small qantities of materials such as glue, soap etc. These materials, known as dispersing agents, make slurrying easier through improved wetting of the carbon black particles. The dispersing agents may be anionic, cationic and non-ionic. With carbon black, the anionic type is more effective. The requirement of dispersing agent varies with the type of black and the normal range is from 0.6 to 1.0 for hundred of black. A major disadvantage of this type of masterbatch is that it does not offer the desired quality in tyre tread stocks. This is believed to be due to the attachment of the dispersing agent to the surface of the black particles, preventing adequate rubber to black bonding and hence reduced property of the masterbatch vulcanisate (32).

25.10.1.2 Non–dispersant type

Reduction in vulcanisate properties of the dispersant type masterbatch as compared to those obtained with dry mix resulted in the production of the non-dispersant type. Here special techniques have to be applied to slurry the fine particles of black. The main attractive features of this type of masterbatches are their high tensile strength, abrasion resistance, decreased permanent set and reduced electrical conductivity as compared to those obtained with dry-mixed vulcanisates.

25.10.1.3 Banbury dried type

Recently, it has been reported that the banbury, apart from being used as a mixer, can be used effectively for drying wet crumb. When wet crumb is dried in a banbury, part of the water is squeezed out past the ram while the rest evaporates quite rapidly since the surface of the rubber is constanly renewed. Drying is effected within 2.5–3 min compared to hours required in hot air driers. At a definite stage of drying, the black to be masterbatched is added direct and mixed. Black should be added prior to the complete drying of the crumb as rubber gets heated up rapidly at the dry stage and cause serious deterioration. Some black is however lost along with the steam escaping the ram. The process is still in the experimental stage and needs improvement before being exploited commercially.

25.10.2 Production of masterbatches

This involves various operations like preparation of slurry blending coagulation and drying (18).

25.10.2.1 Preparation of slurry (carbex)

The first step in production is the preparation of carbon black slurry (carbex). The black may be slurried by dry grinding, wet grinding or steam grinding techniques.

Dry grinding is carried out in a micropulveriser or in the Fitz mill. The powder may then be slurried by the direct addition of water using a high speed stirrer. In wet grinding, the dry ground powder is incorporated into an aqueous solution of a dispersing agent using a high speed stirrer. This may be done in a continuous manner involving continuous weighing of black and metering of solution. It may as well be done in a semicontinuous fashion where two units have to be used for the continuous production of the masterbatch. Steam grinding is carried out in a fluid energy mill where the fluid used travels at sonic or supersonic speed. With carbon black, the fluid used is steam. Black is added and is instantaneously slurried by a fine spray of water.

25.10.2.1 Blending

Blending of latex and carbon black slurry is the second stage. Emulsion/dispersion of extender oils and anti-oxidants are also added simultaneously. In the case of non-dispersant type of masterbatch, the carbon black particles can easily absorb soap micelles from the latex particles. This can lead to destabilisation of latex.

25.10.2.3 Coagulation

Coagulation may be carried out by:

(i) Creaming and coagulation using salt and acid;

(ii) Shock coagulation; or

(iii) Continuous coagulation.

In creaming and coagulation method, the pre-coagulum formed during the creaming steps is found to contain a higher than average concentration of black and the coagulum formed on acidification a lower concentration. This non-uniformity results in a poorer dispersion and inferior vulcanisate properties as compared to those obtained with dry mix. In shock coagulation, carbex is added to an excess of the coagulant. This results in formation of fine crumbs of uniform quality which are faster drying and have superior vulcanisate properties. In continuous coagulation, the well blended carbex stream is metered into a tank containing an excess of the coagulant which is violently agitated. The coagulated crumb overflows into another tank where it is washed free of the excess acid and other non-rubber constituents like the dispersing agent.

25.10.2.4 Drying

The well washed crumb is then passed over a rotary filter. This may be finally dried in rotary drum driers and pressed in hydraulic presses to compact shape.

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26 MANAGEMENT OF RUBBER PLANTATIONS

Chapter 26

MANAGEMENT OF RUBBER PLANTATIONS

The word management has different meanings. It is often used to refer to the group of managerial personnel of an enterprise. It is also used to denote the process of managing. Sometimes the word 'management' is also used to describe the discipline, viz the body of knowledge and practice called management. The fundamentals of management are universal in nature and, therefore, are applicable to rubber plantations also. The major elements of management are planning, organising, staffing, directing and controlling. The important functional aspects of management relevant to rubber plantations are capital requirement, budgeting, maintenance of records and registers and store keeping.

26.1 Fundamentals of management

26.1.1 Planning

Planning is the conscious determination of courses of action (4) or a statement of objectives to be attained in future and an outline of the steps necessary to reach them (3). The purpose of planning is to obviate uncertainty. Forecasting has an important place in the planning of operations in the plantations. It would involve the collection and analysis of data from the plantation with a view to taking appropriate decisions. Budget is the common form of plan that is generally found in the plantations. Budgets are statements of plans in quantitative terms as well as standards against which performance can be measured (5).

26.1.2 Organising

26.1.2.1 Organisation chart

Organisation comes into being only when two or more persons are associated in an endeavour. The fundamental principles of organisation are authority, responsibility and accountability. Authority is the right to decide or act independently in the discharge of responsibility. Accountability is a subordinate's obligation to report his activities and results to his superior. Responsibility and accountability go together. Responsibility is an obligation to perform, whereas accountability is an obligation to inform (1).

The purpose of organisation in the plantation is to create a framework of duties and responsibilities for the persons employed. An organisation chart can be used to show who reports to whom in the plantation. It shows hierarchical structure with positions on a scale running from top to bottom linking different ranks. The chain forms a communication network flowing upward, downward and horizontally. The existence of subordinates at different levels implies that the subordinates should be effectively controlled. The concept of span of control has relevance in this connection. Span of control refers to the maximum number of subordinates that can be placed under one manager.

26.1.2.2 Departmentation

There are different departments or sections in the plantation. Departmentation is the executive action in dividing and arranging personnel and facilities in specialised units (5). The most widely used basis for departmentation is along functional lines such as production, marketing and finance.

26.1.2.3 Delegation and decentralisation

A degree of delegation and decentralisation is inevitable in the plantation as the manager alone cannot run the set-up. Decentralisation and delegation are closely related concepts. Decentralisation

is in relation to position while delegation is in relation to person. Decentralisation and delegation are effective tools for preparing management succession.

26.1.2.4 Co-ordination

Since organisation involves the collective effort of a number of persons, co-ordination of their activities is essential. It is necessary because of the complexity, specialisation and departmentation of a large organisation. Activities in the plantation can be co-ordinated by the manager while the relations between the company and the plantation can be co-ordinated by the managing director.

26.1.3 Staffing

Staffing is also known as personnel management. In management theory, personnel management refers to manning the organisation structure through proper and effective selection, appraisal and development of personnel to fill the roles designed into the structure (4). Personnel management also includes manpower planning, recruitment, training, promotion and transfer of personnel. Some writers have also included administration of compensation, demotion and termination from service as part of it. The important aspects of staffing are job analysis, recruitment, training and development, personnel appraisal, transfer and promotion, and salary and wage policy.

26.1.3.1 Job analysis

Job analysis is the basis for manpower planning. Job analysis seeks to discover what is expected from the person on the job, how the job is performed, the skills and experience required and the opportunity for advancement. To find the quality as well as the quantity of work expected from each job, job standards are established. Time study and work load analysis would give the necessary information for establishing such standards.

26.1.3.2 Recruitment

Manpower planning leads to the concept of recruitment. Recruitment is the calling of candidates for positions to be filled. It includes

the identification of the sources of candidates. Recruitment may be simple or complex, depending upon the position to be filled and can be from sources within or outside the organisation. Recruitment from outside may involve any one or more of the following methods: selecting applicants already on the file, calling applications by advertisements, recruitment through agencies, scouting for talents in schools and colleges, and approaching professional bodies. The sources within the organisation are nomination by present employees and trade unions. In plantations these agencies are relied upon for recruitment of workers. While this is the case of workers, the managerial and supervisory personnel are recruited largely by advertisement. The purpose of selection is to find the best candidate from the applicants. Important methods of selection are interviews, tests, references and physical examination. Factors like education and training, skill, experience and physical characteristics are taken into consideration for selection.

26.1.3.3 Training and development

Training and development are also part of personnel management. Usually, a new recruit is given facilities to acquaint himself with the organisation. The purpose is to give a broad understanding of the working of the organisation. To gain first hand knowledge, on the job training is also given. Apprentice training is now adopted in most organisations. Training is aimed at the improvement of skills to perform specific tasks while development emphasises an unfolding process and carries an implication of growth and maturisation (2). Employment usually provides opportunities for both.

26.1.3.4 Personnel appraisal

Personnel appraisal refers to the procedure adopted for evaluating the personalities, contributions and potential of group members (2). There are different rating methods, many of which make use of specific character of the person and his work.

26.1.3.5 Transfer and promotion

Transfer and promotion would be inevitable in any organisation. Transfer is generally a change in position without a change in status

or pay (3), while promotion may be either or both. Sometimes transfer may be resorted to correct an original mistake in selection. Promotion from within is the procedure the employees favour. Sometimes, it is incorporated in the collective bargaining agreement concluded between management and workers. Seniority based on length of service is the usual basis for promotion.

26.1.3.6 Salary and wage policy

Salary and wage policy are also the most common subject for collective bargaining which form the usual basis for incentive payment. Job evaluation is the adopted method usually to determine the salary and wages. The purpose of evaluation is to find out what a job is worth. There are four principal systems of evaluation: (i) ranking system (ii) classification system (iii) point system and (iv) factor comparison system. Ranking and classification systems are adopted in the plantations.

26.1.4 Directing

The purpose of direction is to create an internal environment that will induce subordinates to work at the level of their full capabilities (4). For proper direction, the plantation should establish a clear objective. There should be harmony of interest between the employer and the employee regarding the objective. The employee should be made to understand the goal of his position, its scope, purpose, and authority. Order, motivation, leadership and communication are important aspects of direction.

26.1.4.1 Order

Order is the link in the direction process. Order has been defined as an instruction by a superior requiring a subordinate to act or refrain from acting in a given circumstance (4). An order can be general or specific and written or oral. In the plantation, oral orders take the predominant position. Delegation of authority is also a form of direction.

26.1.4.2 Motivation

The instrument of direction is motivation. It is the inducing of people to act in a desired manner. Motivation demands the proper understanding of people. Some writers have noted that satisfied needs are seldom sufficient to motivate. The role of the plantation manager is to discover each man's needs as he perceives them and determine and implement a system of inducements. The inducement can be negative or positive. Positive inducement can be both financial and non-financial. Granting increment, bonus, and promotion are financial inducements. Non-financial inducements include making people important, recognising achievement, giving status and providing challenging assignments. Lack of a conducive atmosphere or lack of scope for advancement can be negative inducements. In addition, punishments can also work as negative inducements.

26.1.4.2 Leadership

Many writers on management emphasise leadership as an important quality of a successful manager. Leadership has been defined as the art of inducing subordinates to accomplish their assignments with zeal and confidence (4). A good leader cultivates empathy, objectivity and self knowledge. It has been noted that people tend to follow those in whom they see a chance to fulfil their own desires. The emphasis now is on participative rather than authoritarian management. However, the choice depends on the environment, people, and the needs of the plantations.

26.1.4.3 Communication

Communication is an important element in the direction process. Establishing an efficient network of communication is essential in the plantation where the place of work is spread over a wide area. The ability to communicate and influence people is an essential attribute of a manager. Proper communication is also necessary for establishing standards, measuring performance, and correcting deviations. In the plantation, communication facilities are used mainly for recruitment, giving operating instructions, ensuring safety and discipline and appraising personnel. One of the duties of the

plantation manager is to receive, store, process and disseminate information.

26.1.5 Controlling

The purpose of control is to find out whether what is done is what is intended to be done. Establishing standards of performance is the first step of control. The standards are intended to measure the results and the measurement would involve detecting and correcting deviations from the agreed path. It is not possible for the plantation manager to observe every activity; hence control should be on critical points. The control techniques introduced in the plantation should be objective, economical and easily understood. Various techniques are adopted for controlling.

26.1.5.1 Statistical methods

Establishing procedures and guidelines is a traditional method used in government for the purpose of control. This has been followed in other organisations also. Among the non-budgetary controls, statistical analysis is the most important one. Relevant data are analysed and presented as tables or charts. Statistical analysis has wide scope in rubber plantations. Statistical quality control (SQC) is another method of control which obviates the examination of every individual unit of production. In rubber plantations, the rubber maker or the factory supervisor, with some training, can ensure the quality of rubber with the aid of SQC. Electronic data processing can also be introduced as an aid to control.

26.1.5.2 Standard cost

Standard cost is another control technique. It is worked out by taking the cost of materials and labour and adding a standard overhead. Though standard cost rarely equals actual cost, it will provide a means to measure actual cost. Since cost estimates are made by many plantations, this technique can be fruitfully employed. Break-even chart can also be used to analyse the cost.

26.1.5.3 Audit

Financial and accounting data can be analysed with a view to finding out the profitability of the company controlling the plantation. Such analysis can also reveal the position of the company in the rubber plantation industry. Internal audit is the most common technique used in industry and government for control.

26.1.5.4 Programme evaluation and review technique (PERT)

PERT is also a new development aimed at facilitating better control. Under this method, every significant event that occurs at different stages of a project is listed out. The sequence of events and their relationships are shown in a network diagram and specific time is set for the completion of each item. PERT has a practical utility in the plantation when major construction or new planting or replanting programmes are launched.

26.1.5.5 Other controls

Other control techniques that can be applied are management audit and employee attitude surveys. Large companies have scope for introducing even operations research.

26.1.5.6 Human attitudes to control

Human attitudes to control have been widely examined by management writers and it has been found that workers generally dislike controls since controls imply an element of restriction and compulsion. Therefore, the plantation manager has to devise ways and means to make the workers accept reasonable systems of control. It has been observed that to get the best results, subordinates should be encouraged to participate in setting standards.

26.2 Capital requirements

For setting up a plantation, many operations have to be undertaken such as clearing of the area, employing sizeable work force, procuring stores of substantial value, constructing roads and buildings,

and providing other infra-structural facilities. All these call for substantial investments for which funds have to be arranged.

26.2.1 Cost of development of a rubber plantation

The cost involved in setting up a plantation can be grouped under two main heads, (i) agricultural operations and (ii) engineering works and capital equipments. Under the Indian conditions, rubber has an immaturity period of about seven years. The expenditure incurred for agricultural operations during that period is capitalised and is termed as developmental cost. There are three classes of expenditure during the period, viz labour cost, material cost and general expenses. The normal items of expenses under these classes are listed below:

26.2.1.1 Cost of agricultural operations

Labour cost:

The following are the items of work requiring labour:

1 Felling and clearing;
2 Terracing, lining, and pitting;
3 Filling and planting;
4 Fixing shade baskets;
5 Pruning and thinning;
6 Weeding and mulching;
7 Manuring;
8 Spraying, dusting etc;
9 Cover crop establishment;
10 Drainage and miscellaneous works;
11 Boundary protection and foot path; and
12 Watch and ward.

Material cost:

1 Planting materials;
2 Shade baskets;
3 Fertilizer;

4 Chemical and other stores;
5 Cover crop seed; and
6 Estate tools and implements.

General expenses:

1 Staff salary;
2 Printing and stationery;
4 Postage, telegrams and telephones;
5 Repairs, and maintenance (vehicles, buildings, roads, etc);
6 Land tax;
7 Audit fees;
8 Electricity charges;
9 Labour amenities; and
10 Rates, taxes, insurance etc.

The general expenses listed above relate to estate activities only and exclude head office expenses. The cost of labour works out to about 50 per cent of the total development cost, cost of materials about 35 per cent and general expenses about 15 per cent.

26.2.1.2 Engineering works and capital equipments

The items also form a substantial part of the investments needed for setting up a plantation. The requirement has to be assessed for the plantation as a whole. Major items of cost under these heads are the following:

Estate buildings, roads, vehicles etc:

1 Estate office buildings and stores;
2 Vehicles;
3 Furniture and equipments;
4 Plant and machinery;
5 Power generation and distribution equipments;
6 Water supply arrangements;
7 Fencing; and
8 Internal roads and culverts.

Township and housing;

1 Residential buildings (staff quarters and labour lines);
2 Other buildings (hospital, school, creche, canteen etc); and
3 Furniture and equipments.

26.2.2 Methods of raising finance

Methods of raising finance vary depending on the form of organisation controlling the estate. The form can be public limited company, private limited company, partnership or individual.

26.2.2.1 Public limited company

A public limited company can raise finance by resorting to the issue of equity shares, preference shares and debentures, by obtaining loans from financial institutions and by accepting deposits from the public. The Companies Act imposes certain controls on the raising of capital by the public limited companies. The preliminary expenses for floating a company have to be met by the promoters of the company. The fixed capital requirements of the company may be met by issuing equity shares to the public. The preference shares carry fixed rate of dividend and debentures carry fixed rate of interest. Additional capital can be raised from special financial institutions and banks. The Agricultural Refinance and Development Corporation is one of the institutions providing long-term loans for agricultural purposes. A company can also accept fixed deposits from the public. The internal sources of capital are the reserves and surpluses ploughed back into the business.

26.2.2.2 Others

Private limited companies, partnerships and individuals have to approach mainly banks, friends and relatives for arranging funds. The Agricultural Refinance and Development Corporation also provides long term financial assistance to them through commercial banks. Commercial banks and Agricultural Co-operative Societies also provide financial assistance to rubber growers, for meeting their capital needs.

26.3 Estate budget

In the case of rubber plantations, the expenditure incurred during the immaturity period creates an asset in the form of a developed plantation. As far as mature rubber is concerned, budgeting consists of estimating the expenditure, income and profit. It is desirable to prepare estimates for each division. Separate estimates may be prepared for the processing operations. Price of stores, wage rates, rubber prices etc should be related to the budget period.

Budgeted profit and loss account can be prepared by classifying the expenditure as capital/revenue. Capital expenditure results in the creation of permanent assets which are used continuously for earning revenue. Further, any amount spent to improve the revenue earning capacity of the asset is also a capital expenditure. In rubber plantation, the cost of land, buildings, plant and machinery, vehicles etc are capital expenditure. All establishment expenses and repairs, replacements and renewals of original equipments to keep them in efficient running order are treated as revenue expenditure. Thus, office salaries, rent, taxes, insurance, advertisements and other expenses incurred to run the plantation are treated as revenue expenditure.

In the course of the year, the actual expenditure under the above heads can be compared with the estimates given in the budget. This comparison enables the management to take corrective action promptly.

26.4 Records and registers

In a rubber plantation, a large number of workers and staff is employed in the field, factory and office. Their attendance and serivce records have to be maintained for the purpose of calculating wages, salaries, bonus, provident fund contribution, leave, gratuity etc. Certain records are to be maintained under the various statutes. Records of different activities in the field and factory have to be maintained for control purpose. Details regarding collection, processing and despatch of crop are also to be maintained. As stores of substantial value are consumed in the field and factory, stock records have to be kept up-to-date. Large amount of money is to be received for payment of wages, salaries and for meeting other expenses. Accounting records are necessary for this purpose, and also for the analysis

of expenses under different heads. The following are some of the important records to be maintained in a plantation office and factory.

26.4.1 Records in the office

26.4.1.1 Field history book or field register

This would serve the purpose of a permanent record regarding the planted area and may be maintained field-wise. It should contain details like year of planting, planting materials, number of trees, operations during each year, cost incurred each year, girth measurement, tapping history, yield record etc.

26.4.1.2 Field maintenance register

This record is designed to allocate the daily activities of field workers so that appropriate costs can be apportioned among the fields concerned.

26.4.1.3 Divisional crop book

This is for recording the daily receipt of latex and scrap from each field.

26.4.1.4 Attendance register/muster roll

This is meant for recording and checking the attendance of all workers for each day. Separate records may be maintained for different types of workers.

26.4.1.5 Check roll

This provides detailed information regarding the payment to be made to the workers. It contains particulars regarding attendance (based on muster roll) rate of wages, incentives, deductions and the net wages to be paid to each worker.

26.4.1.6 Building register

This is for recording the plinth area, cost of construction etc of buildings for the purpose of paying taxes.

26.4.1.7 Stock record or stores ledger or inventory register

This is to record receipt, issue and balance of stock of plantation stores and other materials.

26.4.1.8 Attendance register, pay roll, service records

These relating to the staff in the field, factory, and office have to be maintained.

26.4.1.9 Books of account

These include cash book, journal and ledger.

26.4.1.10 Other registers

These are :

1 Leave register;
2 Leave with wages register;
3 Sickness benefit register;
4 Maternity benefit register;
5 Festival advance register;
6 Disciplinary action register;
7 National and festival holidays register;
8 Weather protective payment register;
9 Register of adult workers; and
10 Register of non-adult workers.

