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JOHNSON'S
COMPLETE RUBBER MANUAL

BY

REGINALD J. JOHNSON
Visiting Agent for Tea & Rubber Estates, and
Valuer for the Agricultural & Industrial Credit Corporation of Ceylon.
Author: Johnson's Note Book for Tea Planter's.

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PREFACE

It gives me considerable satisfaction to present this volume which covers all aspects of the Rubber Growing and Manufacturing Industry as a practical guide to Rubber Planters and beginners in particular. I have endeavoured to present the vast amount of knowledge and scientific data on this subject in an interesting, methodical and organised form taking the reader from the point where land is cleared to the maintenance of the full grown rubber tree, through manufacture to the process of vulcanisation which precedes the manufacture of rubber articles of everyday use.

The book will be found to be of immense value and paramount importance as a work of reference at a time when most of the original stand of Rubber is drawing to the end of its useful life and when vast replanting schemes are being undertaken in all rubber growing countries as it embodies almost all the advances made in the industry during the past quarter century through scientific research and practical experience.

The efficient management of a Rubber Estate today requires the command of specialised knowledge at one's finger-tips and as such I commend this work which is almost encyclopædic in conception and execution to all Estate Managers and their Assistants who will find their tasks lightened and made the more interesting by its study and constant use.

R. J. Johnson

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(*Frontispiece*)

A grand old Parent of the Rubber Plantation Industry.

One of the very few remaining trees in the East grown as an original seedling imported from Kew Gardens, still to be seen in its 70th year at Heneratgoda, Ceylon.

CHAPTER I.

INTRODUCTION

THE REMARKABLE STORY OF RUBBER

RUBBER is one of the most wonderful materials in the world and it has played a vital part in the rapid advancement of our modern civilization and science. Without it Motor Cars, Aeroplanes and most of the every day necessities in which rubber plays an important part could not have been developed to their present day state of perfection.

It may be that a wood boring beetle did the world a good turn when it began to attack a tree and caused the tree to give out a juice to heal its wounds. This juice which perhaps first astonished man in the wild forests of Mexico and the Amazon was effused to heal the wounds in the bark of a tree caused by the wood boring beetle and protected the tree by becoming solid.

The story of Rubber before the first Europeans went into the Amazons is lost in the mists of time. Probably the first men from the West to be astonished by the sight of rubber in use were the crew of Columbus, who in the late 15th century found the natives of Hayti playing with solid balls which bounced up into the air. They were made from the coagulated juice of a tree. In 1731 the Paris Academy sent La Condamine on a scientific expedition to the equator and he sent back samples of a blackish resinous mass called "CAOUTCHOUC" (pronounced *Kowchook* and means unvulcanised rubber) and reported that the natives of Peru and Brazil covered linen with the material and wore rubbered shoes.

It was not until the middle of the 18th century that people began to pay much attention to this remarkable stuff which was working wonders among these natives of America—the "Red Indians" as their discoverers imagined them to be, so that they named this remarkable material "*India Rubber*" after them.

Certainly, in the meantime, rubber had found a use and one to which children still put it to this day, for Dr. Priestly mentioned in 1770 that it was useful for *rubbing* lead pencil marks off paper and that a little cube of it about ½" square could be got for 3 shillings! Even at this price artists were glad to have it, but that was practically the only use then known for it. It was not until 20 years later, in 1791 that the first attempts were made to use rubber in industry. Then Samuel Peel invented a process for covering cloth with rubber dissolved in turpentine. For waterproofing garments it was smelly and sticky, but the idea led to attempts by other people and in 1823 Charles Macintosh, a thoughtful Scotsman, made the first satisfactory waterproof coats called 'mackintoshes' after his name.

Thus began one branch of a very big industry which started to develop after 1836 when Thomas Hancock of London found that caoutchouc cut into small strips and kneaded under the influence of heat, became plastic and could be cut into any desired shape.

Now the natural rubber was very sensitive to changes of temperature. It became stiff and hard when it was cold, and soft and sticky when hot so that a waterproof which was stiff in cold weather and sticky on a damp warm day, or beneath the sun's rays, was exceedingly uncomfortable.

Inventors were still hard at work and seeking to overcome this when Charles Goodyear in America and Thos. Hancock in England made almost at the same time, a discovery which may be looked back upon as the greatest step in the development of the rubber industry. This was the notable discovery about 1840 of *Vulcanisation*—the discovery that by heating powdered sulphur with soft rubber, the rubber lost its sticky character and became elastic, pliable and pleasant to touch over a wide range of temperature. Goodyear had been working at his discovery for years, suffering bitter poverty and the jeers of his fellow men, but he ultimately conquered.

While others then proceeded to new discoveries by varying his method, Goodyear found that by adding more sulphur than he had first used, and heating the mixture at a higher temperature for some hours he could produce a hard substance like ebony, and so we got *vulcanite*, from which many useful things such as gramaphone records, combs, pipe stems and similar articles are made. It was this newly treated rubber which made cycling possible. The rubber tyre gave the "bone shakers" as the old bicycles & velocepedes were then known a new form, new life and new dignity. But the first rubber tyres were small and solid. Motor Cars as we know them today could never have been run at high speed with tyres of this sort.

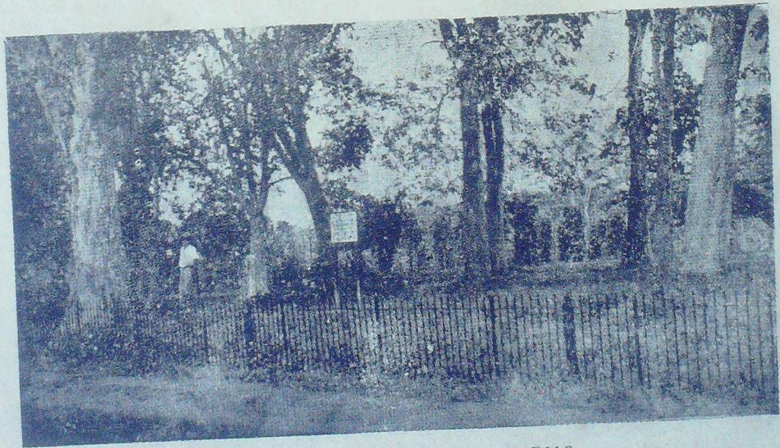
In 1888, Mr. J. B. Dunlop, a Scottish veterinary surgeon in Belfast thought out and produced the first practical pneumatic tyre for his bicycle. The invention of Mr. Dunlop was taken up by others all over the world, and the new discoveries stepped up the demand for rubber which has now become a major crop of the world and its cultivation on scientific lines was undertaken in almost all tropical and sub tropical countries. Men soon learned to value the rubber tree. Once when the American native wanted rubber, he gashed the tree with a hatchet. He got plenty of rubber no doubt, but insects and fungus pests entered the wound and the tree died. Now trees are tapped on scientific lines with special knives which make a cut just deep enough for latex to flow out. Cutting is started well up the tree and is made lower week by week so that when the lowest cut has been made those at the top have healed and can be opened again.

The species of the rubber tree introduced into the East and South America is known as the *Hevea Brasiliensis*, and the circumstances connected with its introduction are indeed most interesting. According to the official record, Hevea rubber was introduced into the East by the Indian Government at the advice of Sir Joseph Hooker, who was then the Director of Royal Gardens, Kew. For some time prior to 1876, Sir Joseph Hooker had been endeavouring to obtain viable seeds of

Hevea Brasiliensis from the Amazon Valley, but no success was met with until the great botanist, Mr. H. A. Wickham was commissioned by the India Office to supply the seeds.

Mr. Wickham collected thousands of seeds in Brazil, but the authorities of that country were naturally jealous of their industry and would not let the seeds out of the country to start a rival industry. Mr. Wickham fortunately found a newly built ship without a cargo at the mouth of the Amazon in 1876, and pledging the credit of the Indian Government to charter the ship, got his seeds secretly on board, spread them out on crates in the hold and managed to get the ship cleared before the Brazilian Government could know anything about it.

A great number of the seeds safely survived the long journey to Kew Gardens. The orchid and propagating houses at Kew had been specially prepared for their reception, and the seeds were planted. They throve so well that a fortnight afterwards, the glass houses afforded a pretty sight—tier upon tier of young Hevea plants, over 7000 of them! The young plants were shipped off to India, Ceylon and Malaya and so today we have our rubber plantations with millions of trees in them.



Veteran Rubber Trees at Kuala Kangsar, F.M.S.,
grown from the first seeds obtained from Wickham plants.

CHAPTER II

NEW CLEARING WORKS

Virgin forests afford the best land for opening up because any soil which produces rich jungle vegetation will generally produce also the best cultivated crops. The vast majority of rubber plantations in India, Malaya and Ceylon are situated on land which once carried almost impenetrable tropical forests. Elevation is a limiting factor in the selection of suitable land. While Rubber will flourish in the wet zones from sea level to 2000 feet, the growth near this upper limit is not as rapid or the yield so satisfactory as on elevations below 1500 feet.

Soil. This subject will be discussed in closer detail and more comprehensively in a later chapter and it will suffice here to say that a planter will not go far wrong in his selection of land if he lays it down as his first consideration that the land must carry good jungle. Next he should examine the soil with regard to the following points:-

Colour. A dark coloured surface soil usually means a good supply of organic matter or humus, and a dark brown or reddish brown soil, if it be also of good depth, may as a rule be depended upon to prove a satisfactory investment.

Texture. A good idea of the texture of a soil can be obtained by wetting a few small lumps and kneading them between the fingers to a dough-like consistency. The difference between heavy clays and sands is then noticeable and gives an idea of the ease or difficulty there will be in preventing the formation of a hard surface during dry weather. The best soil is one which can be worked up into a fairly stiff dough but which does not become extremely sticky in the process.

Sub-soil. The nature of the sub-soil is also a matter to be considered. A soil is not necessarily satisfactory throughout because the surface appears loamy and dark and rich in colour;

any soil which has been under natural vegetation for some time will accumulate a surface layer of dark coloured, easily worked soil due to the constant decay of the vegetable matter, while below it may remain hard and intractable. To find out the nature of the sub-soil, it must be examined, and to do this holes may be dug here and there and the character of the lower layers noted.

Rock and semi-hard rock. A soil which lies upon rock, semi-hard rock or cabook is better avoided unless the planter is prepared to use dynamite when holing and throughout the later operations as well, though an ordinary cabooky soil responds well to cultivation.

Clay. If the sub-soil proves to be a heavy clay, it must be remembered that the root growth will be slow, and good drainage is absolutely essential. Deep digging or forking will also be required to prevent surface wash.

Sand. A sandy sub-soil is generally not encountered unless the surface soil is also sandy. If it does occur, it is advisable to avoid such land, as it will certainly suffer severely during dry weather and the improvement of such a soil is extremely difficult.

Soil Analysis. This is of much less importance than is ordinarily supposed, but if any suspicion exists as to the presence of limestone it would certainly be advisable to have the soil tested for lime, magnesium or acidity. The presence of excess lime in the soil is a disadvantage in rubber cultivation, and it is advisable to seek expert or scientific opinion on such land before deciding to open.

Lay of Land. Although, other conditions being favourable, flat land is necessarily more easily worked and generally more productive, it is by no means impossible to grow good rubber upon steep or rocky hill sides. Hilly jungle land usually shows a fairly good soil, though it must not be forgotten that the expenses of opening, cost of subsequent working and fall in yield increase with altitude. A rocky hill side is often fertile, partly because it has good natural drainage and partly because the pockets of soil

Light Jungle

Dense Jungle

between the boulders are rich in plant food derived from the decomposition of the rock and the accumulation of plant debris. Slab rock near the surface is of course objectionable, because it means a shallow soil which suffers quickly from drought. In general the soil on hill sides is shallower than that on flat land or in hollows. Land subject to severe winds should also be avoided.

Swampy Land is not likely to prove satisfactory unless there are facilities for thorough drainage, and flooded areas on the banks of rivers, though rich in alluvial soil, should be opened with caution, owing to the risk of bark rot and other diseases later on. Flood land where sand has silted up is better than that on which alluvial soil only has collected as the evaporation of moisture is more rapid. In any case the usual duration of the floods must be taken into consideration.

Fern Land. Fern land and land where impoverishing root crops such as Tapioca have already been grown should be avoided. Bamboo is usually a sign of a fertile soil.

Accessibility. The best favoured plantation is that which not only provides facilities for opening suitable roads on the property itself, but has good means of communication in the way of outlet roads, a railway in its vicinity or water transport.

Labour. Much of the ultimate success of a clearing will depend upon its facilities for obtaining labour, and healthy surroundings will be all important for the maintenance of a prosperous and contented labour force.

SURVEY

An accurate plan is, undoubtedly, one of the most valuable contributors towards the economical working of an estate, and the following description of the various classes of surveys will be useful.

When land is bought a plan of it should always accompany the deed of purchase, and if all the outer boundaries of the block are plain features such as streams and roads, the purchaser will experience no difficulty in going round them in order to satisfy himself that he is actually in possession of all the land comprised in the plan. It is generally the case, however, that portions of the outer boundaries, and sometimes the whole of them, traverse forest or scrub,and if these boundaries have not been thoroughly cleared and handed over in that condition to the purchaser, it should be his first duty with the object of avoiding future litigation —to have them "defined".

To do this the surveyor has first of all to make his original survey, in which he picks up as many of the natural features such as junctions of streams, portions of roads, landmarks, blazed trees, etc., as are shown on the title plan. This is plotted on the standard scale of 4 chains to an inch, and after the title plan has been enlarged or reduced, as the case may require, to the same scale, and a tracing has been made of it, this tracing is laid down over the original survey plan when the correct position of the boundary can be found with respect to the pickets and points picked up in the original survey. The bearings and distance of the various lines forming the boundary can then be taken off the plan, and the surveyor returns to the land and cuts them out, or "defines" them. The best way to mark a boundary after it has been defined is to cut a drain. It is absolutely false economy to attempt to mark it *permanently* in any other manner, for although a surveyor can generally pick up an old blazed boundary through forest, it is impossible for the layman to do so.

The cost of boundary defining depends chiefly on the nature of ground traversed and the amount of surveying required to fix the title plan. At the same time that the boundaries are being defined it is an economical plan to have the land cut up into suitable blocks for opening, but if this is not done the surveyor must be called in to survey the clearing as soon as it has been burnt.

The next class of survey to be dealt with is the fully detailed one, which is made after the estate has been opened out. This allows for the survey of all roads, buildings, field boundaries, main ravines, timber belts etc., and the splitting up of the various fields into convenient working blocks of about 10 acres each by natural boundaries such as roads, belts and streams. To make a fully detailed survey plan absolutely complete the title plans should be enlarged and fitted on, in order that encroachments by, or on, the estate can be located and, if necessary, defined, and also to ascertain the position and extent of any uncultivated lands belonging to the estate.

Road Traces. The fees for these vary according to the length of road and the nature of the country traversed. The plans furnished are:-

(a) Longitudinal section, in sheets of one mile each, giving gradients and the cutting or filling in at each 100 foot peg to attain those gradients.

(b) A survey plan showing the line of the trace (this is always inserted on the same sheet as the Longitudinal section, and above it).

(c) A plan, or plans, giving sections, spans, etc., of all the main bridges.

Tramways. The cost of a tramway trace is governed by the degree of accuracy and the nature of country traversed. Whether or not a surveyor is called in to prepare a section of the tramway beforehand is a matter which generally rests with the Engineers who are to erect it, but it is absolutely imperative that the original line should be put in by a careful man, as the least deviation from the straight — due to careless work or a badly adjusted theodolite—leads to perpetual wear on the ropes and consequent expense and loss of power.

CHAPTER III.

FELLING CLEARING & OPENING OF LAND

Felling. Having selected the land and determined its nature, clearing operations may be commenced. There are two methods.-

1. To fell, so as to uproot the stumps. First, all small trees and wild growth are cut down and then the larger trees are felled. The roots round the tree are cut through and the weight of the top boughs brings the tree down with a crash completely uprooting the stump. In the case of large round topped trees, the branches on one side can be lopped and the tree be thus made to fall in any desired direction. Most forest trees are surface rooters but some are buttressed and are difficult to cut low. This method of felling and uprooting stumps at the same time is expensive, but is cheaper than clearing out the stumps afterwards by hand. All branches should be cut directly the tree is felled.

2. The more common method adopted is to fell, leaving the stumps standing, but in this case care must be taken to cut the trunk as close to the ground as possible, say, not more than 3 to 4 ft especially in the case of heavy timber. All trees should be made to fall in one direction. Where facilities are available, modern machinery or even elephants are used for this work which is definitely quicker, cleaner and far more cheap in the long run. Wind belts of jungle should always be left upon exposed ridges.

Burning off. At least a month should be allowed after the whole clearing has been felled to ensure a successful burn. The importance of a good clean burn off at the commencement is obvious, and means a large saving in clearing the land later on and also in weeding. Burning must always take place when the weather is hot and dry. Notice of the date should be given to the owners of any neighbouring properties or buildings so that all due precautions can be taken by them. If this is attended to no

Top. Felling Light Jungle

Bottom. New Clearing. Main drainage outlined in foreground, and felled trees awaiting burning in the background.

subsequent claim for damage can be made. Bamboo torches or other combustible material is necessary for firing. The burn off should take place about mid day when the sun is hot. The direction of the wind should be watched and fire should be set at points about 25 feet apart.

Clearing. After the fire has completely burnt out and the ground is cool, clearing may be commenced. All unburnt twigs and branches should be piled into regular heaps, placing a few heavy logs over the heaps to keep the small stuff together, and these can be again burnt off. The axe coolies go over the cleared ground and lop all side branches up to about 15 inches in girth and these are again heaped and burnt.

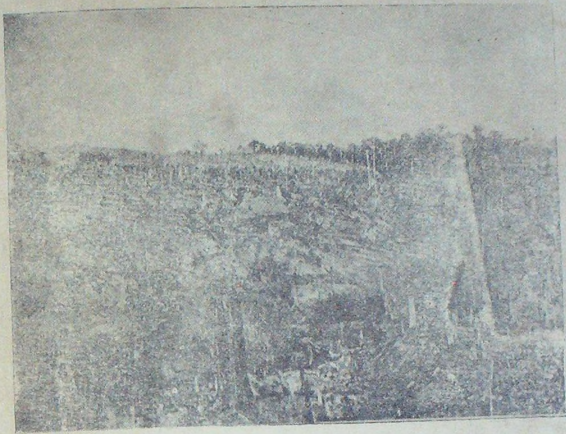
Timber that can be used for buildings, bridges etc., should be removed and stacked in a convenient place for sawing and seasoning—other wood suitable for props, fence posts and chests can be put aside for immediate use, but the great thing is to clear the land as thoroughly as possible before planting operations are commenced. Generally timber with the exception of a few varieties deteriorates rapidly when felled and left in the open, and so should be sawn up as soon as possible and put under cover.

Preparation for Planting. There can be no other opinion than that ideally all land requried for planting should be perfectly clear of timber of every description. After felling and burning, under ordinary conditions a certain amount of clearing is effected, but in actual practice this amounts to comparatively little. Big logs and stumps are left because the cost of clean clearing is judged to be prohibitive and uneconomic. Surface timber is gradually to be tackled. The objection to this procedure is really not strong, but unfortunately an important point is generally overlooked.

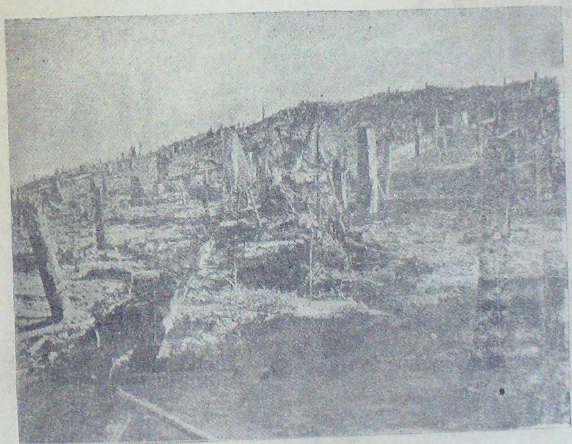
Granted that most of the dreaded diseases travel beneath the surface of the ground by means of buried timber, it is plain that, as far as stumps are concerned, the chief source of danger lies in the existence of the roots. If these were carefully exposed and removed, the isolated stumps would then not be such potential infection points. It follows from this argument that the importance of removing buried timber cannot be too strongly insisted upon. It is not uncommon to find that some years after the opening of an estate, and after surface timber has been removed, a large number of trees are affected with *Fomes lignosus* (formerly known as *Fomes semitostus*). Such cases are directly attributable to the existence of buried timber, and no local treatment will be successful unless the whole of the area is dug over carefully and all pieces of timber removed. The counsel of perfection would be to remove them at once in order to avoid all risk of Fomes and other fungoid diseases, but this is entirely a question of expense.

T. Petch in his book "The Physiology and Diseases of Hevea Brasiliensis" states: "The decay of stumps is brought about by the agency of fungi, the spores of which alight on the exposed wood and germinate there. The fungus feeds unseen on the tissues of the stump and in due course constructs fructifications on the exterior of it. The majority of these fungi can only live on dead tissues, but some are parasites and it is the latter that cause trouble. All the root diseases of Hevea have been found to originate on a neighbouring stump and there is no known root disease of Hevea which attacks the plant directly. Each stump, therefore, affords a centre of disease. Unfortunately most of the jungle trees are hard wood trees and therefore they are not likely to decay completely under 6 years. The effect of root disease is soon evident on a young tree, but it might spread to a considerable distance from an old tree before its effect on that tree was observable."

Roads and Transport. The next step will be the tracing and cutting of roads. This must be done with the main purpose of gaining easy accessibility to all parts of the land. Well planned roads for vehicular traffic will greatly save labour and facilitate supervision of all works. Gradients should be carefully chosen so that there will be no undue strain on haulage vehicles or draught animals, and wherever possible slopes should not be made steeper than 1 in 20 or 1 in 15.



Young Planted Area showing heavy original jungle in the background



Young Clearing with Timber showing Planted "rubber stump" in foreground

Young Clearing about 3 years planted on virgin soil.
Original Jungle timber slowly rotting.

With regard to field roads, a gradient of 1 in 15 or even less is preferable as an easier gradient will not get up a hill quickly enough. At the same time, steep gradients under 1 in 10 should be avoided as they make the roads easily liable to be washed away during heavy rains. Field roads should be cut to facilitate proper working and supervision of work in the fields. The paths should be made, where possible to run diagonally across each other whereby the land is divided into quadrilateral blocks. This system gives easy accessibility. It is good practice to cut the roads with a slope towards the bank so that the risk of wash is minimised because the channel formed by the bank and the road provides an easy course for the water to flow. Inadequacy of side drains is another cause from which roads suffer much damage. If the drains are not capable of carrying away the flood waters during heavy down pours then the water will rush down along the roads causing extensive damage. Tracing of roads should be made in a manner which will entail the least amount of building up or blasting. Cutting is by far the cheapest method and should be resorted to as much as possible.

General Principles of Road Construction. It is essential that roads be put in before drains, in order to prevent the road being crossed or debouched upon by any drain except a leading one. It is also important that the system of roading a property should be well considered before commencing to trace, and one road at least must be considered as a main road, with the object of converting ultimately into a cart road. The direction of this road must therefore be first considered, and care should be taken to see that it will connect up well with any outlet roads leading to a main Government road, or with any other important point of communication. Having decided this, the other roads will be merely subsidiary ones required for inspection purposes of the area to be developed.

Cart Roads. As the work of building a cart road is a heavy one, as good a lay of land as possible should be selected avoiding heavy rocky portions, large water sheds, etc. It will depend a good deal upon the nature of the soil as to whether the road will have to be metalled or whether it can be kept as a gravel road. Of course the nature of the traffic that will ultimately use it will be a determinating factor. Having decided upon the general scheme of road to be adopted, the gradient must next be determined. It can be taken that the gradient of a cart road should in no case exceed 1 in 17, and 1 in 30 is about the average for practical purposes on hilly or undulating land. It must, at the same time be remembered that the object in view is to reach a given point by the quickest route so that too much must not be sacrificed to the trace.

Road Tracing. The tracing of a road may be done with the aid of a dumpy-level though an ordinary road tracer will, as a rule meet the purpose. In the construction of a cart road of any extent it will be found advisable to obtain the services of a surveyor to make the trace, measure up the earth cutting, culverts, etc., and subsequently to supervise the actual construction. Diagrams are here attached showing a section of a cart road traced and surveyed. As the terms "surface height from datum", and "formation level" mentioned on the diagrams are not readily understood, the following definitions will be useful.

> **Surface Height from Datum.** "Datum" is an imaginary line parallel with the horizon. Its object is to simplify all calculations in levelling operations by referring them to one fixed standard. Some well-known and clearly defined mark is selected for the purpose and from this standard all heights are relatively adjusted.
>
> **Formation Level.** This is the actual level to which the road is constructed, whether by cutting or filling in as the case may be. In cases of cutting the formation level is less than the surface height from datum by the actual amount cut and vice versa with filling in.

Testing the Tracer. In order to see that the tracer is in good order it should be tested on a level bit of ground. The cross bar on the aperture of the tracer should exactly agree with that on the sight pole on level ground. A factory floor or tennis court may be used for the purpose and a shot be taken at about 25 ft. distance.

How to use the Tracer. It may be assumed that the reader understands the general use of a road tracer, but for those not conversant with it, it is necessary to state that after deciding upon the gradient required and having fixed the weight at the corresponding figure on the right hand side of the instrument, the screw must be firmly adjusted and the pole held absolutely upright. If the weight is inclined too much to one side or the other the reading will not be correct. The cooly holding the sight pole must be told to raise or lower it as the case may be, but any inclination to adjust the tracer to the sight pole must be avoided.

Rough Trace. To obtain the effect of a general scheme a flying trace had better first be taken. This is done by placing poles 5ft. high with a white piece of paper or rag attached, at whatever distances the shots are taken along the proposed route and a very good idea of the trace can then be obtained by observing the whole scheme from a distance. Shots can be taken at a distance of 70 to 100 feet. The tracer can be adjusted so as to work up or down hill or on a level. At each point where a shot has been taken and found correct a peg is driven into the ground.

Detailed Trace. Having satisfied oneself as to the general correctness of the trace, it must be worked out in detail at intervals of 10 ft., and a couple of split pegs placed at each point crosswise. At this point drive in also a stout level peg at least 6 to 9 inches long, flush with the ground. These "level" pegs must be absolutely true to the tracer and on no account should they be altered or removed afterwards. The cooly will naturally be inclined to raise the level of the road and thus diminish the cutting task when the road is actually being constructed. In line with the "level peg" another one should be placed at right angles at the desired distance to denote the proposed width of the road, these pegs forming the inner edge of the road.

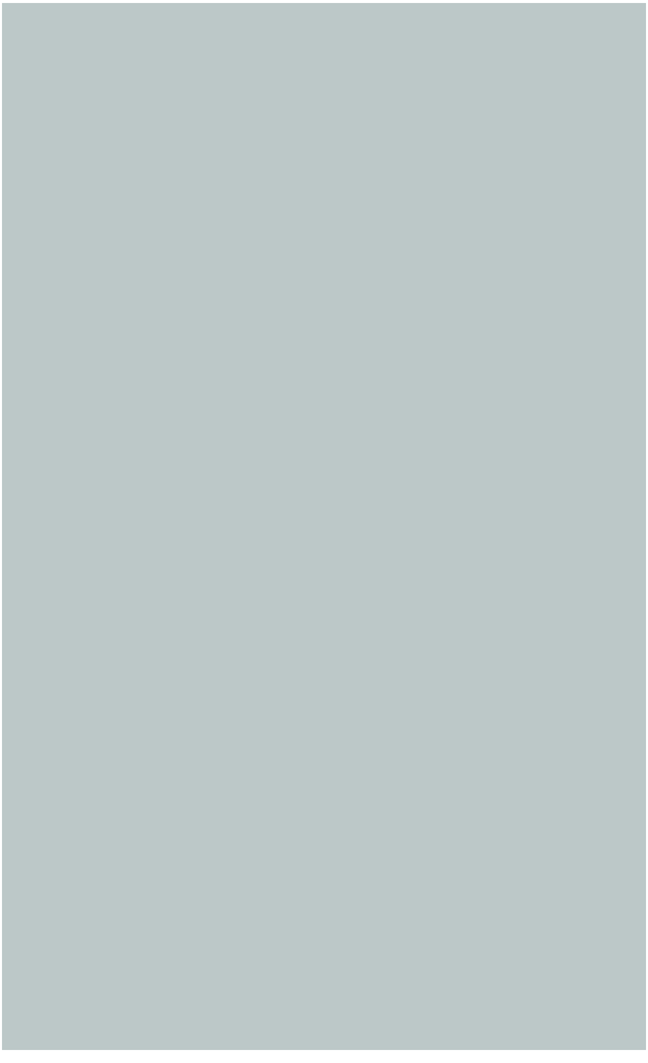
In tracing a road, care should be taken to avoid, if possible any rise and fall in the line of direction; the fall should be continuous though not necessarily in one gradient. When altering the gradient it should always be at a cross drain or natural ravine, otherwise it will be impossible for the side drain to carry off water. Roads should always meet or cross at a cross drain for a similar reason.

In laying out a zig-zag road care should be taken to construct a level stretch at each bend so that carts and vehicles can pull their loads on to the level portion before turning. These bends may be extended still further as sidings in order to accommodate passing traffic. The width of the road at the bends should be increased by 50 per cent. It may be found possible later on to do away with the zig-zag by carrying the road further when the bend will be turned into a junction. Several roads connecting together should always meet at a saddle of the hill, this being by nature the most favourable junction. A cart road should be barrelled at the centre, and the sides shaped to a slope, with a fall of 4 inches from the centre. This will be equivalent in a 12 ft. road to a fall of 1 in 18 on the tracer from a peg in the centre to the one at the side.

This camber or crossfall should be obtained by slightly increasing the thickness of the bottoming and metal at the centre of the road, and not by cutting the earth formation to the fall. The best method is to cut the road level from side to side for its full width at formation level and then excavate the space in the centre for the bottoming. This leaves a solid berm on either side which keeps up the edge of the bottoming and prevents it from spreading. These berms can be trimmed off to the desired level after the consolidation of metal has been completed.

The width of the roadway when the ground allows it, should be increased as under:—

(a) Where the slope of the natural ground from the roadway formation downwards is more than 1½ horizontal to 1 vertical the width of the roadway should be 16 ft. in the solid.



Young Clearing with Timber
Note the young rubber plants in the foreground

(b) In double cutting the width of roadway, including side drains, should be 18 ft.

(c) On embankments the width at top overall should be 16 ft.

(d) At culverts the width between parapets should be 12 ft.

Excavation or Earth Work. All timber along the site must first be removed by a special gang. The actual cutting should be done in section either by contract or by day work. Sides of cuttings should have a slope of not less than 60 deg. towards the road and all cut earth should be shovelled well away on the lower side. When cliffs of a rock formation have to be negotiated it is useful to note the direction of the strata. Should the strata be vertical the bank must be cut well back or it will break away and come down, but if the strata is almost horizontal the bank will be fairly firm and not so much slope will be required. To avoid large rocks it is quite feasible to alter the trace slightly without the difference being noticeable to eye. If soft rock is encountered it is better to cut into it than to build round it, but with hard rock a wall can often be built as cheaply as the cost of blasting. Before doing any blasting all rock that it is possible to remove with crow-bars should be rolled out of the way. The best way to pay for rock blasting is to give out the work to contractors at cube rates (1 cube=100 cubic feet). A section of the road should be taken in hand, and the superintendent accompanied by the contractor should measure up all rock in that section. It is impossible to gauge the exact size of an irregular rock but it is not difficult to get within 10 per cent. of it. If the work is done on contract the contractor should supply all blasting materials, jumpers, etc., and should sharpen chisels, and also clear away the rock. The advantages of this method of payment are that there is no theft or waste of explosives and no boring except where necessary.

Embankments. The slopes of embankments should not be steeper than 1½ horizontal to 1 vertical.

Before commencing to tip an embankment the turf should be removed and the full width of the bottom of the embankment from the toe of one slope to the toe of the other pegged out. A shallow trench should then be cut along the line of the toes of the embankment to hold the earth and prevent sliding. If an embankment has to be tipped on sloping ground it is well to cut a series of steps in the existing ground to give a key to the newly tipped earth. As far as possible embankments should be formed in horizontal layers and the sides should be kept higher than the centre in order to retain moisture which assists settlement. If the embankment is formed outwards from the centre, the centre becomes trodden down by the coolies and the sides are loose and uneven settlement results. An embankment should always be formed to a slightly higher level than finally desired so as to allow for settlement.

Double Cuttings should be avoided if possible. They are difficult to drain and induce more wear and tear than a single cutting. With a single cutting the earth is deposited on the outer edge of the road, so widening it and providing more space for stacking metal. In any case depot sites for piling metal should be provided at intervals in order to avoid obstructions to traffic. On a road leading to a bungalow or factory white washed stones placed near culverts or steep banks are an aid in the dark. All blind corners, especially those at cross roads, should be rounded off and sharp curves are to be avoided whenever possible.

Wallaby Jack. A Wallaby jack is useful for removing stumps, for log rolling and for general lifting purposes. The Wallaby jack is fitted with a patent automatic gear by which the load on jack is lowered by oscillating the handle; the same in raising, the alteration from raising to lowering or *vice versa* being effected by a thumb piece pivoted on the standard of the jack. To lower turn the thumb piece down—to raise turn it up. To drop the rack when the weight is off, let the jack lean well back, pull it up a little and the pawls will drop out of the notches. The jack should be oiled regularly. There are also several other types of jacks in the market to suit individual needs.

Top: New Clearing showing Holing and Draining operations in progress.
Bottom: New Clearing ready for Planting. Trees felled and burnt but stumps remaining.

Culverts. As far as possible, wooden bridges should be avoided because they are as a rule false economy. Stone culverts are to be preferred as they are more permanent. Culverts can be built either of cut stone or rough stone and should always be made larger than required for the normal flow of water to prevent choking. Their size and dimensions will depend on the class of traffic they are meant to carry. Culverts can be built with dry stone without mortar; with cut stone culverts the stone should be well dressed and the filling up of gaps with small stones should be avoided. The size of stones for the abutments should be as follows:—

Height — 12″
Length — 18″ to 36″
Width — 12″.

Culverts are meant to take drainage along natural channels and not artificial ones, and must not be placed too far away from a change of gradient. Otherwise there is a danger of their silting up. Often a number of small openings are preferable to one large high one, since the latter entails a greater height of embankment, and it is cheaper to build one double 2′ x 2′ culvert han one of say 4′ x 2′. The lower lip of a culvert at its fall beyond the road should be paved with stone to prevent erosion by the force of water. This is generally called an 'apron'. Parapet walls should be built along culverts where there is any fall and side rails should be provided to bridges. It must be noted that bridges should never be situated at bends in streams as the crossing there will be apt to broaden and the force of water at the bend will scour the embankment.

Drains. The main purposes of drains are:—

(i) To carry off superfluous water during rains.

(ii) To prevent soil erosion.

All drains should be therefore cut in such a manner that they will permit the maximum retention of water by the soil and at the same time help to conserve the top soil of the land and prevent its loss by being washed away out of the property. At the same time, drains should be adequate for draining off the excess water during heavy rains. Good deep drains with silt pits, bunds or reverse slopes will pay dividends in the course of time. They are vital for the conservation of the soil on which the entire economy of the land depends.

Leaders. Before commencing excavation of lateral drains, the first step is to establish the natural water courses of the land. These are usually ravines or large natural drains which should be deepened and cleared of obstructions. On the shoulders of a hill where there is no natural drain, leaders should be put in at not more than 90 ft. apart and should be cut 2 feet wide and 1 foot deep. They will soon wash to a greater depth.

Side Drains. The lateral drains should be traced along the contour of the land in very easy gradient of 1 in 80 sloping gently into the leader drains from opposite sides at regular intervals, but they must not meet at the same point in the leader drain; otherwise the double flow of water will increase the width and depth of the leader to enormous proportions. On the question of spacing between the lateral drains, no hard and fast rule can be laid as this will depend on the lie of the land. On flat land the drains could be conveniently spaced 60′ apart; in gently undulating ground between 30′ and 40′ apart; and in steeper terrains a spacing of 20′ will be found to be adequate. Too great a slope will involve too rapid a rush of water and the washing away of soil.

In most of the properties which were opened up more than 50 years ago, drains were originally cut at steeper gradients. But these are being corrected in the present time either by reversing their slopes within the drains or by filling them and cutting new drains of easier gradients. The usual size for side drains in former years was about 18″ x 18″ with silt pits of 2′ depth at intervals of about 30′. The present day, however, favours the trench system where side drains are cut along the contour of the land in easy gradients of about 1 in 80 forming a series of trenches and bunds. The normal dimensions are as follows:—The trenches are 12′ long, a foot wide and 2′ in depth followed by a bund 3′ long and 1½′ in height which is the spill level of the water. This may also be described as the "lock and spill" system and helps to conserve the soil effectively catching most of the top soil which would otherwise find its way into the ravines and be lost. Alternatively, the bottoms of the drains could be provided with a series of steps at 1½′ intervals so as to produce a backward slope between the steps.

When draining is commenced, cutting should take place from the top of each hill and the spoil spread out at least 3′ well *above* the drain. This will obviate not only the filling up of newly cut drains below, but also act as a soil conservation measure in that the soil excavated will eventually find its way only into the drain and the silt pits from which it was excavated and no further and thus remain permanently on the land.

Cleaning Drains. In the course of time, drains become silted up and it will become necessary to have them cleaned out. Care should be taken to distribute such excavated soil *above* the drains from whence it came. If it were thrown below the drains, it defeats the purpose of soil conservation.

Terracing. Where plentiful supplies of stones are available, terraces should be constructed midway above lateral drains as an additional soil conservation measure. The foundation of the terraces should be made with large flat stones. Terraces will adequately serve their purpose if they are 18″ in height and 18″ in width. Again, they should as far as possible follow the contour of the land. In steep areas, terrace construction is far more economical, providing stones are available, than excavation of drains and effectively prevent wash. While terraces are under construction, care should be taken to see that they lean slightly against the slope to ensure strength to withstand the weight of silt which will collect above them in the course of time.

Planting of green manure shrubs such as *Crotalaria anagyroides*, *Tephrosia vogelii*, *Tephrosia candida (Boga medelloa)* and *Indigofera endecaphylla* in close formation about 3′ above all lateral drains and also between drains will provide an admirable system of "live terraces" which will hold the soil and prevent wash.

CHAPTER IV

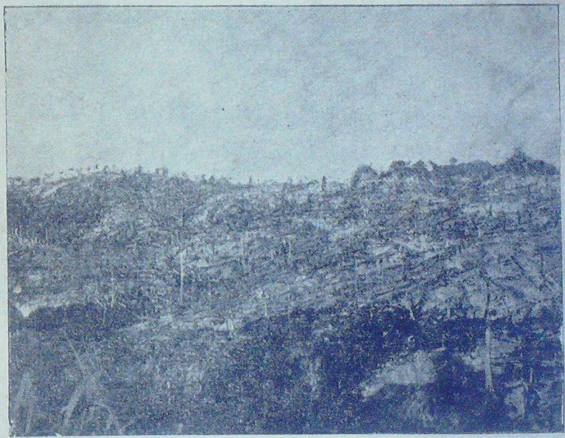
LINING AND HOLING

Lining. As many of the old rubber plantations are still carrying the original stand of rubber, we propose to outline here the lining and holing systems adopted in former years in comparison with modern methods.

The old method of lining was carried out in a manner to ensure a maximum of sun light across the rows. For this purpose the base line was laid out as accurately as possible to run North and South by means of a lining compass. The lining rope was as a rule 350 feet long and carried at regular intervals of 20, 24 or 30 feet according to choice tags or coloured tapes which marked out each offset line. Having marked out the base line, attaching a small red or white flag to the top of each pole, the offset lines were then laid in an East to West direction. Observations with the lining compass was accurately taken to ensure exactness.

The offset rope carried tapes at the decided planting intervals of, say, 20′ and one rope lay always at the point where the offset line leaves the base. The lines were tested from time to time to prevent errors due to the rope shrinking or stretching. This method permitted lining operations to be taken and completed in sections of 350′ x 700′ which were the limits of the base line and offset line ropes. Having pegged out the offset lines, the work for the section was complete and the next section was commenced.

Holing. In order to ensure sufficient space for a good sized stump to be planted in the holes without having to trim the side roots or damage and mutilate the tap root, and also with the main idea of encouraging girth and not height, the holes cut for rubber are usually of substantial and ample dimensions of 2′ x 2′ x 2′. Where



An example of a recently planted area

rocks, large stones or stumps and similar impediments are encountered near the peg, the hole should be definitely moved up or down the line and never to the side. Crooked rows present a distressing sight in later years though trees standing in places closer together are not noticeable and will not present an uneven appearance. The holing programme should follow the lining work closely for pegs left in the ground for too long are apt to get lost and this will cause considerable trouble. On steep land it is advisable to cut the holes about 1′ above the peg and on no account should the peg be removed far from the hole as it will be required again to mark the spot when the hole is filled. Again where holes are dug in steep places, a small drain round the upper part of the hole should be cut to prevent the stump or seedling being damaged by wash. A hole should not be cut within 5 feet of a road or on the edge of a leading or side drain. It only means that the plant will have to be pulled up later on. The earth removed while holing should not be scattered about but be placed at the lower side of the hole so as to get a flat surface by the plant and this will also act as a terrace. The depth measurement should always be taken from the *lower* side on hilly land. To check the correct dimensions in holing a wooden frame of the required size will be found very useful. It is better to allow as long an interval as possible between holing and filling. This will ensure proper aeration of the soil If it is decided to do holing with dynamite, a hole slanting at an angle of 45° must be drilled below each peg. If a hole of 2′ is required, the primary hole drilled for the charge should be of the same depth. Half a dynamite cartridge will be sufficient for each hole. The use of dynamite makes holing not only cheaper and quicker but the growth of the tree is also accelerated due to the thorough loosening action on the soil and the roots of the young plant or stump are able to operate with greater efficiency. Consequently the tree comes into bearing much more rapidly.

Filling Holes. This work may be done either 2 or 3 weeks before or immediately before the actual planting of the stumps or seedlings. It should be borne in mind that correct filling in of the holes is a very important operation and requires very careful and conscientious supervision. For on this work depends the vigorous growth of the plant in its early stages. Indifferent and careless filling will cause the plants to become stunted and poor in growth which of course can never be remedied later. The workers for this task should be provided with earth baskets and small mamotties. The hole should be cleaned out of any gravelly or unsuitable soil, twigs and stones. This should be replaced by all the available top soil which may contain ash and charcoal both of which are beneficial to the plant. Sufficient *surface soil* to fill the hole should be collected from about 5 feet or more away from the hole and after picking out all unsuitable material such as stones, twigs etc., this soil should be used for filling. When the hole has been half filled, the soil should be trampled down and the balance of the hole may be filled in the same way. Great pressure must be avoided and it is an important point that any earth removed from the bottom of the hole should NOT be used for filling in as this will be deficient in humus and plant food. Care should be taken to remove all water in the hole by means of a coconut shell or can if filling is carried out in rainy weather. Finally it should be seen that the plant does not stand in a hollow. The filled in soil should form a slight mound.

CONTOUR PLANTING METHODS

At this stage of our progress it is opportune to examine the present day contour method of lining and holing as adopted in modern times before discussing the final task of planting seedlings or stumps. There are 2 methods and are generally known as (a) the Contour Platform Terrace System and (b) The Contour Trench System both of which have the following ultimate aims.-

1. To conserve soil and plant food and avoid soil erosion.
2. To utilise all potential plant food to the maximum advantage.
3. To keep soil moist.
4. To discourage surface feeding.

Generally under average conditions the depth of the top soil containing valuable plant food in which is found organic matter ready for assimilation and humus is about one foot. Below this approximately 4 feet of subsoil is found, but this depth is often less and occasionally greater. The older planting methods already described with rows running up and down the slope seldom permitted the sub soil to become a useful factor and caused loss of top soil which was accentuated by clean weeding. One foot of soil per acre is equivalent to approximately 43,500 cubic feet and weighs about 80 lbs. per cubic ft. or 1555 tons per acre. Under ordinary planting methods done without sufficient care in relation to the conservation of this valuable asset, most of this 1 ft. layer of top soil containing nature's best and useful plant food is washed away within three to four years of opening a hillside clearing. The average quantity of fertilisers which can be economically applied can never be more than ¼ ton per acre and therefore it does not require much imagination to realise that this enormous loss of top soil cannot be replaced and neither can the original fertility of the soil restored by the addition of ¼ ton fertiliser per acre. From the point of arresting soil erosion both systems are equally effective. We shall describe both methods and consider how a judicious combination of both can be achieved.

The Contour Platform Terrace System. The general idea with this method is to divide the hillside into sections of terraces about 20 feet broad. The holes for the rubber are as near the centre of the terrace as possible and with the point selected for the hole as an imaginary pivot, the top soil on the upper slope is thrown on the top of it. The top soil from the hole was taken out and the sub soil was then removed and thrown forward. The top soil from the hole was then replaced so that it did not come in level with the top of the hole which was afterwards filled with green manure loppings. The general result was that the face of the hill had been completely changed. The steep slope had been replaced by a series of steps, the top surface of each step having a slight rake in the direction opposite to the slope of the hillside. Most of the top soil was thus piled up *under* the sub-soil on the forward side of the terrace. The sub soil was exposed on the surface to the influence of aeration, percolation and earth worms and its plant food possibilities were thus more rapidly exploited. Before commencing any earth shifting on a large scale, careful judgment must be exercised to determine the best width for the terrace so that earth shifting will be as small as possible. Fig. 1 shows the land before earth shifting and Fig. 2 after the operation and gives the reader a clear idea of the transformation. To commence, first lining for holes at the predetermined distances of, say, 15 feet apart and thereafter lining for the width and position of the terrace should be undertaken with careful supervision.

It is very important that all terraces should be sloped backwards into the hillside. The newly formed embankments should be rammed in as lightly as possible to prevent wash. Now it will be seen that instead of stone terracing, draining and silt pitting, energy has been expended in reshaping the face of the hill. Where the fall of the contour occurs in the horizontal plane it is cheaper to make small terraces instead of one big terrace round the hill face. Partition bunds, however, should be left in with every change of level; otherwise erosion will take place.

Now we shall consider as to what happens in say ten years from Fig. 3. Beneath the surface on the forward side was preserved the plant food containing the original top soil. On the surface was the original sub soil in which the potential plant food had been made assimilable for feeding through exposure to the elements. The terrace being sloped backwards, humus, leaf mould and green manure loppings had all been washed backwards and had made a heavy deposit of plant food as shown on the right hand corner of the diagram tending to balance the top soil which was originally thrown to the left side of the hole. Rain water had percolated owing to the maximum water pressure being exercised against the hillside. The resulting action was the satisfactory aeration of the original sub-soil strata on this side rendering it

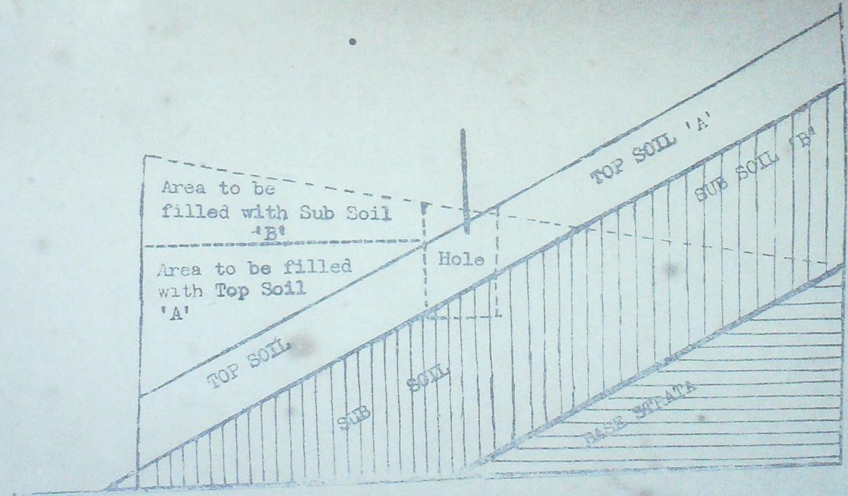


FIG. 1.
Land before earth shifting

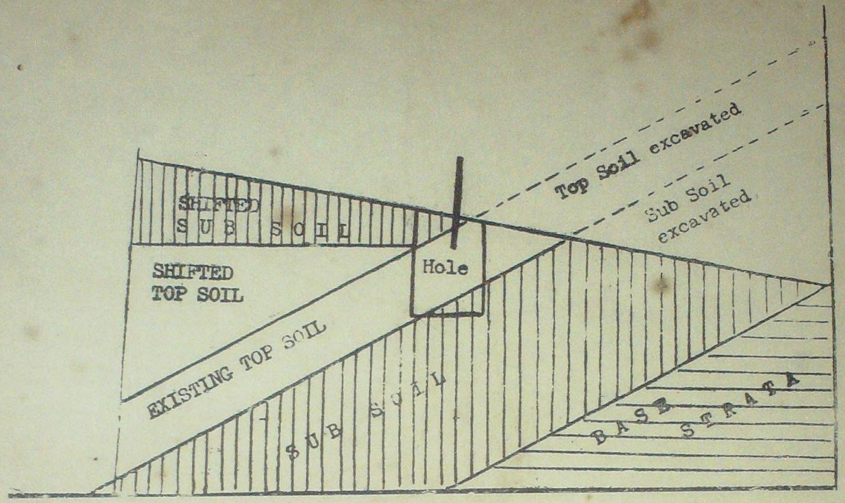


FIG. 2.
Land after earth shifting

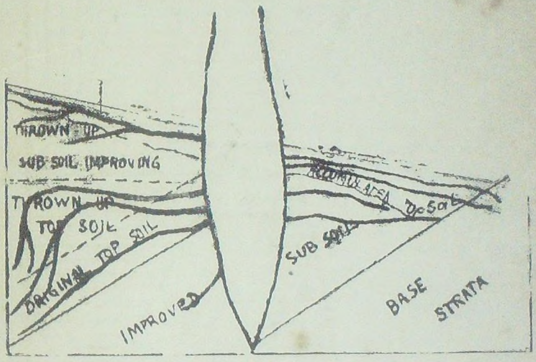


FIG. 3.
See Text on Page 26
Note Accumulated Top Soil on right.

capable of nourishing the tree. The only plant food actually moved by water was always being taken backwards and downwards in the hillside instead of forwards and downwards to be lost.

There are many ways of opening land by this method some of which are expensive involving expenditure of much labour whilst others are economical and quicker all bringing about similar results. Here local experience, careful planning and forethought will secure a satisfactory and high standard of work at a reasonable cost.

The advantage of the system described are many and may be briefly summarised as follows. It makes it impossible for any soil to be washed off the terraces. The filtration of plant food before it reaches the base of the hill will be enormous and counteracted to a great extent by capillary action, and the sub soil is being improved all the time, and however deep the pan base may be, the water will get there by slow percolation, and aerate the sub soil on its way. Leaf mould cannot be washed off and consequently the surface is likely to be always moist under it and earth worms have a chance of assisting cultivation. The tendency for the feeding roots will be chiefly downwards towards the water. This system further improves the low level water supply of the land considerably and silting of river mouths and banks will be less resulting in fewer inundations of low-lying areas. Deep application of fertilisers is not compulsory and even if manure is broadcast or dibbled in, nothing is lost. The approximate weight of material removed from the land in the form of latex in fifty years is half a ton per tree. With 1 foot of top soil and 4 feet of sub soil available on the land each tree will have approximately eighty tons of continously improving soil to draw upon for nourishment. This system facilitates efficient isolation of any tree suffering from disease cheaply by cutting two cross trenches. There is no danger of roots being severed. The root system is enabled to act with maximum efficiency all the time on the feeding circuits. Damage by wind becomes negligible as there is an anchorage of aproximately 40 tons of soil on a 10 year old tree and 70 tons on a thirty year old tree. The upkeep costs are far less than ordinary clearings.

Contour Trench System of Planting. For opening land with a view to dense planting and thinning out later to the normal stand, the trench system is most particularly suited. It is equally efficient and efficacious from the point of soil conservation. The principles involved are that Rubber must have moisture, maximum bacterial action must be encouraged, erosion should be prevented and dense planting must be possible at low initial cost. The trench system allows for the planting of 1000 trees per acre costing no more than for 200 trees per acre over and above the actual cost of plants. Briefly the method of opening on this system is as follows.

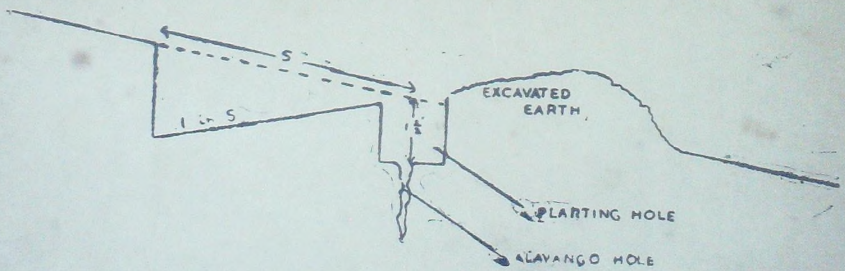
Soon after the jungle growth has been burnt off, large level trenches of 2′ depth and 2′ width are cut along the contour of the land. The vertical distance apart being that at which it is desired that ultimate trees should stand.

The trenches are so worked out, bunded and filled that their catchment area will hold water to the equivalent of a fall of 8″ rain in 12 hours. As the plants are placed inside the filling, it is obvious that no holing as such is required and plants may be placed at any distance apart in the trenches by merely dibbling them in. Given sufficient trenches, there is no limit to the number of plants. Root growth is fast and vigorous, anchorage perfect and every particle of moisture which falls on the land must pass into the trench. A continuous opening-up action is proceeding at the base and lower sides of the trench the whole time. Water under the influence of gravity makes voids in the trench base, rootlets enter the voids, grow and enlarge them. The next fall of rain again enlarges the void and the action of the root continues. This recurring action may be summed up as the breaking down of the sub soil by the roots which are in turn stimulated by the passage of the food contained in the upper soil particles washed down and passing over their feeding surfaces. The trench system will repay rich dividends to any planter who has taken the trouble to acquire local experience of what to expect in the way of rate of percolation of rain water over different strata of soil structure which will vary in different places and at different elevations.

Lining. In order to secure the maximum number of unbroken contours, lining on the contour should be started on the steepest part of the land. If the planting distance has been decided at say 20′ x 15′, that is 20 feet between the contour lines and 15 feet between the plants, we start off by marking a base line running up and down the slope and have the line pegged off at 20 feet intervals. Now commencing from the uppermost peg, using a road tracer we trace a contour line at O gradient, and we peg this line at 15′ intervals to denote the holing distance. Parallel contour lines are thus traced from each peg previously marked on the base line. It will be experienced that the lines will begin to diverge as soon as the slope of the land changes to a more moderate gradient, but the lines must be continued regardless of the distances between each. Where the adjacent contours diverge more than 30 feet apart, intermediate contours could be inserted later. On steep land it would be preferable to space the contours farther apart and have the trees closer together on the contour lines. For example a distance of 25 feet between the contour lines and 12 feet between the trees is preferable and it gives approximately the same stand per acre as 20′ x 15′. This is very important where platforms have to be cut and on very steep land it may be necessary to space the contour lines as much as 30 feet to prevent the cut earth from one platform falling on to the one immediately below it.

At every point traced, the tracing should be marked off by driving a couple of pegs crosswise into the ground. At this point a stout "level" peg about 9″ long should be driven flush with the ground. These level pegs must be absolutely true to the tracer and on no account should they be altered or removed afterwards. In line with the "level" peg another one should be placed at right angles at the desired distance to denote the proposed width of the platform to be cut.

Holing & Filling-Contour Platform or Trench System. Where planting is to be done on the contour platform system, the cutting and filling of the holes should precede the cutting of platforms or trenches. Modern planting methods favour holes of 1½′ x 1½′ x 1½′, or of a size corresponding to the size of stock to be planted. This hole should have its bottom loosened to a further depth of 1 ft. with an alavangoe to allow for the tap root. Hard bottomed holes can be advantageously loosened with half a stick of dynamite. In filling holes, it will be useful to mix any green material available with the excavated soil after removal of stones, roots, twigs etc., and use it for filling the hole except for the top 12 inches which should be filled with surface soil. The green material should not be excessive nor should it be concentrated at the bottom of the hole. The best method is to use about half a manure sack of green material sprinkled with 4 oz. of Sulphate of ammonia to quicken the rate of decomposition and thereafter place it in layers alternating with the layers of earth in the bottom half of the hole. If cattle manure or compost is available, about 25 lbs. per hole may be usefully mixed with the earth for filling. In this connection, it should be noted that the cattle manure should be well rotted. Wood ash not exceeding 1 lb. per hole may also be mixed with the earth to advantage. In this case, planting should not be done immediately but delayed about a month. The decomposition of green material results in high temperatures within the hole and if plants are put in immediately, losses will be suffered. Other ways of improving the nutritional value of the soil may be done by mixing organic manure such as Animal meal and Saphos Phosphate at the rate of 8 oz. each along with the soil of each hole. In this case, the plant or stump may be planted immediately. On no account should any fibrous matter such as coconut husks, straw etc. should be used in the filling of the planting hole.



Holing - Contour Platform system

After the filling of the holes is completed, another line is traced parallel to the already traced contour line by taking points 5 feet up the slope from the pegs marking the centre of the filled holes. The bank is cut downwards along this line at a slight outward slope from the vertical to form a platform which slopes towards the bank at a gradient of 1 in 5 from the centre peg.

The excavated earth is thrown on the lower side to form the outer portion of the platform. The earth at the edge of the platform may be built up into a bund until the filled earth consolidates and should be later levelled off. Otherwise the roots grow up into the bund and root exposure occurs as the earth washes away. The existing main drains should be retained and an uncut section of 3 ft. allowed at points where a platform meets a drain. A spill should be provided at the level of the young trees to allow for overflow of surplus water from the platform to the drain. When cutting of the platform has been completed the soil should be deep envelope forked to break up the hard sub-soil and facilitate the penetration of feeding roots.

Silt-Pitted Drains. It is not essential that the drains should be traced exactly on the contour, and on steep land it is preferable and safer to give them a very gentle slope of say 1 in 80. When replanting, use of old drains may be made use of if their gradient is not excessive. Very steep drains, however, should be plugged at 10 to 12 feet intervals with stone spillways to make more efficient lock and spill blocks.

Spacing. On land steeper than 1 in 7, the drains should be spaced 20 to 30 feet apart, according to the planting distances decided on. On flatter land, the distance between the drains may be slightly increased.

It is important that an efficient drainage system should be established as early as possible after the land has been cleared. The drains and platforms should be lined before holing is commenced. The planting points can be lined separately between the drains or marked at a fixed distance from the drains. The latter method is often more satisfactory if the contours are irregular.

In order to provide skeleton drainage throughout the area quickly, the whole drain should be cut to a depth of about 9 inches and afterwards deepened into a series of silt pits 10′ long x 2′ wide and 1½′ deep with a bund of 2 or 3 feet between the silt pits.

It must be noted that cutting of drains should always be commenced from the top of the slope, and all loose stones should be thrown down the hill and built into a rough wall or terrace about 2 or 3 feet below the drain. In rocky areas, where continuous drains cannot be cut, silt pits should be cut wherever possible. Stone terraces also provide very useful protection in such areas.

Rainfall in the tropics on occasions reach very high levels and it is neither practicable nor desirable to make provision for the retention of the whole of the water on the land. In the construction of all forms of contour earth-works, the natural drainage lines in the folds of the land should be left open and provision made for the overflow of surplus water into them from platforms, trenches and lateral drains. When the distance between two natural drains is excessive, i.e.- more than about 400 feet on steep land, an artificial drain should be made. This should be cut wider at the top than at the base, suitable dimensions being 3′ wide at the top, 1½′ wide at the base and 1½′ deep. Since the contour earthworks are designed to trap most of the water falling on the land, it is only after exceptionally heavy rain that leaders will carry an appreciable volume of run off water. The introduction and growing of natural covers should be encouraged in the drains and above them and this will greatly help them to retain their original form.

ESTIMATE OF TASKS AND COSTS.

The Tables given below are intended merely to serve as a rough and ready guide and to give the reader some definite idea as to what the costs will be for opening and maintaining an acre of rubber during the first seven years prior to bringing the trees to bearing.

The figures have been prepared with an eye to the increasing costs of labour and materials. They cannot be taken to apply to any particular district or estate as numerous unpredictable local factors which vary from place to place have to be considered together with the frequent fluctuations in the prices of materials. Nevertheless, these figures will be useful in that they will give the beginner a good idea as to how costs should be estimated for practical purposes.

Estimate of Costs per Acre

TO PLANT 200 HOLES PER ACRE.

Average Tasks per worker per Day.

Felling & Clearing (Jungle)	— 20 to 30 coolies per acre required according to the land to be cleared.
Felling & Clearing (Old Rubber)	— 3 to 4 trees per labourer.
Lining	— 1½ to 2 labourers per acre according to nature of land to be lined.
Pegs (cutting and stacking)	— 700 to 1000 pegs per labourer.
Holing—30″ x 30″ x 30″ holes	— from 8 to 12 per labourer.
24″ x 24″ x 24″ holes	— from 15 to 20 per labourer.
18″ x 18″ x 18″ holes	— from 25 to 30 per labourer.
Filling 30″ x 30″ x 30″ holes	— 30 holes per labourer.
24″ x 24″ x 24″ holes	— 50 holes per labourer.
18″ x 18″ x 18″ holes	— 70 holes per labourer.
Draining 18″ x 18″	— 40 to 60 ft. per labourer.
Roads — Cutting average earth	— 60 to 75 cub. ft. per labourer.
Road Side Drain on bridle road	— 80 to 100 linear ft. per labourer.
Weeding — First year 1st round	— 20 labourers per acre.
Subsequent rounds	— 6 to 8 lab. per acre until cover crops are established.

Cover Crops. — 10 to 15 labourers per acre.

Planting. — 3 labourers to plant 200 holes.

1st YEAR

(Costs based on Average Wage of Rs. 3.00 per worker = Str. $. 2.00)

1. Felling & Clearing 25 coolies per acre	Rs.	75.00	$.	50.00
2. Lining including cost of pegs—3 coolies	,,	9.00	,,	6.00
3. Cutting 200 holes @ 10 holes per cooly	,,	60.00	,,	40.00
4. Weeding 1st round @ 20 lab. per acre	,,	60.00	,,	40.00
Weeding 2nd round after 4 months 15 lab.	,,	45.00	,,	30.00
Weeding 3rd round after 8 months 10 lab.	,,	30.00	,,	20.00
Weeding 4th round after 12 months 5 lab.	,,	15.00	,,	10.00
5. Planting cover crops—15 lab. per acre	,,	45.00	,,	30.00
Cost of Cover Crop Seeds per acre	,,	15.00	,,	10.00
6. Planting — 200 budded stumps	,,	100.00	,,	66.00
200 protection baskets	,,	20.00	,,	14.00
5 labourers	,,	15.00	,,	10.00
7. Manure Application—100 lb. Animal Meal 1 application at 8 oz. per plant	,,	25.00	,,	17.00
200 lb. General Mixture (4 applications x 4 oz. per plant)	,,	15.00	,,	10.00
Labour—5 applications at 3 coolies per acre	,,	45.00	,,	30.00
8. Cutting Drains @ 100 lin. ft. per acre @ 50 lin. ft. per lab.—20 lab. per acre	,,	60.00	,,	40.00
9. Building Terraces @ 6 lab. per acre	,,	18.00	,,	12.00
10 Fencing per acre	,,	10.00	,,	6.00
11 Pests & Diseases	,,	10.00	,,	6.00
12 Tools	,,	10.00	,,	6.00
13 General charges including supervision	,,	50.00	,,	33.00
		732.00		486.00

2nd YEAR.

1. Weeding—3 labourers per acre per month—36 labourers	Rs.	108.00	$ 72.00
2. Supplying vacancies including cost of Stumps	,,	10.00	,, 6.00
3. Manure Application—400 lbs. General Mixture for 4 applications of ½ lb. per plant per application for 200 trees including transport	,,	80.00	,, 54.00
Application—4 applications at 2½ lab. per acre—10 lab.	,,	30.00	,, 20.00
4. Pests and Diseases and general inspection @ 10 lab. per acre	,,	30.00	,, 20.00
5. Cover Crops—maintenance @ 1 lab. per acre	,,	3.00	,, 2.00
6. Drains—4 lab. per acre	,,	12.00	,, 8.00
7. Roads and paths—2 lab. per acre	,,	6.00	,, 4.00
8. Repairs to Fences @ 1 lab. per acre	,,	3.00	,, 2.00
9. General charges including Tools, watchmen supervision etc.	,,	50.00	,, 33.00
	Rs.	332.00	$ 221.00

3rd YEAR.

Same as 2nd year plus allowance for Additional cost of manure—500 lbs. Manure Mixture—200 trees @ 2½ lbs. per tree in 4 applications of 10 oz. per tree — Rs. 363.00 $ 242.00

4th YEAR.

Same as 3rd Year. — Rs. 363.00 $ 242.00

5th YEAR.

Same as 4th year plus Additional Cost of Manure at 3 lbs. per tree x 200 trees—600 lbs. and Cost of application—4 applications at 12 oz. per tree — Rs. 400.00 $. 266.00

6th YEAR.

Same as 5th year Rs. 400.00 $. 266.00

7th YEAR.

Same as 6th year plus Additional cost of Manure at 4 lbs. per tree x 200 trees—800 lbs. and cost application—4 applications at 1 lb. per tree Rs. 450.00 $. 300.00

SUMMARY OF COSTS

1st Year	Rs. 732.00	$. 486.00
2nd Year	,, 332.00	,, 221.00
3rd Year	,, 363.00	,, 242.00
4th Year	,, 363.00	,, 242.00
5th Year	,, 400.00	,, 266.00
6th Year	,, 400.00	,, 266.00
7th Year	,, 450.00	,, 300.00
	3040.00	2023.00

COST OF CUTTING DRAINS

AVERAGE TASK PER LABOURER — 50 FEET.
AVERAGE WAGE — Rs. 3/- = $. 2.- PER DIEM.

Distance Apart in feet.	Linear Feet per acre	Chains per acre	Cost per Acre Rs.	$.
30	1452	22	87.00	58.00
35	1244	19	75.00	50.00
40	1089	16	65.00	43.00
45	968	14	57.00	38.00
50	871	13	53.00	35.00
55	792	12	48.00	32.00
60	726	11	43.00	28.00
65	670	10	40.00	26.00
70	622	9	37.00	24.00

Number of Trees per Acre in relation to Planting Distance.

1 Acre = 4840 Sq. Yards = 43,560 Sq. Feet

To obtain the number of trees to the acre planted at various distances, multiply the distance between the trees planted down the line by the distance between the lines and divide that figure into 43,560 sq. ft. The quotient will give the number requited.

Example. Planting distance 20′ x 20′ = 400 sq. ft.
43,560 ÷ 400 = 108 per acre.

CHAPTER V

NUSRERIES AND SEED

Site. Care and good judgment should be exercised in the selection of a suitable location for nurseries. The best jungle soil should be chosen in a spot well sheltered from wind, with good drainage and facilities for watering. If it is possible, the same site should not be used twice for a nursery, but when this is unavoidable, the ground should be thoroughly forked and allowed to lie fallow for a few months before replanting. If an old line site is selected for a nursery, it should be given a preliminary dressing with sulphur or sulphate of ammonia to counteract alkalinity in the soil.

Beds—Layout and Preparation. The selected ground should be cleared of all timber, stumps, stones, sticks and rubbish and thoroughly dug over to a depth of a foot or more and laid out in beds 6 feet broad by 24 feet in length. Care should be taken to see that the beds are perfectly level and should be covered with 4 inches of light and well pulverised soil. The seed can then be covered with 2 inches of fine sifted soil. The seed should not be planted less than 6 inches apart which will give 576 seeds to a bed of the above dimensions. Where, however, a flat land and plenty of space is available germinated seeds may be planted also in pairs of rows 9 inches apart and between seeds. This provides easy access to the plants for budding and other operations.

When putting out the seed in the nursery, care should be taken to see that each seed is *placed flat on its side* or the result will be a twisted root. As soon as the young plants are sufficiently grown, the earth from the passages between the beds or pairs of rows as the case may be should be heaped up until the beds are 9 inches to a foot high. These passages serve the purpose of drains. Another method of sowing seed consists in the use of a board of say 6 feet long by 1½ ft. broad, drilled with holes of suitable size in lines 6 inches apart or on a 9 inch triangular spacing. The board is laid across the bed and a cooly stands at each end with a round stick and bores the holes. Care should be taken to see that the seed is sown not deeper than 1 to 2 inches below the surface.

Watering. Care should be taken to see that when watering is done it is done thoroughly. More harm than good will result from sprinkling water in dry weather on the surface of the beds, for the sun evaporates the moisture very quickly and the surface is caked at once. The best method is to water in the evening only and then to do it thoroughly. A further method of preventing surface caking after watering which might be recommended is to cover the ground with a layer of fern.

Weeding. The beds should be weeded frequently by hand, and this operation serves to break up the surface of the soil which has become caked by frequent watering and drying.

Selection of Seed. This is of the greatest importance and the chief point to consider is the age of the trees from which the seed is selected. In a general sense it would appear feasible to improve the "strain" in the direction of obtaining high yielding trees by selecting seeds from known high-yielders through several generations. But unfortunately the problem is by no means a simple one. It is clear that seeds from a known high-yielder would afford greater chances of a high yielding progeny than seeds selected haphazard in any particular field, even though that field is known to have a high average yield. But *Hevea Brasiliensis* is a hybrid tree, and has been subject for several generations to cross fertilisation by adjacent poor yielders not to mention the cross fertilisation incident for unknown generations in South America before the seeds were brought originally to the tropics.

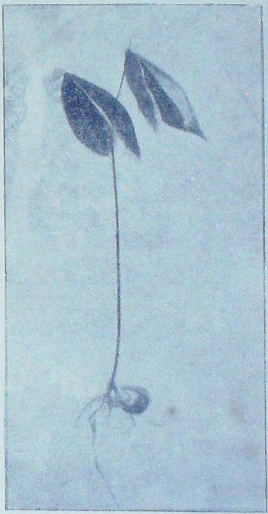
A high yielding mother tree, therefore, may have had many poor yielding ancestors, and cannot be regarded as a certain, or even probable, producer of a high-yielding seed family in the next or succeeding generation. That family will vary widely between individuals, and the fault inherited from ancestors will be transmitted. Following certain laws governing breeding, only a small proportion of the offspring can be expected to possess the high-yielding characteristic of the parent.

By removing the poor-yielding trees, and thus restricting cross-fertilisation to the known high-yielding trees, conditions are improved. If this process could be repeated through several generations, with the additional precautions ensured by artificial fertilisation and isolated breeding plots, it would be possible to guarantee that young plants of succeeding generations would have a higher average yielding potentiality ; but it will be plain from previous statements that the young plants will continue to vary between individuals much in the same way as do existing ordinary plants. It follows that the great variability in young plants raised from seeds puts the method of seed selection alone out of consideration as a practical mode of improving "strain" in the direction of obtaining a continuous high-yielding progeny. It will be understood that "known" high yielding trees are those whose quality has been proved by yield tests ; and it would be necessary for any really sound purpose to have proved the reproduction of this quality in one or more succeeding generations.

Seed selection, however, is of greater value in combination with vegetative method of propagation—Budgrafting, which can be employed with great success on a commercial scale. This will be the subject of the next Chapter.

Germinating Beds. Before seeds are put on the germination beds, care should be taken that seeds are fresh and all small, light or diseased seeds should be discarded. The heaviest seed are the most productive and vigorous. Therefore only the large seeds should be selected for germinating and small and shrunken ones should be rejected.

The germinating beds could be of any convenient size, say about 3 ft wide and 12 or 15 feet in length, and should be covered with a layer of sand or well sifted soil to a depth of about 2 inches.



Seedling, showing Root-System with Seed
still attached.

The seed should be pressed into the sand and placed flat on its side until the top of the seed is just under the surface of the sand. The beds should be kept moist by watering at least once a day, but care should be taken that water logging conditions are avoided. Exposure to direct sunlight is most harmful and the beds should be protected if necessary with coverings of cadjans or by means of sacks laid down over the beds. Alternatively germinating beds can be conveniently laid out in the shade of mature rubber trees.

Daily inspection of the beds should be carried out and the germinated seed should be transferred to the nursery as soon as the tip of the rootlet has forced its way through the seed coat. Every care should be exercised to see that rootlets are not damaged during the transfer. All seeds remaining ungerminated after 14 days should be rejected.

Weeding. From inception of the nursery the beds should be regularly weeded by hand and kept clear of grass and weeds. It is too risky to permit the use of scrapers for weeding.

Manuring of seedlings. If good compost or cow dung is available it should be applied at the rate of 5 tons per acre when the seed bed is being prepared together with 100 lbs. of rock phosphate and well forked in. If compost is not available, the initial manuring of a nursery should be done with 3:1 mixture of Rock Phosphate and Magnesium lime. This should be applied at the rate of 4 cwts per acre and well worked into the surface of each bed to a depth of six or nine inches.

After the lapse of a month from date of planting germinated seeds, a dressing of sulphate of ammonia and muriate of potash in the proportion of 4:1 should be applied on the surface between planting rows at the rate of 1½ oz. per linear yard. Thereafter R 4: 6: 5 manure mixture (100 lbs. Sulphate of Ammonia, 100 lbs. Saphos Phosate, 50 lbs. Muriate of Potash 50% K20) or 40 lbs. Muriate of Potash (60% K20) should be applied at the rate of 1 oz. per plant at 3 month intervals up to 3 months before budding. Further manure should be applied only after bud grafting.

Common Pests and Diseases.

Rodents. Rats, moles and beavers are animals which eat through the taproots of young seedlings or gnaw them near the collar. An effective poison bait is prepared by mixing 1 part of barium carbonate with four parts of bread crumbs or grated coconut and putting the mixture out in the form of small pellets wrapped in paper. Another extremely potent rodenticide is zinc phosphide which is usually supplied as a dry powder that should be included at the rate of 2½ per cent in all baits. When this material is used water should be provided close to the bait. The poison when taken in induces extreme thirst and drinking water has the effect of hastening the action of the poison. This material being extremely toxic to both man and domestic animals has to be handled with great caution. Rats may also be ensnared in traps.

Hare. This pest eats off the top of young plants and is best kept out by surrounding the nursery with wire netting.

Mites. These attack the young foliage causing distortion of the leaves and sometimes defoliation. They usually attack the poorest plants so that manuring and cultivation methods which ensure vigorous growth are to be recommended. Efficient control can be obtained by periodical dusting with sulphur powder or spraying with lime sulphur. Several makes of hand dusters and knapsack sprayers are available in the market to serve this purpose. On a small scale sulphur dust can be applied by beating with a stick on a linen bag in which the powder is loosely contained. If dusting with sulphur alone does not control the mite attack, a mixture of 50% sulphur dust and 50% talc-derris powder containing 2 per cent rotenone may be applied.

Cockchafer grubs. *Leucophilis(Lepidiota)pinguis.* These larvae which are large fleshy white grubs up to 3 inches in length hatch out in the soil and eat off the roots of the young plants just below ground level. There are a number of modern insecticidal preparations based on B.H.C. dieldrin and aldrin which are extremely useful in the control of cockchafer grubs. The required quantity of any one of these insecticidal preparations are sold under various trade names and the concentration of the active ingredient in them varies. The recommended dosage for each product is therefore best obtained from the local agents of the respective insecticides.

It has also been established that the beetles of which these grubs are the larvae, do not usually deposit their eggs on bare soil. So if the area to be used for a nursery could be cleaned of all vegetation before the flight of the beetles takes place, little damage from cockchafer grubs should occur. If this procedure is followed anti-erosion measures must be carefully observed.

Oidium. (Oidium heveae). This fungus may attack the young leaves and cause curling up and distortion or leaf-fall. In older leaves it leads to the formation of yellow spots. The spots become purplish brown in colour and eventually dry up while the dead tissues in the centre may fall out leaving irregular holes. This disease can be controlled by sulphur dusting or by spraying with lime sulphur at intervals of 7-10 days.

Birds' Eye Spot. (Helminthosporium heveae). This fungus causes minute circular spots on immature leaves of rubber plants but is unable to attack mature leaves. The disease is frequently not of sufficient importance to warrant application of control measures. At times, however, severe outbreaks do occur and some artificial control is required. The disease is very resistant to fungicidal treatment.

It has been found that light shade reduces the intensity of the attack, but this is too expensive and has too great a retarding effect on the growth of the plant for it to be recommended.

When a severe outbreak occurs which calls for some control measure, all plants in the nursery should be sprayed each week with Bordeaux mixture or with a proprietary copper preparation until the course of the outbreaks is interrupted.

Scale Insects. Sometimes nursery plants are affected by scale insects of which the two common species are *Coccus viridis (Syn. Lecanium viride)* and *Saissetia nigra (Syn. Lecanium nigrum)*. The insects are usually to be found on green stems, on the petiole, along the midribs, and along the veins of the leaflets. Although the damage done by these insects is not always conspicuous it is good policy to take early control measures. This is especially important if the dry season is at hand or if the nursery has to be sprayed with copper fungicides against "Bird's Eye Spot". The scales are very often parasitized by fungi, *Cephalosporium lecanii* and *Hypocrella sp.* The former causes a white mould to grow over the scale and the latter gives rise to hard spherical growths of about 1/8″ in diameter. When young, these globules are orange-red, when older they are dark brown. These fungi do no harm to the plants but on the contrary are beneficial by the biological control they exert on the insect pest.

When spraying with copper fungicides against *Helminthosporium*, these beneficial fungi are killed off and as the scale insects are not affected, control measures against those become more urgent. In case "Bird's Eye Spot" and scale insects are simultaneously present, a suitable insecticide has to be mixed with the fungicide or else lime sulphur which has both an insecticidal and fungicidal action may be used instead. Lime-sulphur is also indicated when a third type of scale insect, *Asterolecanium pustulans*, occurs. This species is less common, but more difficult to get rid of. It may require several applications of lime sulphur at four day intervals. To control *Coccus viridis* and *Saissetia nigra* oil sprays can be recommended.—e.g. I.C.I.'s Albolineum No. 2 in a concentration of 12-16 pints of albolineum No. 2 per 100 gallons of water. Albolineum can be mixed with Cuprous oxide so as to form a combined insecticidal-fungicidal spray. Spraying with Albolineum should be done in the late afternoon so as to avoid leaf-scorch, which will occur if this material is sprayed during the mid-day period.

Thinning out. At intervals of two to three months, the nursery should be thinned out by the removal of the weaker plants, with a view to reducing the stand by at least 50% before the stage of budding is reached.

Stumps. At a stage varying according to the requirements of the estate when the plants are from twelve to eighteen months old they are lifted from the earth. The roots and head are cut off, and the "stump" is ready for immediate planting in the field. Naturally any appreciable delay in planting, or unfavourable weather conditions will militate against the chances of successful rooting, and it is not uncommon to find that a certain number of "supplies" will be necessary.

Seed at Stake. A method sometimes adopted is to put out seed in the field, in prepared holes which indicate the exact position of the future trees. Usually three seeds are placed in each hole, and if two or three germinate, the plant having the healthiest appearance is retained and the others removed. The possible objections to this method of planting are obvious to those acquainted with field conditions, but in actual practice planting seed "at stake" has often proved highly successful. Naturally the results obtained must depend upon the selection of good seeds, the care exercised in the preparation of the "holes", weather conditions, and the discrimination exercised in the selection of the plants to be retained apart from such disabilities as the depredations of rats and other pests.

Basket Plants. Yet another and perhaps the most popular method is the germination and growth of seedlings in baskets specially constructed for the purpose. These plants are kept under observation until they are of the required age and growth. They are then conveyed to the field, and the baskets are planted in prepared holes.

The baskets being of vegetable material, are liable to be attacked by various diseases while in the nursery or after planting. It is considered advisable, therefore, to treat them by dipping into some disinfectant such as tar, or a mixture of tar and one of the common proprietary disinfectants. Otherwise a disease may be conveyed from the basket to the seedling.

CHAPTER VI

BUDGRAFTING OR VEGETATIVE METHOD OF PROPAGATION

The problem of improving the strain of *Hevea Brasiliensis* has been solved by a combination of budgrafting with seed selection. The earliest experiments in budding rubber trees were made in 1917 and great developments have taken place throughout the succeeding decades.

By "budding" is simply meant the removal of a bud from the branch of a known high-yielding tree and grafting it generally near the base of a stem of a young plant. In budgrafting practice the following terms are used:—

Stock. The whole plant upon which the bud is grafted.

Scion. The shoot developing from the bud.

Mother Tree That tree from which the original bud was taken.

Clone. All the trees developing from buds taken from any individual mother tree.

Proved Clone. One in which it has been proved by actual field tests that the high yielding characteristic of the mother tree has been transmitted to the members of the clone. No mother tree can be considered "proved" until the individuals of the family or clone have been successfully tested over a period of years.

The definition of a "proved" clone would appear to imply that it is not every high-yielding mother tree which is capable of transmitting its characteristic of high yield; and such is actually the case. The progeny (clones) from some mother trees exhibit a reversion in yield characteristic to some poor yielding or moderately yielding ancestor. Hence the stress upon the point that on any large scale no buds should be employed unless taken from mother trees whose clones have been previously proved, on an experimental scale to inherit the high-yielding characteristic.

In contrast with the foregoing observation on the uncertainty of transmission of the high-yield characteristic, it is to be noted that the botanical characteristics of the mother trees are *exactly* reproduced in all the individuals of any one clone. Thus all the trees will exhibit the same type of leaves, the same system of branching, the same markings, shade and colour of seeds,—in short, the same strong family likenesses. The resemblance in the several features is so strong that it is possible to differentiate between, and to identify different clones from various mother trees.

This certainty that the individuals of any clone will reproduce the botanical features of the mother tree becomes of vital importance when considering the question of employing buds from a known high-yielding tree. The point was not so fully appreciated in the earlier stages, but subsequent knowledge and experience now render it possible to eliminate from a list of high-yielding mother trees all those whose progeny will develop certain botanical characteristics which would make the trees less valuable than other clones, although they may be capable of giving large yields.

Some of these defective characteristics are typified in trees which may be liable to disease; which may have a branch formation making them liable to damage by wind-storms; which may be slow in bark renewal, or which may eventually exhibit "fluting" (longitudinal corrugation) on renewing bark, etc.

Reverting now to the uncertainty that the high-yielding characteristic will be reproduced in the progeny from *various mother trees*, it is to be noted, nevertheless, that all buddings *from any one mother tree* will be practically uniform in yield capacity, even though they do not show the high yielding characteristic of their mother. Thus if one bud develops into a high-yielding tree, all other buds from that mother tree will develop into high yielding plants; and if any one bud proves to develop later into a moderate or poor yielder, all other buds from that mother tree will give similar results.

Actually it is found that there is some variation in the yields from individual members of any one clone; but such variation is very small in comparison with the extremely wide variations observed in the yields of trees raised from seeds selected from high yielding trees. The contrast between the possible extent of variation in the two types of trees (bud-grafts and selected seeds) is so great as to justify the remark that all buds from any one mother tree will exhibit practically uniform yield capacity—which may be high, moderate or comparatively poor. It is this extremely wide variation in the yields from selected seeds which indicates the value of bud-grafting as a short-cut in the process of improving the strain of rubber trees.

Following upon these observations, it is now possible to formulate several definite points for guidance in the planning of bud-grafting work:

1. Buds must not be employed in any large scale work until, by earlier experimental work, it has been shown that the mother tree is capable of transmitting her high yielding characteristic through her buds. In other words buds should only be taken from a mother tree by knowledge derived through a "proved clone".

2. All buds from any one mother tree will reproduce the botanical characteristics of the mother. No tree, therefore, should be selected for "proving", even though known to be a high yielder, if it possesses undesirable or suspicious botanical features.

3. A mother tree cannot be regarded as successfully "proved" until its bud-grafted progeny has been tapped over a period of years sufficient to allow observation upon the renewing bark.

4. Similarly no mother tree can be considered "proved" until sufficient time has elapsed to show whether its progeny is free from undesirable botanical features.

5. Once a mother tree has been "proved" in the full sense of the word, one may rely upon the fact that all buds taken direct from the tree, or from the budded progeny of that tree, will reproduce the high-yielding characteristic of the tree.

The knowledge that buds taken from a young tree, developed from a bud grafted from a "proved" mother tree, reproduce the yield characteristic of the original mother tree is useful in practice. Instead of going back to the mother tree for buds which may be difficult to remove from old bark, we can take the required buds from the branch of a young bud-graft. The principle is employed in allowing young trees, in a proved clone, to develop solely for the purpose of cutting off branches which supply "bud-wood"; and the process can be repeated annually. Such groups of young bud-grafted trees are known as "multiplication" or "regeneration" nurseries.

In a previous paragraph mention was made of the possible influence of the stock on which the bud is grafted. The root system of the stock functions in combination with the bud-graft, and the extent to which that root-system exerts an influence on the factors governing yield has been determined. All bud-grafted rubber trees exhibit several typical features:—

1. The existence of a definite change of shape in the stem at the point of union. This has the form of a horse's hoof.

2. The stem is cylindrical in shape to a considerable height; this feature is to be contrasted with the tapering stem characteristic of an ordinary rubber tree. Not only is

the stem of the bud-graft relatively uniform in girth to a considerable height, but, what is of far greater importance, owing to the physiological structure of the tree the yield at a height of about 5 or 6 feet is only little less (if any) than that obtained from a cut of equal length near the base of the stem.

In the case of an ordinary rubber tree it is common knowledge that the yield decreases with the height of the tapping cut; and to a marked degree if the two compared cuts are as far apart as 4 or more feet. The advantage to the bud-grafted tree will be obvious in this respect; and it will also be clear that such a tree can be tapped profitably to a far greater height than is the case with an ordinary rubber tree. This advantage may be quoted as more than ample compensation for any deficiency attributable to a slower rate of bark renewal.

3. As a rule the stem of an ordinary rubber tree is circular in section; that of most bud-grafts is slightly or appreciably elliptical. The point is of no real importance, as far as reckoned.
4. Because bud-grafts emanate from the branch of a mother tree they show a tendency to form branches at a lower height and at an earlier age than ordinary trees developed from seeds, Hence it is often necessary to institute early and systematic pruning.
5. "Wintering" in the individuals of any one clone is remarkably uniform, a notable feature in contrast with trees raised from seeds.
6. Bud-grafts flower and form seeds at an earlier age than plants grown from seeds.
7. The remarkable similarity in physical features between all members of any one clone has already been mentioned.
8. For all practical purposes the yields from individuals of any proved clone approach so near to uniformity, and the growth of the trees is so relatively uniform, that selective

thinning ceases to be an important operation. It follows (a) that there would be no necessity to plant so closely as in the case of trees raised from seeds, and (b) that practically all trees in any field of one age can be brought into bearing simultaneously, whereas such is by no means the case with trees from seed planting.

Seedling stocks (the whole plant upon which bud is to be grafted. Throughout the decades following the early experiments on budgrafting, the importance of using stocks most suitable for success has been fully recognised and considerable experience has been gained in the selection of seed of special clones for the purpose. Indiscriminate collection of mixed clonal seed must be avoided as the condition and quality of the stocks determine more than any other factor the success of the operation and the subsequent growth and yield of the budgrafted clone. Among these, seed of Clone Tjirandji 1 (TJ 1) has proved to be excellent stock. There are several more excellent clones for use as stock and in this connection planters should consult the local Rubber Research Institute and obtain scientific advice before undertaking v. ork on a large scale. There are also many plantations in Ceylon, Malaya, Sumatra, and Indonesia which guarantee supply of clonal seed from authentic budgrafts approved by Rubber Research Institutions and it is always policy to secure supplies of seed for raising best quality stock seedlings from such plantations of repute.

Suitable size of stock. The size of the seedling stocks for budgrafting should be such that it has a minimum of 1 inch or nearer 2 inches diameter at ground level. Although small stocks are convenient for uprooting, transporting and transplanting, it should be borne in mind that the large stocks survive better in adverse conditions in the field and definitely give a greater percentage of success. Moreover, the large stocks will have greater reserve food material for the vigorous development of the budshoot, when the manufacture of plant food is not possible with a regenerating root system and insufficiency of green stem and foliage. Selection of undersized stocks has resulted in poor development of the first whorl of leaves in clearings, and the budded stumps therefore get a very poor start and particularly on poor soil and adverse weather conditions high percentage of losses invariably result.

Again, the use of oversize stocks is not recommended as it results in a lower percentage of budgrafting success. The buds on such stocks tend to be somewhat dormant, though they will grow vigorously but later on will present difficulties in the healing of the cut end of the stock snag. The cost of uprooting and planting of oversize budded stumps will be unduly heavy if this type of material is used on a large scale.

Selection of Mother Trees.—This can only be done by the planter on the spot. From the planter's own information and experience he is able to say which are his best yielders in each field. These should be tapped in the usual way, always by the same tapper, and the daily dry weight should be ascertained from each such tree. From these a further selection can be made, and further tapping yields obtained. Thus it will be possible to decide which are the best yielders on an estate and these should be used as mother trees. Tests should be taken over a considerable period, say one year at least.

As the wood suitable for budding grows somewhat at the extremity of branches it is generally best to pollard such trees as are intended for the propagation of budwood, and young shoots will develop from adventitious buds on lopped branches.

Great care must be taken in the selection of mother trees, for it has been proved that high yielding mother trees do not by any means always produce high yielding off spring. Before anything can be said as to the suitability of a mother tree for such a purpose, it is absolutely necessary that tapping tests should take place from the progeny. As already mentioned there is a great uniformity in all the plants in any particular clone, that is to say, the progeny of any one mother tree raised by the method of budding will very closely resemble one another, but there may be a vast difference between individual trees grown from seed from the *same* mother tree. The tapping tests may be performed when the plant is 3-4 years old. It is interesting to note that when commercial tapping starts the cut should be made about 5 feet from the base in contradistinction to seedlings, for yield does not increase as the cut approaches the base, in fact rather is a falling off shown.

The Supply Transport and Reception of Budwood. In this connection a few words of caution are necessary. The greatest care must be taken in the labelling of all plants from which it is intended to take budwood, and the fullest details should be kept available, whether it is for the grower's own use, or for disposal.

It is of vital importance to a purchaser of budwood for which he has to pay no small price that he should receive the fullest information and nothing is so easy in budding as the mixing of labels and confusion of clones. Further it is important for the buyer to make sure that he purchases his budwood from a thoroughly reliable source; for careless and even dishonest suppliers are not unknown.

Budwood. As regards the budwood itself, it may be green, green-brown, or brown. Best budwood is recognised by its bright brown colour and should be about 1 to 1½ inches in diameter and should be easy to peel. To secure successful results and high yields in later years, only budwood of clones recommended by the Rubber Research Institutes of the country in which planting is undertaken should be used. A period of at least 18 moths is required to propagate budwood from budded stumps planted in a multiplication nursery. It is possible to obtain about 2 yards of budswood from a single budded stump grown in a nursery for 18 months, and about 12 to 15 buds may be looked for per yard of budwood.

Green budwood will not travel and must be used immediately. Budwood which is greenish-brown will remain good if properly looked after from 3 to 4 days. The bright brown budwood is the best and will travel and remain good from 9 to 12 days, and cases have been known of success with budwood over 20 days' old.

When the sticks are brought in they should always be kept with their lower ends in water which must be kept fresh and clean. If it is to be packed up and sent away on a short journey the ends of the sticks should be sealed by dipping into hot "Entwax" and wrapped in plantain leaves, each stick by itself up to about five or six, and then these in turn wrapped up and put in a box sufficiently tightly to ensure that they do not get damaged *en route*. About 50 sticks to a box is a convenient package. If the journey is to be long only brown wood must be sent and the ends should be sealed in the aforementioned manner but instead of wrapping in plantain leaves, wet sacking or hessian should be used, each stick by itself and bundles of 5 or 6 wrapped together. These should then be laid in a box filled with damp charcoal or coir dust.

Immediately on arrival everything should be ready for their reception and use as early as possible. The lower end of the sticks should be freed of the wax by removal of the wood for an inch or so at the lower end and they should then be placed in water.

Preparation of Budwood Multiplication Nurseries. These will be made in the usual manner and seed will be put in about 9″ x 9″ or 1′ x 1′ apart according to space available. This allows for room to bud in the nursery if required. It is advisable in choosing seed for stocks, to procure that produced by heavy yielding trees of vigorous growth. If it is decided to put down *Multiplication Nurseries* the seedlings for stocks should be about 3′ x 3′ apart. In due course they will be budded with the desired budwood and a shoot will appear. This should be allowed to grow for about 12 to 18 months, and should then be cut and used for further budding. Just below where the cut took place two shoots will appear, and these in their turn may be cut and used for supplying. It is not advisable to allow more than 2 shoots to grow on one branch. If more appear they must be removed. In natural sequence then from below the cut of each of the 2 shoots will spring 2 more shoots in the 3rd season, but never should more than four shoots be allowed to grow on one *stock*, and all others must be removed. Having now got the budwood either from Nurseries as above, or from sticks obtained from elsewhere, the actual process of budding must be dealt with.

In Budding of rubber, there is the choice of budding seedlings or budding stumps. There is further the choice of budding in the nursery, or the field.

If it is decided to bud seedlings these should be from 12 to 18 months old and particular attention should be given to selection of those with the greatest girth.

If stumps are to be budded, care must be taken as to the time that this is done and the condition of the growth of the stump. It is no use whatever attempting to bud on to stumps unless the stump has had time to get over the shock of stumping. In either case it is essential to success that good weather should be experienced at the time of performing the operation, and no budding should be done during the wintering, nor in the wet season, and the most suitable months should be selected-neither too wet nor too dry—and it is a good practice to knock off work during the hottest part of the day and commence again later.

It is important that at the time of budding the stock seedling should be growing vigorously and in good health to secure the best possible peeling properties of the bark. Nevertheless, it is a mistake to force the growth of the stock seedlings shortly before budgrafting, and it is inadvisable to use artificial manures which should not on any account be applied within 2 months of budgrafting. Forcing the growth at this time will result in the fresh flush of leaves depleting the food reserves in the stock seedling which may imperil the chances of success. Budding in the nursery may well take place about 5 weeks before the time it is decided to plant out.

No definite rule can be laid down about the effect of action on stock or vice versa but that there is some relation appears certain for it is found that the growth of the root stock is related to the vigour of the scion, and that there is a relation between the yield values of both. There is plenty of room for research into the importance of careful selection of suitable stocks for particular scions.

Clones recommended for use as budwood. Most Rubber Growers have considerable experience of older clones and before making a choice advice should be sought from the local Rubber Research Institution. The following clones are some which have proved to be excellent for large scale planting:—

Prang Besar (P. B. 86)
A.V.R.O.S. (AV. 255)
Wagga (WG. 6278)
Millakande (MK. 3/2)
Proefstation voor Rubber (PR. 107)

The clone which has given consistently high yields and shown good growth and resistance to disease is PB. 86, and under a variety of conditions it has proved to be the best. All the other clones are all high yielding and their superiority of one over the other will depend on environmental conditions of climate, elevation and soil.

BUDGRAFTING PROCEDURE

Materials required. The following materials are required for budgrafting and should be at hand:—

(a) Budding Knife. This is a special one having a sharp, short stiff blade and a spatulate bone projection at the other end of the hasp to facilitate the operation of peeling the bark.

(b) Rubberised adhesive tape in the form of patches, size 3″ x 2″ for covering the graft before binding.

Where adhesive tape is not available waxed cloth cut in strips of patches of size 2″ x 3″ and prepared in the following manner will suffice. The cloth most suitable is cheap calico but not too poor in quality, and should be well washed and cut into lengths of 20 inches. These should be dipped in melted "Entwax", saturated and then drained after which the material may be rolled like a bandage removing superfluous wax. When wax has hardened and is cold, the roll may be cut into strips 2″ wide thus forming strips 20″ x 2″ from which patches 2″ x 3″ could be cut.

(c) Suitable labels which may be of light gauge galvanised iron zinc or aluminium on which the serial, name, number or other tally can be clearly stamped and a small hole made at the top side to pass a wire through. The wire should be twisted and the two free ends fastened round the stock securely. This is of vital importance to prevent muddles.

(d) Coir rope for binding purposes. This is quite effective though in many cases the binding is also done with 1 inch rubberised tape which is expensive and not essential.

(e) A small work box with separate compartments for budding knives, bud patches of rubberised tape or wax cloth all of which should be kept scrupulously clean if best results are to be obtained.

Now, if the growth is propitious, we are ready to perform the operation. The work is very largely dependent on the individual worker. The Estate can provide the best and vigorously growing stock, the best budwood, and suitable materials, but as in every other branch of Rubber Work, extreme cleanliness is a *sine qua non*, and the worker must have the knack, or failure will inevitably follow.

THE BUDGRAFTING OPERATION.

Step 1. Clean the bottom six inches of the stock seedling plant with a rag or cotton waste and all dirt should be carefully removed. Where the stocks are large and the bark is corky, it should be lightly groomed with a coconut husk.

Step 2. A template is set against the stock about ½ inch from ground level. This template will be about 2½ inches long by ¾ inch wide. A sharp deep cut to the wood should be made down the two sides. Make a third cut down to the cambium only making the other two cuts join at the top, in an arch. There will be a slight bleeding of latex which must be wiped off with a rag. The cuts made demarcate the flap of bark which has to be peeled down by means of the spatula end of the budding knife from the top arch exposing the *bud panel* on which the bud patch is to be inserted.

The flap of bark should not be peeled down for at least ten minutes which is the usual time allowed for the latex to dry before opening the flap of bark. In the meantime other stock seedling could be similarly cut and buds selected for grafting.

Step 3. We now take the budwood stick and having selected the bud a similar template as used above but 1/16" smaller is laid over the bud and a strong hard cut is made round all four sides. The entire piece so isolated can then be removed containing bark, bud and wood. This forms the *bud patch.*

Step 4. Now is the moment for care and cleanliness. Holding the bark in the left hand, the wood chip should be removed and will leave a tiny excrescence of the bark. This is the *bud.*

Bud Panel Exposed and Flap of Bark peeled down.

Removal of wood chip from the bud patch.

(By permission of the Rubber Research Institute of Ceylon)

Bud Patch consisting of bark and bud inserted in the panel.
(By permission of the Rubber Research Institute of Ceylon)

Step 5. Returning to the *stock*, gently prize up with the bone spatula of the budding knife the flap cut on 3 sides, and slip behind it the *bud patch* consisting of bark and bud. This will be found to fit perfectly, but the greatest care throughout the operation should have been taken to see that the hand did not ever come in contact with the cambium. It is important also to see that the bud is fixed right side up. This is a mistake a worker often makes.

Step 6. The flap is now gently placed back over the budpatch, and over it is placed the protecting patch of rubberised adhesive tape or waxed cloth and the whole bound up with coir rope which is given one or two firm tight twists round the lower end of the bud panel and wound on spirally and if tape is used for binding it may be wound with a slight overlap keeping a firm but by no means tight pressure as it passes over the bud, and finally winding it off tight, an inch or two above the panel. A few leaves or some sort of shade should be provided over the patch and the work is complete. In a nursery, shade is not required except for plants on the edge directly exposed to the sun.

The whole operation though taking long to describe actually only takes a very little time to perform and a worker and an assistant can do 100 to 125 buddings a day easily.

First Examination. The budding should be left for 3 weeks after which period the bandage is removed and the bark flap covering the bud is cut off. The patch is scratched with the point of a knife above and below the bud and should show green. This proves a good union has taken place though nothing may be visible of the bud. This will shoot, however, when conditions are suitable. Shading must be replaced and carefully watched. The bandage is now not required. If dull weather is experienced, shade may be conveniently omitted.

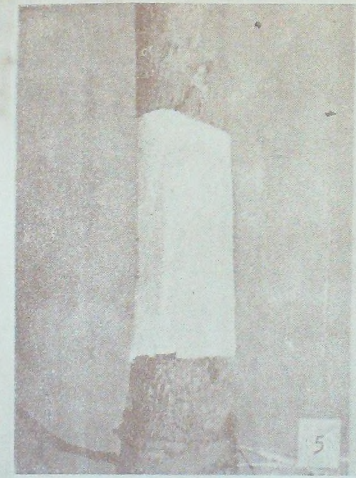
It is not advisable to carry out the first examination during periods of heavy rain, and should the time of inspection fall within a period of rain, the first examination should be postponed for a period up to another 2 weeks.

Second Examination. After another 10 days from date of the first examination, the bud patch is again inspected and if it is still green, the operation may be considered as successful, and the stock should be ringed and a band of bark about an inch wide should be stripped right off about 5 inches above the bud patch. In a few days the bud will begin to sprout. When it is seen that this is doing well, the stock may be completely severed at the ring at an angle of 45° sloping away from the bud. Thus all growth will be concentrated in the new bud, and the snag or end of the stock will be left which will gradually wither away or be removed later.

In the case of nursery buddings, the stock is not cut down until the time of planting out in the field. For long distance transport of budded stumps, it is advisable to cut off about 6″ above the bud.

We are now left with the budded plant but what to do with it remains to be shown. If the budding has been done in the field, there is nothing to be done except remove the snag if it has not been already done, after say, 5 months, but the plants must be constantly "gone over" to see that no adventitious buds have broken out below the point of union, and to break them off as they appear.

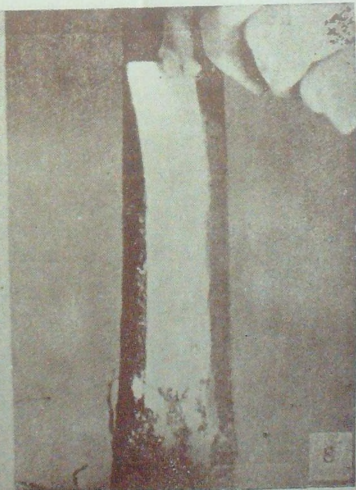
If the budding, however, was done in the nursery, and the plants are to be put out in the field later, it will be necessary to



Flap of Bark placed back over budpatch and rubberised adhesive tape or waxed cloth placed over it.

Binding of replaced flap with coir rope.

(By permission of the Rubber Research Institute of Ceylon)



Removal of Bandage after 3 weeks. Flap of bark covering bud patch is cut off

(By permission of the Rubber Research Institute of Ceylon)

so organize the breaking forth of the bud that when it is moved, it is sufficiently far advanced to withstand the shock of moving, and not too long to run any great risk of damage in transit to the field. It should be say about 1 inch in all. This control is effected by delay in the ringing, and cutting off the top of the stock.

Budgrafting can be carried out throughout the year when the weather is not too dry or too wet. The peeling qualities of the stock seedling bark in most cases will be a limiting factor. During intermittent wet weather periods, the success of budgrafting will depend on the waterproofing of the graft with reliable binding material. The best time of the day for bud-grafting is from dawn to about 10 a. m. and from 3 p.m. till sunset. In nurseries provided there is sufficient shade, budgrafting could be carried out at any time of the day.

Summary of Special Points Relating to Budgrafting.

1. Cleanliness is essential for success. Both hand and budding knife must be kept clean.
2. Before opening the flap of the stock seedling, the surface must be thoroughly cleaned with a rag or cotton waste upto a height of at least 6 inches from ground level.
3. Particular care must be taken to avoid touching of the cambium of the stock panel and that of the bud patch to prevent infection.
4. The bud patch must be inspected to see that it contains the core of the bud. If this core has been broken or left in the wood, the patch is useless.
5. When inserting the budpatch inside the panel, care should be taken to see that it is not rubbed over the cambium of the stock.
6. After the stock has been cut back, care must be taken that no stock shoots are allowed to grow. Otherwise, the transplanted bud will continue to be dormant.

PLANTING AND AFTER CARE OF BUDDED STUMPS AND STUMPED BUDGRAFTS.

Four main factors govern the success of planting stumps:-

1. Condition of planting material in the nursery.
2. The size and vigour of the stump.
3. The care with which the budgrafts are uprooted, transported and planted in the field, and
4. Weather conditions.

In order to avoid failure from adverse weather conditions, planting should be undertaken only at a time when a reliable and reasonable period of wet weather can be expected. This will depend according to the territory or district where climatic conditions can be predicted with a certain amount of accuracy. In districts where the rainfall is below 100 inches per annum the wet weather period is unreliable and it would be best to raise the seedlings for stocks directly in the field and carry out field buddings when the stocks are about 12 months of age.

Size and Age of Stumps. In all budding work it is considered bad practice to allow the small suppressed plants left after selection for budding to grow on to form stocks for the next planting. These plants are naturally lacking in vigour and could not compete with the other plants which reached buddable size earlier. They should therefore be discarded and new even aged beds should be used for the next season's planting material in order that only vigorous stocks could be planted in the field. It has been generally accepted by experience that a large and vigorous stump is satisfactory for successful establishment of budded stumps.

A large stump with plenty of food reserves gives a vigorous shoot with a healthy preliminary whorl of leaves, which is usually able to withstand adverse conditions that may arise subsequent to planting. Such stumps also stand up well to long distance transport. The stumps should be about 1½ inches diameter at ground level and between 12 to 18 months of age. Smaller stocks are satisfactory for field buddings when the stocks are grown as seedlings in the planting holes. The shoot and the first whorl of leaves are are totally dependent on the food reserves of the budpatch and stock, and a vigorous shoot acts as a stimulant for early regeneration of the root system.

Smaller stumps of ½ to 1 inch in diameter are in general use in Malaya and Indonesia with good results. This produces a considerable saving in nursery costs because the plants may be budded at under 12 months of age. In Malaya and Indonesia they are budded at 4 to 9 months depending on the growth of the plants. This allows the nursery to be cleared each year so that less nursery space is required than with older stocks. There is also of course a considerable saving in lifting and transport costs. The planting costs are also reduced by the proportionately smaller hole required. A hole with a cross section one foot square is commonly used with this material.

With a small stump there is less root damage at lifting and planting with the result that the planted stumps becomes rapidly established under normal conditions because the root initials are relatively unharmed and commence growth immediately. With this type of material the budwood used should preferably be of smaller diameter than that for the large stumps in order that the budpatch may fit more snugly. Therefore more shoots should be allowed to grow on the budwood stocks in the propagation nursery to ensure that more slender budwood shoots are produced. If smaller stocks are used they should not be the left overs on the older beds which are usually suppressed plants without vigour. Only stocks from the beds of current age which are not suppressed and are vigorous are suitable.

Method of Uprooting. The care with which the stump is uprooted from the nursery is an important factor in determining its chances of survival. The earth should first be loosened with a fork or alavango so that the lateral roots can come off without damage, especially at the point of contact with the tap root.

The stump is then pulled by an upward lift which may require two men if the taproot is well developed. The taproot should not be cut or broken if it can be avoided. It is, however, in the case of very large stumps necessary to cut a few inches off the end of the tap root to allow it to fit into a particular planting hole.

The plant is then stumped at about 4 to 6 inches above the budpatch, the cut being made at an angle of 45° and sloping away from the bud. The cut end is then dipped in melted grafting wax. Where various clones are used at the same time, it is advisable to write the name of the clones on the cut end with indelible pencil before dipping in wax.

Planting. Owing to high labour costs a modified planting hole is recommended (2½′ x 2½′ x 12″ deep) with centre conical alavango hole for the tap root of 18 inches in depth. A proportion of the earth in the first 12 inches should be excavated for placing in the lateral roots. The tap root is fitted in the centre by opening up with an alavango as shown in Diagram on opposite page. The stump is placed in position with the side roots below ground level, and the bottom of the budpatch about ½ inch above ground level. Where protecting baskets are used the orientation of the budpatch is not important. In some instances bamboo shields placed 4 inches in front of the bud-patch have been successfully used. In general it is preferable to face the bud patch north or south to avoid the rising or setting rays of the sun.

In refilling the hole it is necessary to ensure that the section of the tap root in the central alavango hole is well packed with earth. This is easily done by plunging the alavango three to four times round the tap root by an inward movement. In the modified hole the remainder of the soil can be replaced well above the level of the hole before packing it down with the feet evenly the tap root and laterals, care being taken that the side roots are evenly spread, and not torn off the tap root while treading the earth into position. Careless filling of holes at this last stage is the most frequent cause of casualties.

An application of 4 oz. of rock phosphate mixed with earth in the top 8 inches of the hole is recommended. It is also useful to provide each stump with a bamboo protection basket about 14 inches high and 9 inches across. This fulfils several useful functions. It shades the ground immediately round the plant and can be draped with cover crops to prevent undue loss of moisture in the event of a dry spell intervening shortly after planting. It protects the young shoot from injury and encourages it to grow straight. At a later stage it shades the callus bark growing over the union. In the case of the smaller stumps as used in Malaya and Indonesia the usual hole is approximately 1 ft square in cross section.

After Care. A single good shower of rain following planting can keep the stumps in good condition for about ten days with the baskets draped with cover crop. If persistent dry weather occurs after planting, the stumps should be watered at intervals of not more than 3 days using about 1½ gallons per stump.

The bud can be expected to sprout within about 3 to 4 weeks after cutting back the stock, but the period varies and sprouting may be delayed for several months. After 3 months it will be necessary to supply new stumps to points where the buds are still dormant. In the meantime, and later, the plants should be periodically inspected and any stock shoots, (shoots which develop outside the bud patch) should be removed.

If more than one bud shoot grows from the patch the most vigorous one should be retained and the others removed. The bud shoot should be made to grow with a single unbranched stem up to a height of at least 6 to 7 feet by pruning off any side shoots which develop. At high elevations where the young plants suffer considerably from wind damage and show poor growth the pruning of side shoots above 4 feet can be advantageously deferred until the trees have attained sufficient girth to regenerate without much set back after pruning.

It must be also mentioned that protection baskets if used should be temporarily removed if persistent wet weather occurs between the time that the bud sprouts and the first whorl of leaves matures. Otherwise there will be an increased risk of the young shoot being attacked by *Phytophthora palmivora*.

Cutting the Stock Snag. In the case of small stocks up to 1½ inches in diameter, the snag resulting from the first cutting back of the stock can be left to decay and fall off without further treatment. In the case of larger stocks the snag should be cut off when the bud shoot shows a growth of about 18 inches of brown wood. The cut is made at a slope of 45° so that the top of the cut is about 1/10 inch below the top of the junction between the budshoot and stock.

If the stock is not more than two inches in diameter, the cut surface may be left untreated as callusing proceeds most satisfactorily under such conditions and the risk of infection by wood rotting fungi is not important provided the plant is healthy. The cut surface of large stocks should be protected by an application of white paint.

Where the stock is large and more than two inches in diameter, the snag scar, after the sawing of the snag, should be treated with a suitable waterproof disinfectant, confining the application strictly to the wood and not daubing the thin bark on the edges. Careless applications will considerably delay the commencement of callusing over the snag scar.

The main factor in ensuring rapid callusing is to shade the cut surface adequately. Shade is provided by means of protecting baskets, bamboo shields or by growing erect cover plants in position. The indiscriminate daubing of the snag with disinfectant compounds tends to injure the cambium and delay the development of callus. Such applications are ideally made if confined carefully to the central wood.

Stumped Buddings. This form of planting material is recommended for late supplies after the earlier supplies as budded stumps have failed. The extra budded stumps from nurseries prepared for large scale planting are put out in trenches in the field in convenient positions for supplying. These are allowed to grow for about 18 months with careful manuring as for other planting points. When mature brown wood develops up to 6 to 8 feet in height, and the snag scars have healed over, the trees are stumped in brown wood mid way between two nodes, and used as final late supplies to vacancies occurring up to about 2½ years. This procedure enables the nurseries to be cleared 4 to 6 months after planting making room for fresh planting of seedling stocks.

After transplanting, all shoots which develop towards the top of the stem should be allowed to grow until the plant is well established. The number should then be reduced to three well spaced shoots. If the upper part of the stem dies and shoots develop below six feet, only one shoot should be finally retained in order to ensure a normal branching habit.

CHAPTER VII

NOMENCLATURE OF CLONES

In view of the vast amount of planting material which is becoming available each year as a result of research and field experiments, the desirability of adopting a uniform description of such clonal material and abbreviations was recognised as far back as 1941. In that year a scheme for the uniform description of clones and clonal seedling families as well as their abbreviations was agreed to by the Experiment Stations in the Netherlands East Indies. This Scheme was intended for use in the Netherlands East Indies only, but on the same basis with minor alterations, the scheme was adopted in other Rubber Growing Countries. The Rubber Research Institutes or Experiment Stations should be consulted in case of doubt and up to date information in regard to all clones generally used for commercial culture can always be obtained from them.

The list given below comprises the names of clones and their abbreviations which were used in Ceylon and elsewhere at one time or other. Some of them are out of date and others are no longer used at the present time. For an up to date list, application should be made to the local Rubber Research Institutes. The list which follows is of academic interest to planters as most of the clones were found at one time or other in estate multiplication nurseries before being superseded by others possessing more favourable characteristics:—

A.V.R.O.S.	A.V. 50
Beau Sejour	BS. 3
Bodjong Datar	BD. 10
Bogorredjo	BR. 2
Cultuurtuin	CT. 88
Diyaberiyakande...	DBK. 1
Djasinga	DJ. 1

Glenshiel	GL. 1
Gondong Tapen	GT. 1
Heneratgoda	HEN. 2
Hillcroft	HC. 28
Kali Djeroek	KD. 1
Lampongiana	LAM. 4
Landbouw Maatschappij	LMOD. 53
Lands Caoutchouc Bedrijf Oud Djember	LCB. 1320
Limburg	LIM. 1
Lunderston	LUN. N
Millakande	MK. 3/2
Milleniya	MLN. 162
Pataroeman	PAT. 190
Pilmoor	PIL. B84
... ...	PIL. D65
Planterstrots	PLT. 3
Prang Besar	PB. 86
... ...	PB. 6/9
Proefstation voor Rubber	PR. 107
Rubana	RUB. 393
Rubber Research Scheme (Ceylon) ...	RRC. 4
Rubber Research Institute of Malaya ...	RRM. 500
Sabrang	SAB. 24
Sungei Reko	SR. 9
Tandjong Kemala	TK. 26
Tjiomas	TMS. 438
Tjirandji	TJ. 16
Wagga	WG. 6278
Waringiana	WAR. 4
Wawalugala	WLG. 259

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Gondong Tapen	GT. 1
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Hillcroft	HC. 28
Kali Djeroek	KD. 1
Lampongiana	LAM. 4
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Limburg	LIM. 1
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Millakande	MK. 3/2
Milleniya	MLN. 162
Pataroeman	PAT. 190
Pilmoor	PIL. B84
	PIL. D65
Planterstrots	PLT. 3
Prang Besar	PB. 86
	PB. 6/9
Proefstation voor Rubber	PR. 107
Rubana	RUB. 393
Rubber Research Scheme (Ceylon)	RRC. 4
Rubber Research Institute of Malaya	RRM. 500
Sabrang	SAB. 24
Sungei Reko	SR. 9
Tandjong Kemala	TK. 26
Tjiomas	TMS. 438
Tjirandji	TJ. 16
Wagga	WG. 6278
Waringiana	WAR. 4
Wawalugala	WLG. 259

CHAPTER VIII

GROUND COVERS

In the early days of rubber planting, the importance of the conservation of the surface layers of soil was not fully recognized. For the prevention of soil erosion on steep land entire reliance was placed on earth works such as drains, stone terraces, silt pits—the utilization of all of which is now regarded as only as a second line of defence. Clean weeding was an almost universal practice, and the damage done to bare soils exposed to a tropical sun and rain was gradually realised to be of great consequence.

It is impossible to exaggerate the soil loss that must take place when young clearings are year by year exposed to tropical heat and rain and scraped periodically to remove weeds. Nevertheless, clean weeding in the tropics though appalling in its effects on soil and costly seemed to be the most desirable system from the commercial point of view to the enthusiasts accustomed to agriculture in temperate zones only. Besides, clean weeding was the only system at that time whereby labour could be retained, costs kept near the minimum and the hevea trees made to show the most rapid growth.