26.4.2 Records in the factory

The following records are necessary in the factory:

1 Crop record (estate crop book in the factory);
2 Stock record showing output, despatch and stock of rubber;

3 Idle time and machine utilisation statement in respect of costly machinery like centrifuge, sheeting battery and crepe mill;
4 Assets register showing all information about plant and machinery, vehicles etc; and
5 Factory attendance register, check roll etc.

The above list cannot be considered as exhaustive. Depending on the size and complexity of the estate, the requirements of records and registers may vary.

26.5 Store keeping

The object of store keeping is to ensure that proper quantity and quality of stores are obtained at the proper time and at the lowest price, consistent with the quality desired.

26.5.1 Purchasing of stores

26.5.1.1 Objectives of purchasing

The objectives of purchasing stores are:

1 Procuring of suitable materials of given quality and quantity at the lowest price;
2 Scheduling of purchase operation to ensure steady supply of materials required; and
3 Avoiding too much of stock leading to locking up of capital and too little causing disruption of production.

26.5.1.2 Steps in purchasing

The word purchasing means going into the open market, finding the lowest price at which a standard item is offered and selecting a supplier who offers it at that price. The effective purchasing may be carried out by the following steps:

1 Preparing an accurate statement of the quality and quantity of materials needed;
2 Selecting dependable sources of supply;

3 Following up the order, receiving goods, checking invoices and inspecting goods;
4 Storing the materials to prevent deterioration and making them readily accessible when required for use; and
5 Keeping under full documentary control all the above activities and charging the cost of materials to production for pricing.

26.5.1.3 Materials to be purchased

There are two types of stores required in rubber estates. They are those used at a particular time in a year and those which are more or less in continuous use. The first category includes chemical fertilizers, sulphur, copper sulphate, copper oxychloride, spray oil, materials for rainguarding, spouts and coconut shells for collection etc. Items which are in continuous use are acid, petrol, lubricants, furnace oil, diesel oil, kerosene, ammonia gas, spare parts, empty drums, buckets, tapping knives, dishes, implements, stimulants, cement, iron bars etc. Cost of stores forms about 20–30 per cent of the estate cost of production.

26.5.2 Stores department

The functions of a stores department or section are:

1 Receiving, storing and safeguarding of materials;
2 Issuing of correct amounts of stores;
3 Keeping of stores records which show at all times what is on hand and what has been issued classified according to items; and
4 Giving timely notice when replenishment is required.

The layout and organisation of stores vary considerably with the size of the plantation. However, for proper storage, a store room should be systematically laid out with separate receptacles specially suited to facilitate access, identification and storage of each item of stock.

An indispensable rule is that when stores are drawn from the store room it should be considered in the same way as drawing money

and nothing should be taken out of the stores without a regular requisition slip signed by the appropriate authority. A daily or weekly summary of stock position should be reported by the store-keeper to the controlling authority. Of late, index cards and stock control systems have been introduced for controlling large scale stock.

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27 BY-PRODUCTS AND ANCILLARY ACTIVITIES IN RUBBER PLANTATIONS

Chapter 27

BY-PRODUCTS AND ANCILLARY ACTIVITIES IN RUBBER PLANTATIONS

It is true that latex produced by the tree is the main source of the planters' income which is sustained for a period of 20–25 years. Nevertheless, the by-products as well as materials obtained from ancillary activities in the plantation constitute sources of substantial supplementary income. The main by-products are cover crop seed, rubber seed, rubber wood, sludge and skim serum from centrifuge plants and effluent from factory. Materials obtained from ancillary activities include products from intercrops and honey from apiculture. Another possible activity in the rubber plantation is dairy farming. This can not only supply milk and milk products but also enough cow dung for a bio-gas plant which can provide gas for cooking and lighting purposes as well as manure of good quality as a by-product. Fish culture in effluent treatment tanks is a challenging though unexplored field of activity.

27.1 Cover crop seeds

Pueraria phaseoloides (tropical kudzu) is the most popular cover crop used in rubber plantations in India. Seeds are usually available from second year onwards until the cover crop is shaded out by the closing canopy of the rubber trees. The season for collection of seeds is January–February. A well maintained cover crop yields 30–40 kg of seeds per ha of the plantation. Large quantities of cover crop seeds are being exported. In recent years, the price of *Pueraria* seeds varied from Rs. 8 to Rs. 15 per kg.

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27.2 Rubber seeds

Rubber seed is a source of non-edible oil. The collection of rubber seeds was not widely practised in India until the last decade. However, the increase in the price of non-edible oil in recent years generated interest in the collection and processing of rubber seeds.

27.2.1 Rubber seed, its collection and storage

The weight of the rubber seed varies from 3 to 5 g. The fresh seed contains about 40 per cent kernel, about 35 per cent shell and about 25 per cent moisture, while the dried kernel (5 per cent moisture) contains about 40 per cent oil (11).

The tree starts producing seeds even before the commencement of tapping. The seed fall season in India is between July and September. Powdery mildew desease adversely affect seed setting, and abnormal leaf fall disease caused by *Phytophthora* spp brings about rotting of the pods and damage to seeds. Severe rainfall also reduces the number of seeds that can be collected. The non-availability of adequate workers for collection at a reasonable wage, difficulty in storing the seed, presence of luxuriant cover crop and steep and hilly terrain are other adverse factors affecting collection of seeds. High moisture content of fresh seeds makes it difficult to store them without deterioration. Seeds which cannot be processed immediately should be sun dried to reduce moisture content, kernels extracted (de-cortication of seeds) and dried before storing. Kernels adequately dried in this way could be kept for four months without deterioration (11).

Various estimates have been made regarding the seeding potential of rubber trees (2, 3). According to a study conducted by the Rubber Board, on an average, a healthy tree can give about 500 g of useful seeds during a normal year and this works out to an estimated availability of 150 kg of seeds per ha. The price of rubber seeds fluctuates widely from year to year. The range in recent years has been 30–60 paise per kg.

27.2.2 Estimated availability in India

Very young and very old trees do not produce sufficient seeds to make collection economical. Although the total area under rubber

in India was 236000 ha at the end of 1978–79, after excluding areas planted before 1948-49 and after 1972–73, only 200000 ha may be considered as mature trees capable of yielding seeds in sufficient quantities. It has been estimated that the above area could produce about 30000 t of seeds during a normal year. About 10 per cent of it would be used for raising planting materials in the estates and smallholdings.

27.2.3 Rubber seed oil

27.2.3.1 Extraction

Though rubber seeds are produced mostly in Kerala, the processsing of rubber seeds is concentrated in Tamil Nadu, more particularly in Virudhunagar. The industry had its origin only during the last decade. The scarcity of non-edible oil seeds prompted many millers to make use of this source as a raw material for oil extraction. The millers in Tamil Nadu have certain advantages in the extraction of rubber seed oil. In the first place, the mills have been set up for processing groundnuts, and the groundnut crop starts arriving usually after December while the seed-fall season for rubber is between July and September. This allows the groundnut oil millers to process rubber seed oil using spare capacity. In Kerala, rains occur during July–September, while there is hardly any rain in the interior districts of Tamil Nadu. Thus, during this period, the climate is also conducive to drying rubber seeds prior to crushing. Another advantage is the availability of cheap and plentiful labour for shelling and handling of seeds. These factors have contributed to the development of the industry in Tamil Nadu . However, a few units have also come into operation in Kerala during the last few years. Most of them get dried kernels from Tamil Nadu.

For extracting oil from rubber seed kernel, molasses *(khandassari)* is required. Every 100 kg of dried kernel requires 20–25 kg of molasses. The recovery of oil and cake varies according to the quality of the kernel, the extent of drying and the extent of molasses used for processing. The recovery of oil is usually between 30 and 40 per cent of the weight of the dried kernel.

In October 1979, the price of oil at Virudhunagar was around Rs. 7000/t. During 1979–80, about 3700 t of rubber seed oil is estimated to have been produced in the country.

27.2.3.2 Properties of rubber seed oil

Rubber seed oil is light yellow in colour and free from deposits on standing. It is a semi-drying oil with the following chemical properties (3).

Acid value	4—40
Saponification value	190—195
Iodine value	132—141
Hydroxyl value	12—32
Unsaponification (%)	0.5—1.0
Refractive index 40°C	1.466—1.469
Sp gravity 15/15°C	0.924—0.930
Titra (°C)	28—32

Fatty acid composition (%)

Palmitic acid	11
Stearic acid	12
Arachidic acid	1
Oleic acid	17
Linoleic acid	35
Linolenic acid	24
	100

27.2.3.3 Uses of rubber seed oil

Rubber seed oil can be used for making soap. As semi-drying oil, it can be used as a substitute for linseed oil in the manufacture of paints. Rubber seed oil, in suitable treatment with sulphur, produces a material known as factice which finds use in rubber compound (14). Epoxidation of rubber seed oil with hydrogen peroxide and acetic acid has been reported (15). Epoxidised oil is used in the formulation of anti-corrosive coatings, adhesives and alkyd resin casting.

27.2.4 Rubber seed cake

About 66 per cent by weight of the milled kernel is obtained as rubber seed cake (12). It is rich in protein and its use has been evaluated as a cattle and poultry feed (10,13). Many cattle and poultry feed manufacturers are using rubber seed cake as a constituent of their products. The small quantity of hydrocyanic acid present in the cake does not pose any danger to livestock.

In October 1979, the price of rubber seed cake at Virudhunagar was Rs. 1200/t. During 1979–80, the production of rubber seed cake in the country is estimated at about 7800 t.

27.3 Rubber wood

With the depletion of valuable forests all over the world and with the increase in population, search for new sources of wood is being intensified. In this connection, rubber wood has been found to be a valuable source of timber in many countries. It has been used for manufacturing furniture after treatment and seasoning and also for making fibre boards and hard boards. The Japanese are known to have devised a method for processing rubber wood into pulp for manufacturing paper and rayon. In a recent report from Sri Lanka, the problems and prospects of using rubber wood as a raw material for paper industry have been discussed (5).

A study conducted by the Rubber Board revealed that the average girth of a rubber tree at the time of clear-felling varied between 100 and 110 cm at a height of 125 cm from the ground and that a tree gave

an average of 0.62m^3 of stump-wood and 0.39 m^3 of branch-wood, totalling 1.01 m^3. The study also revealed that on an average, at the time of clear-felling there were 184 trees/ha.

The Rubber Board has chalked out an ambitious programme of replanting and the target for replanting is fixed at 5000 ha/annum. On the basis of the estimated availability of rubber wood, this area could furnish about one million m^3 of rubber wood per annum. The sawn wood was being sold at about Rs. 300–400 per m^3 in the middle of 1980. However, at the estate level, the price is considerably lower depending upon the location and accessibility.

27.4 Sludge from centrifuge plants

The formation of magnesium ammonium phosphate as a sludge in the settling tank and bowl of the centrifuge used in the production of concentrated latex, has already been discussed in Chapter 23. A few samples of sludge collected from factories in Kerala gave the following average analytical results (6).

Source	N%	P_2O_5 %	K_2O%	MgO%
Tank	3.3	37.3	1.2	19.3
Bowl	3.0	32.1	1.0	19.2

Sludge is rich in phosphorus and magnesium and can be used as a slow release fertilizer source for these nutrients, particularly for mature perennial crops like rubber or coconut in areas where the soil is deficient in these nutrients and after compounding suitably with other fertilizer ingredients. Because of its slow-releasing nature, care should be exercised in its use for young tree crops or annual crops. Proper blending with soluble forms of phosphorus or magnesium may be necessary in such cases. However, this can be used as a source of phosphorus and magnesium for cover crops, particularly where the soil is not deficient in potassium. Sludge has been used as a fertilizer for pastures, rice, maize, water melon and as a feed in fish culture (9).

27.5 Skim serum

A report from Malaysia shows that skim serum usually contains about 4 per cent total solids including 0.26 per cent ammoniacal nitrogen

in the form of ammonium sulphate, 0.09 per cent protein nitrogen and about 0.20 per cent potassium (1). Neutralised skim serum obtained from a factory in Kerala contained 0.31 per cent nitrogen (N), 0.64 per cent phosphoric acid (P_2O_5), 0.24 per cent potash (K_2O) and 0.38 per cent magnesia (MgO) (6). The method of using skim serum directly as a fertilizer has been reported from Malaysia (1). According to this report, it is possible to dispose of a factory's entire output of skim serum over an area forming seven per cent or less of the estate, and a dose of 10 l of serum per mature tree three times a year has been recommended. The use of serum can eliminate or reduce the need for nitrogenous and potassic fertilizers, depending on the composition and quality of serum used and the nutrient needs of the plant. However, the exact quantity of serum to be used for tree and the supplemental need for other fertiizers are best determined after assessing the composition of the serum and the nutrient needs of the plant through chemical analyses of serum, soil and leaf samples.

27.6 Effluents from rubber processing factories

During the processing of crop into marketable forms, large quantities of water are used for washing, cleaning and dilution. At present, there are eight solid block rubber factories in the country and the quantity of effluent discharged from these factories alone is about 60 million l a year. The quantity will be increased to about 10 times within a few years when nine more units are established. The quantity available from sheeting and crepe factories will be much more than that from solid block rubber factories. The promulgation of Pollution Control Act in 1974 by the Government of India has made it obligatory for the rubber processing factories to build up facilities to ensure that the effluents let out conform to the specifications prescribed under the Act. Details of these specifications are given in Chapter 20. The treated effluents are excellent as sources of irrigation water for various crops.

27.7 Intercrops

The intercrops raised in the plantations during the immature phase provide additional income to the planter. The most useful intercrop which does not adversely affect the growth of rubber or

cover crop is 'nenthran' banana raised during the first and second year of the plantation. Other intercrops commonly raised are dry-land rice, ginger, tapioca, turmeric and yams. Economic and other aspects of some of these intercrops are discussed in Chapter 9.

27.8 Apiculture

Apiculture (bee-keeping) is practised in many rubber plantations. Honey-bees collect large quantities of nectar from the secretions of extra-floral nectary glands at the tip of petiole where the leaflets join. But these glands are active only for four to six weeks after refoliation during the period from January to March. Nearly 30 per cent of the honey produced in India is from rubber tree collected during this period. During January, the bee-keepers bring lorry loads of beehives and keep them in rubber estates in Trichur and Kanyakumary districts. Honey is extracted at weekly intervals and 8–10 kg honey, which is normally the quantity obtained in a year in a good honey flow area, is collected from a hive kept in rubber estate in three months (4). Hence it is a very profitable subsidiary activity for rubber growers, especially smallholders. During off-season, there is no dearth for pollen, as honey bees get enough pollen from coconut trees but there is a dearth of nectar-yielding plants in rubber plantation. Hence, the beehives should be transported to areas with bee-pasture or kept in the rubber estates with the super removed. In the latter case, no honey could be collected.

Because of weekly extraction, the honey collected will be light and it will contain more moisture. While processing, such honey should be kept under sunlight for more days to remove water.

27.9 Dairy Farming

Rubber plantations are often situated in remote areas where amenities like supply of good quality milk are usually lacking. Electricity may not also be available in the plantation. In such areas, dairy farming with at least five heads of cattle can be profitably practised. Usually, the plantations have enough facilities to grow fodder grasses, particulary along their boundaries. The cow dung obtained can be used for maintaining a bio-gas plant which can

provide gas for cooking and lighting purposes. Absence of winter in the rubber growing areas in South India ensures uninterrupted and efficient supply of gas from the plant.

27.10 Fish culture

Treatment of effluents from both cup lumps and skim using seeding of an algae, *Chlorella* and survival of fish in the treated effluent have been reported (7,8). These findings point to the possibility of fish culture in the effluent treatment tank.

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28 LEGISLATIONS COVERING RUBBER PLANTATION LABOU

Chapter 28

LEGISLATIONS COVERING RUBBER PLANTATION LABOUR

The only specific legislation which covered the plantation labour before Independence was the Tea District Emigrant Labour Act 1932 which regulated the conditions of recruitment of labour for employment in the tea gardens of Assam. Though the Workmen's Compensation Act 1923 applied to the plantations, it did not confer any substantial benefit on plantation labour, as accidents in plantations were few. The Payment of Wages Act 1936, though applied to plantations, was not comprehensive. In 1946, the Labour Investigation Committee observed that the conditions of life and employment in plantations were different from those in other industries and, therefore, the Committee recommended the creation of a plantation labour code covering all plantation areas. The Plantations Labour Act 1951 was thus enacted on the lines recommended by the Labour Investigation Committee.

The matters relating to labour come under the concurrent list of the Indian Constitution. As such, both the Central and the State Governments have jurisdiction over labour matters. This has been the reason for both the Parliament and the State Legislatures enacting legislations on labour. The Constitution, however, has provided that, in case of conflict between a State legislation and a Central legislation on the same subject, the Central legislation shall prevail. The State Government is empowered to amend the provisions of the Central legislation in so far as it relates to that State with the permission of the Central Government.

Most of the labour legislations have been enacted by the Central Government and implemented by the State Governments.

The discussions in this chapter are based on the provisions of labour Acts applicable to the State of Kerala. There may be slight variations in the provisions that are applicable to other States. The Rules may contain the details of forms and registers to be used under different Acts. These are usually prescribed by the State Governments.

28.1 Main provisions of the Plantations Labour Act 1951

The Plantations Labour Act is the most important legislation providing for the welfare of labour in plantations. It is a Central legislation implemented by the State Governments.

The Plantations Labour Act applies to tea, coffee, rubber and cinchona plantations of 10.117 ha or more in extent and in which thirty or more persons are employed or were employed on any day of the preceding twelve months. However, the State Government can apply the Act to any other plantation raising other crops by notification in the official gazette. In 1960, the Plantations Labour Act was amended in order to check fragmentation of plantations into small units with a view to avoiding the liabilities under the Act. As per the 1960 amendment, the State Government can extend the operation of the Act eventhough the plantations did not admeasure 10.117 ha or employ 30 workers. The only condition required is that such plantation should not have been less than 10.117 ha and should not have employed less than 30 workers, before the commencement of the Act.

The Plantations Labour Act contains provisions relating to health, welfare, hours of work and limitation of employment, leave with wages, provisions for enforcing the legislation and the penalties for violating the Act.

28.1.1 Definition of worker

Under the Plantations Labour Act a worker has been defined as to include a person employed in a plantation for hire or reward. But the definition will not include (i) a medical officer, (ii) any person whose monthly wages exceed Rs. 300, (iii) a person who

has been employed primarily in a managerial capacity, notwithstanding his monthly wages, and (iv) a person employed temporarily for construction, development or maintenance of buildings, roads, bridges, drains or canals.

28.1.2 Provisions relating to health

Section 8 of the Act requires the employer to provide wholesome drinking water at convenient places. Section 9 requires the employer to provide separate latrines and urinals for male and female workers according to public health requirements at the rate prescribed under the State Rules. Section 10 of the Act provides that the employer should give medical facilities for the workers and their families as prescribed by the State Government concerned. The Rules framed in Kerala provide for two types of hospitals, viz, garden hospital and group hospital. Garden hospitals are intended to deal with out-patients and in-patients, not requiring elaborate diagnosis and treatment. Group hospitals shall be capable of dealing effectively with all types of diseases normally encountered, but it is not to be used for routine treatment. Admission to a group hospital shall be on the recommendation of a garden hosptial doctor, except in emergency. The employer has an option to have a lien in a nearby hospital with the approval of the Chief Inspector of Plantations at the rate of 15 beds for 1000 workers. The Chief Inspector of Plantations who is appointed under the Act by the State Government can recover the cost of providing medical facilities from the defaulting employers.

28.1.3 Provisions for welfare

28.1.3.1 Housing

Where the workers are resident in the plantations, the employer has to provide them housing accommodation according to the standards specified by the State Government. The plans and specifications for houses can be obtained from the Chief Inspector of Plantations. The houses shall be rent free.

28.1.3.2 Weather protectives

Once in every 12 months the employer shall supply free to every permanent worker a 'cumbly' (woollen blanket) or an umbrella or a rain-coat or a hat of suitable quality approved by the Chief Inspector of Plantations. It is within the discretion of the employer to choose the articles to be supplied.

In estates situated at an elevation of 2500 ft (760 m)or more above sea level, one extra 'cumbly' shall also be supplied to every permanent worker. In case of dispute regarding the elevation, it is the duty of the Chief Inspector of Plantations to arrange for the elevation being determined. In the case of temporary workers, the employer has the option of supplying a special type of 'cumbly' which is returnable on termination of employment or alternatively an allowance of three paise per day's work.

28.1.3.3 Educational facilities

If the number of workers' children between the ages of 6 and 12 in a plantation exceeds 25, the employer shall provide and maintain a primary school or schools for imparting primary education to the children. However, if there is a school run by government or local authority within 3 km from the place where workers reside in the plantation or if the employer is required to pay a tax or cess for primary education, this condition need not be fulfilled.

28.1.3.4 Recreational facilities

A recreation centre or centres with provision for in-door games and where sufficient open space is available, playground or playgrounds shall be provided and maintained by the employer for the workers.