From an agricultural point of view the main objection to a ground cover appeared to have been the conviction that the growth of rubber would be thereby greatly retarded. The impoverishment of the soil and competition for moisture by weeds was held to more than counterbalance their value as preventives of soil movement. Although it was recognized that leguminous crops could be utilised so as to enrich rather than impoverish the soil, their establishment as green manures growing amongst the rubber was opposed mainly on account of the increased difficulty and expense of weeding. To keep weeding costs as low as possible, it was essential that all weeds be eradicated and the ground kept entirely clean. A few planters practised a system of "selective weeding" whereby those weeds thought to be noxious such as Iluk and other grasses were removed and the harmless species retained. But the majority of visiting agents and planters condemned any system other than that of clean weeding from the start.

In direct contrast to these methods it is now the almost universal practice to keep a permanent ground cover under rubber of all ages, and vast sums of money have been spent in the establishment and utilisation of leguminous crops. It was clearly realised by all progressive planters that in the course of time the scouring effect of tropical rains became manifested on estates by exposure of lateral roots, unhealthy foliage and stag heads on hill slopes, and diminution in yields, and it became evident that unless effective measures to prevent soil erosion were adopted, the surface soil containing most of the plant foods and humus would soon be entirely washed into the sea.

Java and Sumatra first saw the beginning of a greatly extended use of green manures and ground covers, and from 1918 experiments with various species of Leguminosae had been carried out by experiment stations. In 1920 many thousands of acres of both young and mature rubber were under a ground cover consisting simply of weeds and indigenous Leguminosae. Interest in green manures was stimulated in Malaya in about 1922. The establishment of leguminous plants on new clearings soon became a general practice. But for some years opinion was sharply divided as to the rival merits of clean weeding and ground covers under mature rubber. Owing to the flat and almost peaty nature of much of the coast land in Malaya, the problems of soil erosion and conservation of humus were not of such acute importance as in other countries. In South India, clean weeding was formerly as general a practice as in Ceylon and the loss of top soil in conjunction with Phytophthora leaf-fall was largely responsible for the poor condition and low yields of many estates in that country. Early in 1920, Tephrosia candida (Boga medeloa) became popular as green dressing and in later years the use of a leguminous ground cover became almost universal. The attention of agriculturists in Ceylon was forcibly directed to the question of soil erosion in The Dept. of Agriculture Year Book for 1924, and it was then stated to be the most serious agricultural problem with which the country was faced.

In addition to the provision of adequate drains, stone terraces and silt pits, the use of contour hedges and ground cover crops was advocated. By 1926 most estate superintendents were taking the question of soil erosion in hand and considerable progress had been made on both old and young rubber estates. Although the growth of leguminous crops on new clearings quickly became an established practice, the "die-hard" advocates of clean weeding advanced various objections to their adoption on old estates. Increased cost of weeding, danger from snakes and leeches, competition with the roots of the rubber trees for food substances and moisture and increased danger from root disease were amongst the objections advanced against green manures and cover crops. The majority, however, soon realised that these disadvantages were outweighed by the conservation of soil and improvement in fertility effected.

In all countries difficulty was at first experienced in establishing and retaining a permanent ground cover in heavy shade, and many species of leguminosae were tried. The use of most of the ground covers at present in general use originated in Java and Sumatra, but the quest for further suitable species was conducted in all other rubber growing countries, and in no country have the possibilities of providing the maximum quantity of green material for mature rubber been fully exploited. As will be evident from the succeeding paragraphs there is at present a wide selection of green manures and cover crops available for use under various conditions.

The extension of the cultivation of green manures and cover crops on rubber estates during the past thirty years has been one of the most notable developments in the rubber plantation industry. From a position in which the retention or establishment of any crop other than Hevea was almost universally condemned, the cultivation of green manures and cover crops has grown until it now fills one of the most important places in the agricultural routine of the estate.

FUNCTIONS OF GREEN MANURES AND COVER-CROPS

The entire economy of any land depends on its top soil and it must be adequately cared for and protected from the wasting influence of the sun, rain and wind. Virgin jungle soil consists of a number of rich layers of humus formed from the vast amount of vegetable material produced from perpetual leaf-fall which is excellently protected from the harmful effects of insolation and the wasting action of torrential rain. Once land is cleared and utilised for agriculture, fertility tends to decline and soil movement begins. In the tropics the action of artificial manures, the decay of organic growth, the rate at which humus is used up are rapid, and it is very important therefore to take suitable measures to conserve the original valuable properties of the soil by endeavouring to approach as closely as possible near jungle conditions in our agricultural practices by protecting the soil with leguminous ground covers.

In addition to drains, terraces and similar earthworks, which are necessary to control both water and soil movement, the growing of ground covers on rubber estates provides the most important means of preventing soil erosion, and maintaining and improving the humus content of the soil. This mode of protecting and enriching the soil is both economical as well as efficacious, the fresh vegetable matter being returned to the soil with greater benefit than when it has been decomposed and much of its goodness lost in the process of rotting and fermentation. For improving the physical condition of light sandy soils particularly, the use of green manures and cover crops is of the greatest value. Briefly the principal benefits derived from the growing of cover-crops are:

1. The supply of humus to the soil which increases its capacity for retaining moisture.

2. It prevents surface wash and soil erosion and protects the soil from the direct impact of rain, sun and wind.

3. It improves the mechanical condition of the soil by the action of the roots of the cover-crops.

4. The covers afford protection to the roots of the main crop from excessive radiation from the ground surface.

5. Cover-crops effectively suppress the growth of weeds and render economy of labour.

6. They help the fixation of atmospheric nitrogen in the soil when the covers belong to the family of *Leguminosae*.

Whilst practically all plants are useful for adding organic matter to the soil when dug into it in a green state, yet all are not equally valuable. However well the first five of the foregoing benefits may be achieved by the use of non-leguminous plants, it is an accepted fact that only leguminous species have the power of utilising and fixing the free nitrogen of the air. It is well known that on the roots of certain leguminous plants there usually occur nodules or tubercles which vary in size from that of a pin's head to that of a pea. These nodules contain bacteria which abstract and fix the free nitrogen of the atmosphere. The nitrogen thus becomes stored up in a combined form in the roots and stems of such plants, and when the roots of these are left in the ground, or the whole crop is dug in as green manure, the soil is considerably enriched with nitrogen. Only leguminous plants (chiefly those of the sub-family *Papilionaceae*) obtain their nitrogen in this way, all other plants, so far as is known at present, depending for their supply on nitrates formed by the soil bacteria from organic substances in the soil. The effect of this property of leguminous plants has long been recognised in agriculture, and crops of this family are therefore esteemed an important factor in the cultivation of major crops.

Low growing creepers are well suited to Rubber plantations because they do not unduly interfere with tapping, and are the most effective in preventing soil movement on steep slopes. In the absence of a ground cover, the soil will lie exposed to the elements, valuable top soil and humus will be carried away by torrential tropical rain, and the fertility of the land will progressively diminish. The root system of cover crops binds the soil particles together and the plants themselves form miniature bunds which help to prevent surface wash. The creeping habit of some species arrests the movement of water over the soil which is further opened and kept porous by their roots and so permitting better penetration and percolation of rain water resulting in less run off and wash.

Cover crops improve and maintain soil fertility by providing a surface mulch by the natural leaf fall and death of leaves and stems. When their growth necessitates their slashing down, they afford ample mulch which goes to enrich the soil with the passage of time. Further they conserve the nutrients produced by them, and provide for the accumulation of humus by death and decay of leaves, stems roots etc. They keep the soil moist and humid under severe drought conditions as can be seen by an examination of soil which is protected by ground covers and that which is not.

In the selection of a good cover crop suitable for rubber, the following points should be considered.

1. The cover should be capable of being easily propagated and multiplied by seed.
2. Its root system should not compete with rubber, but at the same time should be capable of binding soil particles effectively.
3. It should be capable of growing well on average soils.
4. It should tolerate slashing and pruning.
5. It should be able to withstand and resist drought, disease and pests.
6. It should be able to suppress and stifle weed growth.
7. It should be easy to eradicate when required.

8. It should not form products which are toxic to the main crop, and in this connection grasses are noted for this undesirable character.

The family of *Leguminosae* contains several species which possess most of the above desirable attributes in a large measure as compared with other plant families, and the covers used for rubber are invariably leguminous.

Cover plants may be divided into two distinct types:-

(a) Low growing types especially valuable for the prevention of soil wash.

(b) Erect shrubby types which are valuable on new clearings and are used in conjunction with low growing types.

The desirable attributes of a low ground cover may be enumerated as follows:

1. A perennial plant is preferable to an annual on account of its greater permanency.
2. Plants belonging to the family of *Leguminosae* are preferable to others on account of the nitrogen fixing properties of bacteria in their root nodules.
3. A creeping plant which will root at the nodes and thus spread over a large area of ground is desirable.
4. A plant which will entwine and smother grasses and other weeds is to be preferred.
5. The plant should be easily established from seed and should make rapid growth.
6. It should have a well developed root system to aerate and bind the surface soil.
7. It should have a luxurient foliage to provide an effective protection to the soil from the sun and rain and also to provide a plentiful mulch.
8. It should not be subject to diseases or pests liable to attack *Hevea*.

A number of leguminous plants fulfil all the above conditions and it is not necessary to look beyond the *Leguminosae* family for suitable covers. For new clearings, Dolichos Hosei (Vigna oligosperma), Centrosema pubescens, and Calopogonium mucunoides were extensively used in former years. At the present time popular cover crops are Pueraria Phaseoloides (P. javanica), Desmodium or alifolium, Centrosema pubescens, Calopogonium mucunoides, Stylosanthes Gracilis, Mimosa invisa (inermis), and Indigofera endecaphylla. All these plants are described in this chapter.

Erect Green Manures. The most important characteristic of a good green manure plant is that it should provide large quantities of nitrogen and organic matter for the soil. This is mostly supplied by periodically cutting back the plants and burying the loppings. When turned into the soil, the green material not only increases the humus content, but in the process of decomposition, also has the effect of rendering some of the mineral constituents of the soil more readily available as plant foods. Species vary in the extent to which they may be pruned without detriment to their growth, and the ideal cover must clearly be able to stand periodical severe lopping.

As with creeping covers there is a wide range of leguminous plants which can be employed for this purpose. Tephrosia candida (Boga medeloa), Clitoria cajanifolia, Crotalaria anagyroides, Crotalaria Usaramoensis have all been used with considerable success in new clearings.

Mixture of Cover Plants. It will now be appreciated that both types of cover plants, ground covers as well as erect green manures are necessary on new clearings. Although some species of green manures such as Tephrosia candida, Tephrosia vogelii, Crotalaria Anagyroides, Crotalaria Usaramoensis are usually planted in hedges, it is a sound practice to broadcast a mixture of seed of both types so that the various species grow up together. The erect covers then provide the small amount of shade beneficial to the young seedlings of some of the ground covers.

Instances are known in which Dolichos hosei (vigna) was quickly established in this way, whereas by sowing the seed by itself on exposed soil, the plant made little progress.

It has also been found that certain cover crops which make rapid growth at first gradually die off, whereas others which are less quickly established are of greater permanency. It is therefore desirable to plant a mixture of these two types so that the more permanent cover may, in the course of time replace that which made the earliest growth. Thus Calopogonium should be planted in conjunction with a cover such as Centrosema pubescens or Pueraria phaseoloides (javanica). The Calopogonium will provide most of the cover during the first year or two, and this will gradually be replaced by the other species which flourish in the shade of the maturing rubber.

Methods of Planting. In planting up a new clearing with cover crops and green manures, the most important consideration is that the ground should be covered as soon as possible after felling and burning the timber so as to prevent the loss of surface soil and humus consequent upon exposure to the tropical sun and rain and to keep weeds in check. At the same time, whether seeds or cuttings be used, it is valueless to attempt to plant a cover in settled dry weather, and the planting operations should always be carried out when wet weather can be expected.

Whether seeds or cuttings are to be used, the first essential is to clear the area of weeds and subsequently to carry out a regular weeding programme until the cover is thoroughly established. It is the general experience that if the eradication of weeds is rigorously carried out while the cover is becoming established, the thick cover that subsequently develops chokes out weeds to a great extent and enables hand weeding to be carried out at a greatly reduced cost.

All the species recommended above are best planted in new clearings from seed, and unless for some reason seed is not available there is no necessity to propagate vegetatively. Seed of the various species selected should as a general rule be mixed, and for quick germination may be soaked for 24 hours in warm water immediately before planting. Seed treated in this way must on no account be allowed to dry out before sowing. The seed may be planted in small holes two or three seeds to a hole, scattered irregularly throughout the area or may be distributed in rows on loosened soil and pressed well down. The distance apart of the rows or holes and quantity of seed per acre naturally depend on the species used.

When it is necessary to propagate from cuttings care must be taken to use only mature stems, and to press these well down into the soil to prevent them drying out. A useful method of procuring rooted cuttings is to embed coconut shells in the nursery beds before planting seeds and to plant these out in the field when the nursery is well established.

Some species of erect green manures are best planted in hedges thereby forming valuable check to soil movement. These hedges should be planted along the contours and their position should depend to some extent on the method of opening. In Java and Sumatra soil erosion is largely prevented by silt pits the earth from which being used to build continuous ridges about one foot high immediately above the pits. The ground cover is commonly planted on these soil ridges.

On poor soils the establishment of leguminous species may be materially assisted by the application of manure at the time of planting. Phosphoric acid is the chief requirement, and this is probably best supplied by Rock Phosphate or Saphos Phosphate. Bulk cattle manure is often used when available. The manure should be mixed with good surface soil and planted with the seed.

Subsequent Treatment. In order that the maximum benefit from cover crops may be obtained it is not sufficient simply to plant them and ensure their vigorous growth. Erect covers are grown as sources of green material and in order to obtain the maximum quantity of humus the plants must be periodically pruned. The extent and frequenty to which the bushes should be cut back varies with the different species, but in general it is advisable to lop twice a year. In determining the time of the year at which lopping should be undertaken, a number of factors must be taken into consideration. In order to obtain the maximum quantity of food substances, the plants should be lopped when in full bloom before the seed has been set. On the other hand, the seed may be required for further planting. The plants should not be pruned in the dry weather. If possible lopping should be undertaken in showery weather at the end of a monsoon so that the green material is buried in a moist soil. The plants will then have made a small renewed growth before the succeeding spell of dry weather, but will not take much moisture from the soil.

The correct treatment of the loppings provides a debatable problem. There is no doubt that in order that the soil should derive the greatest benefit by the addition of nitrogen and humus forming material, the loppings should in some way by turned in to the soil. It has been shown by The Department of Agriculture, Ceylon that if green material is allowed to dry on the surface of the soil, nearly 50% of the nitrogen may be lost. Where possible, therefore, green manure loppings should be forked into the soil or buried in pits, and it is probably advisable to alternate these two methods. Where expenditure must be reduced to a minimum it is customary to spread the loppings behind the bushes or where platform planting has been adopted, at the back of the platforms.

The extent to which ground covers should be kept back from the young rubber plants is again a debatable point. On the one hand the growth of covers in close proximity to the young plants will result in slower growth owing to competition between the rival root systems for plant foods and moisture, and on the other hand any bare soil will tend to deteriorate as the result of exposure to a hot sun and heavy rain. It is clearly necessary at first to maintain a small area around each young plant free from any ground cover on account of the danger of a cover taking a twining habit and climbing up the rubber plants and smothering them. As the root system of the rubber spreads this cleared area should be kept larger and larger if competition between the roots is to be avoided. The logical outcome of this treatment however, would be the eventual removal of the entire cover, thus returning to the policy of clean weeding. It is clear that a compromise must be effected. Observation in Ceylon and other countries has shown that the growth of young plants is definitely retarded by the presence of a close cover, and it is therefore probable that an area corresponding approximately to the spread of the root system should be kept clear around each plant until the rubber is approaching tappable age. Where the platform system of planting has been adopted it is simple to keep the platforms wholly or partly clear of any green manures or cover plants while the rubber is between the ages of about 2 or 3 years. Where the rubber plants are very young, a cleared area corresponding to the size of the holes is sufficient, and when the rubber is mature the cover may, with certain limitations, be allowed free scope.

It has been found that on areas planted with a mixture of ground covers and erect green manures, the former tend after two or three years to somewhat smother the latter. It is therefore necessary to re-establish the green manures periodically.

Although wind breaks do not strictly come under the category of green manures, in that their primary function is not concerned with soil improvement, by the selection of suitable species, many of the benefits associated with green manure plants may also be obtained. By planting leguminous species the soil is enriched by the fixation of atmospheric nitrogen, and by selecting varieties which not only give effective protection against the wind, but which may also be lopped to yield green material, the dual functions of wind breaks and green manures are fulfilled.

Young rubber plants are very susceptible to strong winds, and their growth may be materially retarded or even completely inhibited when planted in exposed situations. On clearings which are exposed to wind, it is necessary to protect the plants as far as possible by the establishment of wind belts. In the past the use of wind breaks on new clearings has not received its merited consideration.

One of the most effective windbreak trees is Albizzia Molucana which grows very rapidly and has a deep root system. On new clearings it should be planted as early as possible along the ridge of all exposed hills, the establishment and rapid growth of these trees being at first regarded as of equal importance to the growth of the rubber plants. A row of Albizzias planted lower on the slope of a ridge at right angles to the direction of the prevailing wind is also of great value in deflecting the wind above the top of the ridge. Albizzia grows with a spreading habit and quickly forms a substantial wind belt. It is a matter for discretion whether the trees should be removed when the rubber is approaching maturity or whether they should be retained permanently. Mature rubber has been seen growing excellently in conjunction with large Albizzias, and it is of advantage to retain these trees in particularly exposed areas.

Albizzia may also be planted between the rows of rubber both for wind protection and as a source of green manure, but it must be kept pruned so that the young rubber trees are not overshadowed, or "spindly" development of the latter will result. Pruning must however be undertaken with discretion so that the rubber trees are not left without protection when high winds are prevalent. Albizzia can most conveniently be grown from seed in nurseries, and thence planted out in the field.

In addition to the establishment of major wind breaks, Gliricidia maculata may be planted in rows at right angles to the direction of the prevailing wind. If kept lopped at a suitable height, this species gives valuable protection to the young rubber plants in the first two or three years, and also provides a great quantity of green manure. Gliricidia is most easily planted in the form of cuttings about 6 feet in length.

Dadap (Erythrina lithosperma) is also commonly planted in young clearings as an alternative to Gliricidia. In certain localities, it thrives better than the latter. It is easily established from cuttings or seed, grows rapidly and is valuable as a source of green material.

Leucaena glauca grows to a small tree 15 to 20 feet in height and forms a useful wind protection for young rubber. Subsequently, it may be cut low and retained as a green manure hedge.

Green Manures and Cover Crops under Mature Rubber. The value of green manures and cover crops in reconditioning badly washed soil under old rubber was recognized many years before the establishment of such plants became a general custom. This delay in adopting an obviously sound agricultural practice was due not only to the conservative attitude of many influential planters of the old days, but also to the difficulty in finding suitable species which could be easily established and retained in heavy shade. The earliest efforts towards checking soil erosion and providing mulch consisted of "selective weeding" whereby certain weeds thought to be noxious were eradicated and other harmless species retained. When certain leguminous plants were found to be tolerant of the normal shade under mature rubber it was clearly preferable to substitute the mixed weed growth by a leguminous cover, thus obtaining the additional soil enrichment due to the activities of the nitrogen fixing bacteria in the root nodules characteristic of the leguminosae family.

The influence of a ground cover on the growth of weeds has always provided a basis for argument between the respective advocates of clean weeding and cover crops. It was at first feared that the existence of a cover would increase the difficulties and therefore the cost of weeding. It has been the general experience that provided the round is rigorously weeded, while the cover is establishing itself, a thick cover will subsequently be formed which will tend to choke out weeds and thus enable hand weeding to be carried out at a reduced cost. If, on the other hand, weeds are not kept in check while the cover is still thin, a mixed growth will result and the eradication of the undesirable species may present considerable difficulty.

Choice of Species for Adoption under Mature Rubber. The choice of species for use under mature rubber is less extensive than for new clearings. As far as ground cover is concerned it is essential that the plant should be easily established, and should be of a permanent nature. The number of leguminous plants fulfilling these conditions under the shade of mature rubber is relatively limited. As regards erect green manures the same limitation is experienced and the possibilities of supplying mature rubber areas with green manure are as yet largely unexploited.

(a) **Ground Covers.** One of the earliest ground covers to be used was Mimosa Invisa. This is probably unsurpassed on badly washed soils where the foliage of the rubber trees is scanty, and many areas in the Dutch East Indies have been greatly improved by the use of this cover. Mimosa will not however grow under heavy shade and there are various objections to its use which have been considered of sufficient importance to bar its general adoption.

An important advance in the use of cover crops in rubber cultivation was made when it was discovered that Dolichos Hosei, the Sarawak bean otherwise known as Vigna oligosperma, flourished in the normal shade of old rubber. This species was the earliest ground cover to be planted extensively in mature areas, and has remained up to the present time the only important cover in Ceylon. Vigna is easily grown from seed but since seed is somewhat expensive, it is preferable to establish a nursery and thence to plant out cuttings in the field. The plant has a comparatively shallow rooting system and is therefore probably of greater value on flat and undulating land than on steep hill slopes. Vigna has, nevertheless, proved invaluable in checking soil erosion in hilly districts in Ceylon, the clearness of the drainage water bearing adequate testimony to its efficacy.

It is also valuable as a soil builder, and under a thick cover of Vigna a quantity of leaf mulch is always to be found. In addition to the soil benefits due to ground cover, it has been the general experience that a cover of Vigna by inducing moist atmospheric conditions and keeping the ground temperature low, is beneficial to the flow of latex so that late tapping does not result in so great a diminution of yield.

In Java and Sumatra, Vigna has, of recent years, been largely replaced by Centrosema pubescens. This forms a very similar cover to Vigna but is probably to be preferred on acount of its deeper root system, its marked twining habit which makes it very effective in choking out weeds, and its ability to withstand prolonged periods of dry weather. Centrosema is however more difficult to establish in shade than Vigna and at first makes slower growth. Efforts to establish this plant under mature rubber have been made on many estates in Ceylon but except where the shade is light very little success has been obtained. Centrosema requires a fairly good soil, and it is probable that the poverty of eroded soil in conjunction with heavy shade is largely responsible for the different experiences with this cover in Ceylon and Java. It seems likely that once established on a new clearing Centrosema will persist when the trees become mature.

Centrosema plumieri has been seen growing under mature rubber where the shade is light but this species is no more tolerant of heavy shade than C. pubescens, and is generally regarded as inferior to the latter in other respects.

Pueraria phaseoloides (Pueraria javanica) has received considerable attention in recent times and has proved to be of considerable value under mature rubber as well as in new clearings. Although growth is somewhat slow at first, a dense cover is eventually obtained. Pueraria has been planted extensively in Malaya and Indonesia, and in Ceylon it has since take the place of vigna in the majority of estates.

Desmodium Ovalifolium. This is a semi prostrate leguminous plant which does not creep over the ground but which may root from the nodes of branches which lie on the soil surface. It does not suppress the growth of weeds to such an extent as Pueraria, but it has the advantage that it persists well under shade and regenerates well from self sown seed or can be easily established from cuttings.

Various other species of Desmodium have appeared to grow well in, old rubber in Ceylon. Desmodium triflorum is a very small leafed species which forms a close mat over the ground. It is effective as a preventive of soil erosion, but its close mat like growth is an objection. It is not be recommended where other covers can be grown. Desmodium heterocarpum is a sub erect woody plant which is of more value as a source of green manure than as a ground cover. It is grown extensively in South India under the synonym Desmodium polycarpum.

(b) **Erect Green Manures for use under Mature Rubber.** As regards erect green manures, the ideal plant for mature rubber areas has yet to be found. Most of the leguminous species which flourish on new clearings produce but a stunted growth in heavy shade. There is no doubt, however, that humus is the most important soil requirement of the average rubber estate, and the establishment of green manures in addition to cover crops is therefore much to be desired.

Tephrosia candida This plant grows rapidly under mature rubber and although not attaining its full development under shady conditions, is a valuable source of green material. The plant however, must be periodically re-established not only because it weakens under the shade but also because when woody it is liable to attack by some of the root diseases fungi to which hevea is prone.

Crotalaria anagyroides and Crotalaria usaramoensis will both grow in old areas but if an adequate supply of green material is to be maintained they must be frequently replanted. Both species grow more rapidly than Tephrosia but are less tolerant of lopping. They produce seed in great abundance in open areas or where the shade is light.

Methods of Planting Ground Covers. The greater part of the ground covers of vigna under mature rubber have their origin in cuttings. Owing to the fact that the plant is a shy seeder, seed is relatively expensive and the establishment of Vigna by seed over a large area was costly. Where cuttings were not readily available from the neighbouring areas, it was necessary to establish nurseries from seed and thence to plant out cuttings in the field. After cuttings have been removed from the nursery a new flush of growth will take place so that in a few months further cuttings may be taken. A useful method of procuring rooted cuttings is to embed split coconut shells in the nursery beds before sowing the seed and to plant these out in the field when the nursery is well grown.

Provided that good soil is selected and weeds are eradicated there will be no difficulty in establishing a good nursery of ground covers in a short time. In transferring the cover to the field, however, considerable difficulty is often experienced in certain areas. It has been the experience of many planters that whereas a thick cover is easily established on the greater part of the estate, certain areas are apparently unable to support the cover. This is usually due to the absence or scarcity of the particular bacteria without which the plant is unable to make vigorous growth. In such cases large quantities of rooted cuttings or plants should be planted together with a quantity of the soil in which they are growing. The "barren" soil is thus inoculated with the necessary organisms, which multiply rapidly as humus is formed. The split coconut shell method in planting is also useful in such areas.

Centrosema pubescens is best established from seed. Germination usually takes place within 10 to 14 days from the time of sowing, but the growth of the seed is slow and on most soils under heavy shade the plant makes little progress. According to a recent report, very successful results have been obtained in Sumatra by soaking the seed in an extract of crushed Centrosema root nodules thus securing the inoculation with the necessary bacteria.

Pueraria phaseoloides (javanica) is satisfactorily grown from both seed as well as from cuttings. If mature stems about 2 feet long are used, the plant roots very readily. Growth is somewhat slow at first, but eventually a thick cover is obtained.

The establishment of ground covers on poor soil is materially assisted by the application of small doses of manure. Phosphate is the most important requirement and Rock Phosphate appears to be the most suitable source. The addition of a small proportion of nitrogen is also beneficial, and excellent results have been obtained with ammoniun sulphate. Cattle manure when available has also been found useful for starting a cover. Under mature rubber erect green manures are probably beneficial when grown in hedges along contours. In addition to their green manurial properties they are then valuable as checks to soil movement. It must be stated that their value is now being recognized by the majority of estates, and in this connection their value as pre-indicators of the activity of Fomes fungus is considerable. Tephrosia vogelii which is almost similar to Tephrosia candida, is such an useful disease indicator plant.

Tephrosia candida, Crotalaria anagyroides, Crotalaria usaramoensis or Tephrosia vogelii should be sown thickly in rows along the contours midway between the rubber trees. Care must be taken that the growth is not too close to the trees or the drying of the tapping cuts after rain will be seriously retarded by the damp atmospheric conditions caused. Haphazard planting should also be avoided as this will result in interference with supervision of tapping.

Subsequent Treatment of Cover Plants in Mature Rubber. There is no general agreement as regards the correct use of cover plants under mature rubber and in the beginning it was cutomary to allow Vigna to form a complete cover over the whole estate, and although by this means soil erosion was very effectively prevented, it was aruged by some that the cover competes with the rubber trees for moisture and food substances and heavy toll was taken of any manure which was applied. It was thus the practice on some estates in Java and Sumatra to confine the cover to soil erosion ridges reliance being mainly placed on the latter for the prevention of soil wash. Although this method may be suitable on flat or gently undulating ground, it would seem that on steep hill sides on which Hevea is commonly grown, a complete cover is preferable. In such cases the only limitation to the growth of a ground cover is the presence of root disease. In areas where root disease particularly Fomes lignosus is known to be present, it is important that the ground should be kept strictly clean weeded.

In order to obtain the maximum benefit from a ground cover it is not sufficient simply to ensure its establishment and vigorous growth. Although experiences differ with regard to the direct effect of green manuring on latex yield, there can be no doubt that the soil is materially improved by the addition of humus forming tissues so that an increased crop will eventually result. A ground cover adds a certain quantity of humus to the soil by reason of its normal leaf fall, but in the process of decomposition on the surface a large proportion of the available nitrogen escapes into the air in the form of ammonia and is lost to the soil. In order that the soil should reap the maximum benefit, it is therefore necessary that the cover should be periodically buried in the green state.

It must be stated that it is not at present customary to utilise the ground cover as a green manure. Where artificial manures are applied to ground bearing a thick cover, the latter is usually rolled back from the strips or squares to be manured and either left as bunds or replaced on the surface of the ground. There can be no doubt that from the agricultural view point this is not the ideal method, and that the opportunity of incorporating valuable green material with the soil is lost. Alternative methods of incorporating the cover with the soil are forking and burying in pits, and the choice of these two methods is largely dependent on individual preference. Where artificial manures are being applied by envelope forking, the cover can be torn up and forked into the furrows together with the manure. With certain mixtures the cover is often killed, but in course of time, the ground is usually again covered by encroachment from the unmanured strips.

An objection advanced against envelope forking the cover into the soil is that the feeding roots of the rubber are thereby disturbed and damaged. There is however no doubt that forking is itself beneficial in certain areas, and in choosing the method of utilising a cover, the planter must be guided by the condition of the soil in question. Burying the cover in pits has the obvious objection that the green material is thereby less evenly distributed so that the soil loses some of the benefits due to the humus formed.

Another method has been adopted on some estates where the expense of forking has been considered unjustified. The cover is rolled back in strips like a carpet and replaced on the ground upside down. Although this method is doubtless of some benefit a large proportion of the nitrogen and organic matter is lost.

Whatever method of utilising the ground cover may be adopted, it is clearly inadvisable on hilly ground to remove the entire cover at one time. Strips of cover should be retained along the contours so that the ground is not left entirely unprotected against soil erosion.

In addition to the soil improvement consequent upon the incorporation of green material, there is another important reason why the periodical disturbance of a ground cover is desirable. It has been a common experience in Ceylon that healthy covers of Vigna have unaccountably died off after fouror five years of growth, and there can be little doubt that in many cases the death of the cover has been due to a soil factor which for wan't of more exact terminology is called "staling". The disturbance, aeration and enrichment of the soil consequent upon periodically turning in a green cover helps to enable the soil to maintain a fresh growth of the same plant. Ground which has become "stale" should be rested before endeavouring to re-establish a cover and a different species should if possible be used on such areas.

Although a ground cover in addition to its value in prevention of soil erosion can be utilised to provide green manure, a considerably larger bulk of green material can be obtained by growing shrubby leguminous plants and periodically turning them into the soil. There can be no doubt as to the theoretical value of such a procedure, but there is a great diversity of opinion among practical planters as to the economic aspects of growing erect green manures under old rubber. In the first place such species as have so far been used are somewhat difficult to establish and costly to maintain. In order that the soil may derive the maximum benefit, the plants must be lopped frequently, and the loppings forked into the ground or buried in pits. Although forking is undoubtedly beneficial to some soils, its frequent practice is open to objection on account of the damage caused to the rubber roots. It is argued by some planters that the money spent on the establishment and utilization of such plants could be more usefully employed in providing artificial manure. It must be borne in mind, however, that inorganic manures cannot cause any permanent improvement in the chemical and physical condition of the soil unless humus is also present. Artificial manuring should, therefore, be always combined with green manuring.

Establishment of Covers. Cover crops are best established in a new clearing immediately after clearing. Either seed or cuttings should be planted according to the species being used. With creeping covers which root at the nodes such as Centrosema and Pueraria, the cuttings or seed may be spaced up to six feet apart as they rapidly cover the intervening spaces. Types such as Desmodium, however, must be planted all over the area as they do not run and root.

In areas carrying heavy weeds, clean weeded strips should be forked up and the seed and cuttings planted in the strips. When established the intervening strips of weed growth should be gradually removed to allow the covers to spread eventually over the whole area. In such areas, however, only the creeping types which will spread and tend to smother the weeds should be used.

Cover plants may be grown in nurseries and planted as balled plants in areas where risks of dry periods are present.

Seed Treatment. Some species of leguminous cover crops have seed which unless specially treated is difficult to germinate quickly. Seeds which can be advantageously treated are Pueraria and Desmodium. The seed should be either soaked in hot water for 24 hours, leaving the water to cool, or treated with sulphuric acid. For the acid treatment the seed should be put in a glass or other acid resistant container and sufficient concentrated sulphuric acid added to cover the seed. After 15 to 20 minutes, the acid is drained off carefully and the seed washed with several changes of cold water to remove all the acid. The seed should then be soaked for a few hours in cold water and is then ready for sowing. On no account should the seed be allowed to dry out after acid treatment. When using sulphuric acid, care must be taken to avoid splashing and when washing the remaining acid out the first rinse, cold water must be added slowly.

The germination rate of cover crop seed can be greatly accelerated by softening the seed coat and making it more permeable to water which is essential for germination. Seeds which would normally remain dormant in the soil for a considerable time are made to germinate rapidly.

Acid Treatment. One way of achieving this result is by acid treatment which consists in soaking the seed in concentrated sulphuric acid for 15 to 20 minutes. This is best done in practice by placing the seed in a glass vessel say a 4 gallon carboy, and pouring in enough concentrated sulphuric acid to cover them. The seeds are stirred by a rotating motion of the carboy for about fifteen minutes after which as much as possible of the acid is poured off and water added through a hose pipe, at first carefully in order to avoid dangerous spurting and overheating. The tap is then turned on to its full extent and with the free end of the hose pipe placed well down in the carboy, water is allowed to run out of the mouth of the carboy for a few hours to wash off all traces of the acid and to soak the seed. By this method it was found in Malaya that seed which may give 30 per cent germination over 4 weeks will give over 80 per cent germination in 3 to 4 days. It is very important that operators must be warned that concentrated sulphuric acid is very corrosive and dangerous to handle.

Hot Water Treatment. Another way of accelerating germination of cover crop seed is by hot water treatment. This may be done by placing the seed in a waterproof tin container, such as a small latex collecting bucket, adding water to the brim and placing the container in a smoke house, where the temperature may vary between 50° and 55° Centigrade overnight or until the seeds have swelled up. With this method of treatment, the percentage germination may be increased from say 30 per cent in 4 weeks to about 50 per cent in one week. It is therefore less effective than the acid treatment but is probably safer for normal estate use.

Mixed Leguminous Covers. It is often preferred to establish a cover consisting of two or three species of legumes in order that the shade or drought resisting or other qualities of one may be offset by those of another. In Ceylon a mixture of Pueraria phaseoloides and Desmodium ovalifolium is popular as the Pueraria grows vigorously and holds and protects the soil in the young clearing but stands only light shade whereas the Desmodium is of weaker growth but tolerates shade much better and persists more satisfactorily under a dense canopy of rubber. Another useful mixture may be made as follows :-

Calopogonium mucunoides	...	1¼	lbs. seed per acre
Centrosema pubescens	...	1¼	,, ,, ,, ,,
Crotalaria anagyroides	...	3½	,, ,, ,, ,,
	Total	6	,, ,, ,, ,,

Manuring of cover crops. Phosphoric acid is the principal plant food required by legumes for satisfactory growth. It is also essential if efficient nitrogen fixation is to be expected. Many areas are however, suffering from shortages particularly of potash and a suitable manure mixture, containing potash is it necessary and is likely to benefit the covers also. An additional broadcast of 1 cwt saphos phosphate at the time of establishment of the covers gives very good results.

When establishing covers in beds or strips in the plantation a dressing of 4 oz. per square yard of the standard R. R. I. Mixture together with the broadcast saphos phosphate between the strips is usually essential to encourage spreading. Under young rubber there should be little need for cover crop manuring unless the covers are being re-established. Calcium (lime) is also important for cover crops and nitrogen fixation. Some lime is, however, supplied in the normal saphos broadcast and if additional liming is required, it should be done on the advice of the R. R. I.

The idea of dibbling Rock phosphate in the soil when planting ground covers is a good one and will certainly help to promote the growth of the seed. Later on when the cover is established, a mixture containing all three plantfoods, i.e.- Nitrogen Phos. Acid and Potash such as the one below should be broad cast at the rate of 1 cwt per acre :-

3% —	4%	Nitrogen
14% —	15%	Phos. Acid
	7%	Potash

Pests & Diseases. Although cover crops are selected for their resistance to pests and diseases, they are susceptible to damage from Pests and diseases, and attention should be paid to eradicate such pest or disease immediately it is noticed. Cover crops under rubber are liable to attack by various leaf-eating, boring and sucking insects. Eel - worms may also attack the roots, but no serious damage from the latter cause has been reported in Ceylon. Generally speaking it is impracticable to control pests on covers owing to the heavy expense involved unless the outbreak can be checked before it spreads to a large area.

The following information with regard to diseases of cover crops and their control is reproduced below with the kind permission of The Rubber Research Institute of Ceylon from their Advisory Circular No. 56.

Fungal diseases of cover crops. Most woody plants are liable to the same root diseases which attack Rubber. Covers will not bring in root disease but they may assist in its spread if not properly controlled. Areas known to be affected by root disease should be kept clear of creeping covers; the moist conditions prevailing under the cover favour fungal activity, and the strands of mycelium, particularly of Leptoporus lignosus (white root disease) may spread along the older runners of the plants. The covers may also conceal fructifications. Erect covers such as Crotalaria anagyroides can usefully be retained or planted as an "indicator" in disease patches as described in the earlier section. It must, however, be kept under observation and suitable steps taken if it become diseased,

Pink Disease. Woody covers are liable to attack by Pink Disease (Corticium salmonicolor) which also attacks young rubber. This disease which is easily identified in the early stages by the pink coloration of the bark surface, usually attacks the young rubber trees at the junction of the branches with the main stem. Covers attacked by Pink Disease should be pruned well below the point of attack; the prunings should either be brunt on the site or removed in sacks and burnt elsewhere.

The humid conditions arising from the presence of ground covers favour development of stem diseases of Rubber caused by Phytophthora (canker and bark rot). Creeping covers should always be kept back from the base of the trees and because they may conceal the presence of canker, or decay caused by *Ustulina deusta*.

Rhizoctonia and Sclerotium. Herbaceous covers are liable to attack by two sclerotial diseases, Rhizoctonia solani and Sclerotium rolfsii. The effects of the two diseases are somewhat similar. Brown and roughly circular patches of dead plants appear in the cover, ranging in size from a few inches to several yards. These patches are particularly noticeable in areas in which the cover is well grown, since affected areas are somewhat sunken below the general level of the cover. Outbreaks occur most commonly during wet weather. The diseases do not attack Rubber and extensive damage to covers is unusual in Ceylon.

The correct control measure for this type of soil-inhabiting organism is that of soil sterilisation. The procedure usually recommended in Ceylon is to collect the affected plants, together with a border of healthy plants, and burn them *in situ*. The surface soil from the area is scraped up and heated by the fire as far as possible in order to kill the sclerotia. Alternatively the area may be isolated by a trench 18 inches deep and treated with a soil fumigant, e.g.- 1: 50 solution of formalin, 1: 100 solution of copper sulphate. The application should be made at the rate of 1 quart per square foot.

Wart Disease. This disease of Desmodium ovalifolium caused by fungus Synchitrium desmodiae is becoming fairly common in Ceylon. The fungus causes a warty appearance of the ends of the shoots and results in the death of the plant in large patches particularly in wet weather. There is little that can be done economically and the best antidote is to establish a different cover crop. So far no other plants have been affected by this disease.

Soil Sickness. Leguminous cover crops grown by themselves after about 4 to 5 years frequently die out in patches due to poisoning by the accumulation in the soil of by-products which are toxic to the legume which produces them. This seldom occurs when a cover of mixed species is planted. When soil sickness does occur, however, the remedy is either to allow the harmless weeds to grow for about a year by which time the accumulation of toxins will have disappeared when the cover usually regenerates from its own seed or from surviving plants. The difficulty may also be overcome by planting a different species or a mixture of species in the sick areas.

Cover Crop Species for use in Rubber. The more important plants used as cover crops in rubber are described below.

(a) PROSTRATE AND SEMI-ERECT TYPES

1. **Calopogonium mucunoides.** This is a plant indigenous to tropical America. It is a climbing or creeping plant with round

stems, form 1 to 3 metres, covered with a long pubescence. It seems to be adaptable to any soil. Sown in rows 1 metre apart, from 8 to 12 kg. of seed per hectare (2.471 acres), the soil will be covered at the end of six months. Although Calopogonium is of a climbing nature, this characteristic is not very evident on flat ground as the stems take root at every joint. The carpet formed, attains a thickness of 40 to 60 cm. The production of green material is 60 tons per hectare, after six months vegetation which represents 1255 kg. of sulphate of ammonia (20%) per hectare. It tolerates shade fairly well. It produces a good supply of leaves but is sensitive to damage to the young shoots which is likely to occur when the cover is trampled as at time of seed collection. Calopogonium seeds freely and the seed germinates readily. The plants die off in acute dry weather but they quickly regenerate from seed in the ground at the next rains. The seed rate is about 12 lbs. per acre for Rubber.

Centrosema Pubescens. This is a creeping or climbing leguminous plant. It is noted for its shade tolerance in old clearings and prevents the growth of weeds. It grows vigorously and requires attention as it easily twines round the main crop. It is difficult to destroy owing to its deep root system. It gives a large amount of green material with numerous nodules. Centrosema it should be noted does not tolerate poor soils or wet soils well. Seed is produced in large quantities if the plant is allowed to climb, but it seeds poorly when creeping. The seed rate is about 24 lbs. per acre to establish it. It is unpalatable to cattle which do not eat it.

Centrosema Plumieri. This is a climbing plant indigenous to tropical America. It does well on fairly good soils and in low lying areas. At 6 months it gives a yield or about 16 tons green material per hectare though its growth is at first slow, and it is especially suitable to newly cleared land.

Clitoria cajanifolia. This is a small half erect shrub of the family Leguminosae and was originally introduced from America to Java and other Rubber growing countries. It has a well developed root system and therefore is an excellent species for permanent hedge planting. It does not provide so great a quantity of green material as other erect covers, but it has the advantage that it may be repeatedly lopped without becoming excessively woody. It is very effective in checking soil erosion when used as hedges in terrace cultivation. When it is sown 6 inches apart in every direction it covers the soil completely within a few months and gives fairly good shade but gaps may form thus allowing growth of weeds. It has given excellent results in a number of newly cleared rubber estates and is generally utilized as a green manure.

Desmodium gyroides. This is a shrubby plant which has been tried as a cover crop for Rubber in the East Indies. It is indigenous to Java. It has a good and rapid growth and though the yield of green material is small compared to Desmodium ovalifolium, it decomposes very quickly.

Desmodium ovalifolium. This is a semi prostrate leguminous plant which does not creep over the ground but which may root from the nodes of branches which lie on the soil surface. It covers the ground well and is resistant to drought and it has an excellent growth in the shade of cultivated crops and is adaptable to mediocre soil. It does not suppress the growth of weeds to such an extent as Pueraria or Stylosanthes. It persists well under the shade of rubber and regenerates well from self sown seed and can be easily established from cuttings. It is easily controlled in young clearings and does not require pulling back from the young rubber trees but requires fairly continuous weeding. It is susceptible to Synchitrium disease which causes widespread damage to this species. Cattle do not eat it.

Dolichos Hosei (Vigna Oligosperma). This belongs to a genus of herbacious climbers of the family Leguminosae, found in the tropics. It is a plant of ancient cultivation and its country of origin is uncertain. It was introduced to Java in 1909 from whence to Ceylon in 1929, and used as a cover crop for rubber extensively. It is very resistant to shade, but only grows well on loose, fresh soil. It has poor fructification, but is easily propagated from cuttings and rainy weather is essential for this work. It is difficult to obtain seed due to poor fructification. There are about 30,000 seeds to a kilogramme which have a hard tegument and must be soaked in water at normal temperature for 2 to 3 days before sowing. After sowing it takes 2 or 3 months to cover the soil. To save time, cuttings are used, several slips being planted in distances 1.25 to 1.50 metres apart.

It is a twining climbing plant and forms a thin layer of vegetation, very regular and of good appearance. It allows the growth of a certain amount of weeds.

Indigofera endecaphylla. This is an annual or biennial trailing herb, found very widely throughout the tropics. It will stand a certain amount of shade, is easily pruned and is resistant to drought and heavy rains. It prefers a clayey soil, but also gives a good covering on sandy soil. It may be grown from sea level to altitudes of 5000 feet and even more on condition that it is well exposed to the sun. Sown in rows 1 metre apart it assures a covering of the soil in 6 months. It may be propagated by cuttings. The seed is very hard and its germinating power is weak, but this can be increased by soaking the seed for 40 minutes in concentrated sulphuric acid, followed by an immersion in running water for 15 hours. From experiments it has been found that it brings about a marked increase in the nitrogen content of the soil, and in organic matter amounting to nearly 40 per cent. The plant is best propagated from seed and later from cuttings. It is remarkably free from pests and diseases, the only pest of importance being a caterpillar, *Dichomeris ianthes*, which sometimes completely defoliates the creeper, though it very quickly recovers from such defoliation. When a good cover is once established, a reduction in weeding costs may be anticipated though weeding can never be dispensed with. It has the drawback that it is palatable to cattle. It is very effective in preventing soil erosion. It has an abundant fructification. The yield of green material is 15 to 45 tons per hectare. It forms a close soil covering.

Mimosa invisa. This is a shrub of small size, thickly covered with recurved thorns. It has been used in the East during the last twenty five years or more as a cover plant. The duration of its growth is from 1½ to 2 years. Being of a trailing nature, it makes a very good soil covering and in addition enriches the soil through its bacterial nodules. Unfortunately, however, the thorns make it difficult to use, and for this reason and the risk of fire during dry weather, its use is now limited. It is specially suitable for breaking up hard, impenetrable soils. At 5 months it was found to give a yield of about 2 tons green material per hectare. It dies out under heavy shade. Fructification is good. The seeds have a very hard tegument, but the germinating power may be improved by soaking the seeds for three hours in water at 60° to 70° C and the water should be allowed to cool off naturally. With this treatment about 60 to 70 per cent of seeds will germinate. Seeds of a light brown colour should be used, those of a dark colour being of no value. The seed rate is 2½ kg. per hectare.

Mimosa invisa(inermis). This is a thornless variety of Mimosa invisa. It has a prostrate habit with long shoots up to fifteen feet in length. It does not climb but will straggle over supports. The shoots cover the ground to form a dense thick mass of growth and weed growth is greatly suppressed. The plant seeds profusely and the seeds remains viable for a long time. About 3 lbs. of seed are required per acre for planting, and cattle usually avoid it.

Psophocarpus palustris. This is a creeping and climbing species, and the origin of this leguminous cover plant is traced to tropical Africa. It grows equally well in the sun or light shade, and its habit resembles Pueraria Javanica (phaseoloides). It is a vigorous grower and wherever it has been tried, it has proved this and is claimed to suppress weeds including "illuk" very satisfactorily. Like Pueraria and Centrosema it should be pulled back from the young rubber plants frequently. It is now being tried out extensively on Rubber Estates in Indonesia, Malaya and Ceylon.

Pueraria Javanica (phaseoloides). This species of ground cover has been extensively used in all Rubber growing countries. It is a vigorous growing creeper which extends for considerable distances over the ground from the original plant and roots at the nodes of the canes. It provides a heavy development of leaf and extremely good surface protection to the soil. It regenerates readily from self sown seed or from rooted nodes.

The creeping nature of the plant and the fibrous root system provides good protection to wash over the soil and affords good binding qualities. The abundant leaf growth provides a good surface mulch and returns considerable quantities of humus to the soil. This species grows extremely well in open clearings, and thrives on the heavier types of soils and has proved successful on the alluvial clays of the coast. When once established, a dense thick cover several feet high is formed. It will continue to thrive under shade but the growth is less robust but persists better than many others under light shade. Under dense shade, however, it tends to die out.

Pueraria grows rapidly and in young clearings requires to be pulled back from the planting points at least once in three months, or serious competition with the young rubber may result. It suppresses other weeds and grasses very well.

Stylosanthes Gracilis. This is an exceedingly valuable perennial legume, and is usually used as a constituent in tropical pastures. Its importance as a valuable ground cover and green manure is now universally recognized. It is extensively used in Tea, Rubber, Coffee, Coconut, Fruit orchards and in connection with many other major commercial crops. Briefly its advantages are as follows:-

It grows vigorously on any type of soil, and is both drought and frost resistant. It stifles the rankest weed growth through effective cover of the ground and provides tons of leafy green manure on the spot. It checks soil erosion most effectively, increases the soil's porosity and water retention capacity, improves

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It grows vigorously on any type of soil, and is both drought and frost resistant. It stifles the rankest weed growth through effective cover of the ground and provides tons of leafy green manure on the spot. It checks soil erosion most effectively, increases the soil's porosity and water retention capacity, improves its crumb structure, tilth, texture and fertility without deep cultivation — a point of great importance in steep terrains and places subject to heavy wash.

It quickly reconditions the top soil, the greatest asset of any plantation, and turns impoverished land fertile and productive. The rich black deposits of valuable humus which it builds could be seen within a short period of its establishment. Once it has been established, weeding and draining costs are cut out almost completely due to the effective suppression of weeds and prevention of soil movement.

The prostrate and spreading habit of its runners make this Green Manure legume ideally suited for adoption in all plantations. The runners do not climb, but spread prostrate like a carpet on the soil surface, cascading over road banks and ridges and admirably do the work of expensive terraces and bunds. During manuring or forking, the runners can be rolled up like a mat and so will not obstruct the application of fertilisers.

Propagation is done by seéd, though cuttings suitably inoculated, could be used. But the surest and quickest method of propagation is by seed. As one lb. of seed will cover about 2 to 3 acres, the initial cost of seed is not expensive. In point of fact cost of seed per acre works out to be much less than other varieties of ground cover which require larger seed rates per acre.

Good weather, continuously wet is essential for propagation by seed direct in the field. The seed should be soaked for about 8 to 10 hours before planting. The ideal planting distance in rubber areas is 2′ x 2′ which means that seeds should not be planted closer than at a spacing of 2 feet apart straightways and across. The soil between the Rubber should be loosened with forks at intervals of 2 feet apart to a depth of about 4 inches. The soil should be prepared by breaking up lumps and removing stones, twigs and weeds by hand. Not more than 2 seeds at each point may now be sown ½ inch beneath the prepared soil surface. It is desirable to dibble in a little fertiliser such as

Rock phosphate when planting the seeds. As ants are quick to disappear with the seed, it is also advisable to use some insecticide such as Gammexane dust as a deterrent, a pinch of which should be strewn above the buried seed. In the alternative the seeds may be mixed with Gammexane at the rate of 1 oz to 1 lb. seed before sowing. Both methods will be found to be equally effective against ants. It is also desirable to mark the points at which seeds are sown by a small peg or stick to watch growth and to caution weeders and other workers. If no work will be done in the planted area for a month from the time of sowing the seed this precaution will not be necessary. The plants usually begin to show up within 14 to 21 days. Weeding should be commenced after the 6th week. Thereafter Stylosanthes will start spreading rapidly and further growth of weeds will be stifled. The seed rate for rubber is between 3 to 4 ounces per acre which compares very favourably with other varieties which take 3 to 5 lbs. per acre to produce a satisfactory cover.

ERECT COVER PLANTS

The most important characteristic of a good erect green manure is that it should provide large quantities of nitrogen and organic matter for the soil. This is mostly supplied by periodically cutting back the plants and burying the loppings. When turned into the soil, the green material not only increases the humus content, but in the process of decomposition has also the effect of rendering some of the mineral constituents of the soil more readily available as plant foods. Erect covers besides supplying a source of humus and protecting and maintaining the soil, may also be used as windbreaks in exposed clearings to protect the young plants in the first year of growth. As in the case of other types of cover they should be grown close to the rubber plants to prevent too much root competition and heavy shade.

As with creeping covers there is a wide range of leguminous plants which can be employed for this purpose, and the more important ones are described below:-

Crotalaria anagyroides. This is a vigorously growing and branching leguminous shrub which attains a height of 4 to 6 feet within 3 to 6 months, and gives excellent results at elevations above 1000 ft. Its foliage is abundant and lives from 2 to 3 years allowing 2 to 3 prunings per year though it tends to becoming woody with each successive lopping. It is deep rooted and therefore fairly drought resistant. In cold regions its growth is much slower. It seeds very freely in sunny regions if it has been planted well spaced out. The germinative power of the seeds may be increased by soaking them for fifty minutes in concentrated sulphuric acid, and washing them in water. The principal diseases and pests are: Septobasidium bogoriense, Corticium salamonicolor, Ganoderma pseudoferrum, Rhizoctania bataticola, Sclerotium Rolfsii, Parotiella Spagazzini, Cephaleuros virescens and Ragmus importunitas. Helopeltis deposits its eggs on this plant. It is useful when planted in contour hedges as wind breaks in young exposed clearings in the first year of growth. The plants die after seeding, but readily regenerate from seed. If the plants are cut back to about 1 foot in height at time of flowering they however shoot again and survive longer. The cuttings may be used as thatch. If cut back too low the plants usually die. This plant is also very useful for planting as an indicator plant in suspected "Fomes patches". The plant is propagated only by seed and about 6 pounds per acre of seed is required. This is easily the best of all Crotalarias and will produce a large weight of green material in a shorter time than any other leguminous plant grown locally. The loppings have a high manurial value and decompose rapidly. The plant stands lopping rather better than other Crotalarias but it is unlikely that it will stand more than two or three loppings before dying out.

Clitoria Cajanifolia. This is a hardy deep rooted plant which appears only suitable for elevations up to 2500 ft. Clitoria cajanifolia is probably not suitable for a green manure or cover plant, but is unsurpassed for contour hedges to check soil erosion. Its deep rooted habit enables it to weather severe droughts and to stand repeated hard lopping. Hedges of this plant have been lopped repeatedly for over 5 years and have shown no signs of dying out. The estates which have made use of the plant in this manner are enthusiastic over its merits. The seeds are large and very sticky and this makes sowing difficult. It is said however that washing the seed impairs germination. For hedges seed should be sown thick not more than 4 inches apart.

Crotalaria Brownei. The leaves are large but the amount of foliage produced is poor. It is useful for its diffused shade in Nurseries.

Crotalaria juncea. This is a plant indigenous to Java. Its duration of vegetation is 163 days (101 days before flowering occurs), and because of being too short lived it is not extensively used in perennial cultivations such as rubber. It is chiefly grown to produce considerable quantities of green material within a short time. When sown thickly at 2 months it gives on an average a yield of 30½ tons of green material, being 5 tons of water-free product, and 258.2 kg. of nitrogen per hectare. At 6 months there is a yield of 103 tons of green material, 40 tons of water free product and 293.5 kg. of nitrogen per hectare.

Crotalaria laburnifolia. This plant has been tried out with varied degrees of success as a Green Manure. As the quantity of green material received is small, it is not much used.

Crotalaria usaramoensis. This plant may be considered to come second to Crotalaria anagyroides among Crotalarias. It produces the heaviest and quickest of all crotalaria covers. It has been used on some estates for contour hedges but being short lived like all Crotalarias, it is not considered suitable for this purpose. It has also been used at elevations between 3500′ and 5200′ as a source of green material. It does not stand lopping well. The seed is very small and the seed rate is 2 or 3 lbs. per acre. It has a vigorous growth. It is a small shrub 1 to 1½ metres in height within an abundance of leaves. It gives 52 tons of green material, equal to 785 kg. ammonium sulphate (20%) per hectare. Its length of life is variable, depending greatly on local conditions and number of prunings. On an average it varies from 1½ to 2½ years.

Sown in rows of 90 cm. apart in rich soil, or 50 to 60 cm. apart in poor soil, a soil covering will be obtained at about the end of three months. It stands pruning well in the same way as Tephrosia candida, but the lopped plant must be raised a few cms. at each pruning. The germination power of the seeds can be improved by allowing them to soak in concentrated sulphuric acid for 30 minutes to be followed by an immersion in running water for 15 hours.

It has a shallow root system with many nodules and attains an average height of 2 metres in fairly good soil. It has the advantage of not becoming woody, is not obstructive and is easily uprooted. As it absorbs water from the surface of the soil it does not hinder the main crops and it is therefore to be recommended in every way for medium soils.

Crotalaria striata. This species is similar to Crot. usaramoensis but the growth is not so vigorous. It seems better suited to low lying regions than higher elevations and it has the advantage that it will stand up to four loppings per annum without becoming woody or dying out, and it is generally used as a temporary shade in new clearings when other varieties are not available. It gives plenty of green material and good shade. It is self sowing and grows under a light shade and is resistant to drought and has been used successfully in sandy soils.

Desmodium gyroides. This is a tall shrub which attains a height of 5 to 9 feet. It has been tried as a green manure in rubber estates of Malaya, Ceylon and Indonesia. It grows to an elevation of 2500 ft. Sometimes young plants are apt to die out for some reasons unknown, but once growth is established, it thrives vigorously and furnishes a fair weight of loppings. It has a profuse root system on which many nodules are found. After lopping its life is limited to 12 to 18 months. It is useful as a shade for young rubber plants.

Flemingia congesta. This is an erect much branched leguminous shrub which grows to a height of about six feet. It therefore requires periodical slashing to keep it down. Like

Crotalaria, it is useful as a windbreak when planted not closer than 5 feet from the rubber plants. Propagation is done by seed.

Tephrosia candida. (Boga medelloa) This plant came into use as a green manure about 1900 and is one of the best plants for this purpose. It is extensively used on poor soils and employed for contour hedges and is very popular as a cover crop for tea and rubber. It withstands heavy rainfall and long periods of drought. It has an abundant foliage and many bacterial nodules. It has a deep and spreading root system and for this reason should not be planted too near the main crop. Its vegetation lasts from 3 to 4 years and affords 3 to 4 loppings per year. Probably its greatest use is for contour hedges, and such hedges do much to check erosion. It grows to a height of about 6 ft. and periodical lopping is necessary to keep it down. It does well even on very poor soil and stands slashing well. The leaves rot and decompose slowly and provide a thick layer of mulch which helps to suppress weeds. Tephrosia cannot stand dense shade and is only used as a cover and wind break in open young clearings in combination with some creeper such as Pueraria Javanica or Centrosema Pubescens. In the later stages of its growth it tends to become woody. It is often severely attacked by shothole borer and less severely by scale insects. The seed pods are attacked by a number of insects and seed is sometimes difficult to obtain. The plant is very susceptible to attack by root fungi which are also parasitic on rubber, and therefore helps to pinpoint any tree affected by root disease growing near it. The plants rapidly weaken under rubber as the overhead shade increases.

Tephrosia vogelii. This plant shows a considerable resemblance to Tephrosia candida, but is easily distinguished by its pods which are longer, larger and very hairy. The leaves are also larger and the foliage generally more luxurient. It yields a larger quantity of green material when young than Tephrosia candida, but its life is shorter and it does not generally live usefully for more than two years during which period it stands 3 to 4 loppings per annum, and it is useful for growing as contour hedges, to afford light shade to young plants, and protection against wind, and soil erosion.

CHAPTER IX

CULTIVATION

In this chapter we shall consider all the operations of cultivation in the sense both of tillage and of manuring, and with reference to the care of both young clearings and old rubber. The subject is a wide one, and some of the points raised may be considered controversial and therefore hard and fast rules cannot be laid down for many of the field operations where countless natural processes quite beyond human control are continually going on.

Soils and their Formation. The mass of matter covering the earth and forming the outermost layer of the earth's crust which supports all plant life is called "Soil". It is made up of various substances and its depth varies from a few inches to over hundred feet in some places and is formed mostly of inorganic matter which is derived from rocks weathered down by the agencies of climate, water, air and biological factors as we shall see presently.

Soils are formed from the rocks which compose the surface of the earth. These rocks are continually undergoing decay and the products of their decay form the mineral matter of soils. The term "weathering" is used to describe the decay of rocks, and the "weathering agencies" are the natural forces which cause the decay. In tropical climates, the chief weathering agents are rain water and atmospheric oxygen. Rocks although hard, are all more or less porous, and rain water soaks into them to a certain extent even when there are no visible cracks, while in most, if not all of them, cracks and fissures are sooner or later formed by the alternate expansion and contraction caused by variations in temperature. Rain water enters these cracks and exerts its solvent action on the rock material, an action which is quickened by the presence of the carbonic acid which all rain water contains.

Where moisture is present, oxidation of the rock constituents soon begins, iron compounds being among the first to undergo this change. These iron compounds swell when oxidised and in swelling cause further cracking and disintegration. This oxidation, combined with the solvent action of water, transforms the hard surface of the rock into a soft and crumbling layer, the rock being then partially "weathered". The weathered surface soon crumbles or flakes off, exposing a fresh surface to attack, in the same manner in which a piece of iron rusts and falls to powder on exposure. This process though slow, is continuous, and the largest rock masses are eventually broken down. Further destruction is brought about by the roots of plants. These, penetrating the fissures in the rocks, and in their growth exerting great power of expansion, widen the cracks and finally burst the rocks asunder, a process of destruction which can be seen at work where the roots of trees have gained a hold upon a wall. Unless destroyed these roots find their way through the masonry, the wall is cracked by thier expansion, and its ultimate destruction is inevitable.

In this way rocky debris is continually formed, and constitutes the mineral matter of the soil, supplying the potash, phosphoric acid, lime, magnesia, iron, and all the other inorganic materials essential to the growth of plants.

The organic material results from the decay of plant tissue. Its accumulation in soil of the present day has been a very gradual one, beginning with the mosses and lichens and other lowly forms of plant life which first gained a foothold on the rocky surface. Successive generations of these produced sufficient organic matter to support more highly organised vegetation, and so the process went on until the plant life of a normal fertile soil was developed. This accumulation of organic matter still goes on in uncultivated soils, but when cultivation is practised, and crops are taken from the land, the store of organic matter is utilised faster than it is produced, and one of the tasks of the agriculturist is to make good this destruction of organic matter and maintain an adequate supply for maximum crop production.

These remarks will make the phenomenon of soil "exhaustion" more clear. The term has more reference to soils lacking in potash, phosphoric acid, etc., than to those which are merely deficient in organic matter, and it will readily be seen that such exhaustion can only be temporary. The rocky material of the earth's surface may fairly be described as inexhaustible, and a soil which, by continued cropping has been depleted of its mineral plant food, will, if left to itself, recover its fertility by the gradual decomposition of the underlying rock material. As regards organic matter, recovery is slower and may not take place at all unless aided by the growth of crops cultivated for the purpose. The natural vegetation on a temporarily exhausted soil may not be sufficient to produce organic matter faster than the oxidising processes of Nature will destroy it, and so we see the necessity, in these cases, of inducing crops to grow for the express purpose of digging them into the soil and thus adding organic matter more quickly than it would accumulate under uncultivated conditions. This is the principle underlying the practice of green manuring.

Various names are given to soils according to their character and to the conditions under which they have been formed. These classifications are of value when identifying soils from their descriptions but are of little interest to the practical planter. The principal soil types are as follows:—

Sedentary Soils. These are soils which have not moved from their original place of formation. The decomposed rocks have remained where they first lay, and the soils are spoken of as having been formed "in situ".

Transported Soils. These are soils of which the component parts of disintegrated rock have been moved by some cause or another from where the rocks originally fell to pieces and have been deposited in some more or less distant region. The most important transporting agent is running water, although, especially in desert areas, rocky debris is carried away by wind, while in all countries soils are frequently moved considerable distances by gradual slipping down hill-sides, the movement being extremely slow, and imperceptible to the eye.

Running water is very active in transporting soils, and streams and rivers are always more or less charged with soil and rock particles, washed into them by rain. When the stream is rapid, large particles and even boulders are carried along, but as soon as the current slackens the heaviest of these fall to the bottom in turn, and only the finely divided silts and clays are carried on. Water, therefore, exerts a sifting action on soil components and is responsible for the formation of coarse grained sandy soils when the current has been swift, and fine silts and clays in regions of slowly moving water. Flood-water is usually slow-moving, and rests, on the land for some time before receding, and consequently the soils deposited by it are fine-grained silts and clays. These are known as alluvial soils.

Soil and Subsoil. The change from soil to subsoil takes place at different depths under different circumstances. In cultivated soils it occurs at, or just below, the depth of cultivation, while in uncultivated soils it is, as a rule, nearer the surface, and occurs at the depth to which the roots of grasses and similar plants extend. The surface soil is characterised by its darker colour when damp, and the change is usually easily seen.

The subsoil is commonly finer-grained than the surface soil, due to the finer particles being gradually carried down by rain water and by gravity, and it is generally less rich in available plant food ; weathering processes take place more slowly in it, while the roots of plants draw up plant food from it and this plant food is left behind in the surface layer when the plants decay. The subsoil, therefore, although constituting the store-house of reserve food, is not a fertile region. For the reasons stated it is not so well supplied with available plant food, while an even more important deficiency is its lack of bacteria. The useful soil bacteria are confined to the surface soil, which is aerated, and their absence from the subsoil explains much of the failure to improve land by bringing the subsoil to the surface. Cultivation should not comprise such a drastic change in the soil as this, and really deep forking should consist in opening the subsoil without bringing it to the surface. It should be noted, however, that turning over the soil to a depth of six inches or more does not affect this, and is good practice.

What the agriculturist should note in this connection is that when opening up new land the soil should not at first be turned over to any great depth although it should be prised open as deeply as possible. Gradually, as cultivation is continued, the turning over can be carried deeper, increasing the layer of aerated surface soil with its store of available food and its colonies of bacteria.

The Chemistry of Soils and Soil Analysis. The chemistry of soils is again a subject which does not come within the scope of this book. Little information of practical use can be given in a small compass, there are no rapid methods of soil analysis, and no chemical tests of any value that can be applied in the field, or outside a properly-equipped laboratory. Most soils differ remarkably little in chemical composition and it is only in exceptional cases that an analysis will help much towards deciding the fertilizer to be used. For instance, one soil examined will contain only half the percentage of potash found in another, but this does not at all mean that the fertilizer should contain double the quantity. Attention has already been called to the advisability of paying special attention to the percentages of lime and magnesia in the soil and to its degree of acidity. It can be said, however, that soils showing high percentages of lime are uncertain in their behaviour under rubber. The great majority of the rubber estates in Ceylon possess soils containing very little lime, and those few which contain more than this small average quantity are in no case standout properties either as regards the growth of the trees or their yield. Soils with more than 0.25 per cent. of total lime should be regarded with suspicion. In this connection a few explanatory remarks on the real meaning of the items which go to make up an analysis of soil may prove useful. The usual statement comprises the following determinations.

Moisture. This figure represents the moisture which is retained when the sample is allowed to dry by ordinary exposure to the air. This drying is necessary to enable the sample to be sifted, and it is obvious that the moisture thus left in the sample has no reference to the moisture in the field when the sample was drawn. The moisture in the field varies from day to day, and probably from hour to hour, and its determination does not ordinarily serve any practical purpose.

Organic Matter and Combined Water This includes the water combined as hydrated silicates which form the clay contained in the sample, and so is not a true estimate of the organic matter. The less the amount of clay, the more nearly does the figure represent the organic matter, but in no case is it more than an approximation to the truth.

Oxide of Iron, or Ferric Oxide. This figure is of little practical importance in determining the fertiliser requirements of a soil. All soils are abundantly supplied with iron compounds, and there is no case on record of a natural soil suffering from lack of iron. Soils very heavily charged with iron are apt to be deficient in available phosphoric acid owing to its fixation as phosphate of iron but no limits within which this occurs can be laid down. As a general rule, the iron, as determined by soil analysis need not be taken into account when discussing the fertiliser required.

Alumina, or Oxide of Aluminium. This is an equally valueless figure. It is usually highest in soils containing most clay, but it is not an accurate measure of the amount of clay present. Aluminium is not an essential plant food, and its determination does not influence the choice of fertiliser.

Oxide of Manganese. Many soils contain notable quantities of manganese, and in some cases its presence appears to be the cause of sterility or partial sterility. Its presence in sufficient quantity to influence the crop, however, seldom occurs, and is so easily detected by the occurrence of manganese-bearing minerals, that in the great majority of cases its determination is unnecessary.

Lime. This does not necessarily mean that "lime" in the ordinary sense, is present in the soil at all, but merely that if all the calcium found in the soil were combined with oxygen so as to form "lime" (calcium oxide), the amount would be as stated. Actually, the calcium is mainly combined with silica to form silicate and not oxide, and this silicate of lime possesses none of the properties of ordinary "lime." This method of expressing the result is convenient from the chemist's point of view, but unfortunate from that of every one else, and has given rise to much misunderstanding. Thus a soil might contain as much as one per cent. of lime in the form of silicate and still be urgently in need of liming, while another might contain only half the quantity, but present in the form of oxide, in which case far from needing liming it would probably contain too much lime already.

Magnesia. This is oxide of magnesium, just as lime is oxide of calcium. In soil analysis, it means as in the case of lime, that if all the magnesium found were combined with oxygen to form magnesia the quantity would be as stated. It does not necessarily mean that any is actually present as oxide, and as a matter of fact it is almost always present as silicate.

Potash. This represents the potash found by treating the soil with acid. If strong acid is used and the treatment sufficiently prolonged the total potash in the soil is obtained; if weak acid is used under certain standard conditions, what is known as the "available" potash is the result. The usual method gives figures intermediate between these two.

Phosphoric Acid. This represents the phosphoric acid found, as in the case of potash by whatever the method of extraction adopted. The figure is usually intermediate between "total" and "available."

Sand and Silicates. This figure is of no agricultural value. It represents the insoluble portion of the soil left after dissolving the plant food in acid. It may consist of nothing but sand, or may, and almost always does, include difficultly soluble minerals which contain plant food not dissolved out by the treatment adopted.

Nitrogen. This determination differs from the others already described, in that it represents the total amount of nitrogen in the soil, and is independent of any method of treatment with acid. It may not all represent nitrogen immediately available for the plants' use; but as a general rule, it is a better guide to the nitogen requiremnt of the soil than the potash and similar figures are to the soil's need for these fertilisers.

It will be well to note here that the fact that all samples are sifted before analysis, and the determinations made on the "fine soil" only, explains in a great measure why a quartzy soil and a friable loam may, and generally do, give almost identical figures. The analysis takes no account of the proportion of quartz or other inert matter present, for this is all removed before analysis. The figures only refer to the composition of the "fine soil" which may well be the same in both cases although the amounts of fine soil present may vary greatly. The reason for this procedure is the assumption that it is only from the fine soil that the roots draw their nourishment.

These explanations make it clear that soil analysis is not of much assistance in settling the question of the best fertiliser to use, and the fertiliser problem is not an easy one to solve. This book makes no attempt to teach agricultural chemistry, and when difficulties arise the planter will do well to call for expert advice. A sample of soil should be sent, at the same time, everything possible should be told of the past history of the field, what manure has been applied and when, what system of cultivation is carried out, and whether or not the appearance of the trees is satisfactory. Information of this sort from the practical man who knows the estate will, in nearly every case, be of greater help than pages of analytical ffgures. The practised analyst will know how far an analysis is essential and act accordingly.

Soil Sampling. The best method of drawing a sample of soil is as follows :—Dig a hole 18″ deep, leaving a block in the centre of the hole 6″ square. The block will measure 6″ x 6″ x 18″. Make a box of this size and invert it over the block of soil and then remove the whole, box and soil. Nail it up and send it to the analyst, marking the end of the box which contains the original surface soil,

While it is not advisable to lay much stress upon the chemical composition of the soil as revealed by analysis, yet its physical properties should be studied at every opportunity. The soil's behaviour should be noted in all weathers, and especially in extremes of weather. If during heavy rain there is much surface wash, with drains running full of muddy water, it is certain that the soil is insufficiently forked. In dry weather, note whether the surface of the soil is hard and inclined to crack. If it is, insufficient forking is again the cause, and the problem of improving the soil's condition should be seriously considered,

Soil Terms. A knowledge of the terms commonly used when speaking of soils and their properties is useful, and the following explanation may clear up some misconceptions.

"**Organic Matter**" is the material which forms the structure of plants and animals, either living or dead. The stem, roots, bark and leaves of the rubber tree, for instance, are all composed of organic matter. In chemistry, organic matter means matter containing carbon, but to the agriculturist it is chiefly connected with the supply of nitrogen.

"**Inorganic Matter**" comprises the great bulk of all soils, everything in fact, except the remains of vegetation.

"**Inorganic Plant Food**" includes those inorganic materials which are essential to the growth of plants. They are sometimes called mineral plant foods. In problems of soil fertility these are practically restricted to three—Nitrogen, Phosphoric Acid and Potash.

"**Nitrogen**" is really an inorganic plant food, because it contains no carbon, but it is so intimately connected with the organic matter of the soil that, in agriculture, it is usually considered along with the latter.

"**Humus**" is the dark coloured organic material in soils, and is composed of partially decomposed organic matter, either animal or vegetable. Organic matter only becomes humus when decomposed under the proper conditions. Humus contains the active nitrogen of soils,

"**Loam**" is a soil containing from 20 to 30 per cent. of clay, and having, as a rule, a good supply of humus. It is usually easily worked and fertile.

"**Clay**" is the plastic material of soils. It becomes plastic when "puddled" or kneaded with water, and sets hard on drying. Its stickiness causes difficulty in ploughing or digging, but an insufficiency of clay causes a soil to be too loose, and to dry out too rapidly.

"**Sand**" is composed of quartz particles in a greater or less degree of fineness. Quartz is the most resistant constituent of rocks, and remains chemically unaltered, although broken down into small fragments when rocks are decomposed by weathering agencies.

A "Heavy" Soil is a soil cantaining a large proportion of clay, and is so called because it is difficult to work.

A "Light" Soil is one containing little clay and much sand, and is so called because it is easily worked. These names have no reference to actual weight, and a "heavy" clay soil really weighs less than an equal volume of a "light" sandy soil.

"**Tilth**". By tilth is meant the power of a soil to retain a crumb-like structure after cultivation. A soil in good tilth is one which by cultivation has been formed into relatively large, complex crumbs or floccules between which are large air spaces, these being wholly absent in untilled land. It is the direct opposite of the "kneaded" condition of neglected clayey land, and the whole problem of soil management may be summed up in this—strive always to avoid kneading, and seek to bring about crumbling.

Sour Soils. The term "sour" applied to soils is frequently misused. It is a difficult term to define, and probably the best practical definition is: "A sour soil is an infertile soil which is rendered fertile by the application of lime." Any attempt to define sourness in terms of acidity is beset with pitfalls for the non-technical reader, and a great deal of the confusion which existis on the subject of sour soils is due to misapprehensions regarding soil acidity. The above definition has the merit of impressing upon the mind the fact that the first characteristic of a sour soil is that it is infertile.

The great majority of Ceylon soils are acid, but their acidity does not render them infertile, and they have no claim to be described as sour. As a general rule, lime for Ceylon rubber soils is not advocated, at least not for the purpose of "correctting acidity."

Acid, Alkaline, and Neutral Soils. A definition of an "acid" is hardly necessary; everyone knows of the acid taste and corrosive nature of sulphuric acid, nitric acid, etc. Soil acids are feeble organic acids which have these properties to a much less degree, but they are of the same nature, and when pure even weak organic acids have an acid taste. The common sign of an acid soil is that it turns blue litmus-paper red. An alkaline substance is the reverse of an acid. Such substances as soda, potash, lime, magnesia are alkaline and have the power of neutralising acids or destroying their acid properties. An alkaline soil turns red litmus-paper blue. A neutral substance is neither acid nor alkaline and has no action on either red or blue litmus.

Conditions for Fertility. The necessary conditions for fertility are many. The most important are:—

1. A sufficient supply of plant food in the soil.

2. A sufficient supply of water in the soil.
3. A sufficient supply of air in the soil.
4. The presence of the proper bacteria in sufficient numbers in the soil.
5. A climate suitable to the crop.

The last cannot be controlled; the others will be considered in turn.

Plant-food. There are a great many elements which are essential to plant growth, but only three need be considered in ordinary questions of soil fertility. These three are nitrogen, phosphoric acid and potash, and they have to be supplied to soils in order to maintain their fertility, the other elements being, as a rule, present in sufficient quantity to make their further addition unnecessary. Lime and magnesia have special functions and it is known thatthey have a certain influence upon the physical condition of the soil and on the growth of bacteria and the assimilation by plants of other food. It is commonly stated that nitrogen, phosphoric acid and potash have each a special part of the rubber tree on which they act when applied as manure, but this statement is not correct, and has given rise to a great deal of misunderstanding. It is not true, for instance, that nitrogen only affects the growth of leaf, and that potash must be applied before the bark will renew. Each of these three plant foods affects the growth of every part of the rubber tree, and it is a great mistake to lose sight of this fact.

Nitrogen is particularly active in promoting the growth of wood as well as of leaves, but an exaggerated importance is often given to the latter effect because it is most easily seen. The best idea of the work done by nitrogen is got by realising that it is the substance most concerned in the building up of *new tissue*. It is then easy to understand why it produces abundance of leaves and is, at the same time, equally active in promoting renewal of bark and growth of wood.

Phosphoric Acid is required by all parts of the rubber tree just as are nitrogen and potash, and, especially in the earlier stages of growth, it will be useful in promoting root-growth. Applications of phosphoric acid are valuable on heavy clays where roots do not naturally form well, but they are less needed on sandy soils because rapid root-growth takes place in these soils in any case.

Phosphoric acid is sometimes credited with promoting seed formation, but its action in this way on the rubber tree is not definite enough to need special attention.

Potash. Contrary to general belief, rubber does not respond in any marked way to potash fertilisers. Potash is undoubtedly required by all parts of the tree, but if the supplies of other plant foods are adequate, sufficient potash is readily obtained from the soil for all average needs. Its special action is concerned with starch formation, and its effect is not readily seen by the eye. Cases of potash starvation are rare but they might be indicated by dull, lifeless-looking foliage with a tendency in the leaves to die early at the tips. It is a mistake to suppose that potash fertilisers have any marked influence on the growth of wood or bark.

Water and Air. The supply of water and air in the soil is governed by its physical condition. The terms "mechanical condition" and "physical condition" mean the same thing; the latter is the more correct. That the soil should be in good physical condition is of great importance, and the attainment of good physical condition is dependent on tillage and drainage operations and the general care of the soil which every planter should study.

The soil is composed of particles of very varied sizes which are not in complete contact with each other and which only partially fill the space occupied by the soil mass. This gives the soil a certain porosity, greater or less according to the size and number of the spaces between the particles. Under normal conditions these spaces are filled either by air, or by water, or partly by both, and with proper treatment it is possible to modify very considerably the size of these spaces, the amounts of air and water contained in them, and the movements of the air and water to or from the region in which the crop is growing.

This treatment comprises tillage and drainage. Tillage aims at increasing the amount of air and water that enter the soil; drainage ensures that any excess over the required amounts is removed.

When rain water falls on the land it is disposed of in two ways; part soaks in and part runs off the surface. That which soaks in is useful and that which runs off is wholly bad, for in running off it carries with it solid particles of soil, and produces the well-known phenomenon of "surface wash." If the proportion of "run-off" to "soakage" can be reduced, it follows that surface wash also will be reduced. For if no water runs off the surface at all no soil will be washed away.

Following up this line of thought, one cannot but conclude that since a soil with a loose surface soaks up water more quickly than one with a hard surface, wash will be least where the surface is loose. In practice this is found to be the case. It is from the hard unforked surface that rain water quickly runs off, following the line of least resistance and constantly making its path more easy by sweeping away obstacles. The rivulets thus formed are quickly widened and deepened until, as rains continues, they are scoured out into channels carrying torrents of muddy water which bear away enormous quantities of fertile soil.

The porosity of soil, while allowing water to soak into them, also allows it to rise to the surface again by capillary action, just as oil rises in a porous lamp-wick. This happens in dry weather, and the water which thus reaches the surface is evaporated and lost. The rate at which this capillary action takes place depends on the smallness of the spaces between the soil particles, and is greatest when the soil is closely compacted together. If the spaces are made large enough, the capillary rise of water ceases and the loss of water by evaporation ceases. This condition can be brought about by forking, digging, or ploughing the surface so that the soil is broken up into comparatively large lumps and the continuity of the capillary channels is broken. A loose surface may thus be looked upon as a species of non return valve. It allows rain water to enter the soil but prevents it leaving again. While this treatment makes it possible to increase the intake of water to a maximum, it may also saturate the soil too thoroughly, and it is necessary to remove the unwanted excess. This is done by means of drains, and it is infinitely better practice to oversaturate and correct by drainage than to exclude the water in the first instance and suffer from surface wash. Drains act in two ways; they remove water, and they introduce air, and the latter action is by no means the least important. Air is needed by the living organisms in the soil as well as by the roots themselves, and it has been found that the best results are obtained when the pore-space of the soil is half filled with water and half with air. When no drains are provided the soil spaces become completely filled with water, and no air can enter, but in a drained soil the excess of water has a free outlet and runs off, drawing air into the soil to take its place, and this aerating action of drains is of great importance. The advantages of an efficient system of drainage are very many and the importance of this branch of field work can hardly be over-estimated. Rain water cannot enter an undrained soil more than two or three inches, because there is no outlet either for the water which is already there or for the air which becomes imprisoned by the saturation of the surface layer, and a drained soil is therefore more moist on the average than an undrained soil, and so resists drought better. Roots develop more freely when the soil is drained, because they get their proper supply of air and are not checked by contact with a water-logged subsoil. They are encouraged to go deeper, and thus have a greater range of soil from which to draw their nourishment, and at the same time by their ultimate death and decay, they leave holes in the sub-soil which increase its aeration and improve its texture generally. During dry weather, minute portions of soil become soluble at or near the surface, and if the soil is drained, the first rain which falls carries this soluble matter down into the soil for the use of the roots, while in the absence of drains it is carried off by surface wash and lost. Undrained land is cold. A wet soil is warmed more slowly by the sun's rays than a dry one, and the temperature is also kept down by the abstraction of heat from the surrounding soil when moisture is evaporated at the surface.

The good results from drainage are so numerous and so marked that soils have sometimes been classified as "living" and "dead" according to whether they are drained or undrained.

Soil Bacteria. There are three main classes of soil bacteria known as (1) Aerobic bacteria, which only thrive in presence of air. To this class belong those which decompose all kinds of organic matter, separating the nitrogen and transforming it into nitrates for the use of the plant. They are called Nitrifying Bacteria, and abundance of atmospheric oxygen is necessary for their existence. If the soil is water-logged or otherwise badly aerated, these bacteria are killed, and no proper decomposition of organic matter takes place. (2) Anaerobic bacteria which can live without air, taking their oxygen from nitrates and liberating the nitrogen as gas. They are called Denitrifying Bacteria and they may cause considerable loss of nitrogen by their presence in badly aerated soils. (3) Bacterial Nodules, such as exist on the roots of all leguminous plants. The bacteria which are found in these nodules have the power of fixing atmospheric nitrogen, changing it from a gas into solid organic compounds which, when the bacteria decay, pass in solution into the plant for its nourishment. The growth of leguminous crops has, therefore, the effect of increasing the amount of nitrogen in in the soil by so much as these bacteria have assimilated from the air. There is, apparently, no increase in the soil nitrogen while the leguminosae are actually growing, but if part or all of the crop is ploughed into the soil, or otherwise buried, the atmospheric nitrogen which it has received by the aid of the bacteria goes to enrich the soil. These bacteria also need abundance of air for their development, although in this case it is the nitrogen of the air and not its oxygen which is attacked.

While bacteria play a very important part in maintaining the fertility of soils, their control can only be effected to a limited extent, and practically all that can be done is to provide as favourable conditions as possible for the growth of those whose action is beneficial. These beneficial bacteria need a good supply of air for their development and this emphasizes the importance of keeping the soil in good physical condition by cultivation and drainage.

As we have already seen, a soil in good physical condition allows the maximum amount of rain water to soak into it and the minimum to escape by evaporation. Rain water readily soaks into a soil when the surface is loose, but most of it runs off if the surface is hard. On the other hand, evaporation is greatest where the surface is hard and least where it is loose. For both these reasons, therefore, a loose surface is the condition to be aimed at. It is no easy matter to bring a soil into a satisfactory condition as regards a loose surface if it has been left unforked for years, and a point that should be specially noted is that the soil of clearings should be forked from the start. This may be objected to as a counsel of perfection and unattainable in practice, but it should not be dismissed as impracticable without serious consideration.

The functions of soil for our purpose may be classified into three main groups as follows:—

(a) **Physical.** It provides the mechanical support for all plants, and acts as a water reservoir, absorbs and conserves heat from the sun and also forms a medium for the exchange of gases.

(b) **Chemical.** It provides all plant life with all its requirements of soluble salts and nutrients.

(c) **Biological.** The soil organisms both large and small help to improve and and enrich the soil. The micro organisms of the soil are the Algae, Fungi, Bacteria and the Protoza of which the most important ones are Bacteria which acting on raw organic matter for their nutrition convert it into simpler substances of which the important ones being nitrates and carbonates.

The soil is not a static mass, but it is for ever changing. It either improves or deteriorates. We shall now consider the main constituents of the soil in the following order: (i) *Mineral Matter*, (ii) *Organic Matter*, (iii) *Soil Moisture, and* (iv) *Soil Air*.

(i) **Mineral Matter.** The mineral matter in the soil consists of particles varying in size from stones and gravel down to sub-microscopic particles of clay. The large particles consist of rock fragments, and the intermediate particles consist of the secondary products of chemical weathering. A general knowledge of the mechanical composition of soil, which simply means the relative proportion of the different sized soil particles, is of considerable importance to the planter. It will help to characterize the soil and also affords an indication of its physical properties more particularly in regard to its behaviour under cultivation. The following classification of various soils affords a good basis for comparison. The size of the soil particle is called the "texture" of the soil.

Particles of soil	Diameter Limits.
STONES	More than 3 mm
GRAVEL	3 to 2 mm
COARSE SAND	2 to .2 mm
FINE SAND	.2 to .02 mm
SILT	.02 to .002 mm
CLAY	Less than .002 mm

Gravel. This serves the purpose of forming the skeleton or frame work of soil. Up to about 10% it is advantageous. It offsets to some extent the undesirable properties of clay. It facilitates drainage and renders the soil warm and it helps to check losses by radiation. But it does not contribute towards plant food.

Intermediate Particles of Coarse and Fine Sand. This fraction which comprises of particles varying from 2 mm down to about .002 mm diameter are fragments of rock forming minerals such as quartz, feldspars, micas etc. These possess little power of retaining water and soils in which sand forms the principal constituent are comparatively unproductive. But when the sand fractions are balanced by a suitable proportion of finer particles, the soil is sufficiently retentive of moisture and is capable of suitable drainage and can become productive.

Silt. These particles are moderately retentive of moisture and yet permit fairly easy drainage. Soils containing large proportions of silt are usually fertile and easily worked.

Clay. Particles below .002 mm in diameter differ profoundly from the ones already described. They consist almost entirely of material of secondary origin and differ from coarser material. Moreover the minuteness of the size of these particles gives clay some interesting and remarkable properties. It has a great capacity for retaining moisture. It expands and becomes plastic on being wetted and shrinks on drying. It has the property of cohesion whereby clods are formed on drying, and finally it is chemically reactive.

(ii) **Organic Matter.** The organic matter in the soil consists of easily recognizable remains of plants like fragments of leaves, roots, seeds etc., and a dark amorphous material called *humus*. The term "humus" is confined to the organic matter of the soil which has been decomposed and has lost its original structure. This constitutes about 90% of the organic matter of the soil and is mainly responsible for the colloidal or glue-like characteristic of the soil. It is formed from the decomposition of the remains of plants and animals and other organic substances added to the soil. Under natural conditions this means the decomposition of the remains of plants that have grown in the soil. In cultivated soils the additional source is green manure, compost and farmyard manure.

When organic matter is added to the soil, it decomposes. After a time this process slows down till finally it reaches a very low level of decomposition. This slowly decomposing organic matter is *humus* and is almost entirely the work of micro-organisms found in the soil. There are two types of decomposition of plant residues in the soil namely (a) Oxidization and (b) Humification.

Oxidization. The organic matter becomes oxidized by which it is completely lost from the soil in the form of gases.

This process is favoured by moisture, warmth, and æration, and in cultivated soils of the tropics the disappearance of organic matter due to this cause is very rapid.

Humification. By this process plant and animal residues become changed into the dark coloured amorphous material called humus. There are three types of humification:—

1. **Anaerobic Humification.** Humification in the absence, or in a restricted supply of oxygen is termed "anærobic". This condition prevails when plant residues decompose under water or in water-logged soils. A certain loss of organic matter takes place, but the bulk of the plant residues decomposed is changed into humus. Thus in wet soils, the tendency will be for the residues of vegetation to accumulate as humus. The word "anærobic" means pertaining to a micro-organism which thrives best or only in the absence of oxygen.

2. **Acid Humification.** This is the decomposition affecting organic residues in the absence of calcium and other bases.

3. **Humification under semi arid conditions.** Scanty rainfall precludes anærobic conditions. High lime content prevents an acid type of humification. Humus produced under these conditions is darker than that produced under more humid conditions. Now we may proceed to consider the characteristics and properties of soil organic matter in closer detail. They may be described under 3 main headings:—

   (a) Physical Properties
   (b) Chemical Properties and
   (c) Biological characteristics of organic matter.

(a) **Physical Properties.** Soil organic matter is a light bulky substance varying in colour from black or dark brown to more or less colourless compounds. It is porous and exhibits high water retaining capacity. It holds 180% of its own weight in water, When it absorbs water, it swells and increases in volume. Because of this property, it is able, when present in the soil, to absorb all rain water that falls and thereby reduces run off. It also exhibits cementing powers when added to soil and helps in binding particles of soil to form aggregates or structures. In this respect it is more important than clay for it is more water stable and its structure forming properties increase the tilth of the soil. It is colloidal and therefore important in the absorption of ions.

The darker organic matter imparts to the soil a dark colour which helps the soil to absorb more radiant energy. This is important for the biological activity of soil organisms. Because of its porosity and power to form aggregates of individual particles, the æration of the soil is greatly increased. When soil rich in organic matter is wetted, the organic matter absorbs the water faster than clay. This being so, a soil rich in organic matter does not become plastic, nor does is puddle when worked with a high soil moisture content. The available water content is greater in soils which are rich in organic matter, and thus soil organic matter improves the texture of heavy soils.

(b) **Chemical properties of soil organic matter.** Along with organic matter in the soil there are associated several other elements of which the most important is Nitrogen. The nitrogen content of the soil organic matter varies and is normally greater in temperate countries than in the tropics. This nitrogen is made available to the plants by biological activities of soil organisms. At times the nitrogen is used up by the organisms for their own metabolism. By metabolism is meant the continuous chemical change going on in living matter either constructive by which nutritive material is built up into complex and unstable living matter, or destructive by which protoplasm is broken down into simpler and more stable substances. It any case, nitrogen still remains a part of soil organic matter. Soil organic matter exhibits absorptive powers and prevents the wash down or leaching of fertilisers from the soil, and thereby fertilisers and manures are retained in the soil and are made available to the plants whenever they require it. This function also helps in conserving the salts that are formed in the soil as a result of weathering. Soil organic matter increases the solubility of the inorganic constituents of the soil because of its acidity. The nutrients present in it are well balanced and hence do not cause any injury to the soil.

(c) **Biological characteristics oj soil organic matter.** Soil organic matter serves as a source of energy and food for the vast population of micro organisms in the soil. The maintenance of a large amount of micro organisms in the soil is essential for soil fertility. They consume organic matter and in the process convert decaying organic matter into humus and release food for the growth of plants in forms which the plant likes best. The micro organisms are responsible for a number of chemical changes taking place in the soil. These organisms consist of

Fungi which include yeasts and moulds,
Bacteria,
Algae which belong to sub-aquatic plant life,
Protozoa and Amoeba which are microscopic organisms of the simplest structure.

Fungi. Fungi and yeasts act upon certain kinds of organic matter in the soil using this material to build up their own structure. When they decay, they leave behind organic residues which are more easily nitrified. Fungi are present in smaller numbers then bacteria in the soil. They are most abundant and prolific in organic soils with acid reaction. In such soils decompositions are mainly the work of fungi and not so much of bacteria.

Bacteria. These are the most important micro organisms in in the soil. The concentration of bacteria in the soil varies, but in ordinary soils they may be present to the extent of 100 to 300 millions per gramme of soil. The highest figures are obtained in highly cultivated and heavily manured soils. The distribution of bacteria within the soil itself is variable. There is a marked localization of bacterial activity in the vicinity of growing roots where worn out cells decay. Moisture and warmth favour their growth whilst drought and cold depress their activity. There is rapid decrease in bacterial numbers with depth and complete sterility is reached within few feet below the surface. There are several kinds of bacteria and most of which found in the soil fulfil many useful functions in agriculture the most notable of which are decomposition of organic matter and fixation of nitrogen in soil.

Protozoa and Amoeba. These organisms are always present in the soil, and live on bacteria and thereby limit the activity of the latter. Protozoa are easily killed by heat and antiseptics whilst bacteria are more resistant.

(iii) **Soil Moisture or Soil Solution.** The soil solution is the dilute aqueous solution from which plants obtain their nutrient requirements by the medium of their roots. Its composition varies from soil to soil and within the same soil at varying depths according to moisture content. As soils become dry, the solution or moisture becomes more concentrated. The soil solution contains dissolved carbondioxide and therefore has a solvent action on the mineral matter of the soil.

(iv) **Soil Air.** Soil air fills the pore space of the soil. It differs from atmospheric air in the following respect, namely its composition is variable, and it is usually saturated with water vapour. It contains a higher proportion of carbondioxide than the atmosphere and it depends on the bacterial activity of the soil.

Cultivation in relation to physical properties of soil. Physical character and behaviour of a soil are governed by a number of circumstances which are :—

1. Nature, size and distribution of the particles comprising the soil.
2. Colloidal material content of the soil.
3. The relative proportion of organic and in-organic matter in the soil.
4. Moisture content.
5. Structure of the soil and its pore space.

The pore space is not a specific property of a given soil, but depends on its temporary structure. The proportion of pore space depends on the extent to which its primary particles are united into crumbs. The greater the development of the crumb structure, the greater will be the pore space because not only there are bigger spaces between the bigger crumbs, but the crumbs themselves are porous. The formation of soil crumbs depends on the presence of humus which gives the soil that characteristic stickiness which it gets from decayed remains of plants and animals and the chemical action of water in which some of those products of decay are dissolved. This stickiness properly controlled is a most important property and the ingredients which contribute to this characteristic are called "colloids". This soil colloidal matter acts as a kind of cement which sticks the soil particles together and this formation is greatest in soils containing large proportions of organic matter, humus and clay. If there is no organic and colloidal matter, then there would be very little crumb formation. A well developed crumb structure is very important to the growth of plants for the following reasons :—

(a) It facilitates soil aeration.

(b) It renders the soil permeable to water movement and absorbs and retains maximum amount of water and prevents erosion.

(c) Crumb structure tends towards stability against erosion by wind action during drought for the fine particles are anchored down in compound aggregates which are too heavy to be affected by wind.

(d) If favours tillage operations particularly in heavy soils.

From the time land under jungle or grassland is opened up, the action of the sun and air increases the rate at which plant food, organic matter and humus are used up. With continued depletion of these reserves of organic matter, the crumb structure of the soil gradually breaks up and new combinations of soil particles have to be formed to keep the soil in a porous condition to ensure proper soil aeration and existence of sufficient crevices or pore spaces both for moisture absorption and to enable the extremely delicate feeding rootlets of the plant to penetrate into the soil in search of moisture and nutrients. To achieve and maintain this state of soil, cultivation is very necessary whereby air and water are able to penetrate the soil easily.

The micro organisms on which fertility of soil depends require moisture to carry out their functions and cultivation helps to mix the plant and animal remains with soil so that new colloidal matter cements soil particles and maintains crumb structure. For healthy plant growth, air in the minute pores and channels of the soil has to be constantly renewed. The more rain we can absorb and pass through the soil the better is the agricultural practice. Cultivation suppresses weeds and promotes root development and gives the delicate root system of young rubber a better chance to carry out its functions efficiently even in resistant soils. Rubber has weak penetrating root system and is not efficient in thrusting its roots through unkind and resistant soils. Cultivation ensures that application of manures is deep seated. When green manures, compost and cattle manure are incorporated into the soil when cultivation is done, lost humus is restored by the action of bacteria and fungi as described earlier and the soil is kept alive and fertile.

Cultivation should not be carried out in dry weather because the ground will be too hard for efficient forking which cannot be done economically. It also opens out the soil and causes damage to rubber by the acceleration of evaporation of soil moisture. Shallow cultivation is wasteful, more especially when manures containing phosphates which are not readily and easily soluble have to be applied. It is not recommended also for the reason that it is against the interests of soil conservation as it promotes rapid erosion. The results of deep cultivation are both beneficial and excellent on rubber roots. Roots require periodic stimulation to fresh growth and activity. Otherwise after some time they become inefficient and die. It has been found by practical experience that cultivation of alternate rows of rubber every six months stimulates root growth and does not constitute a danger to root development. The steady production which follows deep cultivation amply justifies its adoption.

Cultivation in relation to Green Manuring. The forking-in of prunings and green manures during drought is to be deprecated. The amount of moisture they supply to the soil is quite small; they dry rapidly themselves and open up the soil even more than a straightforward plain forking does. Unless this vegetable matter is composted, it is better left as a leaf mulch. By protecting the soil from direct sunlight this mulch will preserve moisture in in the upper layers of the soil in a much more efficient manner. It is not a highly efficient method of using green manures, but it is more expedient to lose some of the nutrient value of leaf-fall than to risk drought dangers. Where the mulch so formed is supplemented by a really good layer of leaf dropping, it plays a very important part in soil protection where ground covers have not been fully established and it is a very fine protection against erosion when the rains arrive later.

Cultivation in relation to Artificial Manuring. It is as an adjunct to good manuring that cultivation plays its most important part. General experience has shown that shallow manurial applications are fraught with danger in places subject to dry periods. The fine feeding roots of rubber are concentrated very largely in the cultivated and manured depths so that apart from any other considerations a policy of shallow manuring tends to unduly encourage root development in the soil depths that feel the effects of drought first. Moreover, phosphate and potash manures have not the mobility in the soil that nitrogen has so that nothing but deep forking localizes the supplies of these nutrients.

Phosphates deserve a special word. In time, all forms of phosphatic manures revert in the soil to a type of compound that is only sparingly soluble. It is necessary therefore to distribute phosphates in those parts of the soil where the solvent action of soil moisture is reliably steady. Nothing could be more wasteful than the scratching in for a few inches of an insoluble manure like Rock Phosphate (the Saphos and Safaga of commerce).

Cultivation in relation to the Root System of Rubber. Rubber like all other plants absorbs its water and nutrients through the roots and to understand the effects of cultivation on the root system, we shall consider it in some detail.

An examination of the roots of the rubber tree will reveal that the greater part of the roots are covered by a kind of corky material which is impervious to water. Only a small portion immediately behind the root tip is free of this corky layer through which water is drawn into the plant. As the root advances in age and becomes less efficient, this impermeable covering extends over the uncovered portion and the root grows longer and a new region permeable to water is formed. This occurs in the tap root and main lateral roots which explore new parts of the soil in search of water and nutrients. Each main permanent lateral root is provided with a large number of fine delicate rootlets commonly called feeding roots which form a large absorbing area. These feeding rootlets are not permanent. They function for a time and then decay and are replaced by a fresh growth.

These feeding rootlets are of the greatest importance to the rubber tree as they constitute the chief means by which it obtains food and moisture although their life is short. These important feeding rootlets cannot develop and carry out their work efficiently. No rubber cultivation can be carried out successfully without some root disturbances.

Deep cultivation in wet weather will give the desired results. It must be borne in mind that cultivation in any form which entails root destruction will bring about a great deal of harm and should not be permitted. Cultivation must not entail destruction or breakage of a single main lateral root.

CHAPTER X

MANURING OF RUBBER

Cultivation with application of commercial fertilisers and green manures of various kinds is vital to the growth of rubber and ensures a high standard of production and maintains the capital value of soils and trees. Liberal application of suitable fertiliser mixtures together with systematic forking-in of green vegetation is necessary to improve the texture of the soil, its humus content and to arrest disease and to maintain the tree in good health and vigours. We shall divide this subject and consider it under two headings:-

(1) Green Manuring and use of cattle manure and compost,

(2) Application of Commercial Fertilisers.

GREEN MANURING. A newly opened jungle land produces heavy yields of crops, but after several years of continuous cropping, the yields decrease. If this soil be now compared with fresh jungle soil, it will be seen that one of the essential differences between these two soils exists in their organic matter content. The rate at which organic matter is used up would appear to have been increased through tropical agents of growth and decay, and to increase yields and to improve and maintain fertility, the lost organic matter in the soil must be restored. Carefully planned scientific investigations supported by the testimony of planters indicate that in the absence of a sufficiency of humus, artificial fertilisers are powerless to exert their best and most remunerative effect. It is a widely recognised fact that the application of fertilisers to a soil deficient in organic matter is mere waste of time and money.

Organic matter in the soil can be restored in two principal ways:-

(i) By Green manuring, and

(ii) By the addition of compost or other forms of decayed organic matter.

Green manuring is the process of incorporating in the soil, plant material in the green state. If added under proper conditions, this green material undergoes quick decay and adds to the soil not only organic matter in bulk, but also appreciable quantities of nitrogen. Therefore, green manuring is a very useful method of renovating soil fertility.

Green material to be incorporated into the soil can either be grown on site or may be brought from outside. If a crop is to be grown on the land itself to be forked in later, it should always be a leguminous crop. A non-leguminous crop, if grown on the soil will take its nitrogen requirements from the soil and later give back to the soil the same nitrogen or perhaps a little less than it took up. Therefore there will be no gain in nitrogen to the soil from the use of any non leguminous crop which is grown on it. The only gain lies in the bulk of organic matter added. On the contrary, a leguminous crop has the power to fix atmospheric nitrogen through the medium of the bacteria present in its root nodules. Therefore a leguminous crop grown for green manure enriches the land on which it is grown by adding both organic matter and nitrogen to the soil.

In the composition of the leaves, the leguminous crop is generally richer in nitrogen than leaf from non-leguminous plants. If the organic matter incorporated in the soil does not undergo any change, it will be of little use to plants. It is the changing and breaking down of organic matter that makes for soil fertility, and not the mere presence of it in the soil. The factors which govern the decomposition of green material in the soil are:-

(a) The physical state of the soil,

(b) The micro organic population of the soil, and

(c) The composition of the plant material incorporated in the soil.

Physical State of Soil. The rate of decomposition of green material put into the soil depends chiefly on the moisture content of the soil. In the first place the soil should be well drained as water-logging conditions cause changes in the green material which are unfavourable to the crop. There should, however, be sufficient moisture present in the soil. Otherwise decomposition and nitrification are greatly retarded.

The optimum condition of soil moisture for decomposition is $\frac{2}{3}$ to $\frac{1}{2}$ of the saturation of moisture content of the soil. Of course, the optimum condition for different soils varies, but on the average 15% to 20% of saturation moisture content has been found to be adequate.

When soil is dry, green manures should not be forked in as decomposition does not proceed satisfactorily. Heavy rainy conditions on the other hand are also unfavourable because the excessive water in the soil does not allow proper aeration of the soil which is essential for decomposition to take place satisfactorily. The aeration of the soil is connected with the action of micro organisms which function better with greater aeration of the soil. Therefore the best time to fork in green manures is towards the end of the rains when dry weather alternates with showers. These conditions indicate the best climatic conditions for this work.

The micro-organic population of the soil. These organisms are responsible for the decomposition of the green material incorporated into the soil. They are present in vast numbers as already stated earlier. On the addition of organic matter they greatly increase in numbers because organic matter supplies them with a source of energy and food.

Fungi are the class of micro organisms which are chiefly concerned in the decomposition of cellulose material. Therefore it is the fungi that first get to work either on the forked in green material or on the organic matter put into compost pits. The result of their action is the production of carbon dioxide, humus and organic acids. Bacteria on the other hand are chiefly concerned with the breaking up of organic nitrogenous material. They finally produce nitrates.

The composition of plant material. This plays an important part in nitrification. Cellulose and liquified materials resist decomposition. Therefore, plant materials which are too mature such as loppings from bush green manures such as Tephrosias and Crotalarias or loppings from trees such Gliricidias and Dadaps decompose very slowly. On the other hand, immature portions of plants and young tender plants in general contain more readily decomposable constituents such as sugars and proteins in large quantities. These decompose very readily and lead to nitrification in the form of nitrates.

For the formation of nitrates from green material, the nitrogen content of such material should not be less than 2%. Leafy green manures and green material from young plants generally contain a higher percentage of nitrogen. In the case of plant material which has been fibrous or woody, the soil micro organisms have to spend much energy to break them down. In order to obtain this energy for this purpose as well as for their own multiplication, the micro organisms actually make use of the inorganic nitrogen present in the soil instead of liberating it. Therefore, it is a loss to the soil or to any immediate crop if over-mature or woody material is forked into the soil. Such material will contain much less than 2% nitrogen required for quick decomposition.

A crop specially grown for green manure should be cut down and forked in about the time just before it flowers. Green manuring will particularly benefit sandy soils and land where the top soil has been eroded by increasing their humus and nitrogen content and water holding capacity. During dry weather the green material should not be forked in but should be laid over the ground as mulch. Th s will help to conserve moisture. A comprehensive list of trees and shrubs suitable for use as green manures is given in Chapter VIII.

There are many leguminosae which can be used, and the chief point to consider when making a choice is their suitability for the climate and soil of the particular estate or district with which one is dealing. Choose the one which grows most readily. The variations which are found in the percentages of nitrogen in the leaves are of little or no practical importance; it is sufficient to choose one which can be easily grown in the district, and so far as possible one which gives a heavy yield of loppings. Remember that green manuring does not end with the establishment of a particular tree or shrub; these trees are only the source of the green manure, and the act of green-manuring is the burying of the material obtained from them. Another point of importance is that in order to make green manuring a success, the trees should be as carefully cultivated as the main product.

Among those green manures which have proved suitable for rubber are:—

Boga medelloa (Tephrosia candida)
Crotalaria anagyroides.
Crotalaria usaramoensis.
Tephrosia vogelii.
Gliricidia maculata
Albizzia moluccana.

Regarding albizzias, they should be put out in the rubber during the first year. If planted later they are generally unsuccessful. They are useful in protecting the young rubber in the earlier stages, and can be planted either as stumps or as seed at stake.

Burying versus Mulching. In the majority of cases burying is better than mulching, because the latter does not add much to the organic matter in the soil.

In the tropics the organic matter left on the surface soon dries up and oxidises, leaving little or no residue. This is what generally happens to the leaves which fall when the rubber tree "winters," and although they may at first form quite a heavy mulch they do not rot on the surface and form a layer of leaf-mould, but to a great extent dry up and disappear, with little or no benefit to the soil, though what is left helps to prevent wash. With the loppings of green manure trees, the maximum benefit is got by burying them. The burying need not be deep, unless the character of the soil makes it advisable to attempt improvement of the subsoil as well as the surface. The chief point is that the green material should be covered with earth so that it may rot and become part of the soil. Mulching should only be practised when the soil has been regularly forked and has a permanently loose surface. Then, if the addition of organic matter is not pressing, green material may be left as a mulch on the surface, and the remains of it gradually incorporated with the soil during subsequent forkings.

Cattle manure. Although green manure may be considered equivalent to cattle manure, the latter is superior because of its more rapid and complete decomposition. Cattle manure is as valuable to rubber estate as to any other, and where obtainable it should be made full use of. Its beneficial action is largely due to the improvement it brings about in the physical condition of the soil, for it contains only very small amounts of plant food which in themselves would not have much effect. Its value lies in the bulk of organic matter which it supplies, and in the fact that this organic matter contains nitrogen in various forms which are readily assimilated by plants. It is, like lime, employed largely as a soil improver and, therefore, should be applied in heavy doses. Anything up to 10 tons an acre is considered a light application in European countries and there is no doubt that similar applications would be of great benefit to rubber estates, especially where the soil is clayey or cabooky. Nothing very much need be said as to the methods of application, or rather nothing much can be said which will be useful as a hard and fast rule for all estates. One or two fundamental points should be noted, however, and the working details arranged to suit particular conditions.

Top-dressing with cattle manure is bad practice, especially with a permanent crop like rubber. It encourages surface roots, besides wasting much of the good of manure. This argument is similar to that discussed under green manuring; cattle manure must be covered with earth so that it may rot and become part of the soil. This rotting process depends largely on bacteria and requires air, so the manure should not be buried so deeply as to exclude air. The proper depth depends on the condition of the soil; if it is well forked and aerated, the manure can be buried deeper than if the soil is hard and uncultivated. Some of the plant food in cattle manure decomposes slowly and so forms a reserve in the soil, but if buried too deep it is a reserve of which the full benefit is never obtained, and it is less useful for example than a reserve of artificial fertilizers buried to the same depth.

The best results from cattle manure will be got if the conditions favour rapid nitrification at the time of application, and if this is followed by a good deal of rain to carry the nitrates down and encourage the roots to follow. These conditions are probably best approximated to by applying cattle manure in the showery weather preceding the monsoon.

Compost. Compost is a very valuable manure for rubber soils and where plenty of green material, dung, urine earth, vegetable and animal residues and garden or line refuse are available, it affords one of the cheapest and best ways of enriching the humus content of the soil. Compost not only provides nitrogen, phosphoric acid and potash which are essential plant foods but also ensures the improvement of the texture and tilth of the soil. By tilth is meant a well developed crumb structure which favours soil aeration, and renders the soil capable of retaining more moisture and more permeable to water. Compost when properly prepared is comparable in richness to cattle manure and it is possible to make about five times at least its bulk in compost with a given quantity of cattle manure.

Materials necessary for Compost making. All green leafy material, weeds and the like, animal remains, garden and kitchen refuse, droppings of cattle and other farmyard animals, cattle urine impregnated earth are the most suitable materials for compost making. Compost can be made in either heaps or in pits.

General principles for making Compost. The site of the compost pits or heaps should have free contact with earth and air and should possess suitable degrees of warmth and moisture. If there is too much of moisture aeration will decrease and the reaction will cause decomposition to slow down. A high land affords protection against water logging. The economy of labour and transport should be borne in mind and it will be advantageous if the site is easily accessible by a cart road. The earth should be permeable to water and not clayish. There should not be any growing vegetation on the base of the heap or trench. If the base is so covered conditions become acidic, and the soil organisms which normally favour decomposition cannot exist.

The pit or heap should be of convenient size according to the quantity of composting material available. Where the pit method of making compost is adopted, such pits should be between 3 to 4 feet in width and of similar depth. The bottoms should have a slight slope to prevent water logging. With the heap method, the height of heaps should be about 4 feet for easy watering and about 3 to 4 feet in width. The length of the pits and heaps can be made to any convenient size.

Suitable arrangements must be made to afford complete protection of the process from weather and atmospheric conditions. The materials should be sufficiently moist, but not soaking wet when placed in the pit or heap. The importance of the employment of as much variety of material as possible cannot be over-emphasized, and as woody and "stubborn" varieties impede the process, care should be taken to discard such material. A good balance of materials is necessary for the maintenance of optimum conditions of temperature, moisture and æration throughout the period of manufacture. Otherwise an indifferent product will be the result.

Making of Heaps. The following instructions, if carried out with care, will ensure manufacture of humic manure of the finest quality which will exert a very favourable influence on the tilth, moisture retaining capacity, and texture of the soil, and provide at the same time a source of energy, nitrogen and minerals for the various micro-organisms in the soil the importance of which has already been discussed.

1. Prepare base with 3″ layer of well rotted cattle manure well sprinkled with dry powdered urine earth. A convenient size of the base may be 4′ x 12′.

2. Moisten adequately but not excessively.

3. Place a layer about 18″ thick of vegetable matter, refuse, waste or any material as may be available. The coarser material should be placed in the middle of the heap, and so also weeds. There is however a risk with the use of seed-weeds as a proportion usually retain their viability. Heat of the material in outer layers of the heap is insufficient to kill all seeds, and even if they are turned in latter, the thermal activity is by then so much reduced that a good many will probably survive. Addition of wood ash may counteract this to some extent as it tends to decrease acidity slightly and thus eliminate conditions otherwise favourable for germination of weed seed.

   If weeds are gathered before seeding, this type of material is of some value, and when sufficient temperature exists, there can be no danger of weed growth being increased. It must be remembered at the same time that weeds alone will not produce a good type of compost.

4. Moisten the material preferably with a hose or watering can, but avoid excessive watering.

5. Add another layer of cattle manure and urine earth as available to a thickness of 6 inches. Where sufficient cattle manure or urine earth is not available, spread Sulphate of Ammonia evenly over the green material at the rate of ½ oz. per sq. yard of soft material, and 1 oz. per sq. yard of coarse material.

6. Repeat with another layer of composting material 18″ thick as described in Instruction No 3.

7. Continue the alternating layers of composting material and cattle manure, urine earth or Sulphate of Ammonia as described above until the desired height is reached remembering to moisten sufficiently each layer immediately it has been laid. The last layer should be one of cattle manure, urine earth or sulphate of ammonia over which a layer of soil 3″ in thickness may be placed.

8. Care should be taken to arrange the layers of materials lightly one on top of the other. Pressure by trampling is unnecessary and must be avoided. The loose arrangement of the materials creates optimum conditions of adequate æration and promotes rapid heating and breakdown of the material, and rapid shrinkage of the heaps will set in during the first part of the process.

After Care of Heaps. This consists of (a) Turning of the heaps and (b) Watering. Turning hastens decay by affording increased æration and helps to destroy weeds and improves the homogeneity of the composted material. Watering is done to make up for moisture lost in the process. Watering should be done once a week up to the first turn. Thereafter at the second turn and third turn. Watering is also necessary when the temperature goes down.

1st Turn. This may be done on the 14th day after the making of the heaps. They will be found warm in the middle. When turning, the partly decomposed mass should be stacked in the opposite ends of the heaps to permit of the maximum circulation of air. Thorough mixing is of great importance and sufficient water must be added to keep the heap just moist. On no account should it be made soaking wet.

2nd Turn. To be done after 1 month from charging.

3rd Turn. To be done after 2 months from charging. The composted manure may now be moistened and stacked in rectangular heaps about 10 feet long at base, 9 feet at top and 3 to 4 feet high to ripen for one month.

Testing. The efficiency of the process can be tested by observation and without recourse to chemical or biological analysis.

During the first month, fungi are engaged in breaking down the organic matter. The heaps should then contain white fungoid growth, and the temperature should be high.

After the third week, the mass darkens rapidly and becomes crumbly, while there is a slight fall in temperature. Bacteria from now onwards take an increasing share in humus manufacture.

If, at any time, fermentation stops and the heaps or pits cool, insufficient moisture is the most likely cause.

A sour or an ammoniacal, or a sweet apple-like smell indicates congestion and semi-ærobic conditions.. The remedy for this, is to turn the heap at once and to add more dung and ashes.

The final product should have a rich earthy smell.

Application. It is best to use compost as soon as it is ready. For rubber the most suitable rate of application is about 10 tons per acre. The weight of compost normally varies from 40 to 50 lbs. per cubic foot according to the moisture content of the humic manure.

It is obviously of advantage to arrange that application be made a few months after pruning in order to incorporate as much leaf-fall as possible with the compost. The resulting activation of this material provides a very large and valuable addition to the bulk which goes into the soil. The product, when ripe, should be forked in with as little delay as possible in order to avoid the loss of organic matter and nitrogen which would otherwise result. At the same time, application in very heavy Monsoon weather should, as far as possible, be avoided or humus will be washed away and lost.

If compost cannot be used as soon as it is ready, it will be necessary to store it up for use as and when necessary. Everything possible should be done to afford complete protection from the drying action of the sun and leaching due to rain.

APPLICATION OF COMMERCIAL FERTILISERS

Young Rubber. Careful and adequate manuring is very necessary in the early stages of the tree's growth for quick and vigorous development. The nutrients essential for the economic growth of Rubber are Nitrogen (N), Phosphoric Acid (P) and Potash (K). Although the response of young Rubber to manuring is not readily noticed and may be even disappointing, it is prudent to continue the use of a N. P. K. mixture with Potash (K) as the minor constituent in young areas.

Recent trials in Ceylon have shown a small but significant response to the application of Phosphate, and smaller response to Potash and Nitrogen in diminishing degrees. On soils of average fertility the response is as above and not much marked while on really impoverished areas, there can be little doubt that striking responses would result from the application of fertilisers.