28.1.3.5 Canteens

In or near every plantation where 150 or more workers are ordinarily employed, the employer shall arrange directly or otherwise to provide and maintain a canteen or canteens wherein tea, coffee and snacks are sold to the workers on a no–profit basis.

28.1.3.6 Creches

In every plantation where 50 or more women workers are employed, the employer shall provde for the use of their children below six years, a creche or creches according to the standards prescribed by the State Government, with suitable furniture and cradle and under the charge of a woman having the necessary training. In or adjoining a creche, there shall be suitable washroom for washing the children and their clothes. Milk and refreshments, and adequate supply of cloth, soap and oil should be made available for each child while it is in the creche.

28.1.4 Hours and limitations of employment

As per Section 19 of the Act, no adult worker should be required to work in the plantation for more than 50 h a week, and no adolescent or child for more than 40 h a week. In the case of plantations in Kerala, the daily working hours are 9 h for adults, 6 h and 40 min for adolescents and $4\frac{1}{2}$ h for a child. The employer is required to give daily intervals of rest so that the worker is not required to work for more than 5 h continuously. The Act also prescribes for a rest of at least half an hour. The spread over time for an adult should not exceed 12 h including the time spent in waiting for work. The employer is also required to give a day of rest in a week. Since the Minimum Wages Act also applies to plantations and that Act stipulates a maximum of 48 h per week, the provision in the Minimum Wages Act is followed in respect of maximum hours of work in the estates. The employer is required to place a notice of the period of work. As per Section 24, children below the age of 12 should not be required or allowed to work in any plantation. Under Section 25, children and women are prohibited from being employed for work during night. Non-adult workers (above 12 years but below 18 years) are required to obtain certificate of physical fitness from competent authority specified under the Act and to carry a token giving reference to such certificate.

28.1.5 Leave with wages

Adult workers are eligible for leave with wages at the rate of one day for every twenty days of work performed and for young

persons for one day for every 15 days. Only 30 days' leave could be accumulated at a time. The wages are to be paid in the case of time-rated workers at the minimum daily wage and in the case of others (piece-rated or partly piece-rated and partly time-rated) at the rate of average daily wage calculated over the preceding twelve calendar months. Average daily wage is the average of the total earnings for 12 months including dearness allowance, but exclusive of over-time and bonus. In addition, the worker is eligible for the cash value of food and other concessions, if any. Section 32 provides for the payment of sickness allowance at the rate prescribed by the State Government. The sickness benefit is payable for a total period of 14 days in a year. The Plantations Labour Act also contains provisions for maternity benefits. In Kerala, the Central Maternity Benefits Act is followed. It applies to plantations as defined in the Plantations Labour Act. The wages payable are being revised from time to time by the Plantation Labour Committee of Kerala.

28.1.6 Welfare officer

The Plantations Labour Act contains a provision relating to the appointment of welfare officer. Plantations employing 300 or more workers are required to appoint qualified welfare officers in Kerala.

28.2 Main provisions of the Industrial Disputes Act 1947

This legislation was enacted with a view to ensuring social justice and advancing the progress of industry by bringing about harmony and cordial relationship between the employer and the employee. By the 1976 amendment, a new chapter has been added to the Act. The new chapter provides special provisions relating to lay-off, retrenchment and closure in establishments employing 300 or more workers. The Industrial Disputes Act provides the following authorities for the settlement of industrial disputes.

(i) Works Committee;

(ii) Conciliation Officers;

(iii) Board of Conciliation;

(iv) Courts of Inquiry;

(v) Labour Courts;

(vi) Industrial Tribunals;

(vii) National Tribunals; and

(viii) Arbitrators.

For details regarding constitution and functions of the authorities the Act may be referred to.

28.2.1 Definition of dispute

An industrial dispute has been defined as any "dispute or difference between employers and employers or between employers and workmen or between workmen and workmen, which is connected with the employment or non-employment or the terms of employment or with the conditions of labour, of any person." In 1965 a Section was also added which partially modified the definition of dispute so that an individual workman who has been thrown out of employment can raise an industrial dispute. Formerly, a workman had to rely for redressal either on a union or if there was no union on the help of his co-workers.

28.2.2 Strike

The Act defines strike as the "cessation of work by a body of persons employed in any industry acting in combination or a concerted refusal, or a refusal, under a common understanding, of any number of persons who are or have been so employed, to continue to work or to accept employment." Courts have held that cessation of work even for a few hours as a result of the concerted action of the workmen amounts to a strike.

28.2.3 Lock-out

Lock-out is the "closing of a place of employment, or the suspension of work, or the refusal by an employer to continue to employ any number of persons employed by him." The Courts have held that

a distinction has to be made between lock-out and closure. In the case of lock-out the establishment as such is not closed down even temporarily. It has also been held that a lock-out is essentially a suspension of the employees services, the employer being responsible for such suspension.

28.2.4 Prohibition of strike and lock-out

Under Section 22 of the Act, strike and lock-out in public utility services without notice are prohibited. Section 23 of the Act contains a general prohibition of strike and lock-out during the pendency of—

(i) conciliation proceedings before a Board;

(ii) proceedings in labour court or tribunal;

(iii) arbitration proceedings; and

(iv) during the operation of a settlement or an award.

It has been decided by courts that strike resorted to without giving notice as required by the standing orders can never be justified in law. A lock-out declared in consequence of an illegal strike or a strike declared in consequence of an illegal lock-out shall not be illegal.

28.2.5 Lay-off

Lay–off is the "failure, refusal or inability of an employer on account of shortage of coal, power or raw materials or the accumulation of stocks or the break down of machinery or for any other reason to give employment to a workman whose name is borne on the muster rolls of his industrial establishment and who has not been retrenched." The interpretation given by the courts to lay-off is that it should have resulted out of a cause which is independant of any action or inaction of the workers themselves. It has been held that lay-off is entirely different from discharge or closure of business. Lay-off generally occurs in a continuing business. Provisions relating to lay-off and retrenchment will not be applicable to industrial establishments in which less than 50 workmen are employed

or if the establishment is of seasonal nature. The decision of the Government as to the nature of the work shall be final. Section 25–C deals with the right to lay-off compensation for workmen who have completed one year's continuous service. One year's continuous service has been taken to mean 240 days in a year. The compensation shall be 50 per cent of the basic wages and dearness allowance. Compensation is to be paid for the first 45 days. The compensation is not to be paid if the worker refuses to accept an alternative employment in the same establishment, or an establishment of the employer situated within a radius of 8 km or if he fails to present himself for work or if the laying off is due to strike or go-slow in another part of the establishment.

By the 1976 amendment, lay-off can be declared only with the previous permission of the Government in establishments employing 300 or more workers, unless the lay-off is due to shortage of power or natural calamity. If the Government does not communicate permission or its refusal within two months of application, the permission shall be deemed to have been granted by the Government on expiry of the said period.

The above provision will not apply if alternative employment is given with normal wages in the same or another establishment of the employer situated in the same town or village or within such distance as will not involve undue hardship to the workman.

28.2.6 Retrenchment

Retrenchment means "termination by the employer of the service of a workman for any reason whatsoever, otherwise than as a punishment inflicted by way of disciplinary action." But it does not include voluntary retirement, retirement on reaching superannuation or retirement due to continued ill-health. The courts have held that retrenchment means the discharge of surplus labour or staff by the employer for any reason otherwise than as a punishment. The policy of 'first to come last to go' has to be adopted. Section 25–F provides the condition precedent to retrenchment of workmen. Under the section, workman has to be given one month's notice in writing indicating the reasons for retrenchment or one month's

wages in lieu of notice. However no such notice will be necessary if the retrenchment is done under an agreement which specifies the date for the termination of service. In addition, the workman should be paid retrenchment compensation at the rate of 15 days' average pay for every completed year of continuous service or any part thereof in excess of six months. This provision will apply only if the workman has served for not less than one year continuously. Retrenchment had been held by the court as retrenchment of workman on the ground of 'surplusage'. However the trend of the latest decisions is that termination for "any reason whatsoever" otherwise than by way of punishment would amount to retrenchment except in case of voluntary retirement, superannuation and termination on the ground of continued ill health. The retrenched worker will have to be given the first chance when new recruitment is made within one year of his retrenchment. Notice of retrenchment in the form prescribed has to be sent to the Government also.

By the 1976 amendment, no workman employed in an establishment of 300 or more workers, who has been in continuous service for not less than one year shall be retrenched except after giving:

(i) three months' notice or notice pay for the period;

(ii) Paying 15 days' average pay for every completed year of continuous service or any part thereof in excess of six months; and

(iii) Obtaining permission from the Government. If the Government do not communicate permission or refusal within three months, it shall be deemed to have been granted permission to such retrenchment.

28.2.7 Closure

Where an undertaking is closed down for any reason, every workman who has been in continuous service for not less than one year shall be entitled to:

(i) One month's notice or one month's wages in lieu of notice; and

(ii) 15 days' average pay for every completed year of continuous service or any part thereof in excess of six months.

If the closure is due to unavoidable circumstances beyond the control of the employer, the compensation cannot exceed the average pay of the workman for three months.

By the 1976 amendment, an employer who intends to close down an undertaking employing 300 or more workers should take previous permission of the Government at least ninety days before the day of closure. However, this will not apply to undertakings set up for the construction of buildings, bridges, roads, canals and dams. If the Government do not communicate permission or refusal within two months of application, then the permission applied for shall be deemed to have been granted.

28,2.8 Protected worker

The Industrial Disputes Act grants certain protection to the office-bearers of registered trade unions. The number of protected workers shall not exceed one per cent of the total workmen subject to a minimum of five and a maximum of 100 workers. During the pendency of proceedings before Conciliation Officer, Board, Arbitrator, Court or Tribunal the employer cannot take any action against a protected worker concerned in such dispute, excepting with written permission of the authority concerned.

28.3 The Workmen's Compensation Act 1923 (Central Act)

The object of the Act is to provide compensation to a worker who sustains injury or contracts occupational disease or meets with death in the course of and arising out of employment. By the 1976 amendemnt, the definition of 'workman' was enlarged from those drawing Rs. 500 to Rs. 1000 / month. The schedule to the Act, dealing with compensation payable for death, permanent total disablement, and temporary disablement was modified. By the amendment, the maximum compensation has been fixed at Rs. 30000 for death and Rs. 42000 for permanent total disablement, for those drawing Rs. 900 to Rs. 1000 / month.

Under the Act, a principal employer is liable under certain circumstances to pay compensation even to workers employed under a contractor. Commissioners for workmen's compensation appointed under the Act hear and decide claims preferred by workmen.

28.4 Trade Unions Act 1926 (Central Act)

The Act provides for the registration of trade unions. The Act also provides for the appointment of a Registrar of Trade Unions in each State. According to the Act, seven members of a trade union can apply for registration. The Act contains provisions relating to the rights and liabilities of registered trade unions, provision relating to immunity from civil suit in respect of certain acts done in furtherance of a trade dispute etc.

28.5 Payment of Wages Act 1936 (Central Act)

The Payment of Wages Act was enacted to regulate the payment of wages to persons employed in industries. The Act is applicable to plantations also. According to the Act, no wage period shall exceed more than one month. According to section 5 (2) of the Act, when the employment of a person is terminated, the wages earned by him should be paid before the expiry of the second working day from the day on which his employment is terminated. According to Section 5(4), payment of wages should be made on a working day and according to Section 6, wages should be paid in current coins or currency notes or in both. Section 7 of the Act deals with the deductions that can be made from wages. The following are some of the deductions permitted from wages:

(i) Fines;

(ii) Deductions for absence from duty;

(iii) Deductions for damage to or loss caused to the employer;

(iv) Deductions for the house accommodation provided (other than workers in plantations);

(v) Deductions for amenities and services, supplied;

(vi) Deductions for electricity supplied;

(vii) Deductions for recovery of advances;

(viii) Deductions for recovery of loans;

(ix) Deductions for income tax;

(x) Deductions required by the order of a court;

(xi) Deductions for subscription to Provident Fund;

(xii) Deductions to co-operative societies;

(xiii) Deductions for premium payment to LIC with written authorisation; and

(xiv) Deductions for contribution to Union with written authorisation.

According to the same Section, not more than 75 per cent of wages should be deducted wholly or partly for payment of dues of co-operative societies and not more than 50 per cent of wages for other deductions. According to Section 8, if fines are imposed on the worker and deductions are made, it should be in accordance with the provisions of the Act and he should have been given opportunity for showing cause against the proposed fine. Further, the amount of fine should not exceed 3 1/8th paise in the rupee of the wages payable to him during that wage period. Deductions should be recorded in appropriate registers prescribed under the rules framed by the Government. By the 1976 amendment, the coverage of the Act was extended from those drawing Rs. 400 – Rs. 1000 per month. The employer can now pay wages either by cheque or by crediting the same in the account of the employee, after obtaining his written authorisation. Contribution to the Prime Minister's National Relief Fund or such other Fund as the Central Government may specify can be deducted from wages by the written authorisation of employees.

28.6 Industrial Employment (Standing Orders) Act 1946 (Central Act)

The Act requires the employer to define conditions of employment and to make such conditions as uniform as possible. For

the purpose, standing orders are to be framed in all industrial establishments including plantations employing 100 or more persons. According to the scheme of the Act, draft standing orders are to be submitted to the Certifying Officer appointed by the State Government who is empowered to modify them so as to render the orders certifiable under the Act. Such certified standing orders are subject to the review of an Appellate Authority in case of dispute. The Authority also is appointed by the State Government. The draft standing order must be in conformity with the model standing order prescribed under the Act. The standing orders framed under the Act after certification have the force of law.

28.7 Minimum Wages Act 1948 (Central Act)

The Act has been extended to rubber plantation industry. The primary object of this enactment is to make provision for fixing minimum rates of wages in specified employments. These employments are enumerated in the Schedule to the Act. It is open to the appropriate Government to add to the Schedule any other employment in respect of which it is of opinion that minimum rates of wages should be fixed.

When once minimum rates of wages have been fixed for an industry, every worker shall be paid at the rate not less than the minimum fixed. A worker cannot contract out of the right to be paid at the minimum rate or any privilege or concession to which he is entitled under the Act. In addition to providing for fixation of minimum rates of wages, the Act also contains provisions regarding working hours, weekly holidays, paid holidays, overtime etc.

The Act also provides for a special Authority to hear and decide complaints regarding non-payment of wages at the minimum rate or any monetary payment due under the Act.

28.8 Factories Act 1948 (Central Act)

It is a Central enactment containing comprehensive provisions regulating conditions of work in factories. The Act will apply to a factory using power and employing 10 or more workers or to a factory

wherein 20 or more workers are employed without using power. The Act contains provisions relating to health, safety, welfare, working hours, leave with wages etc. The Act will apply to the factory workers in plantations, if their number is as above.

28.9 Employees Provident Funds Act 1952 (Central Act)

It provides for the institution of Provident Funds for employees in certain specified establishments. The establishments are listed in Schedule 1 of the Act. Rubber plantation industry has been covered by the Employees Provident Funds Act. Details regarding the institution of the Fund, its administration, employees required or entitled to join the Fund, payments and withdrawals from the Fund etc, are prescribed in the Employees' Provident Funds Scheme framed by the Central Government under the Act.

28.10 Maternity Benefits Act 1961 (Central Act)

The Maternity Benefits Act is applicable to plantations. According to the Act, a woman worker is eligible for maternity benefits for the six weeks immediately preceding the date of her delivery and six weeks after the delivery at the rate of average daily wages of the preceding three months. The Act also provides for benefits in case of miscarriage for a period of six weeks immediately following the day of miscarriage. In the event of illness arising out of pregnancy, delivery, premature birth of child or miscarriage, the woman shall be entitled to leave for a maximum period of one month over and above the maternity leave or miscarriage leave, as the case may be. The rate of payment will be as above. During her absence from work due to the above reason, she should not be discharged or dismissed excepting for gross misconduct. For eligibility of the maternity benefits, the woman worker should have worked for 160 days in the 12 months immediately preceding the date of her expected delivery. The 160 days work is inclusive of any periods of lay-off during the said 12 months. According to the Act, the maternity benefit for the period preceding the date of her expected delivery should have been paid in advance on the production of appropriate proof and for the subsequent period within 48 h of production of proof of her delivery. The Act specifies that no employer should

knowingly employ a woman during the six weeks immediately following the day of her delivery or miscarriage. If the estate is not providing pre-natal confinement or post-natal care free of charge, the woman worker is entitled to a medical bonus.

28.11 Payment of Bonus Act 1965 (Central Act)

According to the 1980 amendment, the minimum bonus shall not be less than 8.33 per cent of the salary or wage earned by the employee during the accounting year or Rs. 100 whichever is higher. The maximum bonus shall be 20 per cent. The minimum bonus shall be paid even if there is no 'allocable surplus.' In the case of a new establishment, bonus need be paid only if there is profit during the first five accounting years after it started selling the goods produced.

28.12 Payment of Gratuity Act 1972 (Central Act)

It is a Central Act and it applies to plantations to which the Plantations Labour Act applies. The Act is applicable to employees whose wages do not exceed Rs. 1000 per month, but will not include any person who is employed in a managerial or administrative capacity. Gratuity is to be paid at the time of termination of employment, superannuation, retirement, resignation, disablement or death. The qualifying period is five years continuous service. However in case of death or disablement, continuous service of five years will not be necessary. The gratuity is fifteen days' wages for every completed year of service or part thereof in excess of six months, based on the rate of last drawn wages. The maximum gratuity payable is twenty months' wages.

28.13 Equal Remuneration Act 1976 (Central Act)

The object of the Act is to ensure the payment of equal remuneration to men and women workers and to prevent discrimination against women in the matter of employment.

The Act has defined 'remuneration' as to include basic wages or salary and any additional emoluments whatsoever payable either in

cash or in kind. As per Section 2(h) of the Act 'same work or work of similar nature' means work in respect of which the skill, effort, and responsibility required are the same when performed under similar working conditions. According to Section 4, it is the duty of the employer to pay equal remuneration to men and women workers for the same work or work of similar nature. Under Section 5 of the Act, the employer shall not make any discrimination while recruiting men and women for the same work or work of similar nature.

28.14 The Industrial Establishment (National and Festival Holidays) Acts

These are State Acts. These Acts provide the grant of paid holidays on certain festival days and days of national importance.

Under the Kerala Industrial Establishments (National and Festival Holidays) Act, paid holidays have to be given, every year, on 26 January, 1 May and 15 August and on four festival days specified.

29 THE RUBBER BOARD AND ITS ACTIVITIES

Chapter 29

THE RUBBER BOARD AND ITS ACTIVITIES

The background of the enactment of the Rubber (Production & Marketing) Act, 1947 by the Government of India and of the setting up of the Indian Rubber Board thereunder has been dealt with in Chapter 1. The Rubber (Production & Marketing) Amendment Act of 1954 made certain amendments in the constitution of the Board and also changed its name to the Rubber Board. The 1947 Act was further amended by the Rubber (Amendment) Act of 1960. In order to carry out the purposes of the Act, the Central Government have made the Rubber Rules, 1955. The constitution of the Board, its functions as laid down in the Act, collection of funds, organisational set up of the Board and its various activities are discussed in this Chapter.

29.1 Constitution

The Board consists of:

(i) A Chairman appointed by the Central Government;

(ii) Two members to represent the State of Madras, one of whom shall be a person representing rubber producing interests;

(iii) Eight members to represent the State of Kerala, six of whom shall be persons representing the rubber producing interests, three of such six being persons representing the small growers;

(iv) Ten members to be nominated by the Central Government, of whom two shall represent the manufacturers and four labour;

(v) Three members of Parliament of whom two shall be elected by the House of the People and one by the Council of States; and

(vi) The Rubber Production Commissioner appointed by the Central Government, *ex-officio.*

One of the members of the Board is elected as Vice Chairman. The Board meets periodically for transacting business, presided over by the Chairman. Sub-Committees are formed to scrutinise various matters and make recommendations to the Board. Ten such Committees, viz Executive Committee, Research and Training Committee, Economic Research Committee, Development and Extension Committee, Planting Committee, Technical Specification Committee, Statistics and Import–Export Committee, Marketing and Co-operation Committee, Labour Welfare Committee and Staff Affairs Committee are in existence.

The Board has a Secretary appointed by the Central Government.

29.2 Functions

The Act lays down the following as the functions of the Rubber Board:

(1) It shall be the duty of the Board to promote by such measures as it thinks fit the development of the rubber industry.

(2) Without prejudice to the generality of the foregoing provision, the measures referred to therein may provide for:

(i) undertaking, assisting or encouraging scientific, technological and economic research;

(ii) training students in improved methods of planting cultivation, manuring and spraying;

(iii) the supply of technical advice to rubber growers;

(iv) improving the marketing of rubber;

(v) the collection of statistics from owners of estates, dealers and manufacturers;

(vi) securing better working conditions and the provisions and improvement of amenities and incentives for workers; and

(vii) carrying out any other duties which may be vested in the Board under rules made under this Act.