It is generally considered advisable to incorporate Phosphate alone in young areas where the general growth is satisfactory. Backward areas or backward trees in areas where the general growth is satisfactory should, however, receive regular applications of a general N. P. K. mixture. There are also factors other than shortage of nutrients which may be responsible for poor growth such as a high water-table, shallow soil, exposure to wind etc., which should not be overlooked. "Satisfactory growth" cannot be defined in terms which will be equally applicable under varying conditions. An annual average girth increment of about 2½ inches in the higher elevations and about 3 inches in the lower elevations may be considered satisfactory.

The rate of growth can be suitably judged from an annual census in each field, in which the girth of every tenth tree, excluding supplies, is measured, irrespective of whether it happens to be a good one or bad one, and an average figure calculated. Casual measurement of a few selected trees cannot be expected to give the required information. The appearance of the foliage and presence or absence of new whorls are also useful criteria of the standard of growth.

The general fertiliser mixture recommended in this chapter for application is based on ground nut cake, a cheap form of organic nitrogen. There is no objection, however, to the inclusion of an equivalent amount of Sulphate of Ammonia or Nitrate of Soda or other form of organic Nitrogen. Similarly in place of Rock Phosphate, an equivalent quantity of Bone Meal may be substituted partly or wholly. Bone Meal may be found to be more suitable than Rock Phosphate on limestone soils. No provision is now made for the application of Potash in the planting hole, since an adequate supply of wood ash is usually available from timber burned on the land. The quantity of ash applied in the hole should not exceed 1 lb.

The use of cattle manure or compost in place of artificial fertilisers is favoured if adequate supplies are available. The correct rate of application will depend on the composition of the material, but it is suggested that about 10 lbs. per plant be given in the first year rising to 50 lbs. in the 8th year. As the Phosphate content of bulk manures is frequently unsatisfactory, the supply should be augmented by the addition of Rock Phosphate in quantities ranging from 1 ounce to 8 ounces per plant.

Backward Areas. The general mixture detailed below is recommended for Backward plants at the rate of 3 ounces for every inch of girth at 6 monthly intervals. The mixture should be dibbled round the plants or forked in with green manures according to circumstances and the lay of the land. Plants intended for budding should not be manured within 2 months of budding. The mixture is also suitable for use in nurseries at the same approximate rate of application.

GENERAL MIXTURE

		Percentage composition.	
Groundnut cake	14 parts	Nitrogen (N)	4. 9%
Saphos (or other Rock Phosphate)	5 parts	Phosphoric Acid (P_2O_5)	7. 4%
Muriate of Potash	1 parts	Potash (K_2O)	2. 5%

AREAS OF SATISFACTORY GROWTH

A Table setting out the Time of application, Quantity of Manure to be applied and Method of Application, is given on page No. 150 which may be adopted as a guide in the preparation of manuring programmes to suit individual needs, and should not be regarded as a schedule for rigid observation.

TIME OF APPLICATION*			Amount of Manure per Point or Tree	METHOD OF APPLICATION
"Clonal" Seedlings (not to be budded)	Seed-at-stake or Basket Plants (for budding in the field)	Budded Stumps		
2-3 months before planting	2-3 months before planting	2-3 months before planting	1/2 to 1 sack of green material plus 12 oz. groundnut cake	The green material and groundnut cake should be added together to the hole in alternate layers with the soil
At Planting	At Planting	At Planting	4 oz. Rock Phosphate	Mix with the soil in the upper half of the hole.
4 months after planting**	4 months after planting**	—	3 oz. groundnut cake	Dibble in around the plants.
—	—	4 months after planting**	9 oz. groundnut cake	Dibble in around the plants.
1 year after planting	1 year after planting***	1 year after planting	4 oz. Rock Phosphate	Envelope fork 1' to 3' from the plant with green manure.
—	1 year after budding	—	4 oz. Rock Phosphate	-do-
2 years after planting	2 years after budding	2 years after planting	9 oz. Rock Phosphate	Envelope fork 3' - 6' from the plant together with green manure.
3 years after planting	3 years after budding	3 years after planting	12 oz. Rock Phosphate	Partly dibble in 3' - 6' from the plant, and partly fork in 6' - 8' with green manure.
4 years after planting	4 years after budding	4 years after planting	15 oz. Rock Phosphate	-do-
5 years after planting	5 years after budding	5 years after planting	18 oz. Rock Phosphate	Fork in rows 4' - 8' from the trees.
6 years after planting	6 years after budding	6 years after planting	21 oz. Rock Phosphate	-do-
7 years after planting	7 years after budding	7 years after planting	24 oz. Rock Phosphate	-do-

* The time of application may be postponed or advanced slightly according to local climatic conditions in order to avoid manuring during the monsoons.

** This application need be given only where green material (compost or cattle manure) was not added to the planting hole.

*** This should not be applied within 2 months of budding.

Typical example of magnesium deficiency
(By permission of the Rubber Research Institute of Ceylon)

Magnesium Deficiency in Rubber. Magnesium deficiency is characterised by an intervenal yellowing of leaves especially in young clearings, and may be described as a golden yellow colouration starting at the edges of the leaves and extending down between the main lateral veins and spreading towards them. The yellow bands are frequently broken by thin green lines marking the position of the largest minor veins spreading between the main laterals. At a distance the alternate patterning of green laterals and yellow deficient areas present a zebra like appearance and is frequently called "zebra striping". This appearance is common to Magnesium deficiency on a variety of plants.

In many cases it seems to pass away after 2 or 3 years. This is presumably due to the rapid growth of roots taking in a much larger volume of soil and hence foraging more efficiently for the elements in short supply. Although the deficiency may rectify itself, there is a period of a year or more during which the leaves are very short of chlorophyll of which magnesium is an assential constituent, and therefore very inefficient.

Leaves may be considered to be the most important organs of a plant and without them it cannot survive indefinitely and will be overtaken by certain death. In addition to their ordinary functions of aiding moisture transpiration and absorption of carbonic acid gas from the atmosphere, leaves act as the agency by which the plant converts nutrients from the soil and air into food suitable for plant growth. Manure and water in the soil and carbonic acid gas from the atmosphere cannot be absorbed by the plant in the raw form in which these are found. The plant requires power and energy to conver these raw materials into suitable forms such as sugars, proteins. starch, carbohydrates, etc. for assimilation as food. The leaves obtain all the energy necessary for this purpose from the sun through the medium of light and heat. Without leaves, the energy from the sun, raw materials of food, however rich and elaborate, will be absolutely useless to the plant as these cannot be absorbed and assimilated in their raw state. The complicated process of manufacturing food suitable for plant life is accomplished by the leaves. It will be seen therefore how important are the functions of the foliage of the rubber tree in all its different phases of growth.

The discolouration of leaves caused by deficiency of magnesium shows that the trees are receiving a considerable set back, and it will be desirable to take prompt steps preferably to prevent its occurrence, or to cure it upon appearance.

Heavier Potash manuring appears to be a contributory cause as it has been widely found that plants receiving sufficient potash reveal Magnesium deficiencies rapidly if these exist. The remedy, of course, is **not** to cut the Potash out but to supply the deficient magnesium.

There are two main sources of Magnesium available, namely:- (a) Dolomitic Lime and (b) Magnesium Sulphate. The former is cheap and analyses 20-30% MgO. It is comparatively insoluble and should form an excellent long term source of Magnesium for a young clearing. It is, however not so satisfactory in curing a deficiency and it cannot be used in a mixed fertiliser, and so requires a separate application.

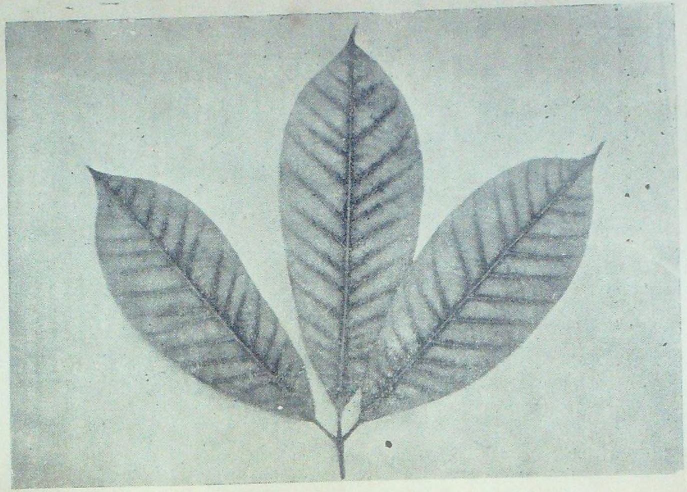
For this purpose a soluble Magnesium Salt such as Commercial Epsom Salts is required and in very bad cases may even be used as a 2% spray on the leaves in dry weather. Generally soluble Magnesium salts have to be imported and are more expensive materials. They analyse about 4% MgO.

A further source is the mixed Potash Magnesium salts formely known as Kainites. The use of these is considerably economic in that both Potash and Magnesium are being bought in the same compound. Such mixed salts could be used in any of the present rubber manurial mixtures. The following recommendations are made by the Rubber Research Institute of Ceylon:—

(a) **Normal manuring:**

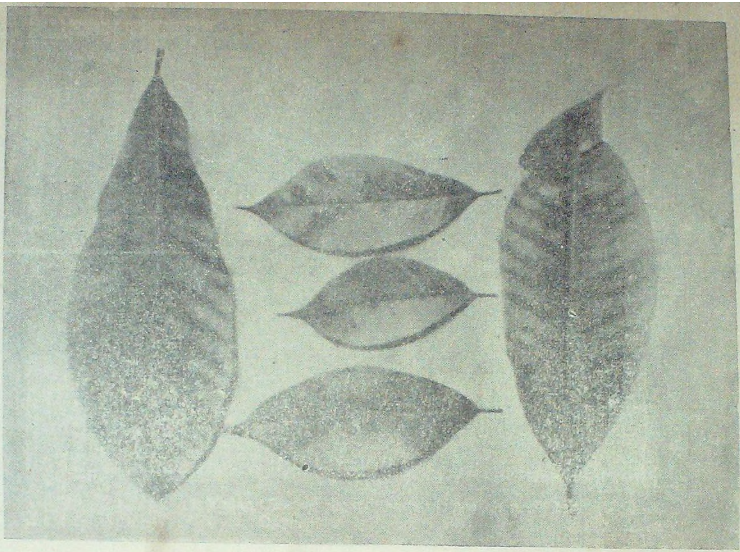
(1)	Dolomitic Lime (Analysing not less than 20%MgO)	1st year	½ lb. per tree
		3rd year	1½ lb. per tree
		5 th year	3 lb. per tree

Broadcast and dibble in the root feeding circle.



Closer view of Leaves showing effects of Magnesium Deficiency.

(By permission of the Rubber Research Institute of Ceylon)



3 Potassium deficient leaves flanked by 2 Magnesium deficient leaves for comparison.
Note the smaller size of the Potassium deficient leaves.

(By permission of the Rubber Research Institute of Ceylon)

(2) **Manurial Mixture.**

Your present mixture may be ordered to contain 1/3 part MgO for every one part of K_2O (Potash) e.g.- R4:6:5: with MgO.

Sulphate of Ammonia	100 lbs.	N	-	20 lbs.
Saphos Phosphate	100 lbs.	P_2O_5	-	30 lbs.
Muriate of Potash	50 lbs.	K_2O	-	25 lbs.
Commercial Epsom Salts	50 lbs.	MgO	-	8 lbs.

The total annual dose may preferably be increased by about 1/5th to make up for the extra constituent.

(b) **Deficiency Treatment.**

(1) Dolomitic Lime 2 lbs. per tree to be forked in.

or (2) Magnesium Sulphate (Epsom Salts) ½ lb. per tree forked in plus 1½ lbs. Dolomitic Lime will give quicker results.

or (3) Magnesium Sulphate - Make up 2% solution (2 lb. Epsom salts to 10 gallons water) together with a "sticker" and spray the trees 2 or 3 times at weekly intervals. Also broadcast 1½ lbs. per tree of Dolomitic Lime as well. This will give faster cure.

In both (2) and (3) above the addition of Dolomitic Lime to the soil is advisable to maintain the satisfactory Magnesium status for which the Epsom salts are a temporary cure. If, however, a manurial mixture containing Magnesium is used the Dolomitic Lime can be omitted.

Potassium Deficiencies. The appearance of trees on affected sites is fairly typical and is best seen by looking at the clearing from a neighbouring hill when the all-over yellow colour or patches of bright yellow can be seen contrasting strongly with the surrounding green foliage. The trouble is not easily seen within the clearing unless it is badly affected. It occurs typically where there is any opening such as wind damage, road, bungalow compound etc. It is believed that the increased total light striking the trees in such a case, causes greater leaf activity and growth and so emphasising the shortage of Potassium and making the symptoms more pronounced.

A close examination would reveal that the leaf yellows from the edges inwards with no differentiation of veins or tissues. The yellowing is uneven and the leaves generally have a central irregularly shaped patch of bright green. Scorching of the leaf tip spreading downwards towards the stalk is a further symptom in advanced cases. It is probable in such cases that the yellowing is largely a symptom of the Nitrogen deficiency, and the scorch of Potassium deficiency.

REMEDIAL TREATMENT.

(a) **Young Clearings.** Heavy applications of R 4: 6: 5 mixture (if not already being used will probably cure the trouble. However it is best to use a mixture of 100 lb. sulphate of ammonia, 100 lbs. saphos phosphate, 80 lbs. Muriate of Potash at the full rates recommended hereafter and apply four times a year.

(b) **Mature Clearings.** It has been found that quantities of 2—4 lbs. each of Muriate of Potash and Sulphate of Ammonia are needed according to the severity of the deficiency. These should be applied at rates of ½ lb. per tree every 2 months for eight months of the year (2 lbs. each per year) between March and October according to the weather and must be forked or pocketed to get below the soil surface. Four small pockets per tree is quite satisfactory, and both manures can be applied at a cost of 1 labourer per acre per application.

Unless the deficiency is a very mild one, two years application (4 lb. of each manure to each tree altogether) is recommended and it will take two years before the symptoms are finally cleared. Thereafter no recurrence is to be expected if R 4: 6: 5 mixture is used regularly, but those who prefer it may use the mixture given under (a) at the same rates as they would apply R 4: 6: 5.

It should be noted that Clone PB 86 is particularly susceptible to Potassium deficiency and steps should be taken with both young and old clearings accordingly. PB 86 is also susceptible to Magnesium deficiency and it would appear that the drawback of this clone is that it is a less efficient forager for nutrient than other clones and hence no risks should be taken with its manurial treatment. The deficiency has also been noticed on clones Glenshiel 1 and PR 107 and possibly TJ 1 and 16.

General Manurial Mixtures. It is not to be expected that soluble nutrients will be present in the soil naturally or will remain in the soil for long periods following application. For this reason applications as frequently as four times a year seem desirable and are an inexpensive insurance against losing a whole year's manure in one heavy rainfall. It must also be remembered that the rubber tree is growing and hence needs food all the year round. It is most improbable that a single yearly application would provide the year round requirements.

There seems little doubt that most soils will need three out of the four elements previously mentioned. These will be in the general order Phosphorous Magnesium Nitrogen and Potash. Therefore a full NPK mixture is desirable with Magnesium applied separately as Dolomitic Lime as already explained. Investigations into tree nutrient content have shown that a mixture N: P_2O_5 : K_2O of the proportion 4: 6: 5: most closely represents the tree's constitution, making allowances for losses of P_2O_5 (Potash) in the soil.

Whether the above mixture will be needed depends on how much of each element the soil can supply. That it does supply some nutrient is shown by the fact that unmanured trees grow, though only about 50% of normal growth. Unfortunately soil analysis is most unreliable unless hundreds of field experiments have been done to check the analysis results, and only very general ideas may be obtained from this method as a result. We are therefore thrown back to our expedient of denoting those areas which are known to be badly in need of potash and those likely to be less in need of it.

For simple lack of knowledge, and because gambling with the future of the young tree seems pointless, drastic deviations from the mixture mentioned above are not recommended.

Recommendations. The following manure mixtures are at present in use in Ceylon:- R 4:6:5 R 4:6:3 R 215 (R 4:6:2)

R 4:6:5 100 lbs. Sulphate of Ammonia
100 lbs. Saphos Phosphate
50 lbs. Muriate of Potash 50% K_2O OR
40 lbs. Muriate of Potash 60%

The above mixture represents the least risk in manuring. At our present stage of knowledge, this mixture is highly desirable on all estates in the Potash deficient areas and on others which are either on (a) very quartzitic soils (b) on cabook (c) on soils exhausted by previous crops.

The mixture may be modified in the case of replantings which have either (a) the old timber left to rot or (b) the old timber burnt and the ashes dug lightly in, and in these cases lower Potash mixtures might be used such as:—

R 4:6:3 100 lbs. Sulphate of Ammonia
100 lbs. Saphos Phosphate
30 lbs. Muriate of Potash (50% K_2O)

The above mixture would be satisfactory outise the Potash deficient areas or where the old timber or its ash are left on the ground.

R 215 (R 4:6:2) 100 lbs. Sulphate of Ammonia
100 lbs. Saphos Phosphate
15 lbs. Muriate of Potash (60% K_2O)

The above mixture is the one formerly in use and it is advised that planters who are satisfied with that mixture (R 215) need not change to the new formula. That is to say where satisfactory girth (3½ inches per year in immature trees) was being obtained there is no reason to change from R 215, but where satisfactory results had not been obtained or Potash deficiencies were clearly in evidence then a change to the new formula may be indicated.

In the event of clearings being burnt and the ash forked in R 215 will be a satisfactory mixture for use and as suitable as R 4:6:3.

In addition to the NPK mixture, Magnesium manuring is also required. In most cases the separate application of Dolomitic Lime will suffice but in stubborn or severe cases Magnesium Sulphate (crude Epsom salts) should be used. As already stated, the latter is more expensive but can be obtained mixed with any of the NPK mixtures which saves application costs. Magnesium Sulphate may also be sprayed as a 2% solution directly on to the leaves as mentioned earlier.

Dolomitic lime should not be applied at the same time as the NPK fertiliser but preferably several weeks after. It is not soluble and if dug lightly into the soil will not be leached out.

On some estates it is the practice to do most or all of the first two years manuring with an organic fertiliser such as Animal Meal. Although this is expensive it appears to be successful and is to be recommended as a practice to those who can afford it. Because it is an insoluble fertiliser there is no harm in applying it in one dose but, as it will take some time before it becomes available, it is recommended that it be used in conjunction with one of the "R" Mixtures—the latter to supply the immediate nutrients and the former long term nutrient. The best practice would be to replace 50% of the "R" Mixture with an equal quantity of organic fertiliser, applying the latter in one dose per year but the former in small doses.

It may be noted that organic fertiliser is compatible with Dolomitic Lime and can be applied at the same time. Animal meal does not contain quite as much of the nutrients as an equal quantity of the "R" Mixture, but this may be balanced by the smaller losses in leaching. The difference is not likely to prove significant.

QUANTITIES FOR APPLICATION

1st Year In planting hole ¼–½ lb. Saphos. Further improvement may be obtained by the use of up to ¼ lb. of organic fertiliser such as Animal Meal.

½ lb. per tree of R 4:6:5 (or R 463 or R 215 in the appropriate cases) in small doses.

½ lb. per tree of Dolomitic Lime (20% MgO or more) when the tree is well established.

2nd Year 1 lb. of R 4:6:5 (or alternatives) to be applied in small doses.

ALTERNATIVELY: (Per Tree)

1st Year ¼ lb. R 4 6 5 (or alternatives) to be applied in small doses.

¼ lb. Organic fertiliser such as Animal Meal to be applied in one dose

½ lb. Dolomitic Lime to be applied in one dose when the tree is well established.

2nd Year ½ lb. R 4 6 5 (or alternatives) to be applied in small doses.

½ lb. Organic fertiliser to be applied in one dose.

3rd Year 2 lbs. of R 4 6 5 (or alternatives) in small doses. 1½ lbs. of Dolomitic Lime (20% MgO or more) in one dose.

4th Year 2 lbs. R 4 6 5 (or alternatives in small doses)

5th Year	3 lbs. R 4 6 5 in small doses 3 lbs. Dolomitic Lime (20% MgO or more) in one dose.
6th Year	3 lbs. R 4 6 5 in small doses
7th Year and subsequently	4 lbs. R4 6 5

It will be noted that after 4 years a full time use of R 4 6 5 mixture is made in view of the very high yield effects associated with Potash. If a NPK mixture containing MgO is used, then Dolomitic Lime can be omitted. On burnt off clearings the 1st year's Dolomitic Lime application can be conveniently omitted or postponed to the 2nd year.

Time of Application. The times of application of fertilisers are either the refoliation period or periods of suitable weather for the operation. As far as possible application should be avoided on days when heavy rain is expected, particularly if the soil is already saturated with previous rain.

Method of Application. The inorganic mixture available can be suitably applied by broadcasting although it may be desirable to fork land which has not been cultivated for several years. Application of the manure in every row is advised. Where the manure is forked in, it should be done by deep envelope forking, facing down the slope. In broadcasting it is suggested that the manure should be spread under the cover crops as far as possible, and that any manure which adheres to the leaves should be brushed off with a soft coir broom. This is fairly effective in preventing scorching of the foliage. Grass cover should be removed in the strips where manure is applied, and any woody plants or ferns should be cut back to ground level before application.

It has also been recommended that manure be applied in several small doses. This means splitting the yearly application up into 2 to 4 doses. In regions of heavy rainfall 4 doses are

5th Year	3 lbs. R 4 6 5 in small doses 3 lbs. Dolomitic Lime (20% MgO or more) in one dose.
6th Year	3 lbs. R 4 6 5 in small doses
7th Year and subsequently	4 lbs. R4 6 5

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It has also been recommended that manure be applied in several small doses. This means splitting the yearly application up into 2 to 4 doses. In regions of heavy rainfall 4 doses are recommended and in those areas of light rainfall or where good weather can be predicted with reasonable certainty it might be lowered to 2 applications per year.

The manure is best "pocketed" at 4 pockets per tree per application. "Pockets" are made by driving in the fork to full depth and rocking once or twice to give a cut in the soil wide enough to put in the fertiliser. If labour is trained to make the "pockets" in a different position each application will be approximately all round the tree which will also have been ring forked in the process. The "pockets" *should be as far out from* the trunk as are the further-most leaves in the main canopy. This method has been proved simple and inexpensive and can be conveniently continued even when the trees are mature. It has been successfully employed in remedying deficiency symptoms. Although any form of forking which definititely incorporates the fertiliser in the soil is satisfactory, "pocketing" is advocated to avoid the risk of the fertiliser being washed away over the soil surface, particularly over steep slopes though the probability of wash even on flat or gently sloping land makes "envelope" for king or "pocketing" preferable to an ordinary broadcast of manure followed by a dibble into the soil.

ORGANIC AND INORGANIC FERTILISERS

Organic fertilisers may be described as those which have their origin in organic matter such as vegetation, fish and refuse from animals. Inorganic fertilisers, on the other hand are those which are chemically or mechanically prepared and have their origin in minerals or which are obtained from the atmosphere. The organic varieties of manure cannot claim superiority over inorganic fertilisers. Organic fertilisers are expensive to purchase and to transport by reason of their bulk and weight. Moreover as the nitrogen content of organic fertilisers is small, large quantities will be needed to make up the correct dosage per acre. The organic and inorganic varieties of fertilisers which are in common use are listed below in alphabetical order and briefly described.

Ammonium Nitrate. (Inorganic). This material is manufactured by passing Ammonia gas through Nitric Acid. It has a very high analysis of 30 to 34. 5 per cent. Nitrogen. Since half of the Nitrogen present is in the form of Ammonia and the other half is in the form of Nitrate, Ammonium Nitrate is very quick acting and very soluble. Unfortunately its greatest disadvantage is that it is very hygroscopic and cakes badly, and until this disadvantage can be overcome, it will not be suitable for use in the Tropics despite its cheapness.

Ammonium Phosphate. This inorganic ingredient contains 16 per cent. Nitrogen and 20 per cent. Phosphoric Acid.

Animal Meal. This is a complete fertiliser and is guaranteed to contain 7 per cent. Nitrogen, 10 per cent. Phosphoric Acid and 5 per cent. Potash. It is derived solely from animal residues with the exception of the addition of muriate of potash content up to the guarantee, no animal residues having such a high potash content.

Basic Slag. (Inorganic). This is the residual material obtained in the removing of phosphorus from iron ores in steel manufacture which is subsequently finely ground. The phosphorus content varies from 10 per cent. to 18 per cent. P_2O_5, and is highly valued for use on grassland. It is alkaline containing 40 to 50 per cent. of lime (CaO) on account of which reason it is rarely used on rubber but occasionally on Coffee. It is sometimes used in the establishment of leguminous cover crops for which it is most effective. It has also some Silica and small amounts of trace elements.

Blood Meal. (Organic). This is usually sold on the basis of 11 per cent. or 13 per cent. Nitrogen and is a very expensive fertiliser. This material is collected from slaughter houses and 20 to 25 lbs. of dried blood is secured from 100 lbs. of liquid blood. The drying of the blood is done with or without the addition of other products used to assist drying such as lime, and the dried product is thereafter crushed.

The nitrogen is highly available and it has been claimed that this fertiliser can produce improvement in the quality of Rubber as well as in yields.

Bone Meal. (Organic). Commercially pure bone, raw, degreased or steamed, is ground or crushed to pass sieves of certain sizes. It contains 3 per cent. Nitrogen and 22 per cent. Phosphoric Acid, and is a very useful ingredient for Mixtures in the form of fine Bone Meal as it improves the physical condition and prevents stickiness. Although the coarser grades are still largely used for Paddy manure, because the plant foods are only slowly available and because of the very high prices prevailing, this practice is slowly dying out to be replaced by more effective and cheaper fertiliser mixtures, for manuring rubber.

Calcium Cyanamide. (Inorganic). This is an alkaline fertiliser and is obtained by heating a mixture of limestone with coal in the presence of Nitrogen; sources of supply at present are Norway and Belgium. This material which contains not less than 20 per cent. Nitrogen is a very good drying agent and can therefore be used to improve the physical condition of those fertiliser materials which are subject to caking. It is toxic to plant foliage and is sometimes used as a combined weed-killer and fertiliser. It has given particularly good results when applied to grasses and legumes, and generally it is applied directly to the soil as a single fertiliser material or mixed with Basic Slag. Like Sulphate of Ammonia when applied to the soil a series of chemical and bacterial changes take place, resulting in nitrogen gradually being available to the plant and thus Calcium Cyanamide is less subject to leaching.

Caster Cake. (Organic). This commonly used organic fertiliser contains 3 to 4 per cent. of Nitrogen with smaller percentages of phosphoric acid and potash. It is only used on the basis of its Nitrogen content, and it phosphoric acid and potash contents are not taken into account when making up mixtures with this ingredient. After incorporation into the soil, it takes 3 to 4 months before it becomes sufficiently decomposed to be absorbed by the plants.

Commercial Epsom Salts. This is a source of water-soluble magnesium and it may be applied as a foliar spray or direct to the soil. It contains the equivalent of 16% Magnesium Oxide, MgO.

Crushed Fish. (Organic). The nitrogen content of crushed fish now available is round 4 per cent. and it forms a valuable organic fertiliser in the tropics because under damp and warm conditions it decomposes in the soil very rapidly and is absorbed by the plants more quickly than is the case with other organic fertilisers.

Fish Guano. (Organic). This is the residue after oil has been extracted from fish and is similar to crushed fish. The principal fish used are Cod and Herring, but Whale, Shrimp, Crab and Starfish are sometimes used. This material contains 7 per cent. Nitrogen and 6 per cent. Phosphoric Acid, the Nitrogen being slightly less available and the Phosphoric Acid slightly more available than those present in Bone.

Hoof and Horn Meal. (Organic). This is a very high grade organic source of Nitrogen containing 12 per cent. Nitrogen but is slower acting than Blood Meal.

Kainit. Deposits are found 650 to 5,200 ft. below the earth's surface in various parts of the world, and supplies at present come from from France and Germany. Kainit is an impure source of potash as it contains not only Potassium Chloride but also Magnesium Sulphate, and Magnesium and Sodium Chlorides. The Potash content varies from 14 to 22 per cent. and the Magnesium Sulphate varies from 15 to 20 per cent., and therefore where there is a magnesium deficiency in the soil Kainit could be used for a double purpose.

Leather Meal. (Organic). Scrap leather from the manufacture of shoes and leather goods is ground, roasted or steamed to give an analysis of 5 per cent. to 11 per cent. Nitrogen.

Muriate of Potash. (Organic). Sylvenite is a naturally occurring rock and contains a considerable portion of common salt. The Sodium Chloride is removed and Muriate of Potash is marketed in various grades, the high grades containing 50 and 60 per cent. potash. Supplies at present are imported from France and Germany.

Nitrate of Soda. (Inorganic). Contains 16 per cent. Nitrogen in the form of nitrate and is therefore immediately available, as nitrogen is absorbed by plants in this form. However, the Nitrogen content is liable to loss by leaching under conditions of heavy rainfall. It is relatively expensive compared to Sulphate of Ammonia and its use on rubber estates is small.

The Soda acts as a Potash saver in the economy of some plants and also releases a certain amount of soil potash for the use of the crop. Supplies from Chile are granulated and store and handle well.

Poonacs or Cakes. (Organic). These are the residues which are obtained after the removal of oil from the commercially pure seed, i. e. castor cake, coconut cake, groundnut cake, mowrah cake etc. They contain from 3 to 7 per cent. of Nitrogen together with about 1 per cent. of phosphoric acid and potash but the Nirogen only is guaranteed.

Potassium Nitrate. (Inorganic). This is commonly of Indian manufacture and can be obtained in varying degrees of purity containing from 10 - 14 per cent. Nitrate Nitrogen. and 30 - 46 per cent. Potash (K_2O). It is a valuable highly concentrated fertiliser.

Rock Phosphate. (Inorganic). Deposits of Rock Phosphate are mined in many places, crushed and ground, and supplies are obtained chiefly from Christmas Islands and Egypt. These materials containing about 29.5 per cent. Phosphoric Acid, are largely used for perennial crops since they are especially suited to acid soils and to plants that have a long growing season. The presence of Calcium Carbonate tends to decrease the availability of this material, while Ammonium Salts and Chlorides (especially Muriate of Potash) have sometimes been found to increase its availability.

Saphos Phosphate. (Inorganic). This is a mineral phosphate mined on the coast of the Red Sea. It is very finely ground and has proved a very satisfactory source of phosphoric acid for many years on the rubber soils of Ceylon. It has a guaranteed analysis of 29.5 per cent. Phosphoric Acid.

Slaked Coral Lime. Slaked Dolomitic Lime. (Inorganic). These are produced by burning the original rock limestones in kilns which convert them to the caustic, burnt oxide form and, on slaking with the required amount of water, the products crumble to fine dry powder, i. e. slaked lime. This substance continues to absorb carbon dioxide from the atmosphere and ultimately reverts to the same carbonate form as in the orginal limestone with the exception that it is now in a fine state of division. They are used to ameliorate soils which are too acid, for lime-washing and as as a source of calcium and magnesium.

Sulphate of Ammonia. (Inorganic). Ammonium sulphate for fertiliser purposes was originally a by product of the gas industry but, in addition, it is now made synthetically from the atmosphere in very large quantities. It is soluble in water but is readily fixed in soils containing clay or humus. It is normally taken up by most plants in small quantities in the ammonium form, the greater part being taken up after conversion to the Nitrate form by soil organisms.

It contains 20.6 per cent. Nitrogen and is the most popular form of nitrogenous fertiliser in the tropics as it can be stored without appreciable change under the most humid conditions. Sulphate of ammonia has proved a particularly suitable source of nitrogen for rubber.

It is also well suited for pineapples and paddy since although nitrogen in ammonia must be converted into the nitrate form before intake by most plants these two crops are able to take up nitrogen without this intermediate conversion.

Where soils are over acid or approaching that point, Calcium Cyanamide is recommended for alternative use as a corrective.

Sulphate of Potash. (Inorganic). This is prepared from the Muriate by chemical means and is consequently more expensive. It contains 48 per cent. Potash and is a drier salt and produces in several cases a better quality crop.

Superphosphate. (Inorganic). Ordinary Superphosphate contains 16 to 20 per cent. soluble phosphate and is manufactured by treating Rock Phosphate with sulphuric acid, thus rendering the relatively unavailable calcium phosphate into a more available form, and at the same time removing the toxic fluorine. There is present a small quantity of Calcium Sulphate (not present in Concentrated Superphosphate), which is considered useful under certain soil conditions.

Concentrated Superphosphate containing 40 to 45 per cent. soluble phosphates is manufactured by treating Rock Phosphate with Phosphoric Acid and is more commonly used since the higher plant food content makes for lower transport costs. Superphosphates are normally purchased from Belgium and Holland. This material being partially soluble in water is more rapidly available than Rock Phosphate and is generally used for annual crops.

Synthetic Urea. (Inorganic). This inorganic chemical fertiliser is manufactured from atmospheric nitrogen and has a Nitrogen content of 40 to 45 per cent. Although it has the advantage of permitting nitrogen to be applied in small but highly concentrated quantities, its greatest disadvantage lies in the fact that it is strongly hygroscopic which makes this ingredient almost unsuitable for storage and application in tropical countries.

Guaranteed analysis of the various Organic and Inorganic fertilisers commonly used are given in the following Tables:

ORGANIC FERTILISERS

FERTILISERS.	Guaranteed Minimum Analysis		
	Nitrogen	Phosphoric Acid	Potash
	%	%	%
Animal Meal ...	7	10	—
Animal Meal (Special) ...	7	10	5
Blood Meal ...	11	—	—
Blood Meal ...	13	—	—
Bone Maal ...	3	22	—
Castor Cake or Castor Meal ...	5	—	—
Crushed Fish ...	4	4	—
Crushed Oil Cake ...	3	—	—
Fish Meal ...	4	4	—
Fish Guano ...	7	6	—
Hoof and Horn Meal ...	13	—	—
Sterameal ...	7	10	5

INORGANIC FESTILISERS

FERTILISERS	Guaranteed Minimum Analysis		
	Nitrogen	Phosphoric Acid	Potash
	%	%	%
Ammonium Nitrate ...	34.5	—	—
Ammonium Phosphate ...	16	20	—
Ammonium Phosphate ...	20	35	—
Basic Slag ...	—	19	—
Calcium Cyanamide ...	20	—	—
Hyperphospate ...	—	30	—
Kainit ...	—	—	19
Mineral Phosphate ...	—	29.5	—
Muriate of Potash ...	—	—	60
Muriate of Potash ...	—	—	50
Nitrate of Soda ...	15.5	—	—
Potassium Nitrate ...	10-14	—	30-46
Saphos Phosphate ...	—	29.5	—
Sulphate of Ammonia ...	20.6	—	—
Sulphate of Potash ...	—	—	48
Super Phosphate (Ordinary) ...	—	18	—
Super Phosphate (Concentrated)	—	42	—
Sylvinite ...	—	—	17-20

CHAPTER XI

PLANT SANITATION

PESTS AND DISEASES OF RUBBER

Hevea brasiliensis is subject to many forms of disease due to various causes. Some are contracted from outside sources while others are due to severe treatment, overcrowding and pests. The diseases may be classified under three main headings:—

1. Root and Collar Diseases
2. Stem Diseases.
3. Leaf Diseases.

I. Root and Collar Diseases.

When a parasitic organism attacks the root of a plant, the conducting tissues of the roots are killed. The feeding rootlets may or may not be affected in the first place according to the nature of the attack, but nevertheless the main lateral roots are no longer capable of acting as conducting channels through which water may pass to the stems and leaves of the plant. With the water supply to the aerial portions of the plant cut off, the effect is that of a severe drought. In young trees the effect is rapid. The leaves will suddenly shrivel and turn brown and the tree may die without even shedding its leaves. In a large tree, the effects are more gradual. The leaves wilt, droop and fall and the crown becomes thin, the green shoots die back, the flow of latex fails and after wintering the tree does not wholly recover, but produces foliage on the adventitious branches only and not on the terminals.

Where the tap root is affected the tree will lose its hold in ground and may be pushed or will come down in a gale. All of the above symptoms are similar in nature, though not entirely in degree, whatever organism has attacked the root system, and could indeed be artificially induced by cutting most of the lateral roots. It is apparent therefore that an inspection of the aerial portion of the tree alone will not usually enable a correct diagnosis of the disease to be made. It is not till the roots are examined that the real cause of the trouble is discovered.

Since root disease is so insidious in its early stages it is seldom that the first tree attacked can be saved, and therefore the planter's efforts must be directed towards saving the surrounding trees which are likely also to be affected.

When a lateral root only is affected, this may be cut off, but once the tap root is involved the tree must be completly removed. The object of treatment is to get rid as soon as possible of the source of infection, and to ensure this prompt and thorough measures must be taken as outlined below:—

1. The attacked tree or trees must be entirely removed, and their roots should be followed to the extremities and all parts of the entire root system should be completely burnt on the spot.
2. The extent of the infected area will be defined by the extremities of the diseased roots. This must be surrounded by an isolation trench of at least 2 feet in depth. This trench must be cleared out frequently since mycelium spreads quickly through the soil.
3. Surrounding trees must have their roots exposed and examined and guard trenches must be cut round any trees outside the main area if they are suspected of infection.
4. Earth from the trench must be thrown inside the enclosed area, and thoroughly forked over and all dead wood, stumps or roots removed and burnt.
5. Lime at the rate of 60 lbs. per tree must be forked in.
6. If stumps of any kind exist upon the land these should be removed and burnt.

Most root fungi spread by contact from root to root by means of vegetative mycelium either on the surface of or within the tissues of the host. By the time a tree is found to be diseased it is usually too far gone to be cured by any form of treatment. Control measures have therefore for their object the prevention of the spread of the causative fungus from diseased to healthy trees, and the removal of all actual and possible sources of infection. Were all jungle stumps to be removed from rubber clearings before the rubber matured the danger from the root disease would to a large extent be eliminated. This practice is however too costly for general application, and it behoves the planter to keep a careful watch for cases of root disease and, when discovered, to treat these promptly and carefully to prevent their spread.

The growing of Tephrosia vogelii in between the rows of rubber is most useful in locating and pin-pointing root disease. This valuable green manure spot lights immediately the presence of Fomes, Ustulina, Poria, Sphaerostilbe repens, and such other root diseases beneath the soil surface by wilting at the affected spot, and so helps the planter by a casual glance to locate the disease and take immediate control measures before it assumes formidable and disastrous proportions. Most of the dreaded diseases travel beneath the surface of the ground by means of buried timber and decayed roots long since forgotten. It is not uncommon to find that some years after the opening of a clearing and after all surface timber has been removed, a large number of trees are affected with Fomes, and the removal and uprooting and burning of wide areas of Rubber becomes inevitable. This could have been easily avoided if the existence of the disease was detected at the early outset. Therefore in addition to growing ground covers, Tephrosia vogelii should also be planted in between the rows for both green manuring purposes as well as for the prompt detection of root diseases. This is of particular importance in new clearings and replanted areas.

The root and collar diseases which are dangerous to Hevea Brasiliensis are:—

"Fomes Lignosus" or White Root Disease showing Mycelium on rubber root.

1. Diplodia Dieback and Collar Rot.

2. Fomes lignosus (Syn. Leptoporus lignosus) - White Root Disease.

3. Fomes Lamaoensis (Brown Root Disease.)

4. Poria hypobrunnea.

5. Ustulina zonata (Lev.) Syn. Ustulina Vulgaris - Tul. and Ustulina deusta - Hoffm.

6. Sphaerostilbe repens.

Fomes Lignosus. (Syn. Leptoporus Lignosus). This root disease commonly called "White Root Disease of Hevea" is caused by the fungus *Leptoporus lignosus* (Klot) Heim ex Pat., and is commonly known amongst planters as *Fomes Lignosus.* It is characterized by the production of a white rot in the butt and roots of the attacked trees, and the disease is one of the commonest and certainly the most formidable to which the rubber tree is liable. The fungus has a wide variety of hosts and will readily attack any dead jungle stumps or roots which are left lying in a cleared area. It is from such dead wood that infection in a rubber clearing usually originates. Rubber stumps left after thinning out or old tea roots which have not been properly eradicated may also become centres of infection.

Description. The first step in the identification of any root disease is careful exposure of the lateral roots. Any tree showing symptoms which are general to root diseases should have both its laterals and tap root exposed. When the tree is attacked by *Fomes Lignosus* which name is now superseded by *Leptoporus lignosus* the fungus will usually be immediately evident as a mycelium consisting of white or yellowish or pinkish strands running over the surface of the roots and adhering firmly to the bark. This mycelium is the vegetative part of the fungus. From these external strands fine threads of myceli penetrate into the cortex and wood of the root rendering it soft and tindery, and at the same time extracts the food supply from the root. The water supply being cut off from the stem of the host plant, the latter cannot survive and dies.

The next stage is the formation of the fructification or fruit but this does not appear until the disease is in an advanced condition or the tree is dead, but the primary stage of the disease having been observed on the rubber tree, the fructification should be looked for on neighbouring stumps in the affected area. It may also form on a rubber tree that has been blown down or at the base of a diseased tree that is still standing. In rocky areas the fungus may be found among corners of the rocks and the mycelium may be covering the whole of the rocky surface. Low lying swampy lands are particularly favourable to the growth of the fungus, and it must be remembered that the mycelium can travel through the soil.

Many wood rotting fungi of the class to which *Fomes* belongs have similar mycelial characteristics, and in some cases the fungi cannot for certain be identified without fructifications described above. The strands of *Fomes*, may however be distinguished from those of other harmless fungi by the manner in which they adhere closely to the bark of live roots. Fungi which are not parasitic on Hevea roots can merely grow over the roots without penetrating the bark. In many cases the identification of a mycelium in the soil of a suspected area is not easy. Careful observation and experience, however, will usually enable a planter to tell whether the fungus is dangerous or harmless.

If the diseased tree has shown symptoms in the foliage the attack in the root system will probably have reached an advanced stage. Many of the laterals will be affected and the fungus may have reached the tap root. *Fomes* causes a soft and sometimes a moist rot of the wood. Diseased roots soon become disintegrated and lose all their mechanical strength so that affected trees may be blown over by a high wind before being discovered.

The fructifications of *Fomes* are not formed until the disease is in an advanced stage or the tree is dead, and a diseased tree should always be found and removed before fructifications are formed. In any infected area a search should be made for fructifications on neighbouring stumps or dead wood. The fructification is produced as a bracket growing out horizontally from the diseased wood. When fresh the upper surface is rich red brown in colour with a lighter coloured margin, whilst the under side, which consists of a large number of very minute pores, is orange in colour. As the bracket becomes older and dried up the upper surface fades to a pale orange colour while the lower surface becomes dark brown. On breaking the specimen in two the upper layer will show white and fibrous and lower red-brown. This colouring serves to distinguish the fructification from that of a harmless fungus, *Polyporus zonalis*, which is similar in colouring but does not show the two layers in section.

Although these fructifications produce spores which may be blown about and cause fresh infection, the chief means by which the disease spreads is by vegetative growth of the mycelium by contact from one root or stump to another. Control methods must accordingly be such as to prevent the spread of the fungus from diseased to healthy trees. The fungus can, to a limited extent, travel independently through the soil, though it will always be found that that the mycelium is somewhere attached to a piece of wood from which it draws its nourishment. Under moist conditions the spread of *Fomes* mycelium in the ground is very rapid, and this fact makes *Fomes* most dangerous of all root diseases.

Control. Were all jungle stumps to be removed from rubber clearings before planting took place, the danger of Fomes as well as of other root diseases would be practically eliminated. The practice would undoubtedly be found to pay in the long run but it involves considerable outlay in time and money and is not always practicable. Failing a complete clearance the stumps of all trees known to be agents of specified diseases might be marked and uprooted and it is important in this respect to follow up and eradicate all the lateral roots of the stump as well as the stem itself.

The spread of *Fomes* can be prevented by isolating the area in which the fungus is present by a trench of adequate depth of at least 2 feet, and as a still further precaution it is safer to put another trench round this again to include a ring of trees outside the infected area. All soil from the trenches should be spread inside the trenched area as the mycelium can work through the soil. All parts of affected trees that cannot be saved and as far as possible all roots must be removed and burnt on the spot; and the whole ground, both inside the trench and for some distance round about, should be limed at the rate of 60 lbs. per tree which will help to destroy the mycelium. Any cover crop present must also be removed and burnt together with the roots. No cover must be allowed to grow on an affected area, and it is imperative that the isolation trenches must be kept clean.

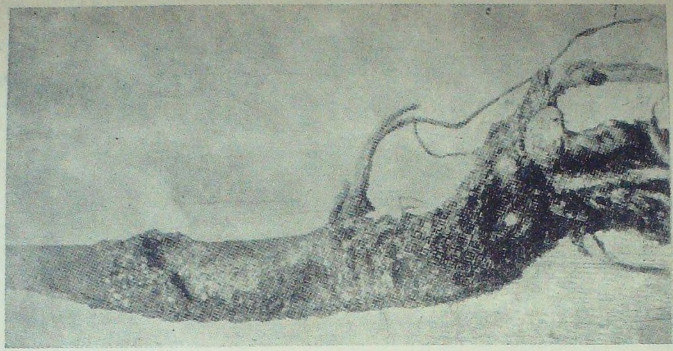
The essential points in root disease treatment may be summarised as follows:-

1. Remove all affected trees including the entire root system, diseased or otherwise, and also the cover crops in the affected area, and burn on the spot.

2. The diseased roots should be followed up working outwards from the centre of infection until the limit of the disease on all sides is found.

3. Isolation trenches of at least 2 feet in depth should be dug outside and completely enclosing the affected area. These trenches must be kept clean.

Supplying Vacancies. Provided the clearing is not older than 2 years, any vacancy resulting from root disease should be supplied without delay. Seedlings or stumped buddings could be used for a further year. Thereafter, it will be uneconomic to to supply vacancies unless they occur in a group because young



Brown-Root Disease (Fomes Lamaoensis) showing incrustation on surface.

plants cannot compete with the older and bigger plants already present around them and will not develop to useful maturity.

Fomes Lamaoensis. (Brown Root Disease of Hevea Brasiliensis) This disease caused by the fungus *Fomes Lamaoensis* is commonly known to planters as Brown Root disease. It originates from old jungle stumps and it is found on a wide range of hosts including rubber, tea cocoa and kapok and is common to most countries in the Eastern tropics.

Although it is one of the commonest root diseases of Rubber, on account of its slow rate of spread, does not cause so much damage as *Fomes Lignosus*. Whereas *Fomes lignosus* spreads independently through the soil from a jungle stump, and may attack a number of trees in one spot before any one of them shows signs of disease, *Fomes lamaoensis* spreads extremely slowly and probably only along the root of the trees. It does not, therefore, infect the neighbouring trees unless their roots are in contact with those of the diseased trees, and its progress is so slow that as a rule the first affected tree is dead before the neighbouring trees are attacked. In general, therefore, only one tree is killed at each centre of infection unless the dead tree is left standing for some years.

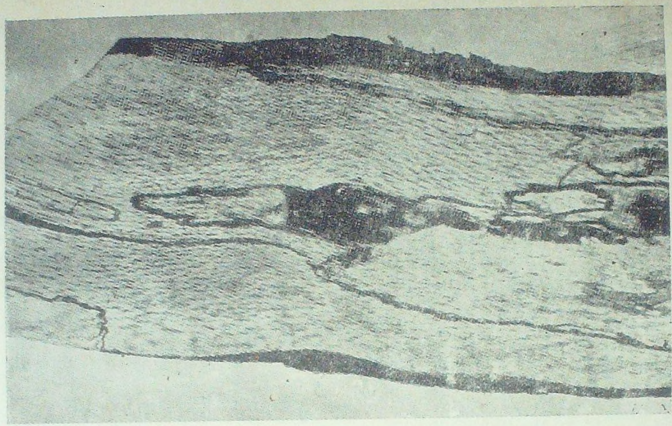
Description. The aerial symptoms exhibited by trees affected by Fomes lamaoensis do not differ from those of other root diseases. The leaves wither and fall off and the tree dies. But, if the roots are exposed and examined, the special characteristics of Brown root disease are immediately evident, and there can be no confusion or mistake in the diagnosis. The roots, and particularly the tap root, are encrusted with a mass of sand, earth, and small stones to a thickness of 3 to 4 millimetres, and this crust may extend up the stem for several inches. This mass is cemented to the root by the mycelium of the fungus which consists of tawny brown threads, collected here and there into small sheets or nodules. In the early stages the predominating colour is brown, and the name given to the disease then appears appropriate, but as it grows older, the fungus forms a black, brittle continuous covering over the brown masses of hyphae. In all stages, however, the disease is distinguished by the encrusting mass of stones and earth which cannot readily be washed from the root.

On scraping away the outer coat, the cortex of the root is found to be decayed and usually coloured brown or brown mottled with small white patches. The diseased root is soft and permeated by fine brown lines, which are really edges of plates of brown tissue. When the decay is advanced, this brown tissue forms honeycomb structures in the wood. The decayed wood is usually dry, but when the tree is growing under moist conditions, the cells of the honeycomb are often filled with water. The disease sometime takes the form of a collar rot via a lateral root as for *Ustulina* which see.

The fructification of F. Lamaoensis is very seldom found, and is of little importance to the planter. Occasionally at the base of a dead tree a thin velvety dark brown crust may be found in small patches.

Control. The same control measures as described for *Fomes lignosus* should be carried out. Since most of the fungus is, as a rule, removed with the dead tree and as the disease is a very slow one to develop, it is not often that a neighbouring tree dies after the first one had been removed providing such removal was clean and thorough. It is therefore seldom that the disease has to be followed outwards to any great distance from the source of infection.

Poria Hypobrunnea. This is one of the uncommon diseases to which Hevea is prone and it originates from old jungle stumps, or may even start from stumps of Hevea left after thinning out. The symptoms of this disease are a wet rot of the wood and the appearance of reddish lines and bands in the



"Ustulina Zonata" Root Disease showing black lines in root.

decayed wood. The fungus does not destroy the bark completely and often a pipe like structure of dead cortex is formed.

On young trees the mycelium forms stout red strands on the exterior of the tap root. If cut, these strands are seen to be white internally. When old the strands turn black. The root is often found to be encrusted with stones and earth as in Brown Root disease (Fomes Lamaoensis), though never to so great an extent. The diseased wood is soft and friable and permeated with red sheets.

In older trees the diagnosis is often more difficult. The mycelium may have turned completely black though red strands are sometimes found on a recently attacked lateral root. The diseased wood is generally soft and wet and exposed wood surfaces are reddish-brown in colour.

The fructification is uncommon but is sometimes found at the collar of a diseased tree. It forms a flat plate closely applied to the surface of the root or stem. When young it is yellowish white but subsequently turns reddish-brown. The upper part consists of a layer of small tubes which are seen in a surface view as small holes.

Control. The treatment is the same as for Fomes Lignosus.

Ustulina Zonata. This fungus is very common in jungle and will develop on most dead jungle wood and stumps. It has a large number of hosts and is one of the most destructive parasites on rubber, and is often found on Hevea logs and stumps left after thinning out. It is more liable to attack old than young rubber.

Symptoms. *Ustulina* may attack a rubber tree in three different ways:-

(1) As a root disease.

(2) As a collar rot at the base of the trunk.

(3) As a wound parasite on the stem of the tree, developing on old canker patches, in the

branches broken by the wind or sawn off, or on trees scorched by fire, or in Pink Disease wounds which have not been treated by some preservative.

The disease is said to be able to attack an undamaged tree in the forks irrespective of any previous wound.

(1) **As a root disease.** *Ustulina* may gain entry to the root system of a rubber tree via the tap root or a lateral root. Whatever the mode of attack, the fungus has usually spread to both tap and lateral roots before the disease is discovered. Where the tap root is destroyed the tree is often blown over before any sign of disease is noticeable in the foliage. The disease commonly spreads up a main lateral root and attacks the collar on one side. If the disease is not noticed the fungus slowly spreads along the laterals and round the tap root, and as the decay of the roots progresses the branches gradually die back.

Unlike *Fomes lignosus* the fungus does not produce any external mycelium, and it is to this fact that the comparative slowness of the progress of the disease on the individual tree is due. Diseased wood is dry and tindery with irregular but clearly defined black lines running through it. These lines are really edges of thin sheets of black tissue. Although these black lines invariably occur in wood attacked by *Ustulina* they are not always an indication of this disease since other fungi of the class to which Ustulina belongs also form such lines. The most reliable diagnostic symptoms of *Ustulina* in Hevea roots is the formation of white or slightly discoloured "fans" of mycelium between the bark and the wood.

The fructification of *Ustulina* is seldom formed on roots since these are not exposed to the air; it will be described in connection with collar rot in paragraph (2).

(2) **As a collar rot at the base of the trunk.** An attack at the base of the trunk is one of the commonest and most destructive manifestations of *Ustulina*. The disease may spread to the collar up a lateral root or may occur quite independent of any attack in the root system. In either case the disease is often not discovered until fructifications are produced. By this time the fungus will have penetrated the wood for a distance of some inches into the trunk, and if all the diseased tissue is excised, a large hollow is formed. A tree attacked in this way will probably show no symptoms in the foliage, and will yield latex freely on the opposite side and above the affected area. The diseased wood shows the same characteristics as described for root attack.

The fructification is first seen as a small whitish flat cushion upon the surface of the stem, and when young has a soft velvety surface. The colour soon becomes greenish grey with a white margin, and subsequently the fructification hardens and becomes darker in colour until when mature it is black and brittle in texture. Each fructification is about four or five centimetres in diameter, but several may arise side by side and fuse together into a continuous plate of considerable size. The fructifications are typically corrugated or concentrically zoned. When the fructification is young it produces conidiospores upon the surface of the cushion. These are easily detachable and being blown about by the wind provide a dangerous means of fresh infection. Later in the life history of the fructification a second spore form is produced in minute cavities just below the surface. When these spores are ripe they are extruded through the mouths of the cavities which are seen as black points on the surface of the mature plate.

A fructification very similar to that of *Ustulina* is produced by a closely allied fungus, *Kretzschmaria micropus*. The fructification is similar in colour and consistency but is divided up into a coral-like mass. For practical purposes the planter may consider *Kretzschmaria* to be a modified form of *Ustulina*.

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(3) **As a wound parasite.** Ustulina may gain entrance to the woody stem of the tree through any wound or damaged part. Whether the disease originates in an old canker patch, on a broken or cut branch, or in a fork, the symptoms are similar to those where the root or collar are involved. Attack in the stem is due to spore infection, the wind borne spores lodging in rotten bark scales or any other similar unevenness. The mycelium penetrates the bark and the wood and causes the typical friable rot. The affected branch may be blown off but, as a rule, the fructification will be formed before the disease is sufficiently far advanced, and the disease should be spotted. The decayed area is usually of considerable dimensions before the disease is found and very large fructifications are sometimes seen. Latex frequently exudes from the tissue round the wood and is seen as black streaks running down the stem. In the later stages boring beetles may gain entrance to the wood.

When the fungus develops in the fork of a tree independent of any wounded surface, the same symptoms are observed, except that in these cases the fructification may spread down the trunk for a foot or more.

A slow rot of exposed lateral roots is often mistaken for *Ustulina* but the symptoms are very different. The decay is slow and the dead tissue is not friable, no definite black lines are seen only a general darkening of the decaying wood, and the wound always appears to be healing, whereas with *Ustulina* the surrounding bark is always dying back.

Control. In cases of root attack the method of treatment is as described for *Fomes lignosus*. Owing to the slower rate of spread of *Ustulina* it is not often found that many trees in a group are affected. Since *Ustulina* is almost entirely a wound parasite its incidence can, to a large extent, be controlled by enforcing strict methods of estate sanitation. All dead stumps and logs must be burned, since if left lying in the field they are readily attacked by *Ustulina* and provide sources of fresh infection. All wounds caused by broken or cut branches must be tarred to prevent entry of the fungus. For a similar reason canker patches must not be neglected. A careful watch must be kept for fructifications of *Ustulina* at the collar of the tree or in the branches, and any case treated immediately. The best remedy lies in excision of decayed tissue and an application of tar. If badly attacked, the tree and all roots must be removed and burnt *in situ*. If there is hope of saving the tree, all affected parts either on root or stem, should be cut away taking care that all the diseased wood is removed, otherwise this treatment is a waste of money. The cut surface should be tarred and if a large hole is made a filling of cement may be necessary to strengthen the tree.

In the case of collar attack all diseased tissue must be chisselled out and the resulting cavity filled with some type of permanent filling. Concrete with a cement facing has been found very successful provided that the filling is finished off level with the surface of the wood and not brought out flush with the bark. Such work is more successfully done if the disease is detected at an early stage. Periodical tree to tree inspections should therefore be made, and any bark which seems rotten should be carefully examined.

When *Ustulina* is discovered aloft it is usually necessary to cut off the affected branch, or where a fork is attacked, to pollard the tree below the bark. If the main trunk of a large tree is attacked the disease may sometimes be treated by excision of all diseased wood and bark. In cases where the latter method is employed particular care must be taken to remove all diseased tissue or else the treatment will be a waste of time and money. It is a sound measure to paint over any young fructifications with tar or disinfectant before commencing the treatment in order to prevent spores being blown about and causing fresh infection. *Ustulina* need never be feared as a root disease if the following preventive treatment of general sanitation is systematically enforced:—

(i) All logs and stumps must be removed from the ground and burnt.

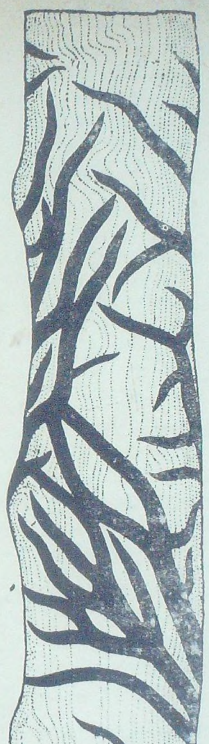
(ii) All wounds should be tarred and where branches have broken off these must be pruned to a smooth finish and the wound tarred.

(iii) All trees must be inspected at regular intervals and any damage or wound should be promptly treated.

Sphaerostilbe Repens. This disease occurs most frequently in wet, swampy or sour soil, though it has been found in normally drained ground occasionally. The fungus also attacks Arrow root, Papaw, and Canna, and is found on Jak and Dadap logs from which it may be liable to spread to Hevea.