(3) It shall also be the duty of the Board:

(i) to advise the Central Government on all matters relating to the development of rubber industry, including the import and export of rubber;

(ii) to adivse the Central Government with regard to participation in any international conference or scheme relating to rubber;

(iii) to submit to the Central Government and such other authorities as may be prescribed half-yearly reports on its activities and the working of this Act; and

(iv) to prepare and furnish such other reports relating to the rubber industry as may be required by the Central Government from time to time.

29.3 Funds

Under provisions of the Act, the Board levies as a cess a duty of excise on all natural rubber produced in India. The collections remitted to the Consolidated Fund of Inida form the main source of funds for the Central Government to pay to the Board under due appropriation by Parliament for purposes of the Act. Sums realised, if any, by the Board by sales of rubber imported or purchased from internal market and sold also form part of the funds of the Board. Other forms of revenue include various licence fees levied, proceeds from sale of rubber produced in Board's research or demonstration farms and proceeds from sale of planting materials raised in Board's nurseries.

The Board maintains two funds, the General Fund and the Pool Fund. Sources of money for the Pool Fund are: (i) sums

realised from rubber marketing operations; (ii) transfers effected from General Fund under approval of the Government; and (iii) cash realisations, if any, made out of implementation of schemes financed from Pool Fund. The Pool Fund is applied only to the rehabilitation of small growers. General Fund revenues are: (i) amounts paid to the Board by the Central Government out of the collections of cess on rubber or otherwise and (ii) amounts realised by the Board by way of licence fees and other miscellaneous receipts. The General Fund is applied to meet the expenses of the Board and expenditure incurred in the performance of its functions other than those met from the Pool Fund.

29.4 Organisational set up

The Rubber Board is attached to the Ministry of Commerce of the Government of India. The Central Office of the Board is established at Kottayam, Kerala State. Various offices, nurseries and experiment stations functioning under it are located in different parts of the country. The Rubber Research Institute of India under the Board functions in an eastern suburb of Kottayam, 6 km away from the Central Office.

The Board has a full time Chairman who is also its principal executive officer. He is responsible for the proper functioning of the Board and the implementation of its decisions and the discharge of its duties under the Act. He exercises administrative control over all departments and officers of the Board. There are four departments, administration, rubber production, research and rubber processing.

The Administration Department which is headed by the Board's Secretary attends to overall financial control, cess collection, market intelligence, licensing for dealing in rubber and for acquisition of rubber for manufacturing purposes, promotion of co-operative efforts amongst small rubber growers, labour welfare, public relations and personnel management. Under this Department, there are four Liaison Offices functioning in New Delhi, Bombay, Calcutta and Madras. The section dealing with Market intelligence, co-operation and licensing for dealing in rubber operates from Wellingdon Island, Cochin.

The Rubber Production Commissioner is the head of the Rubber Production Department. This department is responsible for licensing and registration of rubber estates, formulation and implementation of various schemes required for proper development of plantations, advisory, extension and training services for estates and small-holdings, production and supply of planting materials, supplies of other requisites, establishment and maintenance of demonstration farms and economic research. The work of the department at the field level is managed by seventeen Regional Offices and a large number of field offices functioning at all important rubber growing centres in the country. The department also runs a number of nurseries for production and sale of high yielding planting materials, four tappers' training schools and a few plantations for demonstration purpose.

The Research Department of the Board is in fact the Rubber Research Institute of India (RRII). For administrative purposes, the Institute functions as one of the departments of the Board. The Institute is headed by a Director. There are five research divisions, namely; Agronomy/Soils, Botany, Plant Physiology/Exploitation, Mycology/Plant Pathology and Chemistry/Rubber Technology. Each division is in charge of a Deputy Director and has different sections for dealing with work under separate specialised disciplines. The Institute maintains two experiment stations in Kerala—one of 33 ha around the Institute buildings and the other of 258 ha 50 km away at Chethackal near Ranni in Quilon District and a Regional Research Centre with 80 ha near Agartala in Tripura State. A well stocked library and documentation centre, a mobile soil and tissue testing laboratory, an art and photography unit, a meteorological unit, a civil engineering unit and a medical unit are attached to the Institute.

The Department of Rubber Processing is headed by the Project Officer. It was started early in 1977 for implementation of the Rubber Processing Component of the Kerala Agricultural Development Project (KADP) which is financed by the International Development Association of the World Bank. The department functions in the RRII buildings and operates Board's pilot factory established in 1976 for solid block rubber processing. Besides discharging duties connected with the implementation of the above project component, the department undertakes work of related interest such

as planning and implementation of other modern rubber processing projects, offering advisory and training services and assisting co-operative departments of State Governments and Co-operative societies towards improving the coverage and effectiveness of co-operative movement in the integrated service of rubber smallholders.

A Statistics and Planning Division and a Vigilance Section are also functioning in the office of the Board under the direct control of the Chairman.

29.5 Activities

The activities of the Board can be broadly classified under the following heads:

(i) Control or regulatory;

(ii) Cess collection;

(iii) Research;

(iv) Development; and

(v) Collaboration with international organisations.

29.5.1 Rubber control

Natural rubber is a controlled commodity in India. Its production, sale and consumption have to be carried out under appropriate licences from the Board. Each of the above activities has to be carried out as per the conditions stipulated in the licences. The controls are useful in the collection of essential statistics relating to the industry, ensuring orderly progress of the activities concerning planting, processing, trade, consumption and levy of cess. The various regulations in force are briefly described in the following paragraphs.

29.5.1.1 Licence for new planting or replanting

Any person desiring to newplant or replant rubber should apply for and obtain an appropriate licence from the Board. The power

for issuing the licences is at present delegated to the Deputy Development Officer in charge of the Regional Office having jurisdiction over the area concerned. The form prescribed for application is common to both types of licences. A fee of Re. 1 is payable along with the application for each licence. Separate licences are issued for newplanting and replanting. Each licence specifies the area of newplanting or replanting and it is valid for the calendar year of issue or part thereof. Any right of planting granted by a licence is attached to such land only and is not transferable apart from the land on which such right is permitted to be exercised. It is obligatory on the part of each licensee that only such varieties of high yielding planting materials as are approved by the Board on an year to year basis should be used for planting, Every licence holder has to furnish to the Deputy Development Officer concerned a return giving the areas newplanted or replanted in pursuance of the licence together with such particulars as are prescribed to be given.

29.5.1.2 Registration of estates

Every person owning land planted with rubber should apply to the Board in the prescribed form in duplicate and get himself registered in the books of the Board as its owner. Owner includes any agent, a mortgagee in possession and a lessee of an estate. The application is to be submitted to the Deputy Development Officer of the Regional Office having jurisdiction over the area in which the estate is situated. Registrations are granted after verification of the applicant's title to the land, location, extent planted, year or years of planting, variety of planting materials used and any other relevant particulars. On acceptance of the application for registration, the Board allots a registration number to the estate and returns the duplicate copy of the application to the applicant with the registration number duly filled in. Registrations are normally effected Talukwise and as such there will have to be separate applications for registration of estates owned by the same person in different Taluks, unless such estates are contiguous and lying in one unit. A registration once made continues in force until it is cancelled by the Board on request or otherwise. The registration of an estate can be transferred in whole or in part to a successor in title or to any person who has otherwise acquired the title, provided he applies for the same together with requisite evidence.

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Under the Rubber Act and Rules, owners of rubber plantations are classified into two groups, viz small growers and large growers. A small grower is defined as an owner whose rubber plantation does not exceed 20.23 ha (50 acres) in area. An owner having more than 20.23 ha of rubber plantation is called a large grower. Similarly, a classification of rubber plantations into smallholdings and estates based on the same criterion as above is in vogue.

Every small grower, when required to do so, and every large grower should submit to the Secretary of the Board a true and correct monthly return in the prescribed form giving the particulars of rubber stock held, produced or disposed of by him and an annual return in the form prescribed giving the particulars of total area, area under rubber, production of rubber, manuring, plant protection and labour employed.

29.5.1.3 General permission to growers and manufacturers for transactions in rubber

The Rubber Act stipulates that no person shall sell or otherwise dispose of, and no person shall buy or otherwise acquire rubber, except under and in accordance with the terms of a general or special licence issued by the Board. The Board has by due notification issued a general licence to all registered rubber growers to sell or otherwise dispose of rubber and another general licence to all manufacturers to acquire rubber not exceeding 68.03 kg (150 lb) per year. For quantities exceeding this a special licence has to be obtained.

29.5.1.4 Licence to deal in rubber

Every person, other than a processor, who wants a special licence to purchase, sell or otherwise deal in rubber should apply for it to the Board. If the Board is satisfied with regard to the suitability of the applicant, it may issue a licence. The licence fee for issue of a special licence to deal in rubber is Rs. 100 per year or part thereof.

The powers for receiving applications for licences to deal in rubber and for granting licences are delegated to the Board's

Assistant Secretary (Marketing and Co-operation) whose office is functioning in Wellingdon Island, Cochin.

Every licensed dealer should submit to the Secretary of the Board true and correct monthly returns in the prescribed forms giving the particulars of rubber stock held, acquired or disposed of by him.

29.5.1.5 Licence to acquire rubber for processing and for selling rubber so acquired.

There is rule that every processor of solid block rubber and concentrated latex should grade and market his products in conformity with such standards as are specified by the Indian Standards Institution from time to time.

Every person who wants to acquire rubber for processing or to sell the rubber so acquired after processing or otherwise should apply for and obtain a special licence from the Board. Every such application should be accompanied by a project report in cases where processing units are yet to be established. The Board may issue a licence after satisfying itself with regard to the suitability of the applicant, the site proposed for setting up processing unit, availability of raw materials, availability of technical know-how to the applicant, arrangement for technical specification of the processed rubber and economic feasibility of the project. The fee fixed for grant of the licence is Rs. 100 per year or part thereof.

Applications for the licences are received and the licences are granted by the Assistant Secretary (Marketing and Co-operation).

Every processor should submit to the Secretary of the Board true and correct monthly returns in the prescribed forms giving the particulars of rubber stock held, used out of own production or acquired for processing and disposed of by him.

29.5.1.6 Licence to acquire rubber for manufacturing purposes

Any manufacturer desiring a special licence to purchase or otherwise acquire rubber should apply to the Board in the prescribed form. If the Board approves, a licence may be issued to him. The

fee for a year or part thereof for a licence for purchasing rubber not exceeding 4 t is Rs. 4 and for quantity exceeding 4 t is Rs. 10. If, in an emergency, a manufacturer with a licence desires to sell rubber acquired by him to another manufacturer holding a licence, he has to apply for it in the prescribed manner and obtain a special licence. A licence may be issued in such cases for each transaction. The fee levied is Rs. 5 per licence.

Applications for special licences for acquiring rubber are received and licences granted by the Assistant Secretary (Excise Duty) who operates from the Board's main office at Kottayam.

Every manufacturer should submit to the Secretary of the Board a true and correct monthly return in the prescribed form giving particulars of rubber stock acquired, consumed or disposed of by him and an annual return, also in prescribed form, giving the particulars of consumption of various kinds of rubber in relation to end products.

29.5.1.7 Inter-State transport of rubber

Any transport of rubber across State boundaries should be effected only under a declaration made by the person responsible in the manner laid down in the Rubber Rules. The prescribed declaration forms are issued by the Assistant Secretary (Marketing and Co-operation) from his Wellingdon Island office as well as by the Secretary of the Board and the Deputy Development Officers in charge of various Regional Offices, on payment of the price fixed.

29.5.1.8 Import and export of rubber

Import and export of natural rubber are regulated by the Central Government on the basis of policies adopted and decisions taken from time to time.

29.5.1.9 Price of rubber

The Central Government enforces control on price of rubber by fixing the maximum price or the minimum price or both to be charged in the course of any specified class of business for rubber of any specified

description. Orders in this regard are issued from time to time after taking into consideration cost of production and other relevant factors.

29.5.2 Cess collection

As stated earlier, a duty of excise is levied by the Board as cess on all natural rubber produced in India. The levies were made earlier from the growers. Effective from 1 April, 1961, the procedure has been changed and the cess is now levied from manufacturers. The rate of cess in force from 13 July, 1975 is 40 paise per kg.

For the purpose of assessing the cess, every manufacturer is required to submit regular half-yearly returns for periods from 1 April to 30 September and from 1 October to 31 March showing the total quantity of all rubber (i) purchased or otherwise acquired during such periods, separately for indigenous and imported rubber and (ii) consumed or used in the process of manufacture during the same periods. After the close of each year, each manufacturer should also submit a report from a registered auditor or any other authority approved by the Board certifying the correctness of the returns. The Board, after checking the returns and after making such further enquiry as deemed fit will assess the amount of cess payable by each manufacturer for each half year, issue demand notice and receive payment. If any manufacturer fails to pay the amount within the due date fixed, the Board will arrange to recover it as an arrear of land revenue.

29.5.3 Research

The rubber growing regions in India form a zone distinct from those of the other countries in view of special agro-climatic conditions obtaining here. Soils are largely of laterite and lateritic types, porous and deficient in available phosphorus and potash. The most notable aspect with regard to the climate is the rainfall which is high but quite uneven in distribution. As a consequence, special practices are to be followed in planting, cultural operations, protection against diseases and pests and tapping. Cultivars which can thrive under the local ecological conditions and give the best yields have to be screened and adopted or suitable new ones have to be evolved through selection and breeding. Research on improvements in the processing and presentation of natural rubber has also to be undertaken. India,

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being a major consumer of rubber, also requires research in the area of manufacture of rubber goods. With a view to evolving technologies best suited and appropriate under Indian conditions, the Rubber Board has developed its own research facilities by establishing the Rubber Research Institute of India.

The RRII was set up in a modest way in 1955. The facilities were developed gradually until by 1964 the Institute was in a position to undertake regular and co-ordinated research work.

The broad lines of research work undertaken by the Institute are:

(i) Studies on plant improvement through selection as well as breeding with a view to evolving varieties which are high yielding and possessing desirable secondary characteristics like resistance to diseases and drought, growth, vigour and adaptation to intensive exploitation system;

(ii) Studies on rubber growing soils and their classification, on planting techniques including use of advanced planting materials to reduce immaturity period, on all nutritional aspects including discriminatory fertilizer usage based on soil and tissue analysis, on inter-cropping, on cover crop management and on chemical weed control;

(iii) Studies on the problems of disease and their control including screening of pesticides in laboratory and under field conditions to evolve more economic and efficient control of pests and diseases, crown budding as a technique for the control of important leaf diseases of rubber, micro-biological investigations on rubber growing soils, latex and effluents from factories;

(iv) Studies on physiological and biochemical aspects of rubber synthesis including yield component analysis as an aid to breeding programmes and designing polyclonal seed gardens, on techniques of exploitation including rainguarding and yield stimulation and on tissue culture; and

(v) Studies on improvement in the processing and presentation of different marketable forms of rubber, on development of speciality rubbers and know-how for producing rubber

products and on new fields of application for natural rubber.

For the successful extension of rubber cultivation in non-traditional areas, Regional Research Centres are being established to tackle the special problems encountered in these areas. Already one centre has been established in Tripura to take care of the problems of rubber cultivation in the northeastern region.

The Institute is actively collaborating with the Cochin University in conducting a post graduate B.Tech. course in Polymer Science and Rubber Technology and with the Kerala Agricultural University in conducting a post graduate diploma course in Rubber Production.

The Rubber Board is also undertaking economic research. The unit engaged in this work although not strictly forming part of the Institute nevertheless ensures that there is proper collaboration between itself and the various divisions of the Institute in their Investigative studies.

29.5.4 Development

The Rubber Board is implementing many schemes designed to achieve development of the rubber plantation industry on efficient and economic lines. The following essential requirements have been kept in view in formulating the schemes:

(i) Modernisation of the existing plantations with the object of improving productive efficiency, increasing overall production and reducing cost of production;

(ii) Increasing production through expansion of rubber cultivation;

(iii) Improvement in processing and presentation; and

(iv) Strengthening marketing power of smallholders.

The individual schemes are briefly dealt below:

29.5.4.1 Replanting subsidy scheme

In order to encourage rubber growers to undertake replanting of old and uneconomic plantations, the Board is offering them assistance

under its replanting subsidy scheme. The scheme introduced in 1957 had originally provided for grant of cash subsidy ranging from Rs. 250 to Rs. 400 per acre (Rs. 618 to Rs. 988 per ha). The subsidy rate was raised to Rs. 1000 per acre (Rs. 2471 per ha) in 1960. From 1975, subsidy is being paid at the further enhanced per ha rate of Rs. 7500 in the case of growers owning upto 2 ha of rubber, Rs. 5000 in the case of growers owning above 2 ha and up to 20 ha of rubber and Rs. 3000 in the case of growers owning above 20 ha of rubber. Payments against each case of replanting are effected in seven annual instalments at pre-determined rates after the work done by the grower during each year is inspected and certified by Board's officials. The replanting has to be carried out as per specifications laid down by the Board and after obtaining due replanting permit.

Weaker sections of growers indentified as those owning not more than 6.07 ha of rubber are granted additional assistance by way of reimbursement of cost of planting materials purchased from the Board and established successfully, 50 per cent subsidy on cost of fertilizers used during immaturity period of the replanted fields and a small incentive payment for encouraging adoption of soil conservation measures.

At the close of 1979, a total area of 53000 ha had been replanted against a target of 88000 ha set under the scheme.

29.5.4.2 Newplanting scheme and expansion of rubber cultivation

In view of the high pressure on land, there are limitations for expanding rubber cultivation in States where rubber has been traditionally grown in India. The Rubber Board has, therefore, been carrying out surveys of other States for identifying potential non-traditional areas for development. Many areas in Andhra Pradesh, Goa, Maharashtra, Assam, Tripura, Meghalaya, and Andaman and Nicobar Islands have accordingly been found to have vast tracts of suitable lands. The Governments of these States and Union Territories have been carrying out trial cultivation of rubber in selected plots with the active assistance of the Board. Wherever the trials have fully succeeded, large expansion programmes are being undertaken with the help

and guidance of the Board. The Board has also been assisting the Central Government in planting and maintaining plantations in Andaman and Nicobar Groups of Islands since 1964.

The rate of expansion of rubber cultivation in India has shown a markedly downward trend since 1962. During the eight year period from 1955 to 1962, newplanting was carried out at the average rate of over 12000 ha per year. In the next eight years, ie 1963–1970, the rate of newplanting per year decreased to half of the above. A further reduction by over 50 per cent took place during the next eight years from 1971 to 1978 when the average annual extent of new plantations went down to less than 3000 ha.

Three schemes were implemented in succession from 1962 onwards for expansion of existing holdings and consolidation through improved maintenance of immature areas. Soft loans on easy terms were offered for the purpose. The smallest category of growers were also given additional incentives by way of subsidised fertilizer and planting materials. The schemes did not evoke any significant response owing to (i) inadequacy of loan amount which formed only a small part of the total cost of newplanting, (ii) the long term nature of the mortgage liability to be created on the land for obtaining the loan, (iii) lack of land for expansion with existing smallholders and (iv) non-availability of the facility to new entrepreneurs. The last of the schemes has, therefore, been withdrawn after 1978.

It has been seen that in the smallholding sector, promotion of capital intensive operations such as newplanting and replanting calls for giving a package of assistance covering the total requirements—technical, material and financial. For giving the much needed fillip to newplanting in the smallholding sector, a scheme with a target for newplanting rubber in 4000 ha was introduced on a pilot basis during 1979. The scheme known as Rubber Newplanting Subsidy Scheme, 1979 provided for granting capital subsidy amounting to one-third to half of the total cost that is Rs. 5000 to Rs. 7500/ha, additional input subsidies to weaker sections of the growers identified as those owning not more than 6 ha of rubber including the area newplanted and free advisory and extension assistance. Such of those participants who required credit for meeting advance cash requirements or money to bridge the gap between

the total subsidy amount and the total cost of newplanting were offered bank credit facilities with the interest subsidised by the Board to the extent of three per cent. A moratorium of seven years was arranged as payment of the growers' share of interest. Repayments of loan were arranged to be made in five easy instalments commencing from the end of 10th year of planting. The scheme was made applicable to existing smallholders as well as to new entrepreneurs. The response to the scheme has been overwhelming.

The success achieved in the case of the above scheme has encouraged the Board to formulate a successor scheme on similar lines but with lesser element of subsidy, applicable to both newplanting and replanting as well as to both smallholders and large growers. The new scheme called Rubber Plantation Development Scheme aims at newplanting and replanting 6000 ha/year and is to be implemented for a period of five years, commencing from 1980.