Symptoms. The mycelium of the fungus at once characterises the disease. When the root is dug up the cortex is found to be decayed, but there is no external mycelium. If the cortex is removed black or red flattened strands are found running over the surface of the wood. These are usually about 2 millimetres in breadth, and if the fungus is living, stand out prominently from the wood. When young these strands or "rhizomorphs" are red externally and white inside, but later they become black and form little more than a film on the surface of the root. The outer surface of the rhizomorphs is sometimes clearly marked with a herring-bone pattern. The inside of the cortex and the outer layers of the wood are usually deep blue or purple in colour, and have a particularly foul smell. This smell, although probably caused not by Sphaerostilbe but by secondary organisms, is nearly always present though not entirely distinctive for the disease.

The fructifications of the fungus are produced on diseased tissue or on exposed rhizomorphs, and are of two kinds. The conidial form consists of short, erect, red, hairy stalks surmounted by a white or pinkish globose head. These are produced first and occur in large numbers. The perithecial stage is formed on the same area, but is often not produced at all. The spores are enclosed in sack (asci) within a small case (*perithecium*). The perithecia are very small dark red bodies and are produced crowded together on the mycelium or on the old conidial stalks.



Sphaerostilbe Repens
Stinking Root Disease showing
Rhizomorphs on wood of root.

Control. The source of infection is usually found to be jungle stumps, especially jak. The fungus can also spread through the soil, as in the case of *Fomes*. Dead trees, together with as much root as possible, must be dug up and burnt and neighbouring dead stumps and all pieces of decaying wood removed. The fungus has been found to originate in quite small pieces of dead wood. The infected area must be surrounded by a trench and the ground within thoroughly treated with quicklime.

Rhizoctonia Bataticola (Syn. *Macrophomina Phaseoli*). *Rhizoctonia* fungus enters the root system *via* the small feeding roots and thence travels slowly upwards into the larger roots. It is in the fine lateral roots that the fungus is most commonly found. It produces no conspicuous vegetative mycelium either externally or in the tissues of the root, and will thereby often escape the eye of even the trained observer.

In an affected root the inner layers of the cortex are attacked and the latter therefore usually lies as a loose sheath over the wood. If the cortex is removed the wood is found to be hard, dry, and brittle, and is studded throughout with very minute black spots. These are sclerotia or resting bodies of the fungus and are also found on the inside of the cortex. Fine black or dark brown lines are also sometimes seen in the wood. The symptoms are the same in large roots though larger sclerotia may be found. Attacked roots are undoubtedly killed and rendered functionless, but it has been argued that it is only after the tree has been weakened by other fungal attack or by some physiological cause that *Rhizoctonia* is able to gain entrance.

Treatment. Prevention of the disease by increasing the vitality of the tree by sound cultivation methods and general sanitation would be by far the best method of control. Once a tree has been attacked, its survival is exceedingly doubtful and the earlier it is removed completely with the roots, the better.

Batocera Rubus. In addition to the various fungi described above, the root system of a rubber tree may be attacked by the larva of a longicorn beetle, *Batocera rubus*. It has not been definitely established that this insect can penetrate living cortex and attack a healthy root, and it is usually found in roots which have previously been attacked by *Ustulina* or Brown Root disease. The pest is not of much importance and, as a rule, trees are only attacked singly,

Symptoms. The injury may take two forms —either central or peripheral. In the former case the centre of the tap root is hollowed out, and the tunnel may extend well up into the base of the stem increasing in diameter as the grub grows larger. In the second case the attack is from the outside, usually at or just below ground level. Occasionally the point of entry may occur higher up on the stem. Irregular cavities are eaten through the bark into the wood of the tree. An affected tree behaves as though attacked by root disease. The crown may become thin and the tree ultimately dies, but where the tap root is attacked the tree usually blows over.

The larva is a large fat grub, up to three inches in length, creamy white in colour with a small triangular dark brown head. The body is segmented, somewhat flattened above and below, and tapers from head to tail.

Control. An affected tree should be removed and all roots burnt, and the grubs searched for and destroyed.

II. STEM DISEASES.

Brown Bast. The disease of the tapping panel known as "Brown Bast" is caused by over-extraction of latex. It is not infectious and differs from other common diseases of Rubber which are caused by pathogenic organisms. The disease is fundamentally a progressive dying back of the living substance within the latex vessels, and usually starts just below the tapping cut and spreads from there principally downwards, but also laterally and sometimes upwards. Spread may be rapid, particularly in young and vigorous trees, and it is not uncommon to find

Example showing effects of previous Tapping
Note uneven surface and callosities.

Another Example showing the effects of Previous Tapping illustrating typical callosities and uneven surface.

cases in which the disease has extended right round the tree down the roots, crossing the union in buddings, and even into virgin bark above the tapping panels.

Symptoms. The first symptoms of brown bast development is usually indicated by the failure of the tapper to produce the normal amount of latex from the tapping cut. On examination, the non-laticiferous bark will be found to be dirty yellow in colour and of a sodden appearance; 3 or 4 millimetres inside the cortex will be found a brownish line. The yellow discoloration is always confined to those layers of tissue in which the latex cells and sieve tubes are situated, and it never appears in the outer layers of the bark. It will also be found that portions of the tapping cut remain dry except where the cut is made very close to the cambium. At this stage it frequently happens that the latex bubbles on the cut and fails to run in the usual way so that one or two pads of coagulated scrap are formed with intervals between which are quite dry. It is important that the disease should be located at this stage and this can only be done if a system of regular inspection is carried out.

The tapper may continue to tap the tree but the only result will be a steadily diminishing flow of latex until the whole cut goes dry. A close examination of the cut will then show that tissues are yellowish green and speckled with dark brown spots. Instead of the bark having a gritty texture it is smooth and cheese-like and often watery. A cut made when the sun is shining on to it will show quite clearly the watery condition of the bark.

The next sequence is the appearance of longitudinal cracks in the bark and sections of varying size can be prized off. When once seen, this condition is not likely to be confused with the simple scaling of bark which is common on a large number of trees. If a scraping is made at this time, the brown bast discolourations (of which the spotted "pepper-and-salt" type of appearance is most characteristic) are more noticeable than at any other time and leave no shadow of doubt as to the cause of the drying up of the tapping panel.

The tree may remain in this condition for the rest of its existence, steadily throwing off sections of bark, but still remaining dry and diseased. In other cases, computed to be about 30% per cent. of affected trees, nodular growths appear, and this is the stage with which everyone is familiar. These nodules show an infinite variety of shape and size, and if left untreated they eventually unite with the wood of the tree, and removal without injury is not possible. Unless treatment is carried out at an early stage, the great majority of trees which reach the nodular stage are completely ruined and have to be removed.

It will be seen from the above sequence of events that it is of the utmost importance that the disease should be located in the early stages, and after a little training an intelligent worker becomes very quick to detect cases. Where there is any doubt such trees should be marked for re-examination at a later date. The necessity of such re-examination arises out of the fact that trees sometimes suffer from time to time with "temporary" dryness, and it is difficult to make a correct diagnosis. If due to brown bast the typical symptoms will appear in due course, but if not the trees will after a time renew their normal flow.

The disease may be distinguished from ordinary Phytophthora canker in that :—

(1) No exudation of reddish fluid occurs.

(2) No dark line defines the extent of the disease.

(3) The cracking of the dead bark is usually longitudinal and not in irregular patches.

(4) The brown internal line is not seen in ordinary canker.

Very often it is found that when the tree has "burred" the brown line has disappeared and it is this fact that leads to failure to connect "burring" with "Brown Bast". The cause of this disease as stated before is physiological resulting from tapping. The period of resistance appears to depend upon the powers of the individual tree, but it is now generally accepted that daily tapping is more conducive to this disease than with a more moderate system.

Control. In spite of the statements to the effect that some affected trees recover without treatment, such cases must be extremely rare, for the mass of evidence is entirely against such sef-recovery. Similary, the simple resting of trees which show the early symptoms, has proved a failure as the disease has been found to extend its area during such resting period. It has, therefore, become necessary to adopt some method of treatment in order that affected trees may again be brought into tapping and become of value to the Estate. It is sometimes possible to tap nodular trees after the nodules have coalesced since the surrounding bark is not usually diseased.

Three methods of treatment are practised: (1) Stripping (2) Scraping, and (3) Isolation.

(1). **Stripping**. Stripping involves the complete removal of the bark to the cambium, but for success it is necessary that the bark should be well developed and not be too hard. Many trees with thin hard bark are impossible to strip and any case after stripping it is very difficult to protect the thin cambial tissue from the effects of sun and rain.

In wet weather stripping is exceedingly dangerous owing to the almost certainty of bark rot destroying the exposed tissue, and and in dry weather it is a difficult operation resulting in extremely poor renewal. There is no guarantee that the unstripped portion of the bark will not become diseased and spread infection. Stripping may practically be dismissed as an effective cure owing to the drastic treatment in involves.

(2) **Scraping**. The tools required for the scraping operation are a 9 inch. draw-knife or spoke-shave, a large scraper, and a canker scraper. To ensure success great patience and care must be exercised by the operator, and in this matter workers have

shown remarkable facility, and there is no reason to anticipate that the requisite number of workers cannot be trained to do the work successfully.

The outer bark is removed with the draw-knife, and then the diseased tissues are carefully removed with the large and small scrapers. The scraping must be continued until the latex appears in small pin points and when this stage is reached the scraping should cease even though there are still small lines and points of discoloured tissue to be seen. To endeavour to remove every trace of discoloured tissue usually results in the production of wounds. In practice it has been found that the last traces of such tissue are removed in the scaling which takes place when the bark renews. The scaling is further encouraged by the application of 5% Brunolinum Plantarium solution.

The scraping method enables the operator to locate the limits of the disease, and on completion of the work it is considered advisable to make an "isolation" cut all round the treated area. This is done with a sharp firm-bladed knife, such as a non-clasp hunter's knife. The cut should be cleanly made and penetrate to the wood. Newly scraped surfaces should be protected with sacking, and this will also protect the delicate cortex from exposure to a hot sun. The scraping and isolation method has proved to be very successful and bark renewal is remarkably even and tapping can often be resumed after two years.

(3) **Isolation method.** The actual operation is simple, but success is dependent on the ability of the operator to determine accurately the limits of the disease, and the best results are obtainable only when a highly trained staff is kept constantly employed in locating the disease. By test scrapings the outside limits to which the diseases has spread are defined. Then a deep groove is made with a tapping knife just outside the area known to be diseased and this is followed by a cut to the wood with a sharp knife. This isolation method is most successfully applied to small newly discovered affected areas.

The appearance of nodules is the final stage of brown bast development, though only a certain percentage of cases develop them. If the nodules are detected at an early stage they can be removed quite easily and without injury. Even when they have joined up with the wood of the tree they can be often levered out with a strong rigid knife. Many apparently ruined trees can thereby be greatly improved.

Phytophthora Palmivora (Syn. Phytophthora Faberi). This fungus is the cause of the following four diseases of Hevea, viz:—

(a) Pod disease

(b) Secondary Leaf-fall

(c) Bark Rot

(d) Canker

We shall consider Pod disease and Secondary leaf-fall under the heading "Leaf Diseases".

Bark rot. This is yet another disease of the tapping panel and is known under various names—"Bark Rot", "Black Thread", "Black Stripe", "Stripe Canker" etc. It attacks the recently tapped cortex in wet weather and may cause considerable damage; if it is allowed to develop unchecked the renewing bark may be entirely spoilt for future tapping. Bark rot, however, is fairly easily prevented except under continuously wet conditions, and, once it has occurred, is amenable to treatment which will prevent the worst ravages of the disease.

Symptoms. The disease first manifests itself as a number of vertical, depressed lines about an inch long on the recently tapped cortex just above the tapping cut. These lines soon become black and spread upwards into the renewing bark and downwards into the untapped portion. On cutting into these areas it will be seen that the black lines extend through the cortex into the wood. The number of lines on the tapped surface depends on the intensity of the attack, but they are always found to be parallel to one another. If the disease is allowed to develop and the weather conditions remain wet, the lines spread out laterally forming narrow vertical wounds. Where the lines are close together these wounds coalesce so that sometimes a continuous gaping wound results. Sometimes latex exudes and coagulates in pads between the cortex and wood. The healing of such large wounds is a process taking many years to complete, and in the meantime the bark is untappable. Even if the decay of the cortex does not spread laterally to any extent, the narrow vertical wounds, when healed over, will give the renewing bark an irregular surface difficult to tap.

Control. Prevention of this disease is the best treatment and in order to attain this attention must be paid to:—

(1) The time of opening new cuts. The opening of a new cut or change over from an old one should only be done after the annual leaf-fall.

(2) The angle of the cut should be about 22½ degrees. Too flat a cut will allow the water in rainy weather to settle and rot the bark.

(3) The application of some disinfectant such as:—

5 - 10% Brunolinum
5% Izal
5 - 10% Agrisol
90% Tallow and 10% tar
80% liquid fuel and 20 tar.

With the first three, the preparation must be applied regularly in order to sterilise the tapping cut and kill any spores that have lodged there. Care must be taken to see that the solution is not applied too strong or there will be danger of burning the bark.

They should not be applied until the scrap has been taken from the trees as they have a detrimental effect upon the rubber. With tar and tallow this should be smeared on to the cut very lightly in order to provide an antiseptic water-proof covering, and it must be kept well up to the tapping cut during wet weather, otherwise the application is useless. Any of these remedies will reduce bark rot to a minimum, but they must be applied early before a heavy infection of the trees has occurred and it must be remembered that these medicaments are not as a rule curative, but only preventive. When the black lines have expanded into large patches and the bark is much affected the tree should be rested. Any exposed wood might have an application of tar.

Canker. Moisture is essential for the development of the Phytophthora fungus causing canker in Hevea, and is essentially a wet weather disease. The amount of damage caused by canker in the branches is a debatable point, but when the disease attacks the tapping panel there can be no question as to its serious nature. Untreated canker patches are also liable to afford entry for the spores of *Ustulina*.

Symptoms. Outward signs of canker are not always present. In young trees the affected parts may show dark brown, but in older trees this is hardly noticeable. The appearance of canker in its late stages is well-known to all. Active canker patches during wet weather are sometimes seen to be "bleeding" i. e.- exuding a flow of latex or a reddish or purplish liquid. In many cases, however, the canker develops in the bark over a large area without any open wound or outward indication of the disease. In this instance the first indication of canker is a cessation of the flow of latex. In this case the bark should be lightly scraped here and there in order to examine the cortex. This in healthy Hevea is white, yellowish, clear red or mottled red and white in colour, and under the outer brown bark should be a layer of green. But when the canker has attacked the bark, this green layer will turn black, while the cortex below is also discoloured and presents a sodden grey appearance with the diseased patch clearly outlined in black. In later stages this will turn a dirty red or claret colour, still with the well defined black border. When cankered bark is cut or picked out with a penknife no flow of latex appears.

The disease is spread during wet weather by spores carried by the wind or washed down the stem. They will only germinate in water or on a damp stem. After germination the mycelium penetrates the cortex, destroying it from without inwardly. Canker may be looked for on the bark of the stem or branches, on the tapping cut or round the collar of the tree. Infection may lie dormant in diseased tissue for a considerable period and it is probable that most stem canker is propagated from year to year in this manner.

The most serious type of canker attack is when the tapping panel or collar is affected. Unless the disease is treated promptly the tapping surface may be seriously damaged, and the disease may extend right round the tree and ring it.

Treatment. All that is necessary in the treatment of canker is absolutely clean scraping and excision of all the discoloured cortex. All diseased tissue must be removed and this can be done quite easily since the disease does not extend beyond the discoloured area, and the appearance of the diseased bark is so well marked.

The work is most satisfactorily carried out in dry weather since the bark then scales off readily and very little actual scraping is necessary. Active cases on the tapping panel or collar should, however be treated when found whatever the weather conditions may be, otherwise the disease may spread rapidly and kill a large area of bark. Exposed wood surface must be tarred, but tar must on no account be put on to the scraped cortex. Burning is likely to result, and if all diseased tissue has not been removed the disease will continue to spread unobserved under the tar. No disinfectant is necessary if the scraping is done in dry weather, but in wet weather a 10% solution of Brunolinum in water can be recommended.

Bortryodiplodia Theobromae. (Die - Back)

A dying back of Hevea branches may result from a number of causes. The death of small twigs is nearly always the sign of poor conditions of growth which may be the result of disease or simply lack of nutriment. Thus a general loss of foliage and death of the terminals is a characteristic symptom of root disease, and is also often consequent upon *Phytophora* and *Oidium* leaf diseases. Severe canker may also result in a die-back. "Stag-heads" and dead branches are always seen when rubber is grown under poor conditions such as are provided by badly drained or washed soils.

There is, however, a true "die-back" caused by *Botryodiplodia theobromae* which is usually referred to as *Diplodia*. This fungus has not been known to attack a healthy unwounded stem, but gains entrance through a wound or dead tissue. Any dead twigs caused by the above mentioned factors offer a source of entry to *Diplodia*, and when once this fungus has gained entry it kills the branch back in a very quick and characteristic manner.

Diplodia or true die-back takes two forms:—

(i) In the first it begins by attacking the terminal only passing rapidly thence down the tree and killing the branches successively as it reaches their junction with the main stem. In this form it gains a footing only where the leader has been killed by some other disease.

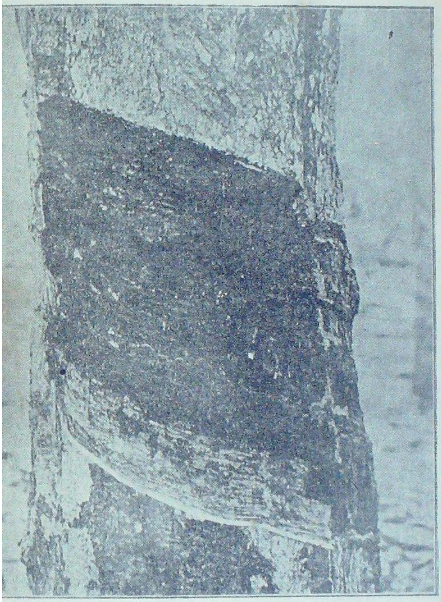
(ii) In the second form it attacks the cortex of the stem or branches. One side of the tree often goes dry and will give no yield of latex, cortex becomes discoloured and brownish internally; and black spores, like a sooty powder, are exuded through the diseased portions of the bark. This form usually originates in the stub of a broken branch.

The fungus may also gain entrance to the cortex of the main trunk or a branch through any wound or rotten bark in a fork. The disease works upwards and downwards, and the first indication may be a cessation of latex flow on the side attacked, by which time it will probably be too late to save the tree. Since the fungus when young is colourless and only turns dark on ageing, the disease has always spread further than is indicated by the extent of discolouration and this point must be borne in mind when cutting off diseased branches.

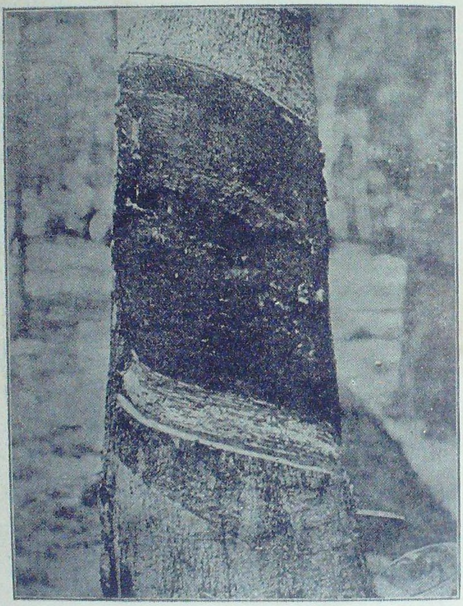
Treatment. Trees attacked by die-back are, as a rule, found in groups and some of them can generally be saved by pruning off the diseased parts. Since Diplodia is a fungus of extremely free growth and flourishes upon dead Hevea wood, it is fortunate that it cannot find entrance into the living tree other than by wounds or broken branches. All dead wood must be removed from an infected area, diseased branches should be sawn off with the cut at a slight slope and the wounds tarred, and all diseased parts should be burnt. The most important means of prevention is the maintenance of strict estate sanitation methods.

When a case of die-back is found, special care should be taken to cut off all diseased branches right down to healthy tissue well below the apparent margin of the disease. It is often found necessary to pollard a tree severely, but this is preferable to leaving diseased tissue behind from which the fungus will spread. In the case of an attack on one side of the main stem it is sometimes possible to cut out all the diseased bark and wood, and tar the wound forthwith. It is seldom, however, that the disease is detected in a sufficiently early stage.

Pink Disease (Corticium salmonicolor). This fungus is a parasite on a large number of cultivated and wild trees in the tropics, and it attacks the branches and stems of Hevea rubber trees. Its occurrence on mature rubber is exceedingly rare though it is more often found on younger trees.



Effects of "Bark Rot" Disease
Cut badly infected and there is no renewal of bark above.



Another example of "Bark Rot"
The Present cut badly infected and there is no renewal of bark above.

Effects of "Bark Rot" showing wounds due apparently to bad tapping, but in reality caused by the disease.

Another Example of "Park Rot" Disease.
Note on right hand the panel next in order for tapping is in very unsuitable position.

Symptoms. The disease usually originates in a fork, the first sign observed being a characteristic pink incrustation of interwoven fungal hyphae over the bark. This gradually extends and may compeletely encircle the tree. At the margin of a rapidly extending pink patch the fungus is sometimes seen as a very thin layer of long silken hyphae. Owing to the fact that the fungus spreads more rapidly over the surface of the bark than within it, the latter is usually healthy towards the margin of the pink patch. Under the central part of the patch, however, the bark has been killed and is brown and dry. Later the pink patch splits into lines running more or less at right angles to one another and becomes faded in colour.

The growth of the fungus is dependent on wet weather and is also favoured by shade. If allowed to develop unchecked the disease will spread rapidly under moist conditions and may quickly encircle and ring a young stem. The disease is spread by spores which probably form upon jungle trees and are thence carried by wind to the neighbouring rubber.

Control.* Both preventive and curative methods of control could be carried out. Preventive measures consist of avoiding too much of thick shade particularly in wet areas if the disease is prevalent. In badly infected areas, the ground should be kept free of fallen branches as these serve as a base for saprophytic growth of *Corticium* and a breeding place for its spores. Shrubby undergrowth should, for the same reason not be allowed to develop in such areas.

Curative measures consist of the removal and destruction by burning all diseased and dead branches. All small branches which are infected with *Corticium salmonicolor* should be cut off about one foot below the affected patch in order to remove the fungus which spreads in the bark from the diseased patch and should be burnt. When trunks and large branches are attacked and not ring-barked, the diseased area should be carefully cut out and the resulting wounds should be painted with tar, and the diseased material should be burnt.

Pink Disease in the early stages of attack on young trees may be arrested by spraying or painting the infected bark with Bordeaux mixture or other copper fungicide. Where the disease has advanced to the stage where leaf wilting occurs, spraying is useless as the fungus has now entered the tissues and it will be necessary to amputate the entire branch or trunk.

Before amputation or excision is carried out it is very essential to paint the affected bark with an Asphalt Kerosene mixture made as follows:—

Asphalt	40 lbs.
Kerosene or Liquid fuel	4 Gallons
Solignum	3 pints

If the above mixture is not conveniently available, coal tar may be applied instead. This precaution is very important and should not be omitted. Its purpose is to prevent the spores of the fungus and infected bits of bark and wood being shaken loose or knocked off and distributed during the pruning or excision. This work should preferably be done in fine weather as the disease is highly infectious in wet weather. The protective application of the asphalt mixture or tar should be applied as soon as the disease is discovered, and the pruning may be delayed to fall in fine weather. When pruning is carried out the diseased material previously coated with tar or protective paint should be burned. When a serious outbreak occurs in a young clearing, it is advisable to spray all the stems of the young trees with Bordeaux mixture or other copper fungicide at three-weekly intervals until the disease has cleared up. Where the disease occurs in mature trees in tapping, the use of copper fungicides should be avoided owing to the detrimental effect of copper upon latex.

Where the attack is recent and there appears to be a chance of saving the affected branch, that is, if no wilting of the leaves has occurred and ring-barking is not apparent, the patch should be painted with a mixture such as Brunolinum Plantarium 10%.

Brunolinum Plantarium Solution. To make 10% mixture add 9 gallons of water to 1 gallon of Brunolinum Plantarium. For 5% mixture, add 19 gallons of water to 1 gallon of Brunolinum Plantarium. If ordinary Brunolinum is used, 1 lb of soft soap must be added to obtain the emulsion. Dissolve the soap in the water and stir in the Brunolinum.

Bordeaux Mixture. This is made as follows:—

Copper Sulphate	5 lbs.
Freshly burned lime	5 lbs.
Water	50 gallons.

Dissolve the copper sulphate in 45 gallons of water in a wooden or earthenware vessel. Make the lime to a uniform paste with the other 5 gallons of water. Add the milk of lime so formed to the copper sulphate solution stirring continuously with a wooden paddle.

Scraping Trees. This is a practice that must be indulged in with caution. There is a great temptation to groom the trees and make them look tidy, but unfortunately the worker is apt to go too deep and injure the tree by penetrating to the green layer underneath the outer corky bark which is the natural protective layer. It is necessary to scrape moderately to find bark diseases and, in doing so, the loose scales and spongy layer are removed. The best implement for this, as far as inspection goes, is a coconut husk beaten out at the end, but very often one finds a sticky mass of bark and rubber that has run off the cut down the tree all coagulated together, and in this case a sharper instrument seems necessary. There are several good tools on the market, but failing anything else a piece of hoop iron will suffice. The grooming of the lower portion of the trunk is beneficial in keeping the bark drier and preventing rot. Of course scraping away cankered bark is another matter entirely, and in that case all diseased portions should be thoroughly prised out and burned.

III. LEAF DISEASES.

Phytophthora Palmivora. This fungus causes leaf-fall and pod disease.

Pod Disease. The fungus attacks the pods while they are ripening and soon become a dirty watery green either in patches or all over. The diseased areas become black and sodden and the whole fruit is soft and rotten. A white or greyish film of mycelium forms on the diseased patches and spreads over the whole fruit. Finally the whole pod turns black, splits along the grooves dries up and remains hanging on the tree for a long time. The incidence of the disease is very markedly dependent on wet weather conditions and a dry spell in the early weeks of the Monsoon will cause a distinct check in its spread. The disease of the pods is economically more important as a precursor to leaf-fall than directly as a factor adversely affecting the seed crop.

Leaf-Fall. Immediately after the fruit rot has set in, the disease spreads to the leaves. The appearance of diseased leaves varies according to the nature of the fungus attack. If a spore from a diseased pod alights on a leaflet, watery blackish green spots are formed. These spread to larger patches either down the centre along the mid-rib or spreading inwards from the margin. More frequently, however, the leaf-blade is not attacked, but the fungus develops on the leaf-stalk or at the base of the leaf-blade, and causes the leaflet to fall. In this case a discoloured area is seen on the leaf-stalk, or at its junction with the leaf-blade. The discoloured stalks often bear a small drop of coagulated latex about the middle of the diseased area. The leaves may fall when quite green, or they may first turn yellow or become mottled. They may fall as a whole in which case the blades are very readily shaken apart from the leaf-stalks, or the leaflets and leaf-stalks may separate on the tree. In the latter case the fall of the stalks soon follows that of the leaflets in contrast to normal leaf-fall.

Phytophthora palmivora is also capable of attacking and killing back young green shoots, and this die-back may extend to

the large branches. Hence, after a severe outbreak of leaf-fall and pod disease, the presence of dead twigs and branches is a characteristic feature. The development and spread of the disease is strikingly dependent on wet weather conditions. If June and July are months of continuous rain, the disease will spread very rapidly and may cause serious defoliation. On the onset of dry weather, the disease is immediately checked, and defoliated trees put out new leaves.

Economic importance of Leaf-Fall. The economic importance of any disease must always be ultimately judged by the loss of crop entailed. The disease is often known as "secondary" leaf-fall, since it follows a few months after the normal annual leaf-fall in the ordinary process of "wintering". When a natural leaf-fall occurs the tree makes preparation by withdrawing valuable foodstuffs from the leaf for safe storage in the stem. When, however, a leaf is attacked by *Phytophthora* no such protective measures are possible, and the leaf carries with it to the ground a considerable quantity of manufactured carbohydrates and nitrogen-containing substances. This loss of food substances incidental to an abnormal leaf-fall is, however, only a small part of the strain to which the tree is subjected. The whole manufacturing system of the plant is affected and while the tree is leafless it is, so to speak, living on its capital. The drain on the resources of a tree which is annually subject to severe secondary defoliation in addition to the normal wintering is thus abundantly evident, and it is not surprising that the yield of areas of rubber on which the majority of trees are thus severely defoliated, is seriously impaired.

Control measures. Many methods of controlling the disease have been tried. Since the fungus "overwinters" in dead branches and pods their removal should, theoretically, reduce the amount of the fungus on the estate. In practice, however, it is impossible to remove all such dead matter, and attempts to control the disease on these lines have, on the whole, given disappointing results. The problem resolves itself into (a) manurial, (b) fungicidal treatment.

Although the application of manures exercises no direct control over the fungus, there is no doubt that a healthy leaf resists infection to some extent. Any measures, therefore such as the application of nitrogenous manures and the adoption of cultivation methods which tend to build up a good strong foliage will ameliorate the worst effects of the disease. In addition a well nourished tree, even if severely defoliated, will more rapidly be able to put out new shoots and leaves and thus recover from the disease.

The disease could also be checked and kept under control by spraying Bordeaux Mixture on the leaves. But as this is a troublesome and expensive task, the method is not to be recommended unless absolutely necessary.

Oidium Leaf Disease. This disease is caused by a fungus belonging to the class of "powdery mildews" —*Oidium Heveae.* The disease has been known in Java since 1918 and was first reported in Ceylon in 1925, and where attacks are severe the disease constitutes a serious menace to the health of the rubber.

Symptoms. *Oidium* can attack Hevea leaves of all ages and effects of the attack differ according to the degree of maturity of the leaf. The disease is first evident as an attack on young leaflets when the trees are refoliating after wintering. If the leaves are attacked when still bronze-coloured and shiny they become dull and faded in patches and may become slightly crinkled. The leaflets may fall in this condition or the tip may first die back, becoming bluish black in colour. The symptoms are very similar when the attack is on slightly older leaves which have just turned green, except that in such cases the curling and crinkling is usually more pronounced. The white powdery superficial growth of the fungus consisting of mycelium and spores is sometimes clearly seen on the petiole and under surface of the mid-ribs of such young leaves, but more often it is only visible with a lens. The fallen leaflets soon shrivel on the ground, but in the case of a severely attacked tree they often form a conspicuous carpet of leaves. All three leaflets of any one leaf do not necessarily fall, so that a characteristic feature of diseased trees is the presence of petioles bearing one or two leaflets instead of three. Trees which are severely defoliated in this way usually put out a fresh crop of leaves and so recover. The secondary leaves may, however, be attacked in turn.

If the fungus attacks somewhat older but still immature leaves the effect is rather different. Such leaves are more resistant and the attack is confined to localised portions of the margin and mid-rib. These are prevented from growing normally with the consequence that the leaflet becomes irregularly distorted into folds and crinkles. Severely attacked leaves are dull and yellowish. The leaflets do not usually fall so that this form of attack is not as serious as that on the very young leaves when complete defoliation on the tree may result. The attack on immature leaves is for convenience known as "primary" attack and occurs soon after wintering.

Oidium fungus may also attack fully mature leaves, such an attack being termed "secondary". The first symptom of a secondary attack is the appearance of small yellowish translucent spots chiefly on the upper surface of the leaflet. The fine superficial hyphae of the fungus can be detected on these spots with a lens, and the subsequent production of spores gives the spots a white powdery appearance. As the spots grow larger they turn purple-brown in colour and eventually dry up, while the dead tissues in the centre may fall out leaving irregular holes. No hard and fast distinction can be drawn between this secondary form of attack and that previously described on the immature leaves; in fact a characteristic symptom of the disease is the existence of distorted leaflets with the mottled appearance of the secondary attack.

Oidium also attacks and destroys the flowers, and the young inflorescences are often thickly covered with a growth of mycelium and spores. In badly-affected areas the complete absence of seed is a characteristic feature of the disease. The fungus is spread by means of *conidia* (spores) which are produced in great abundance on the superficial mycelium. These spores are responsible for the "bloom" often seen on infected leaves. Dry atmospheric conditions are more favourable to the production of spores than are damp conditions.

In low country areas where *Oidium* is not so severe as in certain districts at higher elevations, the disease usually appears in February or March, is active or a few weeks, and then disappears as suddenly as it came. Hence a defoliated tree which puts out a second crop of leaves is rarely attacked a second time and so recovers at the cost of food reserves. So far as is known at present, there are no strains inherently resistant to the disease. Any tree, therefore which produces new leaves during the period of *Oidium* activity will be attacked and partially defoliated, but trees which winter early and whose leaves are mature when the fungus becomes active, escape, except possibly for secondary attack. In severely affected areas, on the other hand, although the disease exhibits a period of maximum intensity shortly after the normal wintering, the fungus may remain active throughout the year. In this way many trees are subject to a continuous process of leaf-fall and refoliation, the leaves becoming smaller and poorer in quality at each successive recovery.

Such a continual defoliation no doubt results in a depletion of food reserves and general lowering of the vitality of the tree. In consequence, a physiological die-back of twigs is a characteristic feature of badly attacked areas. Such dead or dying twigs are liable to afford entry for *Diplodia* which may kill the branch or even the whole tree.

Control. As in the case of Phytophthora leal-fall, there are two main lines along which control may be secured:— (a) Manurial and (b) Fungicidal.

(a) The application of nitrogenous manures, by benefiting the quality and quantity of the foliage, will probably minimize the worst effect of the disease, and will help defoliated trees to recover. However, manurial and cultivation methods of control are quite inadequate in areas badly attacked by *Oidium*. In order to control the disease a method must be adopted whereby the fungus is destroyed.

(b) Liquid spraying with Sulfinette, a lime-sulphur preparation, has been tried but the method is both slow and expensive.

Dusting with finely divided sulphur powder from power driven dusters seems likely to solve the problem of *Oidium* control and very successful results have been obtained. The method has the advantages of being extremely quick and comparatively cheap.

Sulphur Dusting Technique. The application of the sulphur dust is carried out by means of a power driven dusting machine of which there are several makes available, but the principle of operation is the same in all cases. A small two stroke petrol engine drives a fan at high speed, and sulphur dust is admitted into the fan chamber from a hopper and is blown upwards through a chimney outlet. The delivery rate is adjustable by closing or opening the sulphur entry inlet. The machine is fixed to two poles and can be carried by four to six men according to weight of machine used or the land to be traversed. Outfits are compact and weigh from 150 lbs. to 250 lbs. empty, and the capacity of the sulphur hopper varies from 28 lbs. to 56 lbs. The heavier machines will need from 8 to 10 men for easy and quick transport. For use on roads special trolleys are available.

Sulphur Dust. As sulphur dust tends to form lumps under certain conditions of storage, it is advisable to dry the sulphur dust in the sun and have it sieved through a No. 60 mesh to ensure finess of the particles and to enable it flow freely through the machine and to rise high above the tree tops.

Operation. The ideal conditions for sulphur dusting are obtained with a slight steady breeze which allows the sulphur to rise to the required height and simultaneously wafting the dust slowly through the entire foliage.

A strong wind is unfavourable as it prevents the sulphur from rising to the required height. With the air quite still, the work will be exceedingly slow as the dust will not be carried to any appreciable distance. As breezes are likely to change often in both intensity and direction, the sulphur cloud should be carefully watched to ensure that all portions of the field receive their full share of sulphur. Although it is sometimes possible to dust a considerable area from one position, the usual procedure is to carry the machine through the field while it is working and to adjust the output of the sulphur according to the breeze, the slope of the land and rate of progress.

It is worthy of note that the quickest distribution of sulphur is clearly effected when the machine is being moved in a direction at right angles to the prevailing wind, and in such circumstances a belt of 150 to 300 feet can be treated from one line. Existing roads and paths do not always suit the wind conditions and it will be found necessary to carry the machine off them frequently.

Under average conditions, with the machine carried slung on poles, approximately 100 acres can be treated in a full working day which will be dependent on the wind conditions and also on the lie of the land. Where roads and paths facilitate the use of a trolley to transport the machine a larger area of land can be treated.

Since the engine used is air cooled, it is advisable to work it in short bursts of ten minutes duration each. This will enable satisfactory cooling of the engine, and to replenish the hopper, and give the men carrying the machine, which is very hard work, a well earned rest. Pure sulphur is inflammable and care must be taken not to spill the powder either on the hot cylinder or the exhaust pipe as fires may easily be started.

Time and number of applications. Under average conditions the sulphur dust remains active on the leaf as a fungicide for 10 to 12 days, and as the foliage must be protected against attack until it has matured sufficiently to resist attack, it will be necessary to make a number of applications at intervals of 7 to 10 days during the time of refoliation. Dusting the old leaves before they have fallen is of no value and the correct time to start operations is at the very first sign of *Oidium* infection on the young leaves which is shown by crinkling or wilting of the leaflets usually accompanied by a white deposit of spores.

If the fungus is allowed unrestricted development at the outset, it will be virtually impossible to control without the use of a very large quantity of sulphur. Hence the importance of an early dusting is strongly emphasised.

When planning the season's programme it is advisable to allow a margin for wet days and other contingencies such as repairs to the machine. Thus although the average area which can be treated by one machine in a full day is set down at 100 acres, it is good practice not to allot more than 500 acres, to each machine. An estate of 1000 acres should possess at least two machines to ensure that the programme is carried out without interruption from unforeseen contingencies.

Quantity of Sulphur Dust per Acre. The rate of sulphur application will depend largely on the intensity of the anticipated attack of *Oidium*. With a seven day interval, an average of 10 lbs per acre per round may be regarded as a maximum normal dose for the most severely affected areas. With a longer interval the quantity should be increased proportionately.

Supervision. Careful and intelligent supervision of the treatment in the field is an important factor for the success of the operation. Unless every portion of the field is adequately treated, results will be both indifferent and disappointing. Maximum supervision is essential. At least one man should be trained to rectify any minor engine trouble such as cleaning of plug, carburettor jet etc. Such elementary knowledge is essential in the field.

Costs. Approximate cost of one application over 100 acres, assuming to be 1 day's work, is given below:—

(Rate of Application 7 lbs. per acre.)

700 lbs. Sulphur Dust @ -/50 cts per lb. including cost of re-sieving where necessary	Rs.	350. 00	$.235. 00
Labour 10 men at Rs. 3/-	,,	30. 00	,, 20. 00
1½ Gallons Petrol-oil mixture	,,	4. 50	,, 3. 00
	Rs.	384. 50	$.258. 00
Cost per acre per application -	Rs.	3/84	$.2/58

Helminthosporium Heveae.- Petch. This fungus is the cause of the leaf disease of rubber known as *Bird's Eye Leaf Spot of Hevea* which is very common in almost all rubber growing countries. When it attacks young plants in the nursery, it can seriously retard their growth.

Symptoms. Petch gave the disease the colloquial name "Birds Eye Leaf Spot" because of the "birds eye" design of some of the lesions he noticed on the leaves. On young leaves the lesions appear as tiny dark brown spots which have a dull water soaked appearance. Due to the leaf's reaction to the fungus the young leaf becomes very much distorted and remains so during the rest of its life. The diseased spots produce a few spores but do not increase in size.

On leaves in the next stage of growth, when soft and light green, the disease first appears as small yellow spots which can be seen with a lens. A very narrow black edge soon develops around the yellow area. In about two days the leaf tissue within the black margin dies and the attacked area becomes a yellowish spot. In another day or two the yellowish colour becomes whitish and the fungus begins to produce spores.

In about three weeks' time the black margin of the spot becomes raised and reddish brown in colour while the central whitish area becomes like tissue paper. Outside the red brown margin a yellowish halo develops and the whole gives the appearance from which the name "Birds Eye" was suggested. These mature spots are up to one fifth of an inch in diameter and may bear a few spores on their under surfaces. The whitish centres of the spots become very fragile and tear easily and in the case of older spots when the leaves have matured are often represented by a hole through the leaf.

Mature leaves which have reached full growth but which have not yet hardened up develop a disease spot when attacked which is similar to those described under the very young bronze leaf stage. The spots remain separate and become surrounded with a dark deposit of tannin and a poorly developed yellowish halow develops around the tannin deposit. Spores may not be produced at all in this type of spot, and if they do only to a limited extent.

Similar symptoms to those described above may appear on immature leaf stalks and young shoots.

The disease is spread by means of the spores which develop on the central light coloured patch of the lesions on the leaves. The spores develop very rapidly after the initial infection and may be produced within three or four days after the beginning of the infection. The spores are easily carried about by dew and wind and will attack the upper and lower surfaces of the leaves with equal facility, but infection is less likely on a wet leaf. In general mature trees show considerable resistance to the disease and it is uncommon for trees for over three years of age to be attacked with any degree of severity.

Control. Under shaded conditions the disease is greatly reduced due to the fact the spores of this fungus require light for the penetration of the leaf surface by their germ tubes. But as shaded conditions produce environment very suitable for the development of severe attacks of *Oidium*, and lack of sunlight has a retarding effect on the growth of nursery plants, this method of control is not recommended.

The disease is very resistant to fungicidal treatment. Sulphur and lime sulphur treatments are quite ineffective in controlling this disease and it is waste of time and material to apply such fungicides for its control. Copper fungicides such as Bordeaux mixture have given satisfactory results though complete control is difficult. Weekly spraying with Bordeaux mixture or a suitable proprietary copper fungicide should be done in the nursery when a severe outbreak occurs and should be continued until the disease is arrested.

Hypocrella Reineckiana. Henn. This fungus is responsible for the leaf disease known as Orange Gall of Hevea and gets its name from the orange coloured knoblike growths which often develop on the leaves and young stems and branches of rubber trees. The galls do not, however, cause any trouble to the host tree but tend to control scale insects. The protuberances are made up of the threads of the fungus which is parasitic on scale insects of the coccid family. This fungus is common throughout the tropics.

Symptoms. The fungus is usually found on the veins and midribs of leaves as well as on the young stems and branches where the scale insects mostly congregate. It covers the scale insects with a thick coating of hyphae and forms hard spherical knobs usually on the lower surface of the leaves and on the young stems and branches wherever a scale insect is attacked. The hyphae of the fungus penetrate the tissue of the scale insect and eventually kill it while using it for subsistence.

The growths are up to a ¼ inch in diameter and are at first yellowish orange and finally turn black. They are generally smooth and hairless but become minutely roughened when the spore bearing structures inside the fungus body become opened on to its surface to liberate the spores it produces.

Control measures are unnecessary and not advised as the fungus is not a parasite on the rubber plant and does not harm is but is beneficial because it is parasitic on harmful scale insects, which sometimes inflict severe damage on nursery plants and young rubber by causing a leaf fall and withering of the shoots.

CHAPTER XII

THINNING OF AREAS

There is general unanimity regarding the necessity for thinning out and the advantages of wider planting are fully recognized. The principles which govern forestry and the growth of plant life was overlooked in the past by the apostles of close-planting in the desire to cram as many trees as possible into the acre, the idea being that the larger the number of trees the greater the amount of crop. Fortunately the fallacy of this has been realised and at present rubber planters adopt greater common sense and more scientific ideas than in the past.

Number of Trees per Acre. The question of exactly how many trees per acre should be planted at the outset and what should be the ultimate number is by no means easy to decide. Before discussing the point it is well to understand the general principles of the subject. The health of the tree must be admitted to be of primary importance. Where there is overcrowding the results are apparent to the eye, i. e., restricted foliage and branch development, thin bark and weak renewal, increased disease and general loss of vitality are by no means the sum total of trouble. Below the ground the same struggle is going on. The ever increasing mass of root fibre finds no room for expansion, and the food resources of the soil are quickly exhausted. It must be clearly understood that for the healthy growth of the Hevea tree, space, light, air, and cultivation are all very important and essential. Given these there will be a healthy, well developed tree with vigorous bark renewal, greater facilities for cultivation, economy in labour, material and supervision, ultimate increase in crop and decrease in cost of production all of which factors combine for the permanent success of a property.

In the early stages of a clearing the object in view is to establish as quickly as possible a covering of foliage overhead. This protects the soil, and affords shelter from the wind. To attain this even Albizzias or Gliricidia Maculata may be interplanted, but it is also advisable to have more rubber trees than will be ultimately required in order to allow for failures or any damages that may occur. That there is a great deal of variation in the yield of unselected seedling trees is well known, and there is also a great deal of variation in the yield of clonal seedlings. To take full advantage of these variations, it is generally considered good policy to plant at least double the number of trees that it is intended to retain at maturity, and the following distances are suitable:-

13′ x 13′	-	260	trees per acre
15′ x 11′	-	265	„ „ „
18′ x 9′	-	270	„ „ „
21′ x 8′	-	260	„ „ „
24′ x 7′	-	260	„ „ „
25′ x 7′	-	250	„ „ „

From various experiments it has been shown that there is very little retardation in growth from mutual competition between trees planted at 250 to the acre up to the time that they attain an average girth of 12 inches. Once the trees have grown large enough for the canopy overhead to become dense, the struggle for existence sets in and danger of disease arises. The trees begin to grow tall and thin, the lower branches die off for want of light, and the small crown affords no protection to the stem against the effects of rain. This runs down the tree in the form of a current of water which favours canker and fungus, and tends to decay of the renewing bark. Tapping operations too are retarded by a wet-state of the bark.

On hill sides the crown of one tree is raised above the one immediately below, but this is counteracted by the slope bringing the trees automatically nearer together. Stronger trees will outgrow the others and the strain upwards to get full benefit of the light leads to the suppression of the weaker ones. Once the crown has been reduced to few branches the tree can no longer produce good laterals.

Example of widely planted young area, just ready to be brought into tapping.

Field of Old Rubber Trees in which Thinning had been delayed too long. Note height and comparative lack of girth.

As soon as it is apparent that the trees have come into close enough contact to check their further free development, thinning out must commence.

The practice of lopping side branches with the idea of promoting light and air is obviously wrong and a poor substitute for proper thinning. The points to be considered are:-

(a) The age at which thinning should commence.

(b) How much should be done at a time.

(c) How frequently should thinning out be done.

Of course conditions of soil and lay of land will to a great extent determine these, and overthinning has to be avoided since the action of the sun is inclined to destroy humus. As the growth of the tree is considerably greater in the early stages of the clearing, the first thinnings are usually the heaviest. Frequent light thinnings are to be preferred to heavy ones at longer intervals. The power of the tree to respond to cultivation is a guide to the amount of thinning out to be done. In every clearing a proportion of trees are affected in one way or another, either by disease or accident (crowns or stem may be injured by strong winds and such trees are always most liable to attacks by insects or fungi). In selecting trees for thinning out these should be among the first to go. Secondly badly grown or stunted trees; thirdly those too near the road or drain. In the case of double stemmed trees it is advisable to cut them altogether rather than to lop one stem.

The main point to remember is that from the first thinning the trees likely to form the final crop are the ones to be considered. They must be given every opportunity to attain their fullest growth in the shortest possible time. Ultimate equality of distance and evenness of appearance should be arrived at if possible.

(1) In young rubber it is necessary to go by the shape of the tree and type of bark.

(2) The selection in the later stages might depend to a great extent on the yielding capacity of the tree.

It has been shown that there is a close relationship between the yields obtained from a short period of test tapping at 3 to 4 years of age and the yield obtained during the first six years of regular tapping. In view of this relationship it is recommended that trees should be selected for thinning out by test-tapping in the manner described below:-

Test Tapping. A field planted with seedlings is ready for test-tapping as soon as 80 per cent of the trees have attained a girth of 12 inches (diameter 4 inches) at a height of 20 inches from the collar. This stage is normally reached at 3½ to 4½ years from planting.

Trees with a circumference of 12 inches or more are marked with a left to right spiral cut on half circumference at a slope of 30 to 35 degrees. The lowest point of the cut should be 20 inches above the ground.

The steep slope is necessary to give a quick flow and prevent loss of latex when tapping thin bark. Later, as the trees increase in diameter the slope of the cut is automatically reduced so that when the time comes for regular tapping the original test tapping cut will be at about the correct slope for normal tapping and can be re-opened to commence the first tapping panel.

Test tapping should be done daily for ten days. If rain interferes with the work, additional tapping days should be given. For the first five tappings latex is collected but records are not maintained. From the 6th to the 10th tappings, however, each day's yield is coagulated in the cup by the addition of a few drops of 5 per cent formic acid or acetic acid. The coagulated lumps are threaded on wire hooks attached to each tree at a height of about 5 feet from the ground which is a convenient height for rapid observations. It is a great advantage to use small latex cups of a standard size for test-tapping so that the thickness of the lumps will provide a good indication of their weight. The coagulated samples should not be squeezed or flattened before threading on the hooks.

A convenient task will be between 250 to 300 per day, and test tapping may be done in the afternoons if desired and should be undertaken in a season when interference by rain is least likely to occur. It is very important to note that test tapping should not be undertaken just after, during or just before the wintering season.

Selection of Trees for Thinning out. The actual yield of each tree as indicated by the size of the series of 5 test samples will be determined mainly by the inherent quality of the tree and the fertility of the soil in which it is growing. As soil fertility may vary in different parts of a field, the general level of yield will also vary so that high yielders may occur in groups instead of being scattered evenly over the field. It will not be possible to remove all low yielders on ths results of test tapping alone as this would result in a very uneven stand. It is therefore necessary to consider *spacing and yield* together in deciding which trees to remove.

This is done by inspecting the trees in small groups of convenient size and removing from each group the required number of the weakest or poorest trees to reduce the average stand to the required level. The trees so selected for thinning out should be marked with paint and removed at convenient times after inspection. The best time for removal is when the leaves have fallen, as there is then less bulk of foliage to fall to the ground, consequently less risk of damage to the surrounding trees, and after wintering the remaining trees have room for expansion.

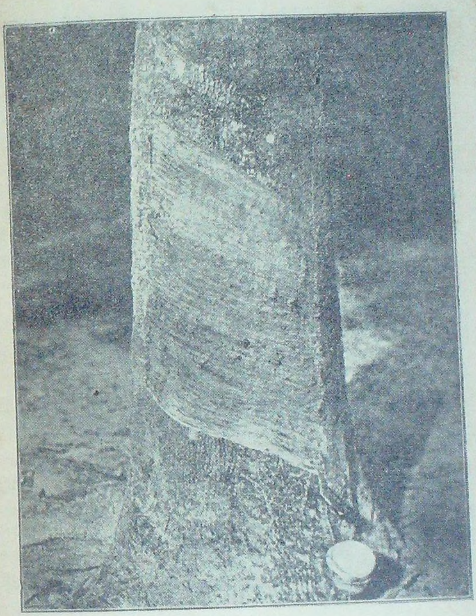
Examples of Thinning out. With a planting distance of 13′ x 13′ in a square planted area, having approximately 260 trees to the acre to be reduced to about half the number, at 130 trees per acre, we shall proceed as follows.

The trees are inspected in groups of 16 at a time taking 4 planting points in four adjacent rows and thinned out as follows:-

1.	Low yielders as indicated by size of test samples	4 trees
2.	Damaged, poorly grown trees, small backward supply trees and trees with deformed and mis-shapen stems	3 "
3.	Vacancies to be counted as trees to be thinned	1 "
		8 "

Taking another case of contour planting with a planting distance of 24′ x 7′ having a similar stand of approximately 260 trees to the acre, the procedure is similar, but it will be necessary to inspect the trees in smaller groups. The trees may be inspected in groups of four adjacent trees along a single contour and the weaker two should be marked out for removal. In the steeper parts of the field where the contour lines come closer, 8 trees could be inspected at a time, 4 from each line and it will be advisable to retain three instead of four to compensate for the greater density of planting. Similarly, where the slope is gentler, and the contours are wider apart about 5 trees out of 8 may be retained.

When a tree has been marked, it must be removed entirely. To keep the stump in the ground with the idea of obtaining further crop from it is a mistake. It tends to root disease as well as to demoralisation on the part of the tapper. As much of the root must be extracted as possible, because any portion of the main stump remaining in the ground is a lively source of root disease in the future.



Example of The Single Cut on a Quarter Circumference
on an Old Tree and on renewed bark.

Single Cut on Half Circumference (Half Spiral)
In this particular instance the cut is changed to the opoosite half of the tree every six months.

CHAPTER XIII

TAPPING

General — Former Systems of Tapping. To hark back forty years in the plantation rubber industry is equivalent to delving into history, since development has been so rapid. It was then thought necessary to place upon the trees a number of simultaneous cuts which the modern planter would judge to be inconceivably excessive. Were it not for evidence in the shape of photographs extant, it would be difficult to convince a young planter that such systems were in fact employed.

It was not uncommon for trees to have from six to ten cuts, sometimes all placed on one half of the tree in a herring-bone fashion, and sometimes divided into two portions, each of which tapped the opposite quarter panel of the tree's circumference. Such superimposed cuts were spaced from 1 foot to 18 inches apart.

On other occasions a spiral cut was employed, commencing at a height of say 5 feet and gradually descending to the cut at the base of the tree.

Later systems varied from several cuts on a half-circumference or on a quarter of the tree, tapped either daily, or on alternate days, to cases in which one-third or one fifth of the tree was employed. Also popular were the systems of the V and half spiral cuts on half the circumference.

It did not take long to recognise that with all these systems demanding a number of simultaneous parings from the same panel of bark, the rate of excision was so heavy that the period available for the renewal of bark was insuffiicient for continuous tapping.

As a result, most of the systems specified have fallen into disuse, and the tendency has since been to reduce the number of cuts or the period of tapping so as to allow for increasing periods of bark renewal.

Physiology of the Rubber Tree. A certain knowledge of the physiology of the Rubber tree is essential to the Planter to understand the principles affecting tapping. The main organs of the tree may be divided into two groups:—

(a) Structural Organs of Nutrition consisting of

- (i) Leaves
- (ii) Stem, Branches and Bark
- (iii) Roots.

(2) Reproductive Organs:—

- (i) Flowers
- (ii) Seed

The LEAVES are the respiratory, transpiratory and assimilative organs and they absorb carbon-dioxide from the air, of which the carbon supplies sugar, starch, and other foodstuffs for the use of the tree, while the oxygen is exhaled.

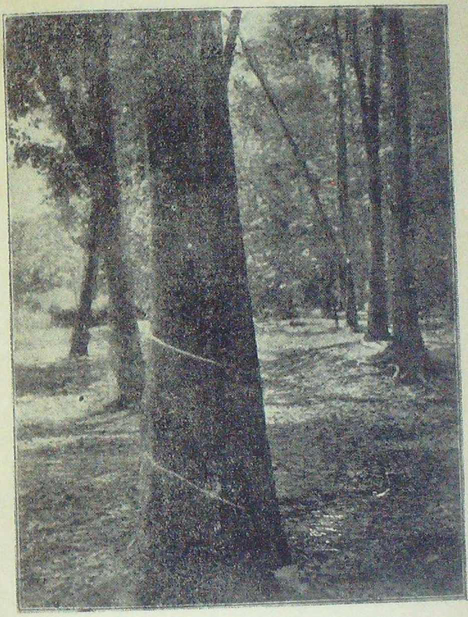
The STEM or trunk serves as a channel of communication between the roots and leaves. Secondly it stores reserve food. Thirdly it supports the branches and foliage.

The stem comprises of five layers as detailed below:—

1. The outer corky or protective bark
2. The Cortex or laticiferous bark (including the bast)
3. Cambium
4. Sapwood
5. Heart wood.

The ROOTS fulfil two functions:—

(a) They provide the necessary anchorage and maintain the position of the tree in the ground.



Example of 2 Cuts on a Quarter Circumference of an Old Tree

Example of Single Cut on Two-Fifths of Circumference.

(b) They obtain from the soil the water necessary to the growth of the tree together with certain mineral salts which form part of the food supply, such as nitrogen, phosphorus and potash.

That part of the rubber tree which chiefly concerns the planter is the bark, and of this the most important layer is the CORTEX containing as it does the latex cells. The outer bark varies considerably in different trees, in some it has a rough, uneven surface, while in others it is smooth, finer-grained and lighter in colour. As a rule the thick-barked trees are the easiest to tap, the thinner ones being harder of tissue and more liable to wounds.

Included in the cortex are the "sieve-tubes", a system of conducting channels which convey the manufactured food downwards from the leaves and branches. These tubes lie close to the wood and, together with certain other elements, form what is known as the "bast".

Between the cortex and the sapwood lies a delicate glutinous layer called the CAMBIUM as thick as an ordinary sheet of paper but which supplies the growing cells for the increase in thickness of stem, branches and roots. *In tapping this must be left protected* by a thin wall of cortex, which if pierced means a rupture of the cambium causing a wound. This protecting wall requires to be nicely judged; it should be thin enough to allow of all possible benefit being obtained from the latex cells, while if too thin the effects of the sun may cause shrinkage of the bark resulting in bark die-back. It must be remembered that the cambium is continually building up new tissue. On the one side it is adding to the wood and on the other to the bark.

The latex cells form an entirely separate channel from the other layers of tissue, so that nothing is gained by deep cutting into the wood. While at the same time, the production of latex is a strain upon the food supply and general vigour of the tree,

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The latex cells form an entirely separate channel from the other layers of tissue, so that nothing is gained by deep cutting into the wood. While at the same time, the production of latex is a strain upon the food supply and general vigour of the tree, and drastic methods of tapping with danger of injuring the cambium and even the sapwood inside, are greatly to be deprecated.

The object in view in tapping is naturally to obtain the maximum yield of latex with the minimum damage to the tree and at the lowest possible cost. Although various systems are in vogue, that which is most widely of employed is the one cut on the half spiral on alternate days.

The advantage of the *One Cut System* are enumerated below:-

1. Bark economy. Very much less bark is consumed annually while the yield of latex is just as high.
2. Quicker bark renewal. The food supply is interrupted at one point only.
3. The tapping area will be nearer the base of the tree where the number of latex cells is greatest. The higher up the tree is tapped the sooner does scrap oxidization sets in.
4. The proportion of scrap will be about 5% lower than with two or more cuts.
5. Shortening of the downward channel. This improves the symmetry of the tree and elimination of the second cup holder resulting in less damage to the bark.
6. Extreme simplicity which is advantageous to both tapper and supervision.
7. Economy in labour, time, material and costs.