29.5.4.3 Planting materials

It has been mentioned that a condition stipulated by the Board for granting licences for newplanting and replanting of rubber from 1963 is that only high yielding planting materials approved by the Board on an year to year basis should be used for the plantings. The Board draws out and publishes its planting material recommendations every year (see Appendix I). The Board also takes appropriate steps to ensure that the approved materials are available to growers in adequate quantities and at reasonable prices. The Board has been procuring and distributing high yielding planting materials from its earliest years. It started establishing its own nurseries in 1960. It now runs several nurseries and increases their number progressively. The planting materials produced are distributed mainly to small growers who are allowed 25 per cent concession in price. Large growers are given supplies to a limited extent and at cost price. As the planting materials produced by the Board are not adequate to meet the demand, a large number of private nurseries, duly inspected and approved by the Board, are allowed to sell budded stumps and budwood of approved clones. The Board's involvement in the field brings about the needed quality control and price moderation.

29.5.4.4 Schemes aimed at improvement of cultural practices in smallholdings

For popularising fertilizer application and adoption of spraying against abnormal leaf fall disease caused by the fungus *Phytophthora* spp, the Board has been for long offering 50 per cent subsidy on cost of fertilizers used by weaker sections of small growers in immature areas planted exclusively with rubber and not intercropped with seasonal crops, 50 per cent subsidy on cost of copper fungicides and diluent oil used by all categories of small growers for spraying in immature as well as mature areas and loan of plant protection equipments free of hire charges or at nominal charges. As the schemes are considered to have served their purpose to a good extent, they are being progressively discontinued.

A scheme for sale of seeds of the legume, *Pueraria phaseoloides* which has proved to be an excellent cover crop in rubber plantations in India has been newly implemented by the Board. The seeds are sold through various Regional Offices in conveniently sized polythene packets. Price subsidy to the extent of about 20 per cent of the actual cost is given to smallholders.

29.5.4.5 Scheme for improvements of processing and presentation

Small growers in India do not generally sell their sheets as wet, unsmoked sheets as most of their counterparts in other countries do. A small percentage of them has regular smoke curing facilities. Others dry their sheets in the open or expose them to smoke at least above kitchen hearths. The quality of their sheets is, in general, fairly tolerable. For bringing about further improvements, the Board has been implementing schemes for distribution of sheeting rollers on easy hire purchase terms arranged through their own co-operative societies and for subsidising to the extent of 50 per cent of the cost for the construction of small, cheap smoke houses in individual holdings. The response to either of the schemes has not been satisfactory. It is now considered that the thrust in future should be towards central processing for production of solid block rubber.

By way of encouraging central processing amongst small growers, the Board has already assisted three co-operative societies to put up

a factory each for production of solid block rubber, centrifuged latex and pale latex crepe. These are functioning satisfactorily.

Under an agreement with the World Bank, financial assistance from International Development Association is now being availed of for expanding the existing co-operative solid block factory and setting up nine new co-operative factories of 10 t per day capacity each by 1985. These factories would progressively convert 25000 t of smallholder rubber into solid block form by 1986.

In order to facilitate the working of the co-operative factories, crop collections are being arranged to be effected through smallholder development centres organised at all important smallholder localities. Three such centres already established on a pilot basis are operating successfully. At these centres, the collection of latex and scrap rubber is linked with efforts towards modernisation of smallholdings through provision of a package of services. The centres function under the co-operative societies which buy the rubber for central processing. The Rubber Board gives comprehensive assistance for establishing and maintaining the centres. Apart from technical advice, training and supervision, the Board grants financial assistance as follows:

(i) Rs. 10000 per centre as a subsidy for establishing the centre and developing transport facilities; and

(ii) Interest subsidy up to 10 per cent, after the first 5 per cent is borne by the co-operative, on the working capital needed for advancing inputs to small growers.

29.5.4.6 Marketing of smallholders' rubber

Since 1960, the Rubber Board has been actively encouraging formation of co-operative societies for organised marketing of smallholders' rubber. Assistance is given to such co-operatives in the form of share capital contribution, soft loans for working capital and technical guidance. There are 37 co-operative societies engaged in marketing of rubber. These have amongst them membership of 60000 rubber small growers.

A central federation of the primary rubber marketing co-operative societies has been established with the active assistance of the Rubber Board. This apex Institution, known as the Kerala State Co-operative Rubber Marketing Federation Ltd., is operating from 1973 with Cochin as its headquarters. The Federation purchases rubber from the primaries functioning in rubber growing areas and sells direct to consuming industries located in far away cities as Bombay, Delhi, Calcutta and Madras. Besides rubber marketing, the Federation does mixing and distribution of rubber fertilizers, supplies other estate requisites, undertakes aerial spraying of rubber plantations against abnormal leaf fall disease and carries out other activities helpful to small growers. The Federation also runs a soil and leaf testing laboratory for the benefit of the members of its primaries.

The primary co-operatives have been together marketing only less than 10 per cent of the smallholders' total rubber crop. However, they are keeping up keen competition with the private trade and helping members to realise fair prices. Rubber smallholders in India generally get at their nearest market centres prices equivalent to about 98 per cent of those prevailing at the main producer markets of Kottayam and Cochin.

29.5.4.7 Advisory, extension and communication services

The scheme for giving advisory, extension and communication services to growers has been one of the earliest to be implemented by the Board. The advisory and extension services are rendered free of charges. The work is primarily handled by the technical officers called Field Officers and Junior Field Officers deployed in the field, under the various Regional Offices. Their minimum qualification is graduation in Agriculture or Botany and they are given intensive in-service training in all aspects of rubber cultivation and production before posting to various field stations. There is one Field Officer or Junior Field Officer for about every 1250 plantation units and their number is being progressively increased not only for attending to the new units coming into existence but also for enabling more efficient and effective service. They also attend to the field work connected with the implementation of other development schemes and thereby develop a close rapport with the growers.

Services of specialised nature required by any grower are handled by senior technical officers or scientists from the Research Institute as appropriate. Advisory and extension assistances to large growers are also generally rendered by the senior level officers. Apart from giving service to individual growers, the officials of the advisory and extension unit undertake mass contact activities such as exhibitions, village level group discussions, seminars and study classes amongst growers. Senior officers including the Chairman of the Board make it a point to participate in as many of such programmes as possible. The growers generally evince keen interest in the technical subjects and the discussions generally turn out to be lively and useful for both the growers and the Board.

Growars are encouraged to elicit technical and other information through correspondence with the Research Institute and with the office of the Rubber Production Commissioner. Technical and general nformation is also given through publication of free advisory leaflets, subsidised journals, articles in news dailies, broadcast of talks, interviews and lessons over the radio and screening of instructional films.

Each Regional Office of the Board is provided with a Rubber Tapping Demonstrator who visits individual holdings, gives advice and conducts demonstrations on correct methods of tapping, protection of tapping panels against diseases, rainguarding and chemical yield stimulation. He also conducts small group level discussions and demonstrations from time to time.

The mobile soil and tissue testing laboratory operated by the RRII moves continuously in smallholder areas for giving on–the–spot advice on discriminatory fertilizer application based on rapid soil and tissue testing. The service is rendered free of charges to smallholders. Soil and leaf analysis service for large growers is undertaken by the Institute on payment basis.

The Board has been establishing and maintaining a large number of demonstration fields in smallholdings at various important centres with the object of educating growers on scientific, cultural and production practices. Each field was maintained for ten continuous years. The demonstration fields newly laid out are in non-traditional areas where the benefits would be derived by growers who are new to rubber cultivation.

29.5.4.8 Training

The necessity for training is felt to the maximum extent in the area of efficient exploitation of crop. This is more so in the case of smallholders and the tappers employed by them rather than with large estates. Accordingly, the Board has established four Tappers' Training Schools in which smallholders, their workers and other dependents are given comprehensive training in tapping and allied practices in a training programme of eight weeks duration. The trainees are also given free accommodation and suitable stipends during the period of the training. The schools are kept itinerant in the sense that each of them functions at a particular centre for a year or two and then re-establishes at a different centre so that the training facility is available at all important localities.

The Board gives free training to newly recruited plantation executives of public sector plantations in non-traditional areas. Each course lasts for two months and covers all aspects of cultivation and production.

The Research Institute is imparting occasional one-month orientation training to senior executives of all large plantations. Refresher courses for entrepreneurs engaged in small and medium scale rubber goods manufacturing industries are also conducted by the Institute.

A full-fledged smallholders' training school under the Board is soon to be established for imparting free integrated training courses for smallholders at the school and for giving short courses lasting for about a week each at selected village level centres.

29.5.4.9 Board's publications

The Board publishes various books, periodicals and pamphlets which are intended for those connected with rubber plantation industry. The particulars of these publications are given below:

(i) Rubber Board Bulletin: The Rubber Board Bulletin is published from 1951. This is a quarterly publication of the Board issued in English. The Bulletin usually contains research papers based on

work conducted at the Rubber Research Institute of India, scientific articles and other topics of interest to rubber planters.

(ii) 'Rubber': This is published from August, 1965 and is a monthly magazine published by the Board in Malayalam. It is mainly intended for the large number of small rubber growers who are not conversant with modern scientific methods of rubber cultivation and processing. Technical articles written in popular style and columns dealing with matters of practical interest to rubber growers are regularly published in the magazine. The subscription to the magazine has been fixed at a nominal rate of Rs. 3.00 per annum so as to be within the reach of even the smallest rubber grower.

(iii) Indian Rubber Statistics: The Indian Rubber Statistics is published annually from 1958. Statistics relating to area under rubber, production, import, consumption, price of rubber, manufacturers and dealers of rubber, rubber goods production, taxation, labour and various other miscellaneous topics, besides world rubber position, are contained in this publication. It is illustrated with charts and graphs.

(iv) Rubber Growers' Companion: This is a rubber growers' guide cum diary published every year from 1962. In addition to the calendar and diary for the year, details of various aspects of rubber cultivation and production, information on the activities of the Rubber Board, the development schemes implemented by the Board and statistics pertaining to the rubber industry are incorporated in this publication.

(v) Rubber Statistical News: This is a four-page monthly in English published from July 1975. It contains relevant and up to date statistics on rubber. Annual subscription is Rs. 10.00.

(vi) Price: Price is a fortnightly bulletin published in English giving details of price of rubber in important centres.

(vii) Advisory Pamphlets: The Board keeps publishing a number of advisory pamphlets on various aspects of rubber cultivation and processing. Rubber growers can get copies of these pamphlets free on request.

29.5.5 Collaboration with international organisations

Research and development in natural rubber transcend national boundaries and are today undertaken with global perspective and understanding amongst planners, decision makers, scientists and development workers. In such of those areas as found feasible, active collaboration in the work on bilateral or multilateral basis is also effected. These are achieved through three appropriate international organisations, viz International Rubber Study Group (IRSG), Association of Natural Rubber Producing Countries (ANRPC) and International Rubber Research and Development Board (IRRDB). The Government of India have joined the IRSG and the ANRPC. The Rubber Board is a member of IRRDB.

30 RUBBER STATISTICS

Chapter 30

RUBBER STATISTICS

Rubber cultivation in India was started on a commercial scale in 1902. Even though the plantation industry passed through many vicissitudes, its rate of growth, over the years, has been phenomenal. Table 30.1 depicts the trend in growth rate of area, production and productivity of rubber on a five year interval basis except for the period from 1902 to 1926. The area under rubber in 1980 is estimated at around 260,000 ha, production at 152,000 t and productivity at 800 kg/ha.

Details of the distribution of rubber area in India are given in Table 30.2. The number of rubber growing units at the end of March 1979 was around 156,000 out of which 580 were estates of area above 20 ha and others were smallholdings of up to 20 ha. Statistics regarding further break-up of estates and small holdings according to their size are given in Table 30.3. At the end of March 1979, about 37 per cent of the total area under rubber was under high yielding budgrafts, 43 per cent under moderately yielding clonal seedlings and the rest under low yielding planting materials.

A study conducted by 'Commerce' in November 1979 revealed that rubber led all other crops in regard to growth rate in production during the period from 1950–51 to 1977–78. Also, in the international scene, statistics published by the International Rubber Study Group (IRSG) revealed that India led all other countries in growth rate of production of natural rubber (vide Tables 30.4 and 30.15).

The number of persons employed in rubber industry is estimated to be over 180,000. In addition, a number of persons also depend on processing, transporting, marketing and other connected activities. The growth rate of employment in rubber plantations is depicted in Table 30.5.

In the early years, price of natural rubber was subject to extreme fluctuations. The average market prices of rubber during the periods 1935 to 1942 and 1964–1979 are given in table 30.6. In May 1942, Government of India fixed prices statutorily and the control was in force till the end of September, 1946. After a short break, Government re-introduced statutory control over prices in December 1947. The prices fixed since 1942 were reviewed and revised from time to time. During the period from 17.12.1947 to 15.12.1963 and again from 20.10.1967 to 15.11.1968, both maximum and minimum prices of various grades were statutorily fixed. Since 16.11.1968, only minimum prices have been statutorily fixed. The statutory prices fixed at various periods are given in Table 30.7.

During the first three decades of the present century, practically the entire rubber produced in India was exported. Although some rubber goods manufacturing units came up in the 1920's, because of the incongenial industrial climate, most of them had to be closed down. The real beginning of the industry can, however, be said to have taken place after 1930 with the International Rubber Regulation Agreement which came into operation in 1934. As a result of the quota system introduced under the Agreement, a large proportion of Indian rubber was left over in the country which became available for internal consumption at very low prices. During the period, some of the large overseas manufacturers of rubber goods also began to decentralise their production and to establish their subsidiary factories in India. Consequently, consumption of rubber started increasing steadily and by 1947, it exceeded the production. After 1947, India became a net importer of rubber. This position continued till 1970. After 1970, import gradually declined and it was banned in April 1973. In 1973–74 and 1974–75, small quantities were exported to relieve the glut in the domestic market and to ensure economic price to the rubber growers. Export continued in 1976–77 and 1977–78. However, the improvement in demand and the setback in production during 1978–79, resulting from adverse climatic conditions and strike of plantation workers, made it necessary to resume import of rubber. Under the present pace of development, India may have to continue import for some more years. The annual trend in production, consumption, import and export is depicted in Table 30.8. In 1979–80, consumption of natural rubber in India was of the order of 165,000 t. Consumption in 1980–81 is expected to exceed 170,000 t.

To supplement the production of natural rubber in meeting the demand, India is producing synthetic rubber also. The first synthetic rubber factory, established by M/s Synthetics and Chemicals Limited, commenced production in 1963 in Bareily in Uttar Pradesh with a production capacity of 30,000 t of styrene butadiene rubber per annum. This factory is also producing nitrile rubber since 1973 in limited quantities with a licensed capacity of 2000 t per annum. The second synthetic rubber factory established at Baroda in Gujarat by Indian Petrochemical Corporation Limited to manufacture poly butadiene synthetic rubber went on stream in 1978. The capacity of the factory is 20,000 t. The annual trend in production, consumption and import of synthetic rubber is as shown in Table 30.8. It may be noted that besides the different varieties of synthetic rubber produced indigenously, the rubber goods manufacturing industry also required certain varieties of special purpose synthetic rubbers which had been imported.

Table 30.9 gives the details of state-wise consumption of rubber. Maharashtra is the leading rubber consuming State in India, followed by West Bengal, Tamil Nadu, Uttar Pradesh and Kerala. The rubber goods manufacturing industry is one of the major industries in India. The industry not only produces practically the entire range of rubber products required in the country, but also has developed a good export market for the products. The pattern of use of rubber according to major end products is given in Table 30.10 and growth rate in value of rubber products exported is presented in Table 30.11.

All estimates predict a wide gap between demand and supply in the coming years. According to the projections of the Planning Commission (I and M Division) in 1980, the requirements of rubber (in t) during 1984–85 and 1989–90 would be as follows:

	1984–85	1989–90
Natural rubber	237,000	342,000
Synthetic rubber*	45,000	63,000
Total	282,000	405,000

(*Comprising Styrene butadiene, poly butadiene and butyl rubber)

Tentative projections of supply (in t) is as follows:

	1984–85	1989–90
Natural rubber	192,000	268,000
Synthetic rubber (capacity)	59,000	59,000
Total	251,000	327,000

Production capacity of natural rubber up to 2000 AD is tentatively assessed as follows:

	Total Area (ha)	Tappable area (ha)	Production (t)	Yield/ tapped area (kg/ha)
1985	300,000	196,000	201,000	1025
1990	350,000	226,000	290,000	1280
1995	400,000	268,000	426,000	1590
2000	450,000	331,000	665,000	2010

World rubber position is depicted in Tables 30.12 to 30.20. India is ranked 4th among the producers and 7th among the consumers of natural rubber in the world.

Table 30.1

Area, production and productivity of rubber in India

Year	Area (ha)	Production (t)	Productivity (kg/ha)
1902–03	200	..	..
1910–11	11,900	80	..
1925–26	30,900	6,400	..
1930–31	32,300	6,500	..
1935–36	49,600	12,500	..
1940–41	56,000	16,100	..
1945–46	61,600	16,700	..
1950–51	69,000	15,800	284
1955–56	83,900	23,700	353
1960–61	129,900	25,700	365
1965–66	164,700	50,500	448
1970–71	203,100	92,200	653
1975–76	224,500	137,800	772
1980–81	260,000	152,000	800

Note: Figures for 1980–81 are estimates

Table 30.2

Details of area under rubber in India at the end of 1978–79

Name of Taluk/District State/Union Territory	REGISTERED						UNREGISTERED	
	Holdings		Estates		Total			
	No. of units	Area in ha	No. of units	Area in ha	No. of units	Area in ha	No. of units	Area in ha
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1. Trivandrum District								
1 Trivandrum	132	327	2	51	134	378	15	12
2 Nedumangad	3610	4907	16	789	3626	5696	340	301
3 Chirayinkil	314	390	..	..	314	390	29	27
4 Neyyatinkara	1190	1496	4	193	1194	1689	105	95
Total	5246	7120	22	1033	5268	8153	489	435
2. Quilon District								
1 Quilon	90	183	..	..	90	183	5	5
2 Kotterakara	2507	3061	9	299	2516	3360	166	122
3 Kunnathur	3011	3583	7	1998	3018	5581	148	90
4 Pathanapuram	5110	5846	32	5521	5142	11367	233	165
5 Pathanamthitta	9175	8747	30	5691	9205	14438	607	471
6 Karunagappally	3	4	..	..	3	4	..	..
Total	19896	21424	78	13509	19974	34933	1159	853
3. Alleppey District								
1 Mavelikara	522	479	1	26	523	505	27	20
2 Thiruvalla	3577	2933	1	26	3578	2959	135	103
3 Chengannur	546	401	..	..	546	401	20	21
4 Karthikappally	3	4	..	..	3	4	..	..
5 Kuttanad	8	6	..	..	8	6	..	..
Total	4656	3823	2	52	4658	3875	182	144

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
4. Kottayam District								
1 Kottayam	11516	8128	9	324	11525	8452	320	199
2 Meenachil	25747	23131	12	881	25759	24012	2093	1616
3 Vaikom	2964	2253	..	..	2964	2253	86	48
4 Changanacherry	8756	6688	16	2228	8772	8916	270	140
5 Kanjirappally	9567	10069	33	2229	9600	12298	474	346
Total	58550	50269	70	5662	58620	55931	3243	2349
5. Idukki District								
1 Peermade	2030	2480	17	3054	2047	5534	247	162
2 Devikulam	327	549	2	77	329	626	42	76
3 Udumbanchola	920	710	..	..	920	710	307	236
4 Thodupuzha	7678	7006	10	1926	7688	8932	1110	790
Total	10955	10745	29	5057	10984	15802	1706	1264
6. Ernakulam District								
1 Moovattupuzha	8911	8471	5	223	8916	8694	320	279
2 Kothamangalam	1859	2581	13	623	1872	3204	31	48
3 Kunnathu Nadu	2686	3477	4	132	2690	3609	116	108
4 Alwaye	755	1314	1	2553	756	3867	30	43
5 Parur	16	62	..	..	16	62	..	..
6 Kanayannoor	2194	1875	..	..	2194	1875	53	47
Total	16421	17780	23	3531	16444	21311	550	525
7. Trichur District								
1 Trichur	253	646	8	1018	261	1664	14	50
2 Mukundapuram	603	1155	8	3481	611	4636	26	31
3 Thalapilly	683	1889	11	761	694	2650	27	60
Total	1539	3690	27	5260	1566	8950	67	141

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
8. Palghat District								
1 Palghat	97	329	8	558	105	887	12	38
2 Alathur	735	3208	15	834	750	4042	74	193
3 Chittur	130	284	1	80	131	364	9	36
4 Ottapalam	218	597	3	152	221	749	29	24
5 Mannarghat	813	2427	20	878	833	3305	143	209
Total	1993	6845	47	2502	2040	9347	267	500
9. Malappuram District								
1 Ponnani	28	133	2	82	30	215	..	..
2 Perinthalmanna	893	2806	29	1646	922	4452	47	148
3 Tirur	46	145	..	..	46	145	..	..
4 Ernad	2745	8230	52	4606	2797	12836	481	946
Total	3712	11314	83	6334	3795	17648	528	1097
10. Kozhikode District								
1 Kozhikode	2941	5970	45	3846	2986	9816	362	372
2 Quilandy	1589	2517	8	1612	1597	4129	137	132
3 Badagara	669	1370	4	286	673	1656	63	78
4 South Wynad	849	1247	11	429	860	1676	243	322
Total	6048	11104	68	6173	6116	17277	805	904

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
11. Cannanore District								
1 Cannanore	36	119	..	..	36	119	23	44
2 North Wynad	752	970	1	38	753	1008	154	145
3 Tellicherry	2543	4480	7	669	2550	5149	401	471
4 Thaliparamba	5894	8732	24	1248	5918	9980	1144	1023
5 Hosdurg	1994	3430	18	1180	2012	4610	454	412
6 Kasaragod	71	151	5	171	76	322	38	124
Total	11290	17882	55	3306	11345	21188	2214	2219
Kerala Total	140306	161996	504	52419	140810	214415	11210	10431
12. Kanyakumari District								
1 Thovala	36	125	13	902	49	1027	10	11
2 Kalkulam	2002	2729	11	2428	2013	5157	148	181
3 Vilavancode	1375	2159	15	2663	1390	48822	78	109
Total	3413	5013	39	5993	3452	11006	236	301
13. Madurai District	1	10	2	142	3	152	..	..
14. Nilgiris District	18	92	2	161	20	253	..	..
15. Coimbatore District	..	..	2	221	2	221	..	
16. Salem District	2	23	..	..	2	23	..	..
17. Tirunelveli District	5	28	..	..	5	28	..	..
Tamilnadu Total	3439	5166	45	6517	3484	11683	236	301
18. South Kanara District	237	429	17	5964	254	6393	98	228
19. Chickmaglur District	8	77	2	98	10	175	..	..
20. Coorg District	9	51	4	1253	13	1304	..	..
Karnataka Total	254	557	23	7315	277	7872	98	228

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Andaman & Nicobar Islands	..	..	4	988	4	988	..	..
Tripura	7	36	1	470	8	506	..	..
Goa	5	10	2	401	7	411	See foot note	
Andhra Pradesh	2	1	1	30	3	31		
Maharashtra	1	4	..	..	1	4		
Grand Total	144014	167770	580	68140	144594	235910	11544	10960

Note: Unregistered area under commercial/experimental plantations in northeastern region in ha: Assam 1004, Tripura 814, Meghalaya 208, Manipur 188, Mizoram 87, Arunachal Pradesh 12 and Nagaland 7, total 13280.

Table 30.3

Classification of registered holdings and estates in India according to size at the end of 1978–79

Size group	No. of units	Area in ha	Average size in ha
Holdings			
Up to 0.40 ha	30159	7937	0.26
Above 0.40 ha and up to and including 2 ha	96208	83320	0.87
Above 2 ha and upto and including 4 ha	11377	30021	2.64
Above 4 ha and up to and including 6 ha	3181	14922	4.69
Above 6 ha and up to and including 10 ha	1797	13316	7.41
Above 10 ha and up to and including 20 ha	1292	18254	14.13
Total	144014	167770	1.17
Estates			
Above 20 ha and up to and including 40 ha	272	7766	28.55
Above 40 ha and up to and including 200 ha	241	19616	81.39
Above 200 ha and up to and including 400 ha	25	7493	299.72
Above 400 ha and up to and including 600 ha	16	7792	487.00
Above 600 ha and up to and including 800 ha	10	6949	694.90
Above 800 ha	16	18524	1157.75
Total	580	68140	117.48
Grand Total	144594	235910	1.63

Table 30.4

Growth rates in production of major crops in India during 1950–51 to 1977–78

Crop (a)	Weight in the official index	1977–78 Production in lakh t	1977–78 Index(b)	Annual rate of increase (per cent) between 1950–52 (c) and 1963–65	1963–65 and 1976–78	1950–52 and 1959–61	1959–61 and 1976–78	1950–52 1976–78
1	2	3	4	5	6	7	8	9
Rubber	0.19	1.5	202.9	7.5	10.6	6.0	10.7	9.0
Safflower	0.09	1.9	176.6	..	8.4	..	..	..
Wheat	12.16	313.3	173.6	3.9	8.0	5.1	6.4	5.9
Tapioca	0.81	64.9	130.2	..	7.2	..	..	..
Potato	1.41	81.5	196.4	4.4	7.1	4.9	6.3	5.8
Ginger: dry	0.07	0.5	247.7	2.6	6.1	0.9	6.2	4.3
Sweet potato	0.43	15.9	90.1	..	4.6	..	..	..
Coffee	0.24	1.2	188.7	6.8	4.6	9.7	3.6	5.7
Guar seed	0.18	9.4	232.6	..	4.5	..	..	..
Sugarcane; gur	7.01	187.8	154.0	3.5	3.1	4.0	3.0	3.3
Tea	1.85	5.6	142.2	1.9	3.0	1.7	2.9	2.4
Niger seed	0.10	1.4	146.5	..	2.8	..	..	..

1	2	3	4	5	6	7	8	9
Castor seed	0.11	2.6	213.4	—0.9	2.6	—0.3	1.5	0.8
Rape seed and Mustard :	1.73	16.7	117.3	3.0	2.5	3.5	2.3	2.7
Arecanut	0.60	0.1	148.4	..	2.4	..	..	..
Cardamom :	0.21	2.0	105.6	..	2.3	..	..	..
Cashewnut :	3.06	59.5	97.2	4.3	2.3	4.7	2.6	3.3
Maize :	2.83	47.1	98.7	3.1	2.2	2.9	2.5	2.6
Bajra :	33.98	526.8	134.7	3.5	2.1	4.5	2.3	2.8
Rice :	1.01	29.0	153.7	3.0	1.8	4.1	1.5	2.4
Ragi :	1.35	18.9	106.0	—1.3	1.3	—0.3	0.1	..
Tur :	1.87	8.5	104.6	..	1.2	..	..	..
Coconut :	0.43	5.0	122.2	1.3	1.2	1.6	1.1	1.3
Linseed :	1.11	38.1	117.9	..	1.1	..	..	..
Tobacco :	1.14	4.5	125.2	2.9	1.1	2.4	0.8	2.0
Barley :	1.34	23.1	80.3	—0.3	0.9	1.3	—0.3	0.3
Cotton seed	1.19	24.3	127.6	..	0.9	..	..	..
Groundnut :	4.82	60.7	117.6	4.0	0.9	4.3	1.5	2.5
Jowar :	4.86	118.2	119.7	2.8	0.8	3.7	0.8	1.8
Pepper: black :	0.08	0.3	137.4	1.1	0.8	2.7	0.1	1.0

Cotton: Lint	:	3.01	12.1	126.8	5.1	0.7	5.0	1.8	2.9
Gram	:	3.58	54.5	104.7	2.6	0.6	6.0	—0.7	1.6
Chilli: dry	:	0.11	4.7	107.9	2.5	0.1	1.3	1.3	1.3
Other pulses		3.14	44.6	102.9	1.3	0.1	1.7	0.2	0.7
Coriander	:	0.01	1.9	273.2	..	..	..	..	..
Small millets	:	0.81	21.1	114.8	0.1	—0.1	1.2	—0.6	..
Sesamum	:	0.62	4.9	110.6	0.9	—0.2	—0.5	0.8	0.4
Mesta	:	0.15	3.2	153.3	7.6	—0.7	7.8	1.1	3.4
Jute	:	0.81	9.6	107.6	3.1	—1.1	1.8	0.5	1.0
Turmeric	:	0.31	1.2	85.9	..	—1.6	..	..	..
Sannhemp	:	0.06	0.6	86.9	..	2.1	..	..	..
Foodgrains	:	68.12	1,256.1	132.8	3.1	2.8	3.8	2.5	2.9
Non-foodgrains	:	31.88		132.6	3.3	2.1	3.4	2.4	2.7
All commodities	:	100.00		132.7	3.2	2.6	3.7	2.4	2.9

Notes : (a) Crops are arranged in the descending order of growth rates between the period 1963–65 (a) and 1976–78.

(b) Base: Triennium ending 1969–70 = 100

(c) Average of the triennium 1949–50, 1950–61 and 1951–52 and so on.

(—) Nil or negligible.

SOURCE 'COMMERCE' Annual Number 1979. Vol. 139 No. 3577.

Table 30.5

Average number of persons employed daily in rubber plantations in India

Year	Number
1961	101776
1962	106363
1963	113528
1964	115595
1965	122481
1966	126958
1967	135104
1968	139795
1969	144423
1970	146591
1971	147902
1972	148040
1973	150909
1974	154214
1975	157754
1976	162660
1977	168500(p)
1978	175000(p)
1979	180000(p)

(p)—Provisional

Table 30.6

Average market price of RMA—1 grade rubber in India

Year	Price in Kottayam market (Rs/100 lbs)
1935	27.14
1936	40.60
1937	48.77
1938	36.04
1939	45.77
1940	55.53
1941	55.90
1942(up to 26.5.42)	61.60

Year	Price in Kottayam/ Cochin market (Rs/100 kg)
1964	325
1965	360
1966	591
1967	410
1968	436
1969	545
1970	489
1971	444
1972	465
1973	493
1974	798
1975	827
1976	653
1977	671
1978	934
1979	1071

Note: During the intervening period from 27 May 1942 to December 1963, Government of India has statutorily fixed the price of rubber either as a fixed price without indicating maximum and minimum or indicating both (30.7). Hence during this period, market prices have not been quoted.

Table 30.7

Price of RMA—1 rubber as fixed by the Government of India

Period covered	Price/100 lbs F.O.R. Cochin		
	Rs	As	Ps
27.5.42 to 18.2.43	71	8	0
19.2.43 ot 9.4.44	77	5	0
10.4.44 to 31.7.44	77	5	0 + bonus 11 1 9
1.8.44 to 30.9.44	77	5	0
1.10.44 to 31.12.44	77	5	0 + bonus 11 1 9
1.1.45 to 30.6.45	77	5	0 + bonus 33 5 3
1.7.45 to 31.1.46	100	0	0
1.2.46 to 29.4.46	77	5	0
30.4.46 to 30.9.46	87	1	0

Period covered	Price in Rs./100 lbs F.O.R. Cochin					
	Max			Min		
17.12.47 to 7.6.48	72	8	0	71	8	0
8.6.48 to 31.10.48	78	8	0	77	8	0
1.11.48 to 6.3.51	90	8	0	89	8	0
7.3.51 to 20.5.51	122	8	0	121	8	0
21.5.51 to 27.10.52	128	0	0	127	0	0
28.10.52 to 14.2.55	138	0	0	137	0	0
15.2.55 to 23.9.55	150	0	0	149	0	0
24.9.55 to 31.3.61	155	12	0	145	12	0

Period covered	Price in Rs/100 kg F.O.B. Cochin	
1.4.61 to 27.4.62	329.60*	327.40*
28.4.62 to 15.12.63	325.20**	323.00**
16.12.63 to 19.10.67	..	323.00
20.10.67 to 15.11.68	416.00	415.00
16.11.68 to 11.9.70	..	415.00

Period covered	Price in Rs/100 kg Nearest district headquarters	
12.9.70 to 5.8.77	..	520.00
6.8.77 to 16.4.79	..	655.00
17.4.79 onwards	..	825.00

* Price since 1.4.61 excludes sales tax
**Price since 28.4.62 excludes sales tax and cess

Table 30.8

Production, consumption, imports and exports of natural and synthetic rubber in India (t)

Year	PRODUCTION			CONSUMPTION			IMPORT			EXPORT
	Natural	Synthetic	Total	Natural	Synthetic	Total	Natural	Synthetic	Total	Natural
1960–61	25,697	..	25,697	48,148	7,397	55,545	23,125	8,097	31,222	..
1961–62	27,446	..	27,446	48,410	10,186	58,596	22,528	10,121	32,649	..
1962–63	32,239	..	32,239	53,553	10,723	64,276	23,360	10,297	33,657	..
1963–64	37,487	8,075	45,562	61,155	11,959	73,114	26,275	8,812	35,087	..
1964–65	45,616	11,633	57,249	61,057	15,285	76,342	15,003	3,315	18,318	..
1965–66	50,530	14,741	65,271	61,765	21,553	85,318	16,357	2,735	19,092	..
1966–67	54,818	22,358	77,176	68,685	23,592	92,277	23,544	5,606	29,150	..
1967–68	64,468	19,942	84,410	74,518	23,324	97,842	9,551	3,127	12,678	..
1968–69	71,054	25,868	96,922	86,615	27,238	113,853	8,548	2,909	11,457	..
1969–70	81,953	28,689	110,642	86,213	30,636	116,849	17,821	4,736	22,557	..
1970–71	92,171	29,791	121,962	87,237	33,160	120,397	2,469	5,014	7,483	..
1971–72	101,210	32,911	134,121	96,454	37,209	133,663	437	5,627	6,064	..
1972–73	112,364	21,832	134,196	104,028	33,913	137,941	356	6,044	6,400	..
1973–74	125,153	23,542	148,695	130,302	23,921	154,223	52	5609	5,661	27,00
1974–75	130,143	17,712	147,855	132,604	24,376	156,980	..	6,939	6,939	350
1975–76	137,750	25,119	162,869	125,692	32,452	158,144	..	5,928	5,928	..
1976–77	149,632	23,212	172,844	137,623	33,701	171,324	..	7,716	7,716	12,296
1977–78	146,987	27,288	174,275	144,967	34,751	179,718	..	8,816	8,816	11,078
1978–79	135,297	28,054	163,351	164,524	37,600	202,124	14,750	10,655	25,405	..
1979–80	148,470	29,524	177,994	165,245	40,588	205,833	32,200	15,755	47,955	..

Table 30.9

Statewise consumption of rubber (t)

State / union territory	1965–66			1970–71			1975–76			1978–79		
	NR	SR	Total	NR	SR	Total	NR	SR	Total	NR	SR	Total
West Bengal	27,091	10,234	37,325	30,988	11,634	42,622	27,300	9,090	36,390	28,169	6,634	34,803
Maharashtra	16,018	5,886	21,904	19,696	9,897	29,593	28,400	10,668	39,068	35,671	10,386	46,057
Tamil Nadu	9,889	2,768	12,657	17,548	5,966	23,514	20,900	4,140	25,040	19,833	4,423	24,256
Punjab	..	..	..	2,277	206	2,483	5,743	227	5,970	9,505	472	9,977
Haryana	4,555	1,901	6,456	4,475	2,439	6,914	11,110	3,109	14,219	11,661	3,307	14,968
Kerala	3,353	517	3,870	6,739	1,798	8,537	9,268	1,062	10,330	16,905	3,297	20,202
Delhi	1,076	66	1,142	1,956	199	2,155	4,168	591	4,759	6,075	815	6,890
Gujarat	882	70	952	1,192	161	1,353	2,138	447	2,585	2,782	798	3,580
Uttar Pradesh	444	32	476	1,160	153	1,313	9,672	1,363	11,035	18,041	3,965	22,006
Karnataka	242	72	314	631	609	1,240	1,920	953	2,873	3,480	858	4,338
Goa	..	..	..	..	..	..	3,483	268	3,751	4,164	186	4,350
Rajasthan	..	..	..	..	..	..	..	..	..	5,563	1,889	7,452
Andhra Pradesh	..	..	..	..	..	..	..	..	..	2,038	165	2,203
Others	215	7	222	575	98	673	1,590	534	2,124	637	405	1,042
Total	63,765	21,553	85,318	87,237	33,160	120,397	125,692	32,452	158,144	164,524	37,600	202,124

Table 30.8

Production, consumption, imports and exports of natural and synthetic rubber in India (t)

Year	PRODUCTION			CONSUMPTION			IMPORT			EXPORT
	Natural	Synthetic	Total	Natural	Synthetic	Total	Natural	Synthetic	Total	Natural
1960–61	25,697	..	25,697	48,148	7,397	55,545	23,125	8,097	31,222	..
1961–62	27,446	..	27,446	48,410	10,186	58,596	22,528	10,121	32,649	..
1962–63	32,239	..	32,239	53,553	10,723	64,276	23,360	10,297	33,657	..
1963–64	37,487	8,075	45,562	61,155	11,959	73,114	26,275	8,812	35,087	..
1964–65	45,616	11,633	57,249	61,057	15,285	76,342	15,003	3,315	18,318	..
1965–66	50,530	14,741	65,271	61,765	21,553	85,318	16,357	2,735	19,092	..
1966–67	54,818	22,358	77,176	68,685	23,592	92,277	23,544	5,606	29,150	..
1967–68	64,468	19,942	84,410	74,518	23,324	97,842	9,551	3,127	12,678	..
1968–69	71,054	25,868	96,922	86,615	27,238	113,853	8,548	2,909	11,457	..
1969–70	81,953	28,689	110,642	86,213	30,636	116,849	17,821	4,736	22,557	..
1970–71	92,171	29,791	121,962	87,237	33,160	120,397	2,469	5,014	7,483	..
1971–72	101,210	32,911	134,121	96,454	37,209	133,663	437	5,627	6,064	..
1972–73	112,364	21,832	134,196	104,028	33,913	137,941	356	6,044	6,400	..
1973–74	125,153	23,542	148,695	130,302	23,921	154,223	52	5609	5,661	27,00
1974–75	130,143	17,712	147,855	132,604	24,376	156,980	..	6,939	6,939	350
1975–76	137,750	25,119	162,869	125,692	32,452	158,144	..	5,928	5,928	..
1976–77	149,632	23,212	172,844	137,623	33,701	171,324	..	7,716	7,716	12,296
1977–78	146,987	27,288	174,275	144,967	34,751	179,718	..	8,816	8,816	11,078
1978–79	135,297	28,054	163,351	164,524	37,600	202,124	14,750	10,655	25,405	..
1979–80	148,470	29,524	177,994	165,245	40,588	205,833	32,200	15,755	47,955	..

Table 30.9

Statewise consumption of rubber (t)

State / union territory	1965–66			1970–71			1975–76			1978–79		
	NR	SR	Total	NR	SR	Total	NR	SR	Total	NR	SR	Total
West Bengal	27,091	10,234	37,325	30,988	11,634	42,622	27,300	9,090	36,390	28,169	6,634	34,803
Maharashtra	16,018	5,886	21,904	19,696	9,897	29,593	28,400	10,668	39,068	35,671	10,386	46,057
Tamil Nadu	9,889	2,768	12,657	17,548	5,966	23,514	20,900	4,140	25,040	19,833	4,423	24,256
Punjab	..	..	..	2,277	206	2,483	5,743	227	5,970	9,505	472	9,977
Haryana	4,555	1,901	6,456	4,475	2,439	6,914	11,110	3,109	14,219	11,661	3,307	14,968
Kerala	3,353	517	3,870	6,739	1,798	8,537	9,268	1,062	10,330	16,905	3,297	20,202
Delhi	1,076	66	1,142	1,956	199	2,155	4,168	591	4,759	6,075	815	6,890
Gujarat	882	70	952	1,192	161	1,353	2,138	447	2,585	2,782	798	3,580
Uttar Pradesh	444	32	476	1,160	153	1,313	9,672	1,363	11,035	18,041	3,965	22,006
Karnataka	242	72	314	631	609	1,240	1.920	953	2,873	3,480	858	4,338
Goa	..	..	..	..	..	..	3,483	268	3,751	4,164	186	4,350
Rajasthan	..	..	..	..	..	..	..	..	..	5,563	1,889	7,452
Andhra Pradesh	..	..	..	..	..	..	..	..	..	2,038	165	2,203
Others	215	7	222	575	98	673	1,590	534	2,124	637	405	1,042
Total	63,765	21,553	85,318	87,237	33,160	120,397	125,692	32,452	158,144	164,524	37,600	202,124

Table 30.10

Pattern of use of natural and synthetic rubber in India (t)

	PRODUCTS	1975–76			1978–79		
		Natural	Synthetic	Total	Natural	Synthetic	Total
1	Automobile tyres and tubes	62115	17101	79216	83212	20060	103272
2	Cycle tyres and tubes	15979	2756	18735	19972	3832	23804
3	Camel back	5545	2303	7848	8771	1840	10611
4	Foot wears	12387	4135	16522	16884	4508	21392
5	Belts and hoses	8943	894	9837	11138	1526	12664
6	Latex foam	2033	..	2033	3543	..	3543
7	Cables and wires	590	300	890	705	414	1119
8	Battery Boxes	280	561	841	391	706	1097
9	Dipped goods	3478	..	3478	4492	..	4492
10	Others	14342	4402	18744	15416	4714	20130
	Total	125692	32452	158144	164524	37600	202124

Table 30.11

Value of rubber products exported (in '000 Rs.)