The Advantages of *Alternate Day Tapping* as compared with *Daily Tapping* are as follows:—

1. Smaller bark consumption, provided the length of the cut is the same.
2. Quicker bark renewal.
3. Increase in dry rubber content. The percentage of caoutchouc in the latex is highest in the lightest system of tapping and lowest in the heaviest system.

Example of V-cut on Half the Circumference.

4. Less labour is required.
5. Less risk of bark die-back.
6. Less risk of Brown Bast.
7. Increased vitality of the tree.
8. Better class of work.
9. A change over once a year is all that is necessary.
10. The proportion of first grade latex will be higher.
11. With intensive Tapping the standard of rubber will be lowered.

The recognised Systems of Tapping in Ceylon are:—

	Relative Values expressed as a percentage.
(a) A $\frac{1}{4}$ cut on alternate days.	25%
(b) ,, $\frac{1}{3}$ cut on alternate days.	33%
(c) ,, $\frac{1}{2}$ cut on every third day.	33%
(d) ,, $\frac{1}{2}$ cut on alternate days.	50%
(e) ,, $\frac{1}{4}$ cut daily	50%
(f) ,, $\frac{1}{3}$ cut daily	60%
(g) ,, $\frac{1}{2}$ cut daily	100%

The popular systems of tapping in recent years in Malaya are:-

(a) a $\frac{1}{4}$ cut tapped daily (young or medium aged trees)
(b) a $\frac{1}{4}$ cut tapped on alternate days (older trees).
(c) a $\frac{1}{3}$ cut tapped daily (young trees)
(d) a $\frac{1}{3}$ cut tapped on alternate days (older trees)
(e) a $\frac{1}{2}$ cut tapped on alternate days (young and old trees)
(f) a V-cut on a half, tapped alternate days (young and old trees)

Daily tapping is bad principle for a number of reasons as compared with the advantages of alternate day system already detailed. Even daily tapping during the latter part of the year is undesirable as it leads to bad work, the result of temporary labour being employed for this period only, which also frequently follows upon an attack of secondary leaf fall, in which case it is particularly severe upon the tree.

We shall now briefly consider the other systems of tapping:-

(1) *A Quarter cut on alternate days.* The ¼ cut interferes less with the transport of food supply and is advisable under certain circumstances where economy in bark consumption has to be considered, but the shorter cut will not, as a rule, produce the full yield.

(2) *A ⅓ cut on alternate days.* The same remarks apply here and is extremely difficult to change from this system on to any other without overlapping on to bark of uneven ages.

(3) *A ½ cut on every third day.* This has not been sufficiently proved as regards yield, but if found to produce satisfactory crops is the most attractive system of all. With this system it is only necessary to mark out at 16″ from the collar to give an 8 years' renewal at the rate of 4″ per annum bark consumption; but, allowing for 300 tappable days in the year, this method will have to produce in 100 days what the alternate day system produces in 150 days—that is to say the latter system has a 50% greater chance as regards time. The number of tappings being fewer, the yield per incision will have to be greater and this increase will have to come from:—

(a) Girth — the tapping area being nearer the base of the tree the girth will necessarily be greater.

(b) The number of latex cells is also increased.

(c) Wound response — the tree receiving lighter treatment on account of the longer interval and less bark consumption. The wound response should be better and the percentage of caoutchouc higher.

(d) Better bark renewal — the latex tubes increase with the best bark conditions.

TAPPING PROCEDURE.

Year to commence Tapping. This is a question of the density of the latex tubes which increase with the girth of the tree. It has been proved that trees up to 5 or 6 years of age have comparatively few tubes at a height of 24 inches from the ground, and this would point to the seventh year as being early enough to commence tapping.

With the two best recommended system, i. e., half spiral cut on alternate days and half spiral cut every third day, the height at which the trees must be marked to obtain an 8 years' bark renewal will be 24 inches and 16 inches from the collar respectively allowing an annual consumption of 6 inches and 4 inches, and the minimum girth for opening would be

> 24″ girth at 24 inches from the collar on the ½ cut alternate day system
>
> 24″ girth at 16 inches from the collar on the ½ cut third-day system.

Marking out the Trees. Uniformity of height, side and direction of cut should be adhered to when marking out the cup holders. All cuts should be at the side of the tree right or left respectively as one looks up or down the line of trees.

Angle of Cut. The angle of cuts should not be greater than ¼ of a right angle, say 20 to 22½ degrees, and all pairings should be kept parallel to the original cut. Too flat a cut allows water lying on it and is conducive to bark die-back, as well as to an overflow of latex down the stem which entails a loss of first grade rubber and an increase in the percentage of scrap. On the other hand too steep a cut will leave a triangle of unused bark at the base of the tree.

To ensure uniformity of angle, stencil plates may be used for demarcation.

Direction of the Cut. This should be from left to right. This is the natural way for the tapper to hold the tapping knife; only left-handed tappers can tap comfortably from right to left, and this is one of the objections against the V-cut system.

The latex channel should not be cut deeper than half the thickness of the bark, the line of demarcation being only deep enough to guide the commencement of the cut. When the latter becomes the latex channel as will happen when the sides are changed over, it will need of course to be deepened.

The Cup-holders or Spouts. These should be placed 2″ below the allowance of bark to be excised before the next change over. It is a common thing to see gashes on a tree where the spout has been removed two or three times during the year. If the cup-holder is in the correct position it forms an automatic indication that the right amout of bark has been removed.

When the time comes for changing over, the tapped area should measure the same at either ends of the cut. This is important as a tapper while tapping is apt to bear more heavily on his knife as he nears the end of the cut, causing the angle to increase. It is obvious that this will enhance the triangle of untapped bark at the base of the tree and so be wasteful of the tapping area. Strict adherence to the line of demarcation is also important. Carelessness in this respect gives an uneven appearance and entails waste of bark and also of crop.

Number of Cuts to the Inch. The number of cuts to the inch on the two tapping systems mentioned above will be the same as shown below:—

½ alternate at 6″ bark per annum over 150 tapping days
= 25 cuts per inch

½ cut third day at 4″ bark per annum over 100 tapping days
= 25 cuts per inch.

Reasons against Setting Out the Tree at the Bottom Compartment and working Upwards:- This is entirely a question of bark renewal as affected by the downward flow of food supply. If the first cut is opend 6 inches from the ground and the next one 6″ higher, the upper cut will greatly interfere with the food supply reaching the renewing bark in the lower area, whereas with a system of tapping from the top downwards, the food supply follows the cut. It is important, therefore, to fix if possible the maximum height at which it is intended to tap and to avoid coming up even after a period of four to six years.

Marking out. This work should be entrusted to trained tappers under the supervision of a responsible member of the field staff. The Michie-Golledge knife will probably be found the most satisfactory implement for the purpose as well as for tapping generally. It is simple in construction and can be sharpened easily. Bark shavings should not be thicker than an ordinary piece of paper and to ensure this it is necessary to keep all knives *regularly sharpened*.

An important point when tapping is to see that the tapper keeps the knife as horizontal as possible. Common faults are:-

(a) To raise the handle.

(b) To lean more heavily as he nears the end of the cut. This results in a thicker paring and consequent drop in the angle of cut. This tendency can be checked by training the tapper to tap the last half of the cut first.

(c) To pare the same cut twice over. A simple test for this is to observe the parings on the ground and notice if some of them are fresh on both sides.

Wounds. Perhaps the most important point of all in good tapping is the avoidance of wounds. The effect of wounding upon the tree not only renders it difficult to tap the surface again under a considerable period but it actually impairs the vitality of the tree and predisposes it to disease; and in the case of large wounds left unprotected, allows of the incursion of fungoid growth and boring insects.

Excessive wounding will also result in burrs and knots upon the bark followed more often than not by an attack of Brown Bast.

The present day tapper is in most cases a thoroughly proficient workman and with the lengthy period allowed for bark renewal, small wounds have plenty of time to heal over though it must not be thought from this that wounding is in any way to be excused. The only justifiable wound is when the tapper occasionally tests the depth of his cut.

Changing Over Sides. It is generally accepted that to continue tapping the same side of the tree for an indefinite length of time is undesirable, and the only point upon which opinions vary is whether the change should take place once or twice a year.

The advantages of a change-over at stated periods are:-

(a) Increased dry rubber content.

(b) Better bark renewal.

(c) The consumption of bark is more easily checked.

(d) The symmetry of the tree is less impaired.

The arguments in favour of one change only during the year are:-

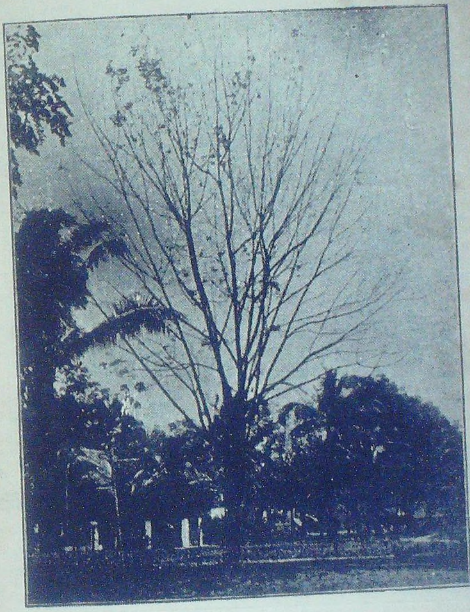
(a) With the present moderate consumption of bark per annum there is scarcely room for more than one change during the year.

(b) If a change is made twice a year, one will occur in the middle of the rainy season when bark rot is almost certain to set in.

(c) With an annual change the interruption to the flow of latex occurs once only.

(d) There is less damage to the tree through the cup-holder being moved once only.

Bark Renewal. This is naturally most healthy and vigorous under the best conditions of treatment and nutrition. Moderate



Leaf-fall - Effect of "Wintering"

Refoliation of same tree after wintering.

tapping stimulates renewal while excessive tapping hinders it. A healthy and freely flowing tree is less liable to the attacks of insects than a badly developed one, and it will be found that closely planted trees require longer intervals between tapping and longer period of renewal.

After six years' renewal when tapping has been carefully carried out it should be difficult to distinguish between old and new bark. When bark is insufficiently renewed there will be found a deep red line between the outer bark and the cortex. This will be seen only in renewing bark and occurs up to about the sixth or seventh year. The maturity of renewed bark is seldom fully matured under the eight years' period.

Resting Period. The normal period of leaf fall or "wintering" of the rubber tree varies to some extent, but may be considered as a general rule to set in about the end of December and to continue till the middle of March, being at its height during January and February.

The reserve food of the tree is still abundant during the actual time of wintering, and the flow of latex is also fairly good in spite of the diminished water supply; but the food store is at its lowest when the tree is producing its new foliage and while in flower, and at this time bark renewal is at its slowest. Once the new foliage is well in, the storage of food recommences. From this it will be seen that the natural time for resting the trees should extend from the end of wintering until the new foliage is thoroughly established — for practical purposes, however, a rest of more than a month or six weeks can seldom be given and the period usually set aside is from about the middle of February to the middle of March. The general appearance of the trees and daily yield will be the best guide as to when to rest the trees. When the crop falls to 50% of the average daily yield for the time of the year it will be time to stop tapping. This point will correspond roughly with the time when 50% of the trees are in new leaf.

When tapping has ceased all spouts should be removed and thoroughly cleaned, damaged ones replaced and the trees set out on the opposite side for the new period of work. Meanwhile in the factory the existing machinery can be overhauled and any additional plant that is required for the new season installed.

It is usual at this time to use surplus labour on repairing roads, drains, terracing, collecting and cleaning cups and spouts, setting out trees for the new cut, grooming etc., etc., and an inspectorate force organised to examine the trees for signs of disease.

Number of Trees per Tapping Cooly. No hard and fast rule can be laid down as to the number of trees a cooly can tap per day as it will be affected by the lay of the land, by the size of the trees, their distance apart, and by the length of the cut, but it has been generally found that 180 to 200 is the maximum number that can be given on average land, if satisfactory results are to be assured.

A bigger task than set out above tends to slovenly work and to a certain percentage of the trees being left untapped. The cooly is apt to select those trees which, in his opinion are good milkers and to neglect some of the more indifferent ones. Again if the cooly's task is excessive, the latter part of it will be performed when the day is growing too hot to obtain the best results.

Distribution of Tapping Plots. In the event of tapping being carried out on alternate days, each cooly on an average lay of land will be apportioned an area containing 400 trees. The boundaries of these areas should be clearly defined, the plots being numbered consecutively as well as the trees in each plot, and the cooly responsible will be allotted the corresponding number which should be stencilled on the boundary row of trees, on his bucket, and entered against his name in the check roll.

Reserve Tappers. A change of tappers is at all times undesirable, but when any one tapper falls sick it is necessary to replace him without delay. Failure to do so may make all the difference in securing the estimate at the end of the year. A shortage of one cooly per diem for 300 days means a loss of from 1200 to 1500 lbs. of rubber in the year. It will, therefore, be necessary to have a reserve supply of tappers, not to do the regular cooly's work if it can be avoided but for substitution where the necessity arises. They must be thoroughly trained men, otherwise their employment will be seized upon as an excuse for bad work. If reserve tappers are not available it can be easily arranged that the four tappers on the adjoining portions can take over another 50 trees each for the time being until the absentee returns to work.

Number of Tapping Days. It must be remembered that there are a good many days in the year when tapping cannot be carried out. In the wetter districts it may occur that there are only about 300 tapping days in the year the balance 65 days being accounted for days of resting, during drought, holidays and days on which rain interferes with the work.

Time to Tap. Operations should commence as early as possible in the morning while the flow is at its freshest, and provided that the previous night has been dry, coolies should begin their work with the day-light. When, however, there has been rain overnight the trees must be allowed time to dry. Damp bark will not cut clean and wounds will occur, also latex will not flow freely on wet bark. The rapid drying of the trees depends greatly upon the planting. Sun and air have better access on a well planted estate than on one where the trees are too closely set.

^ coolies should

Tapping Knives. The Michie - Golledge type of knife is popularly used in Ceylon being well adapted for a high standard of tapping with a minimum consumption of bark. It calls for a certain dexterity in guiding the cut correctly and gives a cleaner cut than the types of draw-knife used in other countries. The average tapper will find it difficult to work on cuts about 40 inches high as the top end of the cut will be beyond his reach for downward tapping.

The drawknife is well adapted for high tapping and the bigger task. Ceylon can ill afford the higher rate of bark consumption associated with the use of this type of knife. It is used for quick tapping on large tasks, generally on a contract basis in Malaya. The conditions of growth for bark renewal are poorer in Ceylon due to soil conditions and incidence of leaf diseases.

In Malaya probably the number of different types of tapping knives may amount to a half-dozen, but those most commonly used are:—

(1) The gouge - straight or bent

(2) The ordinary farrier's knife.

(3) A modification of the farrier's knife such as the "Jebong".

Argument on the respective merits of knives is popular and the subject is controversial. It is claimed for the bent gouge that it is superior to the straight instrument because the leverage being downwards on the handle, the tendency is to lift the cutting edge upward and out of the bark, whereas with a straight gouge the tendency is to push the knife downward into the bark. It is claimed, therefore, that the average shavings taken off by the bent gouge should be thinner than those obtained by the use of the straight instrument.

For similar reasons it is asserted that the "Jebong" and other modifications are superior to the original form of the farrier's knife. These points are generally accepted without great argument, but when comparisons are made between the gouge and the farrier's knife with its modifications, the opinions of Malayan planters are varied and conflicting and irreconcilable and contradictory. Many new types of knives have since entered the market for which strong claims are being made by their inventors or vendors. But on the whole, it may by stated that the best general results are obtained by the adoption of a simple non-adjustable knife.

Collection of Latex. As a general rule latex should not be collected until the tapper has completed his full tapping portion. This allows as much time as possible for the trees to give their yield. Collection before the flow has ceased means excess of earth scrap, though on the other hand late delivery at the factory will entail excess of coagulated lump. Earth rubber should not exceed two per cent. of the crop, and lump rubber not more than one per cent. During the wet season, intermittent morning showers are of frequent occurrence when there may be considerable loss of latex from the cup and down the tree as well as the addition of water to the contents of the cup. On these occasions it is necessary for the tapper to collect his latex as rapidly as possible. They soon become skilful in foreseeing rain and by rapidly going over the ground already tapped, can do much to preserve the latex. The cups thus emptied should be replaced. It might be mentioned here that the, addition of water to the cuts with the idea of encouraging the flow is a mistaken one. It has directly the opposite effect, in that it clogs the cells by causing the latex to coagulate rapidly on the cut and thus interferes with exudation. Another objection to the practice is that water on the cut is frequently a cause of bark die-bark.

Water in Cups. Much discussion used to take place regarding the necessity or otherwise for placing a small quantity of water in the cups when tapping. It was recognized that the permission to use water (with the idea of preventing coagulation) led to much abuse, apart from the question as to the utility of the method. Dirty water was often used, although clean water may have been placed in the buckets when coolies left the muster-ground. The small quantity of water often exceeded the actual yield of pure latex by more than hundred per cent, with the result that on arrival at the factory the diluted latex was below the standard desirable for the preparation of a good sheet-rubber.

Premature Coagulation. Other opinion to the contrary that the possibility of premature coagulation in the cup or bucket is not diminished by the addition of even clean water is now acknowledged. The use of water often obtained from estate drains clearly led to increased trouble. The extent to which such premature coagulation takes place varies greatly under the influence of many factors as follows:—

(a) Cleanliness of cups and spouts (the latter an important item often overlooked, and involving the presence of certain organisms which affect coagulation).

(b) Climatic conditions.

(c) Rate and volume of flow of latex.

(d) Size of tappers' task (involving the length of interval between tapping and collection of latex.

(e) Distance to be traversed between the site of task and the factory.

(f) Care in collecting, to exclude extraneous matter.

(g) Nature of transport; agitation of the latex to be reduced to a minimum.

(h) Nature of the soil, and situation of the estate.

The last mentioned factor is of great importance. As a general rule it is noted that that premature coagulation is less marked on estates situated on comparatively hilly land. The greatest effect is remarked on estates situated on the flat lands of the coastal area where peaty soils are a feature. On many such estates, in spite of the observance of all ordinary precautions it is not possible to receive the latex at the factory without a large percentage of prematurely coagulated rubber being found in the transport vessels.

Anti-coagulants. For this reason, the use of smal quantities of anti-coagulants is common generally in all estates. The effect of these is to keep the latex liquid and thus render possible the preparation of a higher percentage of first-grade rubber than would be otherwise obtained.

Among the better known agents which have such an effect upon latex, Formalin and Sodium sulphite (not bisulphite) are the chief, which when added to the latex prevent coagulation occurring by natural means before collection reaches the factory for processing. Anti-coagulants are particularly valuable for use in wet weather and in addition to Sodium sulphite and Formalin, Ammonia is also used for the purpose. All of these three anti-coagulants can be used with reasonable assurance for the preparation of sheet rubber.

Sodium sulphite is effective in retarding the natural coagulation of latex but is of little value when precoagulation is marked. Ammonia is recommended as a general purpose anti-coagulant and especially for abnormal pre-coagulation as in rainy weather, with young trees or particular clones such as AVROS 49, and Glenshiel 1 under certain conditions. It is used in preference to any other chemical for preservation of latex during transport over long distances. It is unsuitable for general use in the field owing to its volatile nature, but it is eminently suitable for use in a confined space where the gas is prevented from escaping. Formalin is not so effective as ammonia in wet weather or with certain clonal latices. This difficulty is usually overcome, however, by adding a little sodium carbonate to the latex in addition to Formalin.

When the final product is pale crepe rubber, however, considerable care is called for, as colour may be adversely affected both with Ammonia and Formalin.

All anti-coagulants should be added as soon as possible after the latex flows from the tree, and addition to tapping cups is desirable. In practice it is difficult to ensure that this is carried out satisfactorily and it is advisable to compromise by adding half the quantity to the cups and the remainder to the tapper's bucket. Anti-coagulants should not be added in the factory as they do not counteract the results of precoagulation, although sometimes the addition of Formaldehyde assists in sheet preparation by inhibiting fermentation and thus avoids the formation of bubbly sheet.

Sodium Sulphite. This is supplied commercially in the form of a white powder. Samples available are usually over 90% pure as Na_2SO_3. The powder is not stable under tropical conditions and should be stored in a cool place in airtight containers. A stock solution is prepared by dissolving 1 lb. commercial sodium sulphite in 3 gallons of water. Solutions of sodium sulphite deteriorate rapidly during storage and should therefore be used on the day of preparation. The dosage for short period preservation is ½ pint stock solution to 4 gallons of latex; this is equivalent to about 0.05% sodium sulphite on the latex.

The use of Sodium sulphite in latex retards the drying of sheet. Excess Sodium sulphite leads to tackiness on the surface of sheet which is due to moisture and not to oxidation.

Ammonia. Ammonia is available locally in large cylinders containing about 150 lb. gas, which is sufficient for treating latex to give 500,000 lb. rubber. To prepare a stock solution, 1 lb. ammonia gas is bubbled slowly into 10 gallons of water providing a 1% solution approximately. Smaller quantities of ammonia can be purchased locally in the form of a concentrated solution containing approximately 30% ammonia by weight. A 1% solution can be prepared by stirring 4½ fluid ounces of the concentrated solution into 1 gallon of water.

For use as an anticoagulant it is recommended that 0.01% ammonia should be used on the latex. In practice this amounts to adding 6½ fluid ounces of the stock solution to 4 gallons of latex. The use of excess ammonia in latex causes difficultly in coagulation, leading to uneven sheets and trouble in drying.

Ammonia evaporates from solutions on exposure to air and containers should be tightly stoppered. Unopened drums of ammonia solution should be stored in the coolest place available, and immersed in water overnight before being opened. The stopper, should be loosened slowly and any pressure allowed to escape before removing it completely. It is advisable for persons using concentrated ammonia solution or ammonia gas to wear goggles. The concentrated solution is also caustic and parts of the body contaminated should be quickly cleansed in water.

Formalin. Formalin, as commercially available, is a 38% (approx). solution of formaldehyde. This oxidises slowly during storage to form an acid; before use it is advisable to neutralise any acid present by adding a little soda ash. The neutralising reaction can be tested with litmus paper which turns blue in alkaline and red in acid solutions; when neutral, formalin has little or no effect upon the paper, which remains purple in colour. A 1% stock solution is prepared by stirring 4 to 5 fluid ounces of formalin into 1 gallon of water. The normal dosage is at the rate of 3 fluid ounces of stock solution to 1 gallon of latex, which is equivalent to 0.02% formaldehyde in the latex.

In abnormal latices formalin is used together with sodium carbonate. A stock solution of the latter is prepared by dissolving 1 lb. soda ash in 10 gallons of water and is employed at the same rate as formalin, i.e.-3 fluid ounces of stock solution per gallon of latex.

Extra acid should not be required for coagulation if formalin is used alone, but when sodium carbonate is also present, slightly more acid may be required.

Collection Pails. All vessels intended for the transport of latex should have a smooth and curved interior, so that cleansing may be easy. Preferably the interior and exterior surfaces should be glazed, but it is often found that the enamel chips easily, and that the handles are too frail in construction. The shoulder-pieces, to which the handles are joined, are often too lightly attached to the bucket. Something stouter in the shape of enamelled ware is required, without an appreciable increase in weight. Until such a utensil is available, the heavily galvanised pails used on some estates are as good as anything provided they are kept scrupulously clean.

The collecting pails should be kept under cover, when not in use, either at the muster-grounds or at the factory. On some estates coolies are allowed to take them to their quarters, where they are used for various purposes. Curious effects of this practice have sometimes been noticed, in which premature coagulation takes place to a surprising degree especially when buckets are used for the storage or preparation of food, acid in character, and not afterwards thoroughly cleaned leading to the latex of the following day to suffer. Preferably all buckets should have a lid of slightly funnel shape. This is inverted during collection, and thus prevents much dirt falling into the latex.

Collection of Tree Scrap. This work was once carried out by gangs of women and children, the idea in collection of scrap by a gang being that the work is more easily supervised. Many planters, however, prefer to allot a given area to each individual cooly as in tapping, the proportion being one scrapper to every three tappers. This renders each scrapper responsible for certain trees and bad work can be marked down and penalised. The commonest fault in scrapping is that the cooly in picking it off uses a nail or other sharp instrument and causes damage to the tree, and he is also inclined to mislay spouts and cups.

Opinions vary considerably as to the best time to collect scrap. The usual method is to collect it on the day after tapping, but scrapping immediately in front of the tapper is sometimes claimed as preferable for the following reasons.

1. The scrap left on the cut seals it against rain and consequent liability to bark-rot.
2. The tree obtains a full rest between tappings, whereas scrapping on the day after tapping is apt to cause a fresh irritation of the latex cells which may possibly

render the tree more liable to Brown bast, and which in any case would increase the percentage of scrap.

3. In the event of sudden storms the presence of the scrapper in the field at the same time as the tapper facilitates the collection of latex, and a saving in first grade latex is thus made.
4. There will be no scondary latex response in the bark shavings and as very little advantage is obtained by the manufacture of these, there will be a saving in wear and tear of machinery.

The arguments againt the above system and in favour of scrapping the day after tapping are:—

1. The number of scrap coolies has to be greatly increased in order to keep up with the tapper if the spouts and cups are to be properly cleaned as well.
2. If the number of scrappers is not increased the tapper will be obliged to assist in the collection of scrap, in which case his work will probably suffer from carelessness, or the tapping will be delayed.
3. The idea of help from the scrapper in the event of storms is hardly practicable and entails his carrying an extra bucket in addition to two baskets for the different grades of scrap.
4. The application of Brunolinum to the tree is usually undertaken at least once or twice a week, and this must obviously be done in the interval between scrapping and tapping.
5. If the whole work is completed by 10 a.m. there is nothing for the scrapper to do for the rest of the day and this is already a problem as regards the tappers themselves.
6. The sooner the scrap is collected the less it will have oxidised and the better will be the quality of rubber produced from it.

Tree Scrap. The thin film of latex which coagulates naturally upon the surface of the tapping cut after the latex has ceased to flow is known as "tree-scrap". Normally it is collected on all estates, but the method of collection varies. On most estates, it is removed as fully as possible before the tapping cut is reopened. The narrow strips are then placed in a bag or basket carried by the tapper.

Oxidation of Tree-Scrap It is often noted that some scrap is dark in colour, and in this condition it is generally spoken of as "oxidised" scrap. The oxidation is probably due to an enzyme, and also to the presence of chemical substances of a phenolic nature. In the course of laboratory experiments with normal latex, it was found possible to reproduce this darkening due to oxidation by the addition of very small quantities of various phenols used in general chemical processes, and the rapidity with which the darkening was effected depended upon the quantity of the phenol added. If this rapidly oxidising latex be mixed with normal latex, it would seem that the whole bulk of latex is affected by this tendency to rapid oxidation. It is observed that this condition under which any tree may yield rapidly oxidising latex is not a permanent one.

Care of Tree–Scrap. As these scraps eventually give a grade of rubber which compares well with other and better looking grades, care should be exercised in collection and treatment so that its quality is not impaired in any way.

Prevention of Oxidation of Tree Scrap. As a rule the scraps are picked over, and heavily oxidised pieces are sorted out, otherwise the crepe rubber prepared exhibits black streaks. The scraps should not be allowed to remain in the sun which induces "tackiness" and if they have to be kept overnight they may be placed in a weak solution (1%) of sodium bisulphite to arrest oxidation. It should be recognized that such a solution will not "bleach" already darkend scrap-rubber, and the nature of its action is only anti-oxidant.

Bark Shavings. In the matter of collecting bark-shavings much depends upon the organisation and nature of the labour force. Probably on the majority of estates bark shavings are collected systematically, but on quite a number considerable laxity in this respect has been noted. This may arise from lack of adequate supervision. Granted that the trees are well "scrapped" and that the percentage of rubber obtained from shavings under such circumstances would be extremely small (say 2 cent. by weight on the total output), it does not need much calculation to see that annually the loss of rubber to the estate must be considerable. It would also seem to follow that, if the adult labour declines to pick up bark shavings carefully, it might pay to employ children for the purpose. Or, as is done in some places, the adult labour might find it advantageous to collect bark shavings at low rates per pound.

It is a well known fact that if bark shavings be allowed to accumulate in a heap for any but a short period, a fermentative and heating action is set up. The heat developed in these piles of shavinges is so considerable that it is impossible to keep the hand in a heap for more than a second or two. Should this be allowed to persist, as would happen in the case of a break-down of engine or machines, it usually results in the final crepe rubber becoming tacky when approaching dryness.

To avoid this heating effect it is necessary to have spare jars or proper tanks in which the shavings may be soaked in water. In this condition bark-shavings may be kept for many days.

For the same reason (i. e.—the heating effect and consequent tackiness) the custom followed on some estates of allowing coolies to keep bark-shavings in their lines until they have accumulated a fair quantity cannot be commended, quite apart from the possibility of actual loss by theft, which is thus rendered easy.

It will be clear that where the trees are scrapped efficiently before tapping, the amount of rubber to be obtained from the treatment of pure dry shavings would be almost nil, and would scarcely pay the cost of collection and working. In actual practice, however, it is not possible to guarantee that the shavings are free from scrap-rubber. Shavings brought in may sometimes be as having rubber content as high as 35 to 40% upon the total weight of the material treated. The majority of estates are equipped with "scrap-washers"— machines specially designed for removing the bark from the rubber—and if they function efficiently the resulting crepe should be free from bark particles.

Earth Scrap. This, the lowest grade of rubber, is found at the base of the tree. Theoretically, if proper precautions are observed, the amount should be comparatively small, but in actual practice it may be very appreciable. The usual contributory causes are:—

(a) Failure to replace cups beneath the spouts of trees which continue to drip latex after collection.

(b) Collection of latex at too early a stage.

(c) Failure on the part of the tapper to ensure the flow of latex, by means of the spout, into the cup.

(d) Flowing of latex over the edge of the cut before it reaches the vertical channel.

(e) "Wash-cuts" on wet days, when the volume of rain water down the tree is sufficient to wash the latex out of the cup.

The amount of earth-scrap collected on any estate will depend all other things being equal, upon the labour expended in its collection. Certainly on well-organised estates, having ample labour, the amounts collected are huge in comparison with other estates. The ground at the base of the tree below the latex-spout is systematically turned over with pointed sticks, and large clots of rubber are often picked up. Here, again, it is advised that the collected earth-scrap should not be allowed to remain in heaps upon the floor of the factory. It should be placed in suitable tanks containing water, and quite a considerable portion of the cleansing work is thus taken from the machines.

Payment of Tappers. There is no doubt that payment of the cooly by results is the fairest method. At first one is inclined to think that this method will lead to hard tapping and damage to the tree, but in practice it has been found to be otherwise. A cooly soon realises that if he wounds the tree he will have to tap lighter for the next few days in order to rectify his mistake and this will mean loss of crop and consequently loss of income to himself. Payment by results produces a healthy spirit of competition and brings the best and most intelligent coolies to the force. Each field should be classed and rated on its own merits and very little practice will be needed to tell what is a fair rate to the cooly. Payment is made sometimes by the pint and sometimes by the ounce. To obtain the exact dry contents of rubber from the volume of latex, the use of the Metrolac or Latexometer is necessary, there being considerable temptation for the cooly to dilute his latex with water.

However, the arguments for and against the practice are many. In actual result there can be no question that a higher yield is obtained by the adoption of a scheme under which the cooly is either given a bonus based on result or is paid at a definite rate per pound. It is fully recognized, both by advocates and opponents of payment by result that the personal reputation of the tapper is a very important factor. A good skilled tapper will always obtain a higher yield than an ordinary individual from the same task of trees, and without any more injury to the trees. It is argued therefore that such an operative should be given the benefit of his skill. Apart from this it is claimed that even the average tapper does not do his best work if he knows that he will get his daily wage, no matter what his yield may be, as long as he does not injure the tree by wounding. It is claimed that this sense of security leads to shallow tapping which while it has an agreeable appearance, does not produce the available amount of rubber.

On the other hand, it is advanced in opposition that under a scheme of payment by result the tappers' only consideration is the matter of obtaining rubber, and that considerable damage in the form of wounds is done by over-deep tapping. That there is a great deal of truth in these statements is not to be doubted. Much, of course, depends upon the amount and quality of the supervision possible, and upon the standard demanded. It is a notable fact, however that on estates which first introduced the system some years ago, the quality of tapping compares favourably with that of average estates, and tapping is of a high standard. Possibly these are exceptional instances, and there can be no doubt that the opposition of many managers of considerable experience is founded upon the deterioration in the standard of tapping which often follows the institution of payment of tappers by result.

It will be recognised by planters that apart from the personal factor in tapping the worker might be so unfortunate as to be placed in an area from which the yield is naturally low, either by reason of its age or from other natural causes. Obviously such individuals are entitled to special consideration in respect of the rate per pound paid for the rubber obtained. Again, on very hilly land it may be not humanly possible for a worker to tap the usual number of trees. Hence to place him on a parity with other tappers, as far as wage earning capacity is concerned, a higher rate than ordinary must be given. It will be plain, therefore, that on any one estate it is generally impossible to set a standard rate per pound for payment by result; the rate may vary, from lower rates in old and high yielding tasks to higher rates on young and difficult areas of the same estate.

Naturally the actual rates paid will primarily depend upon the average yield per tree or yield per acre, and the lower the average yield the higher the rates to be paid per pound. Thus, on low-yielding properties where the natural conditions render a high yield impossible the rate per pound may be at a higher figure than on high yielding estates.

Conditions affecting Yield. Undoubtedly cultivation is the main factor in determining yield, and estates that have systematically applied manure from the early stages may yield 600 lbs, and over per acre by the 12th year; failing the application of artificial manure, the importance of deep forking cannot be too strongly emphasised. Well considered thinning out, the proper treatment of disease and a sound tapping system are all essential points in the productive powers of an estate. The other conditions affecting yield might be tabulated as follows:-

(a) Soil, its quality, depth and physical condition.
(b) Lay of land.
(c) Rainfall and exposure to wind.
(d) System and quality of tapping.
(e) Adequacy of labour.
(f) Immunity from disease.
(g) Period of resting.
(h) Number of trees per acre.
(i) Number of trees per cooly.
(j) System of payment.

Monthly Percentage of Crop. Figures taken from the principal rubber producing areas in Ceylon point to the following percentages as the average of crop obtained during each month on the one cut alternate day system.

	Monthly %	To date %
January	8½	8½
February	3½	12
March	4	16
April	8	24
May	8	32
June	8	40
July	8	48
August	9½	57½
September	8½	66
October	10½	76½
November	11	87½
December	12½	100

These figures will not only be found useful in checking the monthly output but will be a help to estimating future crops. It is assumed that one month's rest is given during the wintering period. Similar data should be prepared from actual yields in individual estates over a period of years.

The proportion of scrap to latex rubber is usually about 17 to 20%, but it must be remembered that the higher the yield per acre the lower will be the proportion of scrap.

Quality of Latex. The quality of latex will be determined by :-

(a) Age and health of the tree;

(b) Weather and variations of season ;

(c) Frequency of change of sides ;

(d) Soil ;

Trees growing on well-drained land usually show a higher quality of latex than those in swampy ground owing to better root development.

Latex Cups. There are various kinds of cups in use and they may be classified as follows:-

(a) Coconut shells

(b) Glass cups

(c) Earthenware cups

(d) Aluminium or metal cups.

Ceylon. Coconut shells are almost universally used in Ceylon and although more difficult to keep clean than the other three, they are undoubtedly a great saving in cost, both in initial outlay and in the fact that they can be left in the field and cleaned there. The other kind of cups must be transported daily to some spot where there is water to wash them, and then be taken to the cooly's line, for if left in the field there will be considerable loss by theft.

Having decided that the coconut shell is the cup to be used, it is essential that it be kept as clean as possible. To ensure this:-

1. The latex must be collected without the addition of water.
2. The cups must be kept off the ground and inverted when not in use.
3. They must be regularly cleared of scrap.

With regard to No. 1, if the rubber is collected without the addition of water more rubber is left in the cup, but the film is a strong one and can more easily be removed; also water in the cup tends to discolorations of the rubber in manufacture. No. 2, if the cup is kept off the ground, the earth does not get into it and it should be inverted either by placing on a stick in the ground or hanging on the cup "spout". In no case should a nail be put into the tree. If the cup is not inverted the sun will get into the film of scrap and render it tacky; there is also a possibility of contamination from injurious substances being carried by rain from the bark which will discolour the rubber.

Malaya. The importance of cleanliness is so scrupulously recognized generally that the use of coconut shell cups has been discontinued almost entirely. Terne-plate cups ousted the coconut shell, and they had the merit of being cheap. The interior coating of tin did not last long if the cups were properly cleaned. The iron being exposed, with a minutely roughened surface, each microscopic projection served as a point around which latex coagulated. Scrapping the film of interior rubber became more and more difficult, and often the cups were burnt in order to get rid of the accumulation of rubber. The last state of such cups was worse than the preceding one. On some estates fairly successful attempts were made to keep these cups clean by making the coolies bring them into the store each day. Terne-plate cups are not now in common use.

Aluminium cups have their advocates, but much the same argument applies to the difficulty of keeping them clean mentioned in the foregoing paragraph. On many estates, however, they are used with success, the usual method of treatment being to make the coolies bring them into the store and clean them there. Owing to comparative lightness of the material, such a scheme is more feasible than was the case with terne-plate cups.

The cups now most in general use are either of glass or white-ware, and probably those of glass are the most extensively employed. There are many details to be studied in the choice between these two types of cups — e.g., the percentage of breakage in transport and in the field, price when breakage is taken into account, etc.; but these apart, the glass cups have one advantage, namely, the ability of the superintendents to see whether the cups have been properly cleaned. In the case of white-ware cups this means an inspection and handling of individual cups, whereas in the case of glass the point is settled by visual examination at a comparative distance.

Glass cups are made in two patterns, one having a flat bottom and the other a conical base. The latter is convenient for use when wire supports are employed, the cup fitting into a loop placed beneath the spout. Used on the ground its shape is an obvious disadvantage, as unless a hole is scooped for its reception, it has to be propped up with sticks or stones. Often a touch is sufficient to upset the balance, and latex is lost.

The flat bottomed cup, on the other hand may be used with success equally on a wire support or on the ground. It is sometimes said that owing to its shape the ease of cleaning as compared with the half-spherical cup, is diminished and that if the cups when not in use are kept inverted upon sticks placed near the foot of the tree, the breakage is apt to be high. This latter objection is being rapidly removed as the practice of using these sticks is losing vogue for various reasons, and wire cup-holders are coming more into general use.

There are on the Malayan market and in fairly wide use cups of Chinese and Japanese manufacture. These generally consist of brown earthenware with an interior glazed finish. These are cheap in comparison with glass and white-ware cups, but its value will be greater if the glaze extended over the whole of the cup. The outer surface has a tendency to collect rubber and dirt.

Spouts. The spouts commonly used are driven into the tree with a lip attached to hold the cup in place. There are other ways of fixing a cup and one of the simplest and least harmful is to hang it by means of a light wire loop suspended from a tin tack; the spout is then independent pur[illegible] can be made of much lighter metal and need not be driven so far into the tree. The tin tack being galvanised does not do so much harm as would a wire nail, and is quite strong enough for the purpose. The only objection to the latter device is that there is no arrangement for hanging up the inverted cup after use which is important. The French spout adequately deals with this. The spout should not be placed further from the cut than the allowance of bark for the year or half-year necessitates, as the longer the distance the latex has to flow, the larger will be the proportion of scrap, also a lengthy channel is inclined to deepen frequently and which damages the symmetry of the tree.

CHAPTER XIV

TRANSPORT OF LATEX AND COAGULUM

On small estates it is quite easy to arrange for the tappers to carry the latex to the factory, but on larger estates many difficulties may arise. If this involves too long a transport, it is usual for divisional coagulating and rolling centres to be provided which should be limited to one such centre for about 250 acres of rubber. Rolled rubber is easier to transport than liquid latex so that these divisional coagulating centres should be properly equipped with sufficient coagulating troughs or dishes, Shanghai Jars and hand rollers. This will facilitate the bulking of latex immediately it is collected, and coagulation and rolling on the following morning and then transporting to the main factory for processing into smoked sheets. For the manufacture of crepe, the coagulum can be cut up into slabs and transported to the factory in this form. Given uniform equipment in all divisional coagulating centres and uniform rules for treatment of latex, the resulting products of all stations will be of uniform quality.

Transport of latex in bulk from field to factory from field centres where the latex is collected over a distance is done by one of the following means: (a) In large tanks placed on motor lorries, (b) in cylindrical galvanised drums placed on bullock carts or (c) by direct trolley line to the factory which is the best system in that it avoids great agitation of the latex and the time in transit in greatly reduced. Transport by bullock cart is very slow, and the jolting undergone by the latex in transit is not calculated to afford a high yield of first grade rubber. Whatever the means of transport employed it should be the duty of those responsible to see that latex containing vessels are not permitted to remain in the sun longer than is necessary. Lorries and bullock carts must be equipped with suitable hoods.

Cleanliness of Transport Vessels. In order to ensure the highest percentage of first grade rubber, it is very important that the large transport vessels used for bulk transport are maintained scrupulously clean *every day* as a matter of daily routine. Ordinary sluicing with water is not sufficient as this will not afford adequate sterilisation. If they cannot be sterilised by means of boiling water, they should be treated, after ordinary washing, with a 5 per cent. solution of sodium bisulphite every day.

Use of Anti-Coagulants for Transport. When anti-coagulants are not used in the cups or buckets, it is advisable to use them in the bulk-transport vessels. Either formalin or sodium sulphite is employed, but the chief objection advanced against formalin is its loss due to evaporation while the carts are proceeding to the fields or waiting at the collecting centres. For this reason sodium sulphite is now generally employed.

Formula for Use of Sodium Sulphite in Transport.

(i) Dissolve 1 lb. of Sodium Sulphite powder in 3 gallons of water.

(ii) Of this solution, place ½ gallon in the vessel for every 30 to 40 gallons latex.

Transport of Coagulum. Proper precautions must be taken in the transport of coagulum intended for the preparation of crepe if the quality of the resultant rubber is not to be impaired. It scarcely need be remarked that coagulum should be transported in closed wooden boxes or in galvanised iron drums fitted with lids, and preferably sufficient water should be present in these receptacles to allow the coagulum to float. All such containers should receive the same scrupulous attention as the vessels employed in the transport of latex.

The successful tranport of coagulum for sheet manufacture is fraught with much greater disabilities, and it is usual to note on most estates that the resulting sheets from outlying divisons are always inferior in final result to those coagulated and prepared

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TRANSPORT OF LATEX AND COAGULUM

On small estates it is quite easy to arrange for the tappers to carry the latex to the factory, but on larger estates many difficulties may arise. If this involves too long a transport, it is usual for divisional coagulating and rolling centres to be provided which should be limited to one such centre for about 250 acres of rubber. Rolled rubber is easier to transport than liquid latex so that these divisional coagulating centres should be properly equipped with sufficient coagulating troughs or dishes, Shanghai Jars and hand rollers. This will facilitate the bulking of latex immediately it is collected, and coagulation and rolling on the following morning and then transporting to the main factory for processing into smoked sheets. For the manufacture of crepe, the coagulum can be cut up into slabs and transported to the factory in this form. Given uniform equipment in all divisional coagulating centres and uniform rules for treatment of latex, the resulting products of all stations will be of uniform quality.

Transport of latex in bulk from field to factory from field centres where the latex is collected over a distance is done by one of the following means: (a) In large tanks placed on motor lorries, (b) in cylindrical galvanised drums placed on bullock carts or (c) by direct trolley line to the factory which is the best system in that it avoids great agitation of the latex and the time in transit in greatly reduced. Transport by bullock cart is very slow, and the jolting undergone by the latex in transit is not calculated to afford a high yield of first grade rubber. Whatever the means of transport employed it should be the duty of those responsible to see that latex containing vessels are not permitted to remain in the sun longer than is necessary. Lorries and bullock carts must be equipped with suitable hoods.

Cleanliness of Transport Vessels. In order to ensure the highest percentage of first grade rubber, it is very important that the large transport vessels used for bulk transport are maintained scrupulously clean *every day* as a matter of daily routine. Ordinary sluicing with water is not sufficient as this will not afford adequate sterilisation. If they cannot be sterilised by means of boiling water, they should be treated, after ordinary washing, with a 5 per cent. solution of sodium bisulphite every day.

Use of Anti-Coagulants for Transport. When anti-coagulants are not used in the cups or buckets, it is advisable to use them in the bulk-transport vessels. Either formalin or sodium sulphite is employed, but the chief objection advanced against formalin is its loss due to evaporation while the carts are proceeding to the fields or waiting at the collecting centres. For this reason sodium sulphite is now generally employed.

Formula for Use of Sodium Sulphite in Transport.

(i) Dissolve 1 lb. of Sodium Sulphite powder in 3 gallons of water.

(ii) Of this solution, place ½ gallon in the vessel for every 30 to 40 gallons latex.

Transport of Coagulum. Proper precautions must be taken in the transport of coagulum intended for the preparation of crepe if the quality of the resultant rubber is not to be impaired. It scarcely need be remarked that coagulum should be transported in closed wooden boxes or in galvanised iron drums fitted with lids, and preferably sufficient water should be present in these receptacles to allow the coagulum to float. All such containers should receive the same scrupulous attention as the vessels employed in the transport of latex.

The successful tranport of coagulum for sheet manufacture is fraught with much greater disabilities, and it is usual to note on most estates that the resulting sheets from outlying divisons are always inferior in final result to those coagulated and prepared at the central factory. If the flat pieces of coagulum are placed in piles of any height it is common to find, on arrival at the factory, that much adhesion has been caused. There is great difficulty in separating the pieces, and often the successful operation is impossible. It is usual to hand-roll the coagulum before transport, but it is often found that by the time the rubber reaches the factory it has become too hard for subsequent good results.

Sheet making necessitates the employment of only light machines suitable for hand power and one of the strong arguments in favour of the establishment of divisional stations is that the sheets made in them are often better than those made at a central factory as the latex has the chance of being treated when comparatively fresh.

If it is found necessary to transport sheet coagulum, every possible precaution should be taken against piling the pieces. After hand-rolling, some estates bring the rubber from the field-stations to the central factory in drums of water; others have them transported in shallow boxes containing not more than half a dozen sheets in a pile.

Percentage of First Latex and Other Grades. One of the problems confronting an estate manager is the question of the percentage of first-grade rubber calculated upon the whole output. This is a question to which no definite list of figures can apply, as there are so many little factors influencing the result. Some estates are not particularly careful in collecting tree scrap and hence quite a quantity of tree scrap finds its way into the crepe made from bark shavings. On the other hand bark shavings are not collected systematically on some estates, and the total output is thereby diminished. In consequence, the first-grade rubber shows a higher percentage than it would otherwise. Again, if the earth rubber is not regularly collected the percentages of the best grades are higher than they should be. In comparing the percentages of each grade of rubber from any two estates, therefore one should have all the information possible as to the various working details of the estates. Without laying down any definite proportions, which can be applied to all estates, it might be said that taking the averages over a large number of estates, the percentages to be aimed at are:-

First-grade latex	..	75 per cent. to 80 per cent.
Other grades	..	20 " " " 25 " "

For the above figures, it is assumed that all lower grades are collected and accounted for regularly and carefully. The distribution of the lower grades will depend upon the field practices of the particular estate, but the following list might be given for an estate keeping all lower grades distinctly separate:

First-grade latex	.. .. ..	75 per cent.
Cup-washings Coagulated lumps etc.	.. .. ..	10 " "
Tree Scrap	.. .. ..	9 " "
Bark-shavings	.. .. ..	4 " "
Earth Scrap	.. .. ..	2 " "
		100 " "

It is emphasised that the above figures must be accepted as standard though they will prove to be of some assistance to managers to get an idea of what the general rates of percentages may be. There are special circumstances such as distance of transport and the nature of the land which at present would render the attainment of more than 75 per cent. first-grade rubber difficult on some estates, but some method will have to be discovered by means of which such transport difficulties may be overcome.

CHAPTER XV

MANUFACTURE

PRELIMINARY TREATMENT OF LATEX

The Importance of Cleanliness. The highest possible percentage of first-grade rubber could be turned out by a factory only if absolute cleanliness is maintained at every stage of the manufacturing process, and the primary rules in the treatment of rubber apply equally to the manufacture of both smoked sheet and crepe. Upon cleanliness in the field as well as in the factory will depend the colour and market value of the finished rubber. Considering the importance attached to the colour in the dry rubber by consumers and brokers, it must be borne in mind that sometimes extremely trivial causes can mar it, and therefore it is imperative that the best provision must be made for the reception and handling of latex in the field and factory.

In the field, no water should be permitted to be used on the tapping cuts as mentioned in the Chapter on tapping. Buckets should also for the same reason be kept free from all impurities in the field and should be thoroughly cleaned immediately they have been emptied of latex. Otherwise cleaning becomes troublesome after the rubber has coagulated. Any dirt in the latex will appear as dark spots and smudges after the sheet has been rolled and smoked and held up to the light.

Wherever possible, the latex should be received in an outside verandah for straining and measuring to avoid the necessity of tappers to enter the factory and bring in dirt. In some factories a verandah is built outside the wall of the factory and all latex is received there. In others, open chutes are provided which terminate in the straining sieves.

The worker thus stands on the verandah where he removes coagulated lump and impurities from the latex which after measuring is poured down the chute, passing through the sieve into large coagulating jars or tanks. The moral effect of working under the cleanest and best conditions has a salutary effect on the factory workers, and their work is better in consequence. Hose pipes, glazed tiles, clean floors, plenty of light are all factors which considerably determine the final quality of the finished product.

Straining and Measuring of Latex. This is a most important and necessary process and one which usually entails much trouble and time which one could wish avoided. It will be admitted that the trouble could be considerably reduced if strict and stringent measures regarding cleanliness in the field could be enforced. In spite of the knowledge that impurities must not be allowed to enter the cups, tappers will ignore the rule that the cup must not be placed in position until the bark-shaving has been cut. The result is that pieces of bark fall into the cups, and coolies are generally too careless or too hurried to remove them. Again when the cups are placed on the ground, it is easy to realise that dirt may adhere to them. In the collection of latex some of this dirt may fall into the bucket though the proper use of cup holders avoids this to a considerable extent. Nevertheless it may be taken for granted that even under the best of conditions, all latex requires straining.

Undiluted latex, as received at the factory, is of a rich consistency, containing very fine particles of dirt and often minute particles of prematurely coagulated rubber. The latter soon clog a fine-mesh strainer while the former may pass through. In view of the presence of the fine particles of dirt in the latex, fine sieving is essential especially when sheet-rubber is to be prepared. Coagulated lumps of latex must first be removed from the buckets and placed in a separate tank or vessel and the latex is thereafter strained through a No. 40 brass wire mesh, and it is desirable to do a second straining through a No. 60 mesh which should be kept scrupulously clean. The empty buckets are washed and the washings strained over the jars containing the strained latex. It is very important that the amount of water used in cleaning the buckets should be as limited as possible to avoid unnecessary dilution of the bulk.

When all necessary precautions are taken in the field and if the latex is properly handled before reaching the factory, it should represent about 95 to 98 per cent. of first quality latex which should go into the bulking jars while the remaining 2 to 5 per cent will comprise lumps and bucket washings.

To obtain the best colour, inferior grades should be manufactured on the same day of collection and be treated as carefully as the first quality latex. Considerable labour will be saved at the time of straining by keeping the latex as free as possible from all impurities in the field such as leaves, twigs, bark etc. either in the cups or buckets, which if done will greatly minimise the risk of premature coagulation taking place on the way to the factory.

The tapper's task is measured at the time of straining and as a rule paid for per pint or ounce, the rate varying according to the age of the field, lay of land and season. The use of the Metrolac will help to detect the presence of water in the tapper's task.

Bulking of Latex. On arrival of the latex at the factory, it will be found that its quality may vary in colour or thickness from field to field according to the age of the trees or type of clones, soil, weather and nutrition. Again when a new cut is being opened the latex often appears yellow in colour for a short period, and if after straining and measuring is added to other latex without proper mixing, yellowish streaks will appear in the strips of crepe. Rubber manufactured from young trees is often paler than that from more matured trees. Rain water in the latex will also cause a certain amount of discoloration, and in order to reduce the days crop to a uniform quality it is usual to bulk the various qualities of latex together. The operation is best performed in one large vat capable of holding the entire crop of the day, but in smaller estates it is also usual to bulk together as much latex as can be contained in each 50 gallon Shanghai Jar. This ensures uniformity of colour and quality in the finished article to an extent which would not be possible if the crops from different fields were manufactured separately.

Standardisation of Latex. As already stated in the preceding paragraph the quality of the latex will vary considerably from day to day according to the season, rainfall etc. Therefore, in order to obtain a uniform product, the latex is brought daily to a given standard by means of diluting it with a quantity of water varying according to the density of the latex. This standardisation permits a close approximation to uniformity in the finished rubber resulting in a much smaller range of variety to be handled in the subsequent sorting and grading process.

The quantity of water necessary for standardising the latex is determined by the use of an instrument known as the **Metrolac** which shows the *dry rubber content per gallon* of latex, and this together with the measurement of the whole volume enables the calculation of the quantity of water required for dilution of the latex.

How to use the Metrolac. Proceed as follows:—

1. Having filled a glass or metal jar from the bulked latex remove any small lumps of coagulum that may be seen, taking care that the jar is quite full of the bulked latex.

2. Place the Metrolac inside the jar of bulked latex and allow it to sink slowly by its own weight, holding it by the top of its stem, taking care to keep it well away from the sides of the jar.

3. If the jar is quite full as instructed, the liquid will brim over carrying away with it any surface froth or bubbles.

4. The stem of the Metrolac is marked in graduated lbs. and half lbs.with intermediate divisions for the ounces. These figures indicate the dry rubber content per gallon of latex. When the instrument comes to rest in the latex, a reading is taken at the point where the stem emerges from the latex.

5. If the Metrolac is inclined to stick and does not move freely the latex may be diluted with an *equal* quantity of water and it will now be quite easy to take an accurate reading. Multiply in this case by 2 to obtain the original density of the latex before the addition of equal quantity of water.

6. After use, both instrument and jar must be thoroughly cleaned as any particles of coagulated rubber will upset the accuracy of the reading. The instrument being delicate, it should not be scrubbed but washed and lightly dried with a soft cloth.

How to determine the quantity of water required for diluting the bulked latex for standardisation to a given consistency.

(a) Ascertain the volume of bulked latex in bulking tank or Shanghai jar from the check list used at the time of measuring.

(b) Multiply the above number of gallons by the Metrolac reading showing the dry rubber content per gallon in lbs. The resulting product is the total dry rubber content in the bulking tank or Shanghai jar. (The Metrolac reading will probably range from 2 to 4 lbs.)

(c) Divide the above total dry rubber content by the figure it is desired to standardise the latex, say, 1½ lbs. dry rubber per gallon latex for sheet and 3 lbs. dry rubber per gallon latex for crepe. The quotient is the volume in gallons which the latex will attain when diluted.

(d) From the above figure subtract the original volume of undiluted latex in the Shanghai jar or tank. The resulting figure will denote the quantity in gallons of the water required for diluting the latex to bring it to the required consistency.

Example 1.

Bulk Latex in Shanghai jar	=	30 Gallons
Metrolac reading (dry rubber content per gallon)	=	2 lb. 8 oz.
Total dry rubber content of jar	=	30 X $2\frac{1}{2}$ lbs. = 75 lbs
To reduce latex to dry rubber content of $1\frac{1}{2}$ lbs. per gallon, we divide 75 by $1\frac{1}{2}$.-		
Volume of latex when diluted.	=	50 gallons
From this deduct orginal volume of latex	=	50 — 30 = 20 Gallons water

Example 2.

Bulk Latex in Shanghai jar	=	25 Gallons
Metrolac reading	=	3 lbs.
Dry rubber content of jar	=	25 x 3 = 75 lbs.
Latex to be reduced to $1\frac{1}{2}$ lbs. dry rubber	=	75÷$1\frac{1}{2}$ = 50 Gallons
Water required for dilution	=	50 - 25 = 25gallons-

The strength of latex recommended for smoked sheet is $1\frac{1}{2}$ lbs. dry rubber per gallon, and on this basis it will be necessary to calculate the amount of latex that should be put into a 50 gallon Shanghai jar which when diluted with required quantity of water should not exceed the 50 gallon capacity of the jar. The following table shows the volume of latex and water which should be placed in a 50 Gallon jar according to Metrolac readings varying from 2 lbs. to 4 lbs.

Metrolac Reading. (Dry Rubber content per Gallon Latex)		Volume of latex which should be placed in a 50 Gln Jar.		Water required to standardise the latex to Dry Rubber content of $1\frac{1}{2}$ Lbs. per Gln.		Total of Latex plus Water
Lbs.	oz.	Glns.	Pts.	Glns.	Pts.	Gallons.
4	0	18	6	31	2	50
3	15	19	0	31	0	50
3	14	19	3	30	5	50
3	13	19	6	30	2	50
3	12	20	0	30	0	50
3	11	20	3	29	5	50
3	10	20	6	29	2	50
3	9	21	0	29	0	50
3	8	21	3	28	5	50
3	7	21	7	28	1	50
3	6	22	1	27	7	50
3	5	22	5	27	3	50
3	4	23	1	26	7	50
3	3	23	4	26	4	50
3	2	24	0	26	0	50
3	1	24	4	25	4	50
3	0	25	0	25	0	50
2	15	25	4	24	4	50
2	14	26	0	24	0	50
2	13	26	5	23	3	50
2	12	27	2	22	6	50
2	11	27	7	22	1	50
2	10	28	5	21	3	50
2	9	29	2	20	6	50
2	8	30	0	20	0	50
2	7	30	6	19	2	50
2	6	31	5	18	3	50
2	5	32	3	17	5	50
2	4	33	3	16	5	50
2	3	34	2	15	6	50
2	2	35	2	14	6	50
2	1	36	3	13	5	50
2	0	37	4	12	4	50

As coagulation dishes of approximately 1 gallon capacity are normally used for the manufacture of sheet rubber, latex standardised to $1\frac{1}{2}$ will produce a sheet of about $1\frac{1}{2}$ lbs. wt. which is a convenient size for packing and drying. Greater dilution than this will produce a thin sheet of poor quality which when wet will be soft and porous and will roll out too thin and in drying is apt to stretch and assume an irregular shape. On the other hand the richer the latex, the greater the percentage of protein matter which with the evaporation of the surface moisture remains as a thin film or crust, and in drying will form "rust".