Sl. No.	Item	1965–66	1970–71	1971–72	1972–73	1973–74	1974–75	1975–76	1976–77	1977–78	1978–79 (Estimated)
1	Automobile tyres and tubes including tyre retreading materials	27482	55375	66920	60471	67475	87394	85145	184816	168463	126000
2	Beltings	122	1637	752	911	2585	10223	8877	7619	11061	21245
3	Cycle tyres and tubes	2309	4364	4711	5435	9577	13138	9888	15333	18491	10822
4	Hoses	788	1883	1744	773	1438	2117	2735	3544	4536	4982
5	Hygienic, medical and surgical articles of rubber including gloves	211	6183	879	874	3053	2780	2401	7243	11034	4895
6	Rubber footwear	879	1587	1107	2502	1877	3278	1358	1612	1996	1800
7	Rubber-soled footwear with canvas upper	13977	21573	30292	27861	27493	42449	21745	32935	36695	21700
8	Rubber cots and aprons for textile industry	1572	1463	513	146	1145	1154	846	1010	1532	2705
9	Rubber Sheetings	66	471	183	171	207	125	798	301	376	1996
10	Synthetic rubber and substitute	..	..	..	..	..	4084	35	87	..	..
11	Reclaimed rubber	2579	2422	5138	5879	13540	1936	302	2111	2564	2500
12	Others	..	..	..	..	..	9380	11198	16997	14187	23955
	Total	49985	96958	112239	105023	128390	178058	145328	273608	270935	222500

Source: Chemicals & Allied Products Export Promotion Council

Table 30.12

Area under rubber in main rubber producing countries

(In '000 ha)

	End of	Small-holdings	Estates	Grand Total
Malaysia	1977	1360	640	2004
ndonesia	1977	1862	466	2328
Thailand	1974	1334	70	1404
India	1978	180	70	250
Nigeria	1965	208	32	240
Sri Lanka	1975	122	106	228
Liberia	1973	43	77	120
Viet-Nam	1965	25	75	100
Zaire	1959	25	68	93
Burma	1964	28	35	63
Cambodia	1965	..	48	48
Cameron United Republic	1976	..	20	20
Brazil	1965	10	10	20
Philippines	1970	..	22	22
Ivory Coast				20
Others				31
Total				6991

Note: Estate refers to holdings of 40 ha and over except for Viet-Nam where it refers to holdings of over 500 ha

Source: 'Rubber Statistical Bulletin' of the International Rubber Study Group

Table 30.13

World Production, consumption and price of rubber

	Production ('000 t)	Consumption ('000 t)	Price (Per t)		
			Singapore Sing.dollars	London £	New york US dollars
1900 :	45	53	..	275.5	1276.9
1905 :	55	70	..	330.7	1667.4
1910 :	98	103	..	964.5	2267.2
1915 :	173	163	..	314.6	1297.4
1920 :	348	303	..	87.8	360.5
1925 :	535	563	..	322.1	1597.5
1930 :	838	723	422	54.5	225.8
1935 :	843	955	446	55.1	271.6
1940 :	1440	1128	828	110.8	438.7
1945 :	255	267	..	165.3	496.0
1950 :	1890	1750	2393	305.7	906.1
1955 :	1948	1920	2517	308.3	862.9
1960 :	2035	2135	2383	295.3	841.2
1965 :	2353	2445	1544	197.0	566.4
1970 :	3103	2990	1244	187.0	462.5
1975 :	3315	3368	1346	302.1	658.9
1979@ :	3850	3885	2778	607.0	1423.3

@Provisional

Source: International Rubber Study Group

Table 30.14

Production of natural rubber in main producing countries
(In '000 t)

	1970	1975	1979	1980 (estimated)
Malaysia	1269	1459	1600	1575
Indonesia	815	823	905	960
Thailand*	290	355	531	560
India	90	136	147	152
Sri Lanka	159	149	153	151
Liberia	83	83	73	70
Nigeria	65	68	52	55
Viet-Nam	28	20	50	50
Brazil	25	19	25	29
Kampuchea	13	10	10	..
Others	260	190	300	270
Total@	3103	3315	3850	3875

@Including allowances for apparent discrepancies in officially reported statistics

* Exports plus consumption plus changes in stocks

Source: International Rubber Study Group

Table 30.15

Growth rate of production of natural rubber in major producing countries

Year	Malaysia	Indonesia	Thailand	Sri Lanka	India
1969	15.3	10.8	7.2	1.3	15.9
1970	0.1	(–) 7.4	2.5	5.3	12.5
1971	3.9	0.5	10.0	(–)11.3	10.0
1972	(–) 1.1	(–) 5.5	5.6	(–) 0.7	10.1
1973	18.3	14.5	15.7	10.7	12.8
1974	(–) 1.1	(–) 3.5	(–) 2.8	(–)14.8	4.1
1975	(–) 4.3	(–) 3.7	(–) 6.3	12.9	6.3
1976	10.5	3.0	16.1	2.0	8.8
1977	0.1	(–) 1.5	4.6	(–) 3.9	2.7
1978	(–) 0.4	8.0	8.4	6.8	(–)12.5
Average	4.1	1.5	6.1	0.8	7.0

Note: Figures represent percentage increase in production over that of the previous year

Table 30.16

Production of synthetic rubber in main producing countries
(In '000 t)

	1970	1975	1979	1980 (estimated)
U.S.A.	2232	1990	2658	2427
U.S.S.R.*	800	1600	2025	2025
Japan	698	789	1107	1100
France	316	350	541	520
Federal Rep. of Germany	302	316	418	400
Canada	205	173	283	265
U.K.	316	261	278	250
Italy*	155	200	260	250
Brazil	75	129	224	238
Netherlands	200	216	238	210
German Demo. Republic	118	144	150	170
Rumenia	61	99	160	155
Poland	62	108	130	130
Belgium*	50	65	125	125
Mexico	44	60	90	100
China(P)	35	40	80	90
Spain	39	66	85	80
Czechoslovakia*	50	57	60	59
Australia	33	38	43	43
India	30	23	32	35
South Africa	29	32	31	35
Argentina*	39	40	43	33
Others	4	59	224	260
Total	5893	6855	9285	9000

P — Provisional
* — Estimates
Source — International Rubber Study Group.

Table 30.17

Consumption of natural rubber in main consuming countries
(In '000 t)

	1970	1975	1979	1980 (estimated)
U.S.A.	568	666	736	637
Japan	283	285	390	420
China (P)	208	225	370	395
U.S.S.R.*	316	235	215(p)	215 (p)
Federal Rep. of Germany	201	197	185	185
France	158	156	177	170
India	86	129	168	170
UK.	195	171	138	140
Italy	113	118	128	140
Canada	51	72	94	88
Brazil	37	59	76	* 83
Australia	40	50	45	43
Netherlands	22	23	20	20
Others	710	980	1140	1220
Total @	2990	3368	3885	3925

P — Provisional
* Estimated
@ Including allowance for discrepancies in officially reported statistics
Source—International Rubber Study Group

Table 30.18

Consumption of synthetic rubber in main consuming countries
(In '000 t)

	1970	1975	1979	1980 (estimated)
U S.A.	1949	1964	2396	2075
U.S.S.R	NA	NA	1945(p)	1935 (p)
Japan	496	585	830	900
Federal Rep. of Germany	358	360	447	440
France	261	278	318	310
U.K.	278	266	301	285
Ita y	197	220	285	275
Brazil	85	176	225	247
Canada	135	179	232	202
Poland	NA	NA	130	130
China(p)	48	55	100	120
Nether ands	46	57	70	70
Australia	54	50	51	52
India	32	32	38	43
Others	1696	2806	1632	1666
Total	5635	7028	9000	8750

P — Provisional NA — Not available

Source: International Rubber Study Group

Table 30.19 **Percentage consumption of natural rubber in main consuming countries**

	United States of America	United Kingdom	France	Germnay Fed Rep.	Italy	Netherlands	China	Australia	Brazil	Canada	India	Japan	World
1968	23.48	44.38	39.66	40.19	38.46	42.14	81.82	45.12	35.00	29.99	77.45	42.29	36.33
1969	22.81	42.78	39.31	36.83	36.43	41.89	81.63	45.27	33.03	27.78	73.81	38.62	35.21
1970	22.58	41.29	37.75	35.92	36.45	32.45	81.38	42.75	30.09	27.20	73.11	36.33	34.67
1971	21.63	40.21	35.96	34.94	36.95	28.61	80.77	40.33	29.99	24.74	71.75	35.98	33.33
1972	21.85	38.48	34.97	34.75	34.91	28.96	80.77	44.47	27.90	25.88	72.65	34.67	32.43
1973	22.59	36.07	34.75	31.72	33.33	27.54	80.56	44.20	25.49	24.51	83.29	32.06	31.00
1974	25.04	37.47	34.49	32.42	32.89	28.53	80.56	47.95	25.85	25.88	86.14	33.66	32.07
1975	25.32	39.03	36.00	35.39	34.91	28.45	80.36	49.91	24.98	28.74	80.14	32.78	32.40
1976	24.02	33.95	36.82	30.82	34.18	29.15	80.00	46.67	24.69	29.34	79.99	31.46	30.69
1977	24.50	34.94	35.69	29.04	31.76	28.63	80.00	43.88	25.85	30.38	80.52	31.68	30.59
1978	23.40	30.76	35.52	30.10	29.89	26.28	77.92	41.70	24.62	30.40	80.85	32.39	29.78
1979	23.49	31.35	35.77	28.00	30.99	NA	78.72	47.21	25.20	28.78	81.36	31.97	29.95**

N B The percentage figures given above refer to the consumption of natural rubber, expressed as a percentage of total new rubber consumed

* Estimated or partly estimated

** Including year end adjustment NA—Not available.

Source: International Rubber Study Group.

Table 30.20

Estimated percapita consumption of natural and synthetic rubber (kg)

Country/ Region (1)	1966 (2)	1967 (3)	1968 (4)	1969 (5)	1970 (6)	1971 (7)	1972 (8)	1973 (9)	1974 (10)	1975 (11)	1976 (12)	1977 (13)	1978 (14)
U.S.A.	11.43	10.83	12.54	13.15	12.28	13.11	14.26	14.98	13.91	12.31	13.29	15.13	14.29
Canada	7.79	7.67	7.32	8.50	8.73	9.74	10.69	11.18	10.92	11.07	12.54	12.78	12.47
F.R. Germany	6.20	5.71	7.03	8.53	9.20	9.26	9.01	10.46	9.64	9.01	10.30	9.90	10.02
France	6.12	6.38	6.51	7.56	8.26	8.64	8.86	8.96	8.97	8.22	8.56	8.64	8.62
U.K.	7.03	7.01	7.78	8.22	8.53	8.26	8.11	9.25	7.98	7.82	8.87	8.83	8.11
Japan	4.39	5.12	5.91	6.73	7.47	7.76	8.40	9.61	8.42	7.80	8.51	8.87	9.54
Australia	6.61	6.81	8.10	7.58	7.50	7.76	7.91	8.81	9.10	7.26	7.69	6.71	6.92
Netherlands	3.72	3.49	3.84	3.78	5.20	5.83	6.01	6.31	6.41	5.82	5.46	5.34	5.12
Italy	4.27	4.84	4.91	5.25	5.78	6.06	6.21	6.56	6.86	6.05	7.03	7.14	6.67
Brazil	0.91	1.05	1.24	1.18	1.32	1.46	1.62	2.00	2.17	2.21	2.45	2.46	2.55
Eastern Europe	3.74	3.89	4.02	4.15	4.41	4.88	5.40	5.92	6.43	6.86	7.04	7.29	7.64
China	0.26	0.28	0.39	0.30	0.31	0.31	0.30	0.31	0.31	0.31	0.33	0.38	0.41
India	0.18	0.19	0.21	0.22	0.22	0.24	0.25	0.26	0.26	0.27	0.27	0.28	0.31

APPENDIX

APPENDIX I

PLANTING RECOMMENDATIONS

Under the provisions of the Rubber Act and Rules, it is compulsory that planting or replanting of rubber shall be carried out with high yielding planting materials, clones and seedlings approved by the Rubber Board. The Board publishes every year an approved list of planting materials for this purpose. The materials are brought under three categories.

Materials under Category I are recommended for planting on wide scale. When large scale plantings are undertaken, it is however advisable to adopt use of as many of the materials under this category as is practicable. It is also desirable for large estates to reserve up to 20 per cent of the total area for planting older clones of proven local performance, newer promising material and experimental clones.

Category II consists of old clones which still enjoy localised popularity owing to their sustained good performance in the areas concerned and new promising clones. Limitation in planting of these clones to within 20 per cent of the total area in large estates is advised in view of the desirability of progressively replacing older clones with modern high yielding clones of established performance and of minimising the risks involved in the use of clones which are not fully tested.

Clones recommended for experimental planting are brought under Category III. These clones are released on the strength of encouraging results obtained over limited periods in the small scale trials conducted by the Rubber Research Institute of India or in view of the fact that they have been imported into India on account of their good performance in other countries. Growers in general and small growers in particular should exercise care to limit planting of clones in this category to small experimental or observational plots.

High yielding polyclonal seedlings are found to be highly susceptible to brown bast and hence they are to be tapped on half spiral, once in three days (S/2, d/3 67 per cent) system. Small growers who are not in a position to adopt this low intensity tapping system are advised to avoid the use of polyclonal seedling material.

Planting materials approved for 1980:

Category I

(a) Buddings of clones RRIM 600, GT 1 and RRII 105.

(b) Clonal seeds derived from Prang Besar isolated Garden, GG 2, GG 3, GG 4, GG 5 and GG 6 plots PBIG/GG 2, PBIG/GG 3, PBIG/GG 4, PBIG/GG 5 and PBIG/GG 6 of Malaysia.

(c) Clonal seeds derived from the seed gardens of Tamil Nadu Govt. Rubber Plantations in Kanyakumari District and other indigenous polyclonal seed collection areas approved by the Board.

Category II

Buddings of clones PR 107, PB 5/51, Tjir 1, GL 1, PB 86, PB 5/139, PB 6/9, PB 28/59, RRIM 605, RRIM 623, RRIM 628, RRIM 701, RRIM 703, RRII 118 and PB 217.

Category III

(a) Buddings of clones RRII 116, 203 and 208.

(b) Buddings of clones RRIM 704, 705, 706, 707, PB 206, 213, 215, 230, 235, 240, 242, 252, 253, 260, 5/76, 28/83, RRIC 7, 36, 45, 52, 100, 102, 104 and 105, CH 153, Harbel 1, Nab 17 and Wagga 6278.

(c) Other promising clones and clonal seeds specially approved by the Chairman, Rubber Board on merits, under request in individual cases'.

APPENDIX II

Requirement of area for various types of nurseries for producing planting materials necessary for 100 ha

Planting material to be produced	Nursery details			No. of plants required for 1 ha of main field*	Nursery area required (ha)	
	Spacing in nursery	Initial density per ha	Final density per ha		Effective	Gross **
Budded stumps	30 cm x 30 cm	111110	74074	500	0.675	0.750
Seedling stumps	30 cm x 30 cm	111110	88000	550	0.625	0.695
Stumped budding *Max*	90 cm x 90 cm	12350	9880	500	5.000	5.550
Stumped budding *Min*	60 cm x 60 cm	27775	22220	500	2.250	2.500
Polybag 2–3 whorls	—	—	25000	500	2.000	2.000
Polybag 6–7 whorls	—	—	18000	500	2.750	2.750

* This includes the number of plants required for vacancy filling during the first year.

** Gross area includes additional space required for foot paths, drains etc.

APPENDIX III

Number of trees per hectare at different spacing in cm (square or rectangular)

Cm (ft)	180 (6)	200 (7)	240 (8)	270 (9)	300 (10)	340 (11)	370 (12)	400 (13)	430 (14)	460 (15)	490 (16)	520 (17)	550 (18)	580 (19)	610 (20)	640 (21)	670 (22)	700 (23)	730 (24)	760 (25)
180 (6)	2990	2562	2244	1994	1794	1631	1495	1379	1282	1196	1122	1055	996	944	897	862	815	781	749	717
200 (7)		2197	1922	1707	1537	1399	1282	1184	1097	1025	961	904	855	810	768	731	699	670	633	615
240 (8)			1683	1495	1347	1223	1122	1035	961	897	840	791	749	709	672	640	613	586	561	539
270 (9)				1329	1196	1087	996	919	855	798	749	702	665	630	598	568	544	519	499	479
300 (10)					1077	979	897	828	768	717	672	633	598	566	539	511	489	467	450	425
340 (11)						890	815	754	699	652	613	576	544	514	489	467	445	425	408	390
370 (12)							749	689	633	598	561	529	499	472	450	427	408	390	376	358
400 (13)								638	591	551	516	487	460	442	415	395	376	361	346	331
430 (14)									549	511	479	452	427	405	385	366	348	334	321	309
460 (15)										479	450	423	398	378	358	341	326	311	299	292
490 (16)											420	395	376	353	336	321	306	292	229	269
520 (17)												373	351	334	316	301	287	274	264	252
550 (18)													331	314	299	284	272	259	250	240
580 (19)														299	284	269	257	247	237	227
640 (20)															269	257	245	235	225	215
640 (21)																245	232	222	213	205
670 (22)																	222	213	203	195
700 (23)																		203	195	188
730 (24)																			188	180
760 (25)																				173
790 (26)	689	591	516	460	415	400														
850 (28)	640	549	479	427	385															
910 (30)	598	511	447	398	358															
981 (31)	561	479	427	385																
1040 (34)	529	452	395																	
1100 (36)	499	427	373																	
1160 (38)	472	405																		
1220 (40)	447	408																		

Note:—Spacing (ft) has been converted to the nearest 10 cm. (2) The figures in the brackets are the corresponding space in ft.

APPENDIX IV

CASE HISTORY SHEET FOR COLLECTION OF SOIL AND LEAF SAMPLES

1. Name and location of the estate with the postal address of the owner
2. Name of the block sampled along with area in hectares
3. Sample number
4. Depth of sampling
5. Date of sampling
6. Planting material (clone) used with spacing
7. Age of the tree in the sampled area
8. Average girth of the trees in the sampled area (in the case of seedlings the girth at the height of 50 cm from the base and for buddings the girth at 120 cm from the bud union may be given)
9. Elevation above mean sea level
10. Rainfall – Average for last 5 years
11. Slope – Level/gentle/medium/ steep
12. Cover crops:–

    (i) Pure —Pueraria/Calopogonium
    Centrosema/Desmodium

(ii) Mixture

(iii) When established and whether still present

13. Previous history of the sampled area (Here state whether the area is a re-planting or new planting, previously cultivated or virgin area)

14. Manuring history (Here state the rubber mixtures used specifying the various ingredients, composition and quantity applied per tree or per ha for the past three years)

15. Time and method of application

16. Tapping system adopted with average yield for the past three years with initial tapping height

17. Please state whether the sampled field is with rubber or mixed with coconut, arecanut or inter-cultivated with tapioca, banana etc

18. Stand per ha

19. Protective measures adopted against diseases

20. Please state whether rain guarding or stimulants like 'Ethrel' are used, if so give details

21. Any other relevant information

Place: .....

Date: ..... Signature of the Owner/Manager

APPENDIX V

CALENDAR OF OPERATIONS FOR RUBBER

January

(1) Irrigat the nurseries as and when required.

(2) Adopt preventive measures against leaf spot diseases by providing light over-head shade, spraying 0.2 per cent Bavistin or Bordeaux Mixture, if found necessary.

(3) Spray wettable sulphur in nurseries and young plants and dust sulphur in mature plantation against powdery mildew disease if found necessary.

(4) Protect the stem of young plants and mature border trees from sunscorch by white–washing.

(5) Pruning — All stock shoots should be pruned off as and when they are formed. Side shoots of young rubber up to a height of 3 m from ground level may also be pruned off.

(6) Fire belt – A space of about 3 m width may be left along the borders of the estate clean-weeded and free of any mulch material. Sides of roads and foot-paths may also be kept clean-weeded and free of mulch material. Maintenance of roads and buildings may be carried out.

(7) Mulching – The bases of young plants may be mulched, if not carried out earlier.

(8) Arrangements may be made for raising budwood for green budding. Green budding operation can be started now if budsticks are available.

(9) Collect and preserve cover crop seeds.

(10) Preparing land for new planting and replanting can be started.

(11) Tapping can be continued if yield is satisfactory.

(12) Application of wound dressing compounds on the tapping panel may be carried out. If the treated surface is black, white–washing may be done over it.

(13) Collect soil samples for discriminatory fertilizer recommendation.

(14) Transplant green budded plants in polybag.

February

(1) Irrigate nurseries as and when required.

(2) Adopt preventive measures against leaf spot diseases by providing light over-head shade, spraying 0.2 per cent Bavistin or Bordeaux Mixture, if found necessary.

(3) Spray wettable sulphur in nurseries and young plants and dust sulphur in mature plantation against powdery mildew disease, if found necessary.

(4) If green budding is to be undertaken budwood may be arranged. Green budding can be continued.

(5) Collect and preserve cover crop seeds.

(6) Tapping can be continued without giving tapping rest, if found economic.

(7) Application of wound dressing compounds may be carried out. If the treated surface of the panel is black, white –washing may be done over it.

(8) Tapping – Marking of trees to be tapped during the next season is to be carried out. Planters can make use of the services of tapping demonstrators in various Regional Offices of the Rubber Board.

(9) Collect soil samples for discriminatory fertilizer recommendation as and when required.

(10) Transplant green budded plants in poly bags, if not already done in January.

(11) Upkeep and maintenance of polybag plants.

March

(1) Materials for rain guarding may be procured and the operation could be commenced in very large estates.

(2) Procure materials for yield stimulation.

(3) Spray/dust against powdery mildew disease.

(4) Start preparations for spraying against abnormal leaf fall disease.

(5) Procure fertilizers.

(6) Irrigate the nurseries as and when required.

(7) Side shoot pruning in immature plantations may be carried out.

(8) Land preparation for new and replantings.

(9) Tapping – Start tapping on newly opened trees and in those blocks where tapping rest was given.

(10) Latex collection and processing — Cleaning of cups, spouts etc and refixing of them. Use anti-coagulants in case latex shows tendency for pre-coagulation.

(11) Collect soil samples for discriminatory fertilizer recommendation.

(12) Upkeep and maintenance of polybag plants.

April

(1) Apply Ethephon on panel C and D.

(2) Complete the preparations for spraying against abnormal leaf fall disease and start spraying.

(3) Weeding.

(4) Manuring can be done after receiving sufficient pre-monsoon rains.

(5) Budding.

(6) Pruning.

(7) Preparation of land.

(8) Tapping — Start tapping, if not already done in March.

(9) Latex collection and processing. Use anti-coagulants in case latex shows tendency for pre-coagulation.

(10) Rainguarding.

(11) Upkeep and maintenance of polybag plants.

May

(1) Complete rainguarding the trees in the first week itself.

(2) Complete the application of ethephon in 'C' panel in the first week itself.

(3) Complete spraying against abnormal leaf fall and shoot rot diseases.

(4) Weeding.

(5) Manuring.

(6) Budding.

(7) Pruning.

(8) Preparation of land.

(9) Tapping.

(10) Latex collection and processing.

(11) Upkeep and maintenance of polybag plants.

June

(1) Budding can be continued, if conditions are favourable.

(2) Preparation of land — If not completed, complete land preparation by this month.

(3) Planting — Transplant nursery plants into the main field.

(4) Vacancy filling.

(5) Cover crop — Establishment of cover crops.

(6) Manuring of cover crops.

(7) Weeding.

(8) Prophylactic spraying may be repeated if necessary in nursery as well as in main field having young plants against abnormal leaf fall and shoot rot diseases.

(9) Tapping — Since conditions are favourable for the spread of panel disease, apply panel disinfectants regularly.

(10) Pruning.

July

(1) Planting – Seedlings and budded stumps and polybag plants can be transplanted to mainfield, if conditions are favourable. Best time for planting sprouted seeds in the mainfield.

(2) Collect seeds and sow for germination.

(3) Prepare nursery for planting sprouted seeds.

(4) Maintenance of cover crops – Weed cover crop beds to avoid competition and apply fertilizer.

(5) Weed the main field.

(6) New flushes of leaves produced by young plants in nurseries and main field may be sprayed and protected during breaks in the monsoon.

(7) Protect tapping panel.

(8) Staking of young plants.

(9) Latex collection and processing. If the collection cups are wet, add a few drops of anti-coagulant solution in the collection cup.

(10) Prune stock shoots.

August

(1) Budding can be continued, if conditions are favourable.

(2) Seed collection and putting them in germination beds.

(3) Planting – Planting in nurseries and seed – at – stake in the field.

(4) Manure the nursery.

(5) Maintenance of cover crops.

(6) Weeding.

(7) Spray in nursery as well as the young plants in the main field.

(8) Tapping.

(9) Protect tapping panel.

(10) Examine the plants for pink disease and adopt appropriate control measures.

(11) Prune stock shoots.

(12) Staking of young plants.

(13) Latex collection and its processing.

(14) Collection of soil/leaf samples for discriminatory fertilizer recommendation.

September

(1) Ccollection and germination of seeds.

(2) Budding in the field.

(3) Nursery – Planting germinated seeds in the nursery – Manuring the nursery.

(4) Cover crop maintenance – Weeding and fertilizer application.

(5) Weeding.

(6) Manuring.

(7) Pruning.

(8) Remedial measures are to be adopted against pink disease.

(9) Examine the trees for 'Patch Canker'.

(10) Treatment of trees affected by 'Dry Rot', if present.

(11) Protect the tapping panel.

(12) Latex collection and processing.

(13) Start tapping on trees attained tappable girth.

(14) Second round application of ethephon.

(15) Collection of soil/leaf samples for discriminatory fertilizer recommendations.

October

(1) Gap filling in the main field.

(2) Pruning of stock shoots and side shoots.

(3) Manuring in nursery.

(4) Spraying in nursery.

(5) Cover crop maintenance.

(6) Weeding.

(7) Manuring in the main field.

(8) Adopt treatment of pink disease, patch canker and dry rot.

(9) Protect the tapping panel.

(10) Latex collection and processing.

(11) Collection of soil/leaf samples for discriminatory fertilizer recommendation.

November

(1) Manuring in nursery.

(2) Mulching in nursery.

(3) Irrigate the nurseries, if required.

(4) Provide shade baskets for newly planted buddings in the field.

(5) Pruning.

(6) Weeding.

(7) Remedial measures are to be taken against pink disease patch canker and dry rot.

(8) Latex collection and processing.

(9) Application of Ethephon.

December

(1) Irrigate the nurseries, if required.

(2) Spray against leaf spot diseases in the nursery.

(3) Spray wettable sulphur in nurseries and young plants and dust sulphur in mature plantations against powdery mildew disease, if found necessary.

(4) Protect the stem of young plants and mature border trees from sun scorch by white-washing.

(5) Pruning.

(6) Take fire belts and maintain them.

(7) Mulching.

(8) Maintenance of the bud wood nursery.

(9) Green budding can be initiated and arrangements made for green bud shoots.

(10) Collect cover crop seeds.

(11) Start preparation of land for new planting as well as re-planting.

(12) Latex collection and processing.

(13) Removal of rain guards.

APPENDIX VI

GLOSSARY

Acetic acid

A good coagulating agent for latex, 4 ml diluted to 400 ml with water is sufficient for the coagulation of 4 l of standard latex containing 500 g rubber, for sheeting the same day. For the next day sheeting, 3 ml diluted to 300 ml with water is sufficient.

Agallol – 3 and 6

These are organo–mercurial fungicides containing 3 and 6 per cent mercury respectively as methoxy ethyl mercury chloride. Disinfectant for all diseases of bark, brown root disease etc, diluted at the rate of 10 g in 2 l of water for Agallol - 3 and 10 g in 4 l of water for Agallol–6.

Aldrin

This is 1,2,3,4,10, 10 – hexachloro –1, 4,4a,5,8,8a – hexahydro-exo–1,4, – endo –5, 8 dimethano naphthalene not less than 90 per cent. This is a good insecticide (chlorinated hydrocarbon) for the control of termites. The usual dilution is 0.05 per cent or 1 l of 30 EC in 600 l of water. Poisonous and hence to be handled with care.

Ammonia

Used as an anti–coagulant, 0.01 per cent on latex; ammonia content of latex is adjusted to 0.7 per cent as a preservative.

Ansar 529

Mono sodium acid methane arsonate; It is a post-emergent selective weedicide against grasses.

Antimucin WBR

An organo–mercurial fungicide containing 10 per cent phenyl mercury acetate. It is being used against black stripe at a strength of 0.5 per cent.

Aretan

This is methoxyethyl mercury chloride, an organo–mercurial fungicide used as a panel disinfectant and for treatment of bark diseases and brown root disease. Dilution 10 g in 4 l of water; poisonous; use non-metallic containers.

Bavistin (Carbendazim)

This is methyl–2–benzimidazolecarbamate, a systemic fungicide. Use of 0.2 per cent solution of the fungicide in water is effective against leaf spot diseases.

Benlate

This is methyl 1–(butyl carbamoyl)–2–benzimidazolecarbamate. The fungicide is used as 0.1 per cent foliar spray for the control of wilt diseases. It can also be used as a soil applicant.

Benzene hexa chloride (BHC)

This is a chlorinated hydrocarbon insecticide. Not highly poisonous to man. Used as 5 or 10 per cent dust or 0.2 per cent spray for the control of various insect pests.

Borax – Sodium tetraboxate ($Na_2B_4O_7$ 10 H_2O)

This is used as a source of boron.

Bordeaux mixture

One per cent mixture, 1 kg copper sulphate and 1 kg quick lime in 100 l of water . Dissolve copper sulphate in half the total quantity of water in a vessel. Slake the lime and dilute with the remaining volume of water. Pour copper sulphate solution into the lime solution and not *vice versa*. Use copper, wooden or plastic vessels. Do not mix concentrated solutions and then dilute. Use the mixture on the same day. Always filter the mixture to avoid clogging of spray nozzles. The fungicide is effective against shoot rot and abnormal leaf fall diseases.

Bordeaux paste

Similar to Bordeaux mixture, but more concentrated (1kg: 1 kg: 10 l); useful for protecting wounds, treatment of pink disease etc; not to be used on tapping panel.

Calixin (Tridemorph)

This is N–tridecyl–2, 6–dimethylmorpholine a fungicide with protective and curative properties, used for the control of powdery mildew.

Captan

This is *cis*–N–[(trichloromethyl) thio]– 4 cyclohexene–1,2, –dicarboxamide. It is a protectant-eradicative fungicide.

Ceresan (Wet)

This is ethyl mercury chloride, an organo–mercurial fungicide useful as disinfectant for all diseases of bark, brown root disease etc. Dissolved to contain 0.1 per cent –0.2 per cent of the active ingredient (generally 10 g in 1.6 l of water);poisonous and must be handled with care ;solutions to be made in non-metallic containers.

Dalapon

This is 2,2–dichloro propionic acid, a post—emergent weedicide effective against perennial grass. Other trade names are Dowpon or Taffapon.

Diluent spray oil

Mineral oil purified to reduce phytotoxicity and used as a carrier for dispersing oil-based fungicides for spraying with low volume applicator. It is marketed in different trade names such as IOC rubber spray oil, Rinki spray oil, Power oil and Rubber spray oil.

Dithane M–45

It is zinc ion manganese ethylene bisdithiocarbamate. It could be used for the control of bird's eye spot and other leaf spot diseases, The dosage varies from 450–900 g in 450 1 of water.

Dithane Z–78

An organic fungicide containing 65 per cent zinc ethylene bisdithiocarbamate. It could be used as spray for the control of bird's eye spot disease and other leaf spot diseases at a strength of 0.2 per cent (900 g/450 1 of water).

Diuron

3–(3,4–dichlorophenyl)–1, 1–dimethyl urea. It is a pre-mergent weedicide effective against all types of weeds.

Dowpon

See Dalapon

Drazoxolon

4–(2–chlorophenylhydrazono)–3–methyl–5–isoxalone. Effective against red root disease of rubber.

Emisan

Methoxy ethyl mercury chloride, an organo–mercurial fungicide used as a panel disinfectant and for treatment of bark and root diseases; dilution, 10 g in 4 l of water; poisonous; use non-metallic containers.

Endosulfan

6, 7, 8, 9, 10, 10–hexachloro–1, 5, 5a, 6, 9,9a–hexahydro–6,9–methano–2,4,3–benzo (e)–dioxathiepen– 3–oxide. It is an insecticide used for the control of pests of the cover crops especially those of *Pueraria phaseoloides*.

Ethrel (ethephon)

Yield stimulant containing 2 chloro ethyl phosphonic acid as the active ingredient.

Factamfos (ammonium phosphate sulphate)

It is a complex fertilizer which supplies nitrogen and phosphorus.

Ferbam

Ferric dimethyl dithiocarbamate; it is a protective fungicide which can be used against many fungal diseases.

Fernoxone

Sodium salt of 2,4–dichlorophenoxy acetic acid, it is a post-emergent weedicide, effective against dicot weeds.

Fomac

10–15 per cent pentachloronitrobenzene in a grease base, used against black root disease.

Formalin

40 per cent formaldehyde, used in dilute solutions (0.02 per cent) as an anti–coagulant.

Formic acid

A good coagulating agent for latex; 2 ml diluted to 400 ml with water, is sufficient to coagulate 4 l of standard latex containing 500 g rubber, for sheeting the same day. For next day sheeting, 1.5 ml diluted to 300 ml with water is sufficient.

Fylomac 90

An organic fungicide containing quaternary ammonium compound as water soluble paste, standard dilution is 28–50g/10 1 of water; useful for the control of pink disease and mouldy rot.

Gramoxone

This is 1–1', dimethyl–4–4–bipyridenium dimethyl sulphate. It is a contact weedicide effective against all weeds.

Heptachlor

1,4,5,6,7,8,8–heptachloro–3a 4.7.7a–tetrahydro–4,7, methano indene; a good chlorinated hydrocarbon insecticide for the control of termites; usual dilution is 0.05 per cent or 1 l 20 EC in 400 l of water. Poisonous and hence to be handled with care.

Kelthane

This is 4,4'–dichloro–*alpha*–trichloromethylbenzhydrol, used for the control of various species of mites.

Lebaycid

This is O,O-dimethyl O-[3-methyl-4-(methyl thio) phenyl] phosphorothioate, an insecticide used for the control of leaf hoppers and bugs.

Lime

Used for painting stem of plants exposed to sun to prevent sun-scorch; better in effect than china clay; applied in November-January every year till canopy shades the stem; quicklime should be well burnt; this is slaked by adding water, diluted with addition of sticking agent and used for white-washing.

Mahathotex wax

A petroleum product used as a panel dressing compound. The product is yellowish and found to be good for regeneration of bark on tapping panel. It is also found to be good for treatment of wounded and cut surfaces of rubber trees. Mahathotex wax with Thiride is found to be good for treatment of pink disease.

Malathion

O,O-dimethyl S-(1,2-dicarbethoxyethyl) phosphorodithioate, an organo phosphorus insecticide less toxic to human beings. Safe and useful for controlling scales and mealy bugs. Dilution recommended for use ranges from 0.04-0.08 per cent to be sprayed at weekly intervals.

Metaldehyde (meta polymer of acetaldehyde)

This is used for the control of slugs and snails. Meta bait is prepared by mixing metadex, cement, lime and wheat bran (rice bran) in the ratio 2:3:5:16 by weight and the mixture made into a thick paste by adding water and made up into small pellets for broadcasting. Meta may be mixed with tapioca flour and cement to make a paste and painted at the base of the plants. Spraying a one day old suspension of 0.05-0.10 per cent meta in water in the ground area frequented by slugs and snails is very effective.

Oil based copper oxychloride (paste form)

This is copper oxychloride in a paste form dispersible in spray oil, containing 40 per cent metallic copper. It could be used against

abnormal leaf fall disease as a protective spray at the rate of 6.2 l in 31–37 l of oil per ha. It is marketed in different trade names such as Oleocop and Fycol 8.

Oil dispersible copper oxychloride (powder form)

Copper oxychloride in powder form dispersible in spray oil, containing 56 per cent metallic copper. It is sold under different trade names such as Chlorocop 56 and Fycop 56. It could be used for the control of abnormal leaf fall disease as a protective spray at the rate of 8 kg in 37–42 l of oil per ha.

Panel wax

A petroleum compound used for bark regeneration on the tapping panel and also for any other type of wound–dressing on rubber. Since this material is not black in colour, white-washing of the panel wax-applied surface is not necessary. This product is also used with thiride for treatment of pink disease.

Pentachloronitrobenzene (PCNB)

It is a soil fungicide used against root diseases.

Phytar 560

10 per cent cacodylic acid (hydroxydimethyl arsane oxide) used as a silvicide (herbicide).

Picloram

4–Amino–3,5–6–trichloropicolinic acid. It is a weedicide effective against deep-rooted weeds and woody plants.

Polythene or alkathene sheets and bags

Fixed as cover over the tapping panel as a rainguard; useful for despatch of budwood etc. Small bags are useful for raising

seedlings. Strips 18 mm wide can be used in budding in place of wax cloth; black polythene sheets are useful for covering seed beds.

Prometryn

2,4–bis (isopropylamino) – 6–methyl thio–S–triazine. It is a weedicide used for the control of most annual grasses and broad leaved weeds.

Rodafarin

A coumarin derivative for the control of rodents. Repeated feeding is required for causing death. No bait shyness is developed.

Rubber kote

A petroleum product used as a panel dressing material. It has been used for regeneration of bark in several estates. Apply white–wash over rubber kote-treated surface during summer months.

Sandovit

It is an adhesive used at the rate of 40 g in 200 l of Bordeaux mixture.

Seradix B

It is a formulation containing indol butyric acid and is used as a rooting hormone.

Sevin

A carbamate insecticide with contact and stomach poison effect. Sold as 50 per cent wettable powder; sprayed at 0.05 per cent concentration for the control of gallery making caterpillars.

Simazine

2–chloro–4,6–bis(ethyl amino)–S–triazine. It is a weedicide which is effective against most annual grasses and broad leaved weeds. At higher doses, it is used for non-selective weed control.

Snail kill

This contains metaldehyde in the form of granules to be broadcast in the field for the control of snails and slugs.

Sodium sulphite

An anticoagulant used as 0.05 per cent on latex. Excess retards drying of sheets and leads to tackiness on the surface of sheet.

Sulphur

A fungicide used for the control of powdery mildew. Finer the particles of the powder, better the fungicidal effect. Particles passing through 325 mesh are satisfactory; should be dried and should not get lumpy; a mixture of 70 per cent sulphur and 30 per cent talc is equally effective in controlling powdery mildew. Useful for the control of mites also.

Taffapon

(See Dalapon).

Teepol

It is a sticker and spreader used at the rate of 100 ml in 200 l of spray volume (Bordeaux mixture).

Temik 10 G

2–methyl–2(methylthio) propionaldehyde 0– (methylcarbamoyl) oxime.

A carbamate systemic insecticide sold as 10 per cent granules useful for the control of slugs and snails.

Tenac

It is an adhesive used at the rate of 100 ml in 200 l of Bordeaux mixture.

Thiride (wet)

This is tetramethylthiuram disulfide, useful for treating pink disease at a concentration of 2000 ppm incorporated in a petroleum compound like Treseal or Mahathotex wax. One kg of the petroleum compound is heated to liquid stage (90°C), cooled to 40°C and 2.5 g of thiride added before solidifying, stirring the mixture vigorously to produce a homogenous suspension. The mixture is then allowed to cool before applying thinly on affected plants. The mixture may also be applied up to 30 cm above and below the affected region.

Tillex

An organo–mercurial fungicide – ethoxyethyl mercury hydroxide —used for the treatment of root and panel diseases.

Triton AE

It is a sticker, spreader and activator used at the rate of 120 ml in 200 l of spray volume (Bordeaux mixture).

Warfarin

3 (acetonyl benzyl) –4–3–(a–hydroxycoumarin): It is a good bait poison for controlling rats and other rodents, repeated feeding is required for death. Does not develop bait shyness.

Water dispersible Copper oxychloride

Copper oxychloride in a paste form dispersible in water containing 40 per cent metallic copper; used against abnormal leaf fall disease

as a protective spray in low rain fall areas at the rate of 6.2 l in 37 l water per ha. It is marketed in different trade names such as Emulsicop and Fycol 8E.

Waxrex treseal

A petroleum product used as a panel dressing compound for regeneration of bark on tapping panel. It is also used as wound dressing compound.

Zinc phosphide

Used for preparation of bait for the control of rats and other rodents. Pellets are prepard by mixing the poison with wax, sugar and flour in the ratio of 10.5:3:2. The wax is melted and other ingredients added to it in small quantities and mixed thoroughly by continuous stirring. A few drops of coconut oil are added and the molten mixture is poured into paper rolls of 0.5 cm diameter with one end plugged and the paper removed after cooling. Paste is prepared by mixing the poison with vaseline, sugar and flour in the ratio of 5:3:1:1. The mixing is done as described above and poured into collapsible tubes. Charge attractive food materials with the paste and cake; extremely poisonous, warranting great care in handling.

Ziram

It is an organic sulphur fungicide containing zinc dimethyl dithiocarbamate. It could be used as spray at the concentration of 0.15–0.25 per cent against leaf spot disease.

2, 4-D acid (2,4–dichlorophenoxy acetic acid)

A hormonal substance used as a selective weed-killer and sold under various proprietory names; effective against dicots and some monocots (water hyacinth); will harm rubber in high concentration; 'n' butyl ester or sodium salt of 2,4–D in 1–2 per cent concentration in coconut oil and Prowax used as yield stimulant on rubber; causes less damage to bark than 2,4,5–T.

2,4,5–T acid (2,4,5-trichlorophenoxy acetic acid)

A hormonal substance used for killing old rubber or other woody plants; the normal butyl ester of 2,4,5–T at a concentration of 1 per cent (acid equivalent) in a mixture of five parts of palm oil or coconut oil, three parts of petrolatum, is used as an yield stimulant.

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