The above rules in treating rubber apply equally to both sheet and crepe rubber manufacture, and it is emphasised again that the most important point to remember is that absolute cleanliness should be maintained at every stage to obtain the best colour and best prices for the finished product.

FORMULA FOR CALCULATING PINTS OF WATER WHICH MUST BE ADDED TO 1 GALLON FIELD LATEX TO DILUTE IT TO REQUIRED STANDARD DRY RUBBER CONTENT.

$$W \text{ (Water in pints)} = \frac{M \text{ (Metrolac reading in oz)} \times 8}{R \text{ (Standard Dry Rubber content in oz)}} - 8$$

Example:- Metrolac reading ... 3 lb. 6 oz = 54 oz
Standard Dry Rubber Content 1 lb. 8 oz = 24 oz

Substituting above figures in Formula $W = \frac{M \times 8}{R} - 8$

we have $W = \frac{54 \times 8}{24} - 8 = 18 - 8 = 10$ pints water to every 1 gallon latex

The above formula could be used for calculating the quantity of water required for use with any desired Dry Rubber Content standard.

CHAPTER XVI

COAGULATION

Coagulants. There are many substances which cause coagulation of Havéa latex, and a list of the coagulants used successfully in experiments is given below as being of general interest:—

1. Acetic acid
2. Aluminium sulphate
3. Barium chloride
4. Calcium chloride
5. Citric acid
6. Formic acid
7. Hydrochloric acid
8. Hydrofluoric acid
9. Magnesium chloride
10. Mercuric chloride (50%)
11. Nitric acid
12. Oxalic acid
13. Sodium chloride (10%)
14. Sulphuric acid
15. Tannic acid
16. Tartaric acid

It will be plain to see that the number of possible coagulants is a very wide one, but it will suffice to state that the oldest known coagulant, Acetic acid, still remains the most popular. Its position is now being challenged, however, by Formic acid, which is equally safe and efficacious, and also has the advantage of being relatively cheaper in that where Formic acid is used only about half the quantity prescribed for acetic acid is necessary.

Strength of Acid Solution. The strength of the acid solution as well as the quantity used, has an effect upon coagulation

which could be easily seen by taking two separate equal lots of the same latex, and adding to each the same quantity of pure acid, but in each case diluted with different quantities of water. It will be seen that coagulation is quickest where pure acid is employed, and slowest where the acid was most dilute. It will also be found that provided that the quantity of acid employed was sufficient for coagulation, the best and most uniform coagulation is obtained from the use of the most dilute acid. On the other hand, it will be noticed that where pure acid was employed, coagulation is local resulting in lumpy coagulation with a very milky remaining liquor. This is due to the fact that, as coagulation is immediate upon the spot which is first touched by the pure acid, a deal of the acid is enclosed within the rubber at that spot, and hence other portions of latex are deprived of acid. It is in such cases that most air-bubbles are enclosed. As the dilution of the acid solution is increased, the mixing is more thorough and uniform and coagulation is slower permitting the air bubbles to escape to the surface.

Acetic Acid. Pure acetic acid has a strength of 98-100%, and for the satisfactory coagulation of latex by means of acetic acid, the quantity of acid required can be set at a maximum of 1/16 of an ounce of pure acetic acid of 98% concentration for every 1 lb. dry rubber content. Thus, for a Shanghai jar containing 50 gallons of coagulum standardised for sheet 1½ lbs. D. R. C. (dry rubber content) per gallon, the quantity of pure acid required will be 4¾ oz. A full carboy of acid contains 32 pints or 640 oz. (see Table below), and should therefore be sufficient for 640 x 16 = 10,240 lbs.

LIQUID MEASURE TABLE

60 minims	=	1 dram (drachm)
8 drams	=	1 liquid oz.
20 liquid oz.	=	1 pint
2 pints	=	1 quart
4 quarts	=	1 gallon

IT IS VERY IMPORTANT THAT THE ACID SHOULD BE DILUTED WITH WATER AT THE RATE OF 1 PART OF CONCENTRATED ACID TO 100 PARTS WATER BEFORE ADDING IT TO THE STANDARDISED LATEX. This diluted acid solution may be mixed with latex standardised to 1½ lb. D. R. C. at the rate of 1 part diluted acid to 12 parts of diluted latex.

Formic Acid. Formic acid is available in two grades containing 90% and 85% strength, one gallon of which weighs approximately 12 lbs. One part by volume of 90% Formic acid has approximately twice the coagulating power of an equal volume of acetic acid. The word volume is emphasised because Formic Acid having a specific gravity of 1. 20 is considerably heavier than an equal volume of acetic acid which has a specific gravity of 1.05.

Quantities of Acid required for modern requirements. It may be commended to the notice of the beginner that further experimental work as to the quantity of acetic acid or formic acid necessary for complete coagulation would only involve a waste of time and energy. The general figures, 1 part pure acetic acid to 1000 parts of average latex, or 1 part pure formic acid to 2,000 parts of average latex, may be accepted as the rough basis for practical work. In modern practice, however, undiluted latex is usually diluted to a standard which may vary on different estates from 1¼ lbs. to 1½ lbs. dry rubber per gallon.

Latices of the above strengths can be coagulated at a ratio of 1 part pure acetic acid to 1200 parts of standardised latex, or 1 part pure formic acid to 2,200 parts of standardised latex; this quantity need not be exceeded, except in cases where an appreciable amount of some anti-coagulant is present in the latex. In such an event, the proportion may then be raised to 1 in 1000 (acetic acid), 1 in 2000 (formic acid).

Where it is considered advisable, the acid may be used in a ½ per cent. solution for the preparation of sheet rubber; but in any case it is recommended for the sake of uniformity that a 1 per cent. solution is employed in the preparation of both sheet rubber and crepe rubber. In most modern factories, measuring vessels of various capacities are to be found, and it is always more satisfactory to have the solution made up in approximately correct strength at the rate of 1 oz. of pure acid to 5 pints of water (100 liquid ozs). For practical purposes it may be necessary to devise some approximately correct method of procedure for the preparation of larger quantities of stock solution. This may be done by using a 4 gallon carboy or a 4 gallon kerosene oil tin which is *thoroughly clean and not rusty* as a standard measure for preparing the dilute stock acid solution. The capacity of such a 4 gallon container is 640 fluid ounces so that 1/100 part (for acetic acid) would be approximately 6½ ozs., and a 1/200 part (for formic acid) would be 3¼ ozs. This quantity of acid should be measured out by means of a glass graduated vessel, and then an aluminium cup should be cut down so as to hold the exact quantity. This would reduce the making of a solution, sufficiently approximate to 1 per cent. strength for all practical purposes, into a simple operation of mixing pure acid and water in the ratio of 1 cupful of acid to 1 kerosene tin or carboy of water.

The actual quantity of solution required for the coagulation of any volume of standardised latex can be calculated easily from the ratio 1 : 1,200 for acetic acid, or 1 : 2,200 for formic acid. As the strength of the stock solution is 1 : 100, it will be seen that the quantity to be taken is *always 1/12th part (for acetic acid) or 1/24th part (for formic acid) of the volume of latex to be coagulated.*

Example.

(i) If the latex tank holds 50 gallons of standardised latex, 4 Gallons approximately of dilute acetic acid solution will be required, or 2 gallons of dilute formic acid.

(ii) If the latex tank holds 90 gallons of standardised latex, 7½ gallons of dilute acetic acid solution are required, or roughly 3½ gallons of dilute formic acid.

(iii) In the same manner, a tank containing 120 gallons of standardised latex will be found to require 10 gallons of 1 per cent. acetic acid solution or approximately 5 gallons of 1 per cent formic acid solution.

In making the above recommendations, it is assumed that generally all estates standardise the latex for the preparation of both sheet rubber as well as crepe rubber in order to obtain uniformity. It will be imprudent not to do so, but in case average undiluted latex is treated, the quantity of acetic acid to be used should be calculated from the ratio 1: 1000 for acetic or 1: 2000 for formic acid. If the acid solution is to be employed in 1 per cent. strength, 1/10th (acetic acid) or 1/20th (formic acid) of the volume of latex to be treated will indicate the required quantity of solution necessary for complete coagulation unless anti-coagulants have been used, when the quantity must be increased as experience directs. It will be recognised, of course, that undiluted latex may only be used in any case for the preparation of crepe rubber.

Within certain reasonable limits the employment of acetic and formic acids in slight excess leads to no harmful effects upon the quality of the rubber, but ordinarily there would be no justification for the employment of an excess. Many planters consider it desirable, in the case of sheet preparation, to secure a slightly more rapid coagulation in order that the coagulum may be processed on the same day, and placed in the smoke-house before night. There is no doubt that by this method the coagulum is more easily worked, and the resulting sheets have an improved appearance. They are also more free from certain small defects which prevent the best market price being obtained, and on these grounds the procedure would appear to be justified. But the warning that only a relatively small increase of acid should be employed must be heeded, and any carelessness in this respect will lead to difficulties.

Mixing Latex and Coagulant Solution. It is very essential that the mixture of dilute acid and latex should be thoroughly intimate. This can only be attained by careful and thorough stirring with aluminium or wooden paddles, and the acid should be poured into the latex while stirring, and the agitation should continue for such a period as to ensure complete mixing in all parts. For sheet preparation, it is important and essential that the stirring should be done so carefully as to avoid internal bubbles and to reduce surface froth to a minimum. If coagulation is carried out in pans, the coagulant and latex should be mixed in Shanghai jars or other suitable vessels of a capacity not exceeding 50 gallons, and after thoroughly stirring, the latex should be distributed to the pans as quickly as possible in order to avoid premature coagulation in the jars. With good organisation distribution of the latex should be completed within 6 to 7 minutes after adding the acid.

Skimming. The mixing of the diluted acid and latex and distribution to pans produces a considerable amount of froth. This should be removed, otherwise the froth will cause pitting of the surface of the sheet when the coagulum is rolled.

Use of Sodium Bisulphite. If coagulation is allowed to take place either naturally or with the aid of acetic acid, owing to the enzymes normally present in the latex, the resulting rubber will almost inevitably oxidise on the surface except in the case of very dilute or young latices, and so present a dark appearance. Even if this darkening of the surface does not take place in the wet stage, it is often found that a rubber expected to dry to a pale colour does not fulfil expectations, and a dull neutral shade results. This darkening is a distinct disadvantage in the manufacture of pale crepe, and must be arrested at the outset and Sodium Bisulphite is employed for this purpose.

Quantities of Sodium Bisulphite. Although sometimes sodium bisulphite is employed in the preparation of sheet rubber, this is quite unnecessary and may lead to some difficulties and delay in drying.

As the dry rubber contents of latices vary with the age of the trees, the general health of the trees, the season and general climatic conditions, the relative strain imposed by depletion of reserves through tapping etc., it will be clear that the effect produced by a definite quantity of sodium bisulphite in any given volume of latex will also vary, depending upon the potential amount of rubber present. A dilute latex will need less sodium bisulphite than a richer latex to produce the same effect in colour. Hence it follows that if in any factory uniform quantities of the solution are used for any given volume of undiluted latices from different areas of the estate, the effect upon the dry rubber will vary. This explains why some estates obtain different shades of rubber in their pale crepes.

In passing, it may be mentioned that there are certain occasions as in the opening of areas of bark rested for long periods, when the latex is of a rich yellow colour. Sodium bisulphite will not "bleach" this colour, and at this stage the action of the chemical is only to avoid or arrest darkening due to oxidation.

In order to prevent manufacture of different shades of pale crepes, it is advisable to standardise all latices to a uniform dry rubber content as is done in sheet preparation, and then the prescribed quantities of sodium bisulphite will meet requirements in every case. Working with a standard of 1½ lbs. dry rubber per gallon, the following formula should serve as a *maximum*:

(i) Dissolve sodium bisulphite in water at the rate of 1 lb to 10 gallons.

(ii) Of this solution use 1 gallon to every 10 gallons of latex.

Making Sodium Bisulphite Solution. Great care must be exercised in preparing the solution. The powder should be added gradually to the water with thorough stirring which should be continued for five minutes at least, and undissolved particles, sand and other impurities if seen at the bottom of the solution should be removed by straining it through a piece of cloth before using. No solid particles should be allowed to enter the latex.

The Use of Sodium Sulphite in the Factory. While sodium *bisulphite* is employed in the preparation of rubber as an anti-oxidant, sodium sulphite is employed chiefly for its anti-coagulant property. It is not used, therefore, in the making of crepe rubber, but is of service in the preparation of sheet rubber, where the aim is to keep the latex in good fluid condition as long as is necessary, and to retard coagulation slightly so that enclosed bubbles of gas or air may escape. Formulae for its use in the field have already been given. In the factory only a small quantity is used and is always placed in the bottom of the reception vessels prior to the straining of latex into them. The following formula may be adopted as a working basis:-

Formula for use of Sodium sulphite in the factory.

(i) Dissolve 2 ozs. of anhydrous sodium sulphite in 1 gallon water.

(ii) The gallon of resulting solution, placed in the bottom of the reception jar or tank, is sufficient for the treatment of 40 gallons of standardised latex of 1½ lb. dry rubber content per gallon.

The advice previously given regarding the necessity for thoroughness in the preparation of solutions is again reiterated Stirring should be thorough, at least for five minutes, and if there is any sediment or undissolved matter, the solution should be strained through a piece of cloth before using.

Where uniform jars or tanks are in use, the majority of which will contain uniform quantities of latex daily, the practice of using the chemical can be made almost fool-proof. A calculation is made of the quantity of powder required for each vessel daily. The necessary number of lots is weighed out each morning and each placed in an envelope. The process is thus simplified by the fact that the contents of an envelope, neither more nor less, are required for each unit reception vessel.

Fractional Coagulation. This is an expedient adopted in the process of preparing sole-crepe. If to a volume of latex only about one half of the necessary quantity of acid solution is added, and the mixture is allowed to stand overnight, a kind of "creaming" effect is produced. In the morning it is found that partial coagulation has taken place, and the coagulum produced is generally of a pronounced yellow or cream colour. This coagulum is removed, and is known as the "first fraction". By reason of its pronounced colour it is passed through the machines as a separate grade of rubber.

More acid is then added, with stirring, to the residual latex; and the resulting coagulum is used for the preparation of the thin pale crepe from which the ultimate sole-crepe is built up in layers. This thin crepe is extremely pale in colour so much so as to be almost classed as "white" or free from colour. It will be understood, of course, that sodium bisulphite in normal proportions is used in this process also, and the expedient is only practised because of the market demand for the palest possible standard of sole-crepe rubber.

Method for Fractionating and Bleaching.

(a) Collect the field latex, sieve and reduce it to a dry rubber content of 2½ lb. per gallon.

(b) Dissolve 1¼ lb. sodium bisulphite in 6 gallons of water and add the solution to 100 gallons of the standardised latex with thorough stirring.

(c) Add 4½ oz. acetic acid dissolved in 3 gallons of water per 100 gallons of latex and again stir well. Acetic acid is preferred to formic acid for the first stage since the latter is more fierce in its action. Formic acid may, however, be used at the rate of 2¾ oz. dissolved in 4 gallons of water per 100 gallons of latex.

(d) After some hours a yellow clot will form in the latex. This must be carefully removed and set aside for machining into yellow crepe.

(e) Strain the residual latex through a 60 mesh sieve to remove any small yellow clots and coagulate with either 19 oz. acetic acid or 11 oz. formic acid.

(f) Machine the coagula in the usual way. The resultant crepe should be very white.

Air bubbles in sheet rubber is a common defect resulting from errors in coagulation which are listed below, and care should be taken to avoid them:-

1. Insufficient dilution of acid with water. Unless a correctly diluted solution of acid is used, a complete mixing of the acid and latex will not be effected, coagulation will be local and extremely rapid and the bubbles of gas or air produced by the fermentation are unable to escape from the solidifying mass of rubber. Coagulation is most rapid when pure acid is used and slowest where the acid is most diluted. It should be noted that the quicker the coagulation, the greater the number of air bubbles enclosed.

2. The use of too rich a latex. This cannot occur when care is taken to standardise the dry rubber content in all latices.

3. The use of too much acid resulting in very rapid coagulation.

4. The other extreme of too little acid which results in indifferent coagulation resulting in slow continuation of decomposition of the protein constituents of the latex even up to the drying stage.

5. Allowing the latex to stand too long before adding the coagulant whereby a process of putrification sets in which liberates certain gases and these will form bubbles in the finished sheet.

6. Placing acid solution in the bottom of the vessel before pouring in the latex — the solution should be added to the latex and the whole thoroughly mixed with a broad wooden paddle.

7. Acid solution being added to the latex in the dishes and not to the bulk. Insufficient stirring and irregularities in coagulation will result, as well as difficulty when it comes to drying the sheet.

8. Dirty coagulating pans or dishes. Imperfect coagulation may also produce a resinous appearance in sheet rubber. A simple method of judging whether coagulation has been satisfactory is by inspecting the fluid or liquor which remains in the jar or dish over and above the mass of coagulum. This may be clear, turbid, or milky in appearance, but should balance more or less between the two extremes. When almost clear, it may be adjudged that an unnecessary amount of acid is being used. When too milky it shows that certain protein constituents of the latex are escaping and the acid has not been sufficient. Coagulation overnight is recommended both with sheet and crepe. Thus latex bulked at 12 noon will be manufactured at 6 a. m. next morning, having had 18 hours for coagulation. This slow coagulation is advisable, both from the point of view of economy in acid and also because it gives scope for regulating the working hours of the factory.

Air bubbles are also said to form in latex from trees that have recently wintered. When the latex assumes the appearance of curded milk, it indicates that the acid has not been properly mixed or has been too strong. If on the other hand, the liquor left after coagulation is not clear and there is a disagreeable odour it shows that the acid was not strong enough or has not been well stirred. The lower surface of the sheet will have a spongy and pitted appearance and the mass of coagulum will stick to the dish and lead to a badly shaped and distorted sheet. Insufficient stirring of acid will sometimes cause the edges of the sheet to show a bluish tinge.

Coagulating Dishes. It may be mentioned here that badly shaped dishes are inclined to give thick edges to the sheets, and this irregularity leads to difficulty in drying. Placing the dishes on an uneven table surface will also have a similar effect. The best tables for coagulating purposes are of light iron frame work with grooves for the dishes. They take up less room than wooden ones, are easier to keep clean and remain perfectly level, whereas wood is inclined to warp.

Care must be taken to pour exactly the same amount of latex into each dish or the result will be unevenness in size and thickness, and the thickness of the sheet considerably controls the final colour and appearance of the rubber. The best size of dish is about 16″ x 11½″ x 3″. After the coagulum has been poured into the dishes, the scum and froth must be removed. Skimmings will give a streaked light coloured crepe and can be graded with that from washings and lump rubber.

Bulking and Coagulating Troughs. Troughs are a more economical arrangement for coagulation of latex than jars or pans and may be built of plain stone or brick masonry with glazed white tiles to line the interiors. Timber lids cover the troughs and to the lids division boards are securely fastened to give the exact quantity of coagulated latex best suited for working conditions. The combination of lids with division boards prevent the latter becoming distorted and offers a simple method of varying the thickness of the slab of coagulum as the division boards are only fastened to the lids by means of screws and they can be easily altered to give any required spacing.

TABLE FOR

	Gals. of diluted Latex	50			60			70			80			90		
	Dry Rubber content. lbs. per gall.	1¼	1½	2	1¼	1½	2	1¼	1½	2	1¼	1½	2	1¼	1½	2
If sheet is to be made the Following day	Ozs. Acetic	5½	7	9	7	8	11	8	9½	12½	9	11	14½	10	12	16
	Gals. Water	3½	4	5½	4	5	6½	5	6	7½	5½	6½	9	6	7½	10
	Ozs. Formic	3½	4	5½	4	5	6½	5	6	7½	5½	6½	8½	6	7½	9½
	Gals. Water	2	2½	3½	2½	3	4	3	3½	4½	3½	4	5½	3½	4½	6
If sheet is to be made the Same day	Ozs. Acetic	6½	8	10½	8	9½	12½	9	11	14½	10½	12½	16½	11½	14	18½
	Gals. Water	2	2½	3	2½	3	4	3	3½	4½	3	4	5	3½	4½	6
	Ozs. Formic	4	5	6½	5	6	7½	5½	6½	9	6½	7½	10	7	8½	11
	Gals. Water	1	1½	2	1½	1½	2½	1½	2	2½	2	2½	3	2	2½	3½

Intermediate volumes of latex can be allowed for by addition or
AND MUST BE TAKEN AS A MAXIMUM.

LATEX COAGULATION

100			110			120			130			140			150		
1¼	1½	2	1¼	1½	2	1¼	1½	2	1¼	1½	2	1¼	1½	2	1¼	1½	2
11	13½	17½	12½	15	19½	13½	16	21½	14½	17½	23	15½	19	25	17	20	27
7	8½	11	7½	9	12	8½	10	13½	9	11	14½	9½	11½	15½	10½	12½	16½
7	8	11	7½	9	12	8	10	13	9	10½	14	9½	11½	15	10	12	16
4	5	6½	4½	5½	7½	5	6	8	5½	6½	8½	6	7	9½	6	7½	10
13	15½	20½	14½	17½	23	15½	19	25	17	20	27	18	22	29	19½	23½	31
4	5	6½	4½	5½	7	5	6	7½	5	6½	8½	5½	7	9	6	7	9½
8	9½	12½	8½	10½	14	9½	11½	15	10	12½	16½	11	13	17½	12	14	18½
2½	3	4	3	3	4	3	3½	4½	3	4	5	3½	4	5½	3½	4½	6

subtraction. The above figures are the basis for estate work

CHAPTER XVII

PREPARATION OF SHEET RUBBER.

It will be of interest to record that the first form in which plantation rubber was produced was in sheets or "biscuits", and this form remained popular for some years. The sheets manufactured in the early years of plantation history were dark in colour owing to natural oxidation. The results of experiment showed that by diluting the latex, the degree of oxidation was diminished, and later it was discovered that if the soft coagulum was placed in almost boiling water for a short time, the resulting rubber was pale. Thus there arose a gradual demand for pale sheet. Such pale sheets were not in any way superior to the darker variety, but in most cases were inferior. It was also found that sheet rubber on air-drying became covered with external surface moulds and the smell of the drying rubber was most unpleasant. Even when dry, the sheets had to be continually brushed free from moulds, and by the time the rubber reached the market, it became mouldy again. For these reasons, the manufacture of pale sheets gradually lost favour.

The preliminary treatment of latex for sheet manufacture has already been discussed in chapter XV, and does not require repetition.

Uniformity of Product through Standardisation. Operations of receiving, straining and standardising the latex to a uniform dry rubber content by dilution and methods of coagulation have been treated in the earlier pages and there will be no need to elaborate on them further in this chapter. For practical purposes whether sheets are prepared in tanks or dishes, it is usual to standardise for sheet to 1½ or 1¼ lbs. dry rubber per gallon. If dishes are used, the optimum size as mentioned in the previous chapter is 16″ x 11½″ x 3″. Modern installations of coagulating tanks for sheet rubber made of aluminium are becoming popular as tanks constructed of brick and cement and faced with glazed tiles have inherent drawbacks. The glazed tiles, unless extremely well laid, allow the acid serum from which the rubber is removed to percolate between the interstices. Thus "pockets" of liquid collect beneath the tiles, and in process of decomposition of certain constituents dissolved in the serum, disagreeable gases are set free.

The standard of 1½ lbs. dry rubber per gallon latex has a direct connection with the distance between the partitions, or between the slots, in sheet coagulating tanks. Dishes of the aforementioned size have a capacity of roughly 1 gallon latex standardised to 1½ lbs. dry rubber content. Greater dilution brings with it a number of difficulties such as thin sheets of poor quality which when wet will be soft and porous and will roll too thin, and in drying is apt to stretch and assume irregular shape.

Skimming. The mixing of latex or its gravitation from the reception vessels in which standardising of the latex by dilution with water is effected results in considerable amount of surface froth. This is best removed by means of a thin board of a width slightly less than the breadth of the tank or dishes. The skimmings are sometimes placed in pans and later made into a second grade of sheet rubber, or they receive treatment with a small proportion of sodium bisulphite and eventually appear as fine pale crepe.

On some estates a great deal of the frothing is avoided by placing in position at the receiving end of the tank a perforated partition of zinc or aluminium carrying 10 circular holes to the inch. Through this the latex percolates, while the froth is retained on a small area. The froth is removed prior to the addition of the acid. After stirring in the acid solution, the surface is again skimmed, and if the stirring has been properly performed, there should be little froth which can easily be removed.

Rolling and Marking of Sheet Rubber. In past years manufacture of plain sheet, without any markings, was in vogue and this practice has gradually given place to the preparation of ribbed sheet which has a pattern marked on surface. The object in ribbing or marking the sheets is to accelerate drying, and also to prevent adhesion in packing and to give the sheets a good appearance.

When coagulum leaves the dish, where dishes are used, it is about 1½ inches thick, which will roll down to a sheet about 1/8″ thick and about 18″ x 12″ in size and this will permit of two sheets being placed side by side in a chest 18″ x 24″ when packing.

For reasons of practical economy in factory working, it is usual to allow sheet rubber to remain overnight, and the coagulum receives attention early next morning. During the interval averaging about 18 hours, the coagulum consolidates, leaving an almost clear serum if the correct quantity of acid has been added to the latex. Any but the very slightest milkiness in the serum indicates an insufficiency of coagulant. If the serum is always definitely clear, there may be grounds for believing that an excess is being used. If the coagulant has been calculated to an average nicety, the serum should have just a trace of milkiness.

The firmness gained by the coagulum on standing in the serum overnight should enable it to be handled the following morning without any marked stretching. Some estates prefer to handle the coagulum while it is softer on the same day as it is claimed that :-

(a) the coagulum is easier to work, and sheets of improved appearance can be made

(b) there is greater freedom from "bubbles"

(c) the incidence of "rust" is lessened.

The above claims are substantiated in practice. The practice of working soft coagulum is carried out in a large number of estates where it is possible to arrange for the latex to reach the factory early in the day, say, before noon. Three hours are allowed for coagulation, and the working of the rubber is then commenced. As a general rule this means that the operations of rolling and marking must be done, and the rubber placed in the smoke-house before night falls, as a rule about 6–30 p. m.

When the coagulated sheets are taken from the dishes they should be kneaded by hand before passing through the sheeting mills. This operation consolidates them and squeezes out a considerable amount of water. Various types of machines for sheet rubber are in use, both hand and power driven, but all work more or less upon the same principle. The sheets are passed 3 to 4 times through a machine with smooth rolls the space between the rolls being slightly decreased each time. This alteration in distance is worked by means of gears and an indication dial at the side of the machine. After passing through the smooth rolls, the sheets should be washed and then put once through a machine with marking rolls. This operation must be done fairly slowly in order to impress the pattern thoroughly, though if done too slowly the rubber is apt to be cut.

The width of the rollers should be about 24 inches. This permits the sheets to be made to the full width of the packing chests (18½ inches for a plywood chest). If necessary the sheets may be put once through the machine sideways in order to increase the width.

When large crops are being handled it is very desirable to install a proper battery of rollers, the spacing of each being set and the sheets passed from one machine to another for successive rollings. Only light machinery is required for sheet making and while hand operated machines will suffice in estates of small size, in dealing with large crops power driven machinery is desirable. The rolls in each machine for sheeting rollers (6″ diameter) should not exceed 30 revolutions per minute. If driven too rapidly, any inequalities in the coagulum are likely to produce ridges in the finished rubber. The permissible speed for marking rolls is 25 revolutions per minute.

Before using the machines, a sheet of lower grade rubber should always be run through the rolls several times to clean away any rust. Power driven machines with smooth rolls will each give an output of 100 sheets per hour, and hand worked machines about 50. The labour required for a machine with smooth rolls worked by hand will be 3 coolies, marking rolls 2 coolies. When power driven, smooth rolls require 2 coolies, grooved roller 1 cooly. Some machines are fitted with an arrangement for spraying the sheets with water while being rolled, but when the spray is not supplied the sheets should be well washed with clean running water after leaving the machines and then hung upon wooden racks to allow the water to drain off thoroughly before removal to the smoke-house, as a precaution against " rust ".

Marking. Heavy machines are unnecessary for the purpose of putting a pattern on sheet rubber. If the rubber has been properly prepared, a light pair of rolls is capable of exerting sufficient pressure to cause a good well impressed pattern. Rolls are cut in various designs; some with "diamond" grooves on both rolls; some with grooves of varying width and depth encircling the cirumference of the rolls, thus creating a "stripe" effect on the rubber; and some with diagonally cut spiral grooves placed closely together. The choice of a design is an arbitrary matter and should depend upon the effect produced on the rate of drying and the general appearance. Many estates have a particular "brand" or their name cut in the middle of the rolls for purposes of identification. If this is done it is advisable to have the main grooving of the rolls carried into the "branding" strip; otherwise grip will be lacking on this portion and a certain amount of "cockling" of the sheets will result.

The causes of faint ribbing or marking are usually:-

(a) Over-rolling with smooth rolls.

(b) Running the marking rolls too fast

(c) Setting of marking rolls too far apart

(d) Use of too rich a latex which renders the sheet unimpressionable.

(e) Delay between smooth and ribbed rolling which allows the rubber to harden.

Washing and Draining of the Sheets. After rolling is completed, the sheets should be thoroughly washed as stated earlier for at least half an hour in running water. A shorter period is permissible only if the rollers are fitted with water sprays. Each sheet should be placed in the washing tank separately because if a pile of sheets were to be placed in the tank, the sheets in the middle of the pile do not come into contact with the water.

The sheets should then be carried immediately to racks on which they are hung to drip. Generally these racks are situated under cover, but there is every reason why they should be placed in the open air without cover or shade. From continued experience of this practice over a period of years it is found advantageous and to be preferred to the usual method of allowing sheets to drip under cover.

Prevention of " Rust " in Sheet Rubber. When the surface drying of the sheets is too slow, a brownish deposit, commonly described as "rust" occurs on the surface of the sheet. Sometimes the defect is not apparent until the sheet is stretched or scratched. After rolling it is advisable that the sheets should be hung in an airy place to drain for an hour or two and then removed without delay to the smoke-house. In factories in which rolling is carried out late in the afternoon sheets should not be left to drain overnight before being placed in the smoke- house.

Ventilation of the smoke-house is very important. It is not sufficient to allow smoke to filter out through the roof. Definite ventilation should be provided to ensure a good upward draught through the smoke-house; otherwise moisture is not removed. A badly ventilated smoke-house provides a warm damp atmosphere which is very favourable for development of " rust ".

It is shown that "rust" develops less rapidly on sheets rolled the same afternoon. However, in most factories this is not convenient and "rust" can readily be avoided on sheets rolled next morning.

Washing sheets after rolling does not help to prevent "rust" though it is however, very useful for prevention of "mould", and is recommended for that purpose as it does not make sheets more liable to "rust". As "rust" is due to the action of mirco-organisms, it is desirable to reduce the amount of infection with "rust" organisms as far as possible by keeping coagulating pans, jars, tanks and tables thoroughly clean. Wooden untensils should be washed with hot water of above 120°F temperature every few days, as dirty utensils aggravate the formation of "rust"

Use of Para-Nitrophenol. "Rust" and mould in smoked sheet can be prevented by treating the rubber with para-nitrophenol. Freshly machined sheet after being washed thoroughly should be passed through a solution containing 1 lb para-nitrophenol to 100 gallons of water and allowed to soak for ½ to 1 hour. They should then be hung to drip and transferred to the smoke-house.

Smoking of Rubber. The final curing and drying of sheet rubber is effected by a process of smoking. The primary purpose of smoke curing is to dry the sheet efficiently and the second object of smoking is to render the sheet resistant to mould.

Action of smoke. It has been shown by experiment that sheet smoked with "uncombusted" smoke is more resistant to mould than sheet smoked with "combusted" smoke. In general, an open fire at floor level tends to give "combusted" smoke whereas a fire in a deep hole in the floor gives a higher proportion of "uncombusted" smoke. In the process of drying, the sheet rubber absorbs the creosotic and other antiseptic substances from the smoke which prevent or retard development of moulds or other micro-organisms. The presence of the smoke also enables drying to be carried out at a higher temperature than would otherwise be the case.

The antiseptic value of the smoke depends on the way the wood is burnt. A brightly burning fire produces a light pungent smoke deficient in antiseptic, whereas a smouldering fire produces a smoke with a high disinfectant value.

Ventilation of Smoke-House. In order to carry away the moisture in the wet sheets as quickly as possible, efficient ventilation should be provided within the smoke-house. It should be realized that each wet sheet placed in a smoke-house contains approximately ½ lb. of water and that at a temperature of 120° F this requires at least 65 cubic feet of dry air for its removal, and therefore the tendency to imprison smoke in the smoke-houses should be avoided. In a smoke-house containing 3000 sheets a minimum flow of air of 20,000 cubic feet per day is required if the sheets are to be dried in 10 days. This figure is based on the assumption that the air is dry when it enters and completely saturated with moisture when it leaves the smoke-house. In actual practice the flow of air required would be more than double this figure.

There should be ventilation both at the top and bottom of the smoke-house in order to obtain an upward draught. Either the top or bottom ventilators should be capable of being adjusted. Badly fitting doors and windows should be avoided to prevent cross currents interfering with the upward draught. In arranging ventilation, the object should be to obtain a uniform draught throughout the smoke-house. For example if heat is provided by means of a centrally placed fire, the top ventilation holes should be placed near the ends of the smoke-house, and bottom ventilation holes should be distributed round the walls. The best top ventilation is probably provided by a ridged roof running the full length of the building. A baffle plate should be suspended over the fire to assist in distributing the smoke.

Temperature for Smoke-curing. The quality of the smoke will be affected by its temperature, which should not be higher than 120° F., otherwise the smoke will become too dry to penetrate thoroughly. It is important that the smoke and heat be evenly distributed and this is secured by the arrangement of a two storey house. The fire should only smoulder and not be permitted to burst into flame. Too rapid firing or too high a temperature will create bubbles caused by the moisture in the rubber being converted into vapour which is unable to escape through the partially dried surface of the sheet.

When to Fire. It is better that the smoking of the fires be done at night when the atmosphere contains most moisture. During the day the sun accelerates drying and the smoke-house can be entered with comfort in order to examine and sort the sheets.

Spacing of Sheets in the Smoke House. The average size of a 1½ lb. sheet is approximately 24 inches by 15 inches. The reapers on which the sheets are hung should be of round section and ¾ to 1 inch in diameter. They should be spaced 4 inches apart from centre to centre. The vertical distance between tiers of reapers should be 18 inches to permit of sheets being moved about in order to avoid "reaper marks", and also to facilitate turning the sheets over. For each sheet about 17 to 18 inches of reaper should be allowed in order to avoid the possibility of the edges of sheets overlapping. The spacing recommended would prove a real economy by reducing the time of drying, and improving the appearance of the sheets by making it easier for the sheets to be turned over regularly.

Adequate means of lighting the smoke-house by means of shutter windows should be provided, so that the work of turning over and moving the sheets on the reapers can be carried out efficiently. From observations it is known that in the semi-darkness of many smoke-houses this work cannot be properly carried out and accounts for many complaints of reaper marks, uneven smoking and rust.

Fuels for Smoking. Empty racks and reapers should be thoroughly cleaned at every opportunity before placing the wet rubber on them, and the space below each layer of racks should be closed in by fine mesh gauze to prevent soot and ashes rising amongst the rubber.

It is important that the fuel used for firing should be as dry as possible. Wet fuel will give a damp and shiny surface to the rubber. Fuel containing oil, such as coconut husks or rubber seed is also to be avoided in excess. The smoke given out by the fires should be clear blue and not a heavy yellow fudge. Thinned out rubber trees may be used as fuel in conjunction with dead wood, but they must be thoroughly dried first.

Period of Drying. The period of drying depends a good deal upon the thickness of the sheets as determined by the rolling and hardness as determined by the standardisation. It will also be affected by the weather, by the fuel used and by the frequency with which sheets are turned, and to a considerable extent on the ventilation provided in the smoke house and the temperature used for drying.

With satisfactory conditions drying should be completed in from 7 to 10 days. If space is available it is advisable to keep the sheets in the smoke-house a little longer than the actul time required for drying, though care must be taken not to over smoke or the sheets will be too dark and will collect a sooty deposit. On the other hand if the sheets are under-smoked they will be palish and light in colour and collect moulds.

It must be noted that the thinner the sheets, the quicker the rate of drying; the better the sheet has been rolled, the shorter the period of drying; the higher the temperature, the more rapid the drying. The condition of the sheets after rolling depends primarily upon the standard of dilution of the latex and the original thickness of the coagulum. If these factors are correctly controlled, the rolling should give a sheet which is fairly soft and porous i. e., it should not have been subjected to such pressure as to make it both thin and hard. An average sheet of rubber which has been well rolled should be smoke-dried at a temperature of 120°F in about 10 days. If sheets take appreciably longer to dry, then the cause may well be traced to one of the following factors :—

(1) Relative thickness of rubber

(2) Extent and quality of rolling

(3) Temperature of drying

(4) Humidity of fuel used

(5) Lack of adequate ventilation in the smoke-house.

On the other hand, it is often found that thin sheets made from very dilute latex dry so quickly that they are considered to be fully smoke-cured in from five to seven days. It frequently happens in such cases, however, that the smoking is insufficient, and by the time the rubber reaches the market it has begun to show signs of surface moulds. In such a case, the duration of curing has been insufficient or the quality of the smoking is at fault.

CHAPTER XVIII

DEFECTS IN SHEET RUBBER

In this chapter we shall consider the faults which invariably occur in the preparatory stages in the manufacture of sheet rubber before dealing with the defects of the finished product.

Milky liquor or serum. After coagulation of the latex has been completed within the ordinary period allowed, if the liquid residue is not clear and remains milky, it indicates one of the following possible causes:-

(i) Inadequate stirring of latex and coagulant.

(ii) Inadequate acid solution. This may be real or may be indirectly due to the presence of an excess of anti-coagulant such as sodium sulphite or formalin.

(iii) Unsuitability of coagulant in case acetic or formic acids have not been employed.

Coloured Surface Blotches and Unpleasant Odour. Some times the surface of the coagulum exhibits yellowish or bluish streaks and patches. It will be found generally that the yellowish colour is possessed by a slimy substance, of disagreeable odour, which may be scraped from the surface. This indicates that either insufficient acid has been used, or the mixing of latex and coagulant has been at fault.

Dark Discoloration of the Rubber. This may be stated to be a natural process when fresh rubber is exposed to the atmosphere. It is usually described as "oxidation", and it will be noted to be absent, or to occur to a less degree on those portions of the rubber which are protected from the atmosphere by being below the surface of the remaining liquid after coagulation. This surface oxidation may be prevented by the use of small quantities of sodium sulphite or sodium bisulphite. The former is to be preferred.

Soft Coagulum, Spongy Under-surface, Tearing of Coagulum: If the whole mass of coagulum appears to be complete, over-dilution of the latex has occurred. This may apply also to the case in which the under-surface only is spongy and soft. If coagulating tanks are employed, the upper edge may be comparatively hard, while the lower is soft and weak. Often the spongy portion may adhere to the partitions. This prevents the natural rise of the coagulum, due to retraction, as the mass "sets". The pull between the free upper portion and the adhering lower edge causes splitting and tearing of the coagulum, with marked porosity and spongy appearance.

The two factors to receive attention are the standard of dilution and the condition of the surfaces of the partitions. If these have minute cracks into which latex can penetrate, and in which coagulation takes place, the boards should be discarded. Given the conditions indicated above, the tearing and splitting of rubber in coagulating tanks is sometimes augmented by the practice of flooding the tanks when coagulation is judged to be complete. The surface water finds its way downwards between strips of coagulum and the partitions, thus increasing the upward tension between the free and adhering portions. The main idea governing the practice of flooding the tanks is to prevent "oxidation" or darkening of the upper edges. If a small quantity of sodium sulphite is employed as an anti-oxidant and to retard coagulation it is not necessary to flood tanks.

"Pitting" of Surfaces. In pan coagulation this "pitted", appearance is usually limited to the under-surface, while coagulum prepared in tanks may exhibit the defect on both faces. The existence of these numerous small depressions or "pits" points to the presence of bubbles of gas which have been unable to escape freely. As the formation and retention of gas bubbles is not a normal occurrence in coagulation, we are led to infer that some special conditions must have arisen. These may be supplied by one or more of the following contributory causes:

(1) The latex had begun to "sour" before arrival at the factory or while waiting to be treated. This premature coagulation is usually checked or diminished by the employment of anti-coagulants. It is generally accompanied by the appearance of enclosed gas-bubbles in the dry rubber.

(2) There may have been a slight insufficiency of coagulant, or the admixture was not thorough, thus allowing a slow putrefactive change to take place in the incompletely coagulated areas.

(3) The wooden partitions may not have been effectively cleansed. The existence of a thin slime, of bactererial origin, is sometimes noted. This is accountable for putrefactive effects in the surfaces of the coagulum, or in the serum, giving rise to the formation of gases. If these cannot escape freely, by reason of adhesion between the coagulum and the partitions, "pitting" occurs.

Thickened Ends or Edges after Rolling. As a rule these defects may be ascribed to the employment of too rich a latex, or faulty manipulation. Even if the standard of dilution should be correct it sometimes happens that, in the preliminary rolling of a long strip of rubber, coolies begin in the middle, rolling with a forward pressure and tension towards the ends of the strip. This is generally not so much the fault of the coolie as being due to the lack of proper facilities for preliminary rolling. The table should be about 3 feet in height, so that ease of working is obtained merely by natural pressure due to the position in which the worker stands. The use of a heavy wooden roller would contribute towards this result, inasmuch as it obviates the use of force, and the pressure is almost entirely in a vertical direction.

Mis-shapen Sheets. It is sometimes noted that sheets may be wider and thicker at the ends than in the middle. Manipulation alone, as indicated above, is not solely responsible.

The primary cause is to be traced to over-dilution of latex, giving a very soft coagulum which responds too readily to tension and pressure. Faulty treatment in rolling exaggerates the tendency for the strip or sheets to become narrow and thin in the middle, wider and thicker at the ends.

Thickened Patches, Torn Sheets "Dog-ears", Creases. All of these elementary defects are due to careless working. While occasional errors cannot be avoided there is no real excuse for the continuance of trouble to any degree, under average supervision.

Thickened patches are often caused in conjunction with torn sheets, and the trouble may be ascribed to faulty practice in allowing too heavy a pile of wet strips to accumulate before machining; or a comparatively small pile may have been transported some distance. It is difficult to separate the strip, and occasionally the separation is only effected at the expense of two sheets, one of which is torn and the other has a portion of the first strip adhering to it.

"Dog-ears" due to the folding over of corners and the sheets, and creases due the rumpling of the coagulum, are generally the result of haste and lack of average care. Machine coolies, more often than not, will not be at any pains to straighten out folds before passing the coagulum through the rolls.

Greasiness before Smoking. Under ordinary methods of working this should never be encountered. It may be taken to show that the machined rubber has been allowed to remain, either hanging or in piles, far too long before entering the smoke-house. The appearance is most marked if the rubber has remained in a cool and moist atmosphere, for example, if it has been hanging overnight in a closed and badly ventilated factory. In a marked degree this is to be observed in the preparation of air-dried sheets, unless they are exposed, when freshly prepared, to the action of the sun for a period. In the preparation of smoked sheet, the greasy appearance and the cause outlined contribute to a defect which is eventually described as "stretching, rusty".

Surface Blemishes. The coagulum, during coagulation and subsequently, can be contaminated in various ways. In most cases a little extra care would prevent the occurrence of these defects. When the coagulum remains overnight, in the absence of a cover, it is not uncommon to note the presence of dirt from the roof above, or blown in from the outside, the droppings of mice and rats, flies and small insects. In theory these should be seen and removed by the workers. In practice, except while under close supervision, the extraneous matter is often rolled into the soft coagulum.

A fairly common case of this surface contamination is the exhaust from the power unit of the smoke house. Grit and other particles continually find their way into the factory, alighting on the tables, in the latex, in the water, and on the freshly prepared rubber. They are rolled into the soft rubber and lead to marked depreciation in the selling value. The radical remedy seems obvious, but is often beset with many difficulties not unconnected with financial considerations. Other superficial blemishes, such as those due to the presence of rust marks, oil or grease patches etc., are self explanatory, if a little thought is brought to bear upon them.

DEFECTS IN THE DRY RUBBER

Having now dealt with certain defects which are visible in wet rubber we come to the discussion of others which are only perceptible either during or after the drying period.

Unevenness of Appearance This lack of uniformity may refer either to size or colour or to both. Apart from any other contributory causes, this variation is due to a neglect to standardise the dilution of all latices, or to lack of uniformity in the quantity of standardised latex placed in each receptacle.

Where tanks are employed, all sheets from the same tank should be of the same size before rolling and any subsequent disparity in thickness and length must be attributed to some alteration in the width of the gap between the rolls of the machines. Unless all latices are standardised by means of an instrument it is of course probable that the content of one tank may be found to differ from that of another.

In a general sense a thin strip will dry more quickly than a thick one, and should be paler in colour when viewed by transmitted light— i.e., when the rubber is held between the eye and the source of light. It is necessary therefore to guard against the possibility of variations in thickness caused by faulty manipulation. The distance between the squeezing (smooth) rolls and between the marking (patterned) rolls should be adjusted and should remain set until the conclusion of work. In a factory having nothing beyond average requirements in equipment of machines it should not be necessary to have to interrupt the work of the smooth rolls or marking rolls by having to make adjustments. This is, however, inevitable if there is only one smooth-roll machine, as it is always desirable to reduce the thickness of the coagulum by at least two stages through even-speed smooth rolls. In some factories there are three light power-driven smooth-roll machines, the gaps between pairs of rolls being set so as to obtain a gradual thinning effect upon the fresh coagulum, which is then passed once between patterned rolls. With such equipment it is found possible, in some cases, to omit the preliminary hand-rolling, and the strips of coagulum from the tank are passed direct through rolls set with a wide gap. This work demands much care, as it is necessary to avoid any distortion of the coagulum which may be caused by its own weight and length.

Variation due to Oxidation The subject of oxidation has been mentioned already and it will be known that oxidation is a natural process and it could be prevented by the judicious use of anti-oxidants such as the sulphite or bisulphite of soda. In earlier days it was sometimes prevented by steeping the thin rubber in very hot water. In the absence of an anti-oxidant the degree of oxidation may vary daily and in different batches of latex on any one day, so that there is always the possibility of a lack of uniformity due to oxidation effects. This darkening of the surface would be masked by the colour induced by the smoke-drying process but will be evident upon closer scrutiny. To obviate this variation anti-oxidants are used on most estates, but the accidental or misinformed abuse of these chemicals may lead to further lack of uniformity. Hence it is necessary to follow carefully the formulae prescribed by experience.

Colour of Smoked sheets. It may be of interest to note that the effect known as oxidation is attributed to the presence of micro-organisms called enzymes or ferments in the latex. It can also be produced artificially in various ways e. g., by the use of the crude product of wood distillation (pyroligneous acid) as a coagulant, or by the addition to the latex of small quantities of a phenol such as carbolic acid. *It is thus possible to prepare in sheet form a rubber which has the appearance of having been smoke-cured, although it may never have been in a smoke-house.*

It will be clear, therefore, that apart from other causes, the colour of the cured sheets may be influenced by oxidation of the fresh coagulation, and by the constituents of the smoke. It follows that the smoke from timbers which are richer than others in certain chemical bodies set free by combustion will produce a rubber darker in colour.

There is thus no real connection between colour and period of cure, although in a general sense the longer the interval the darker is the colour. Similarly it is now plain that when anti-oxidants are employed in excess the paleness of the rubber is in no degree truly indicative of the period during which the rubber has been smoke-cured.

The influence of the effect of the physical condition of the wet rubber upon the final colour must be thoroughly grasped One may take two sheets of apparently the same thickness, and smoke-cure them in juxtaposition within the same house, only to find that one dries much more rapidly than the other. As a consequence, the first, when fully cured. will be of a medium golden brown colour, while the other, owing to protracted smoking, will be dark. Evidently there most be some distinct difference between the two in physical condition prior to the smoking. Here the factor involved is the rubber-content of the latex. Given two pieces of coagulum of identical thickness, but prepared from latices of different dry rubber content, it will be obvious that to reduce them to similar thickness, more pressure will be necessary in one case — i.e., that piece of coagulum will be much more dense and more consolidated while the other will be comparatively soft and porous. Into the latter warm smoke can penetrate much more easily, and the internal moisture can escape more rapidly. The full cure may be made, say, within 12 days, while the thicker and more consolidated sheet may demand up to 20 days.

To attain uniformity in colour, therefore, the following points must be studied and controlled as far as is possible:

1. Uniform dilution of all latices.
2. Uniform dimensions of coagulating receptacles.
3. Uniform volumes of standardised latex.
4. Uniform quality and quantities of chemicals.
5. Uniform methods of manipulating the coagulum.
6. Uniform conditions of fuel and accommodation during smoke-curing.

Surface Gloss. In the choice of fuel there is room for control if one has good timber available. This point opens up a discussion on the vexed question of "over-smoking" as the term is sometimes applied to a pronounced dry glossy appearance of the surface of sheets. Three main factors are involved:—

(a) The nature of the fuel.
(b) The ratio between furnace capacity and the capacity of the smoke-house.
(c) The rate of combustion.

Obviously any fuel which yields an excessive quantity of tarry matter or creosotic substance would conduce to the formation of a heavy glaze on the rubber. Such fuel, therefore, should at most only be employed as the smaller portion in a mixture with "dead" timber.

It is impossible to lay down any general rules for the guidance of estates, as the timber available varies so widely in nature. Experience must be the only guide, and it should not be difficult to obviate the defect. Even so, there must be minor differences between the results obtained on estates, so that it is not possible to make strict estimations of the smoke-curing period by an examination of the surface appearance of rubber, even under the best of conditions. Some estates find that the rubber has a distinct gloss in ten days, while others may smoke-cure for twice that period without difficulty. Evidently, therefore, the question of available fuel is of prime importance. It may be remarked that very satisfactory results are always obtained from the use of fairly dry timber obtained from thinned rubber trees, mixed with the "dead" timber obtained from thinned rubbers, or mixed with the "dead" timber of old logs and stumps found on the estates.

Again, if a smoke-house has a superabundance of furnaces, producing more heat and smoke than is required, glazing will result. The point is tested by the average temperature maintained and the average rate of drying. The result of a high temperature would be the possibility of volatile tarry matter being driven in excess to the upper chamber. That this effect is eventually produced even at optimal temperatures is evident from an examination of the woodwork within the upper room.

It is clear, also that the rate of combustion exerts an influence. In a general sense a rapid consumption of fuel would augment the quantity of tarry matter passing into the upper chamber over any given period, and the possibility of glazing would be increased.

On the other hand, it is possible that a surface glaze might be formed if the temperatures were uniformly too low, especially if the rubber were rather thick. The rate of drying would be so slow, that if a timber rich in tarry matter were employed, the rubber might be exceedingly glossy. In order to guard against the appearance of heavy glaze, the following points must be observed :—

1. The fuel must be carefully selected by experience.
2. The sheets must not be thick. No sheets should be thicker than 1/8 inch measured in average section across the ribs.
3. The temperature must not be too high. An average working temperature of 120° to 125° F. should be ample.
4. If the sheets are fairly thick, a low average temperature should be avoided. No lower average than 110°F should be permitted.

Dull Black Surface. This is the opposite of the previous case, and generally is accompanied by a fairly heavy darkening of the surface due to " oxidation " effects. The fuel used is too "dead", and needs the addition of some substance containing a fair amount of creosotic matter. The appearance of the rubber does not justify the assumption that it has been over smoked. As a matter of fact, this type of rubber often becomes affected by mildew fairly rapidly, thus showing that the smoking has been inefficient.

It may happen that an estate is in the habit of using a fuel which gives even to a thin sheet a heavy glaze in a comparatively brief period. The general custom is to soak such sheets in cold water, and then to scrub the surfaces, sometimes using soap, in order to cleanse the rubber and free it from the glaze. This operation may be done too well, in which case the rubber will have a dull appearance, and may be rather more liable to develop surface mildew after a time.

Moist Glaze, Greasiness of Surface. This describes the condition of sheet rubber when taken from the smoke-house.

Sometimes the greasiness does not develop until the rubber has been out of the smoke-house for a day or two. This can be traced to two causes :—

(a) The use of an excess of Sodium bisulphite or sodium sulphite. The use of sodium bisulphite is not recommended generally for sheet making. It may cause the rubber to be too pale in colour, and the abuse of it may delay the drying unduly. In the latter case, a trace of the salt may remain within the rubber or upon the surface. If so, as the substance remaining is fairly hygroscopic, it will take up moisture from the atmosphere and cause the surface of the sheets to have a moist and shiny appearance. The moist surface deposit comes away upon the hand when the sheets are touched, and is difficult to remove entirely. On some estates a very small quantity of the bisulphite is employed, as it is found to be of service in the prevention of bubbles, but in unskilled hands the method is open to abuse, and is, therefore, not recommended for general use.

A large number of estates use sodium sulphite in very small quantities as an anti-coagulant and preservative for latex in the field. The abuse of this very useful substance carries its own penalty. The substance is hygroscopic; and if an excess is present the drying period will be protracted, and the sheets will have a very moist surface film.

It may be found sometimes that only some of the sheets are affected. This indicates that, whereas uniform quantities of a solution of sodium sulphite have been served out in all fields, the proportion may have been excessive in the case of fields giving a latex of comparatively low rubber content. What suits the latex from old trees may be excessive probably for the latex of younger trees. This is not an infallible rule, as in the case of older fields in which immature bark is being tapped, it is to be noted that the dry rubber content of latex may be less than that of latex obtained from younger trees.

This type of moist glaze is not easy to remove. Ordinary surface washing has but a temporary effect, and the trouble recurs. The only way of dealing with the difficulty is to soak the sheets for days in running water, or in successive changes of water, and to resmoke until the sheets are dry.

(b) The second type of moist glaze is not so difficult to deal with, and may be removed as a rule by washing the sheet when the rubber is otherwise apparently dry.

It appears to be mainly a matter of unsuitable fuel for smoking and of failure to provide adequate ventilation. A large number of estates have areas which are being systematically thinned out. The logs obtained from such areas are often used as fuel in the very green stage. The smoke thus generated must be moist, and if the building is entirely closed, the moisture must be deposited eventually upon the rubber and racks. Some estates have surmounted the difficulty by opening up the roof-ridge slightly so as to allow the moisture to escape with some of the smoke. But if the logs from rubber trees are to be used, they should be stacked in the sun for some time. Even then, preferably, they should not be used alone. A judicious admixture of dead and rotting jungle-timber appears to give very satisfactory results.

Virgin Spots and Patches. If the description really indicates the defect, it simply means that portions of the sheets are not dry. When cut they exhibit the typical whitish, opaque appearance described as "virgin". It is doubtful whether any rubber answering this description is put upon the market as No. 1 nowadays. But if it does occur, it points to gross negligence on the part of the packer. Sometimes what are taken to be small spots of " virgin " are really patches of tiny air or gas bubbles. The points can be easily determined by cutting through the patch and examining the cut edges.

Surface Moulds or Mildew. The following conditions are favourable to the growth of moulds and care should be taken to avoid them:

1. Storing sheets in a damp place before packing.
2. Packing sheets in wooden cases which are not thoroughly dry.
3. Piling up cases of rubber in a badly ventilated store-room.
4. Placing the cases on a cement floor.
5. Wetting of cases by sea-water or by rain during transport etc.

A Chemical Preventive for Mould and Rust. Para-nitrophenol can be used in two ways for prevention of mould and rust in smoked sheet:

(i) An appropriate quantity is added to the latex before coagulation, or alternatively is dissolved in the acid used for coagulation.

(ii) The sheets after rolling and washing are soaked in a dilute solution of the chemical.

The simplest method is obviously to add the disinfectant with the coagulant, but P. N. P. has a slight clotting influence on latex which may lead to trouble with bubbles under certain conditions. On estates where coagulation takes place slowly P. N. P. can safely be added with the coagulant and this method of treatment is recommended. On other estates where the latex has a tendency to rapid clotting, it is not likely to be satisfactory. It is suggested that estates should experiment with this method of treatment of latex and adopt it if satisfactory.

Incorporation of Para-Nitrophenol (P. N. P.) with latex.

When acetic acid is used as coagulant, the P. N. P. can conveniently be dissolved in the undiluted acid in the proportion of 1 lb. P. N. P. to 5½ lbs. strong acid. The P. N. P. dissolves freely but it is advisable to crush it thorougly before mixing. The mixture does not deteriorate on keeping.

A carboy of acid (45 lbs) should be divided into 2 equal portions, half being poured into an empty carboy. 4 lbs. of P. N. P. is added to each carboy and shaken or stirred at intervals until the P. N. P. is dissolved.

Addition of the P. N. P· has the effect of "diluting" the acid, its strength being approximately 85%. Thus, if the dose of acid required for coagulation was previously 6 ozs. per Shanghai jar, the dose of mixture will be 7 ozs.

Alternatively a 1% solution of P. N. P. in water (1 lb. P.N.P. to 10 gallons water) may be prepared and added to the diluted latex or acid in the proportion of 1 gallon of stock solution to 100 lbs. dry rubber (equivalent to 1 lb. P. N. P. to 1000 lbs. rubber).

When formic acid is used as coagulant, the latter procedure should be adopted, as it is difficult to dissolve sufficient P. N. P. in the strong acid. It should be remembered that formic acid is a faster coagulant than acetic acid and so trouble with clotting of the latex may arise with formic acid and P. N. P., which would not occur with acetic acid and P. N. P.

If it is found that the dose of P. N. P. recommended above causes clotting of the latex, it may be possible to combine the two methods of treatment, adding a small amount of P. N. P. to the latex and afterwards soaking the sheets in a solution of P.N.P. In this case P. N. P. should be dissolved in the undiluted acid in the proportion of 2 lbs. to a carboy of 45 lbs. This corresponds to 1 part P. N. P. to 4000 lbs. rubber and assists in protecting against mould, sheets which are not efficiently soaked.

Soaking Sheets in Solution of Para-Nitrophenol. In this method of treatment the freshly rolled sheets are soaked in a O.1% solution of para-nitrophenol for half an hour. The solution is made up by dissolving 6½ ozs. of P. N. P. in 40 gallons of water in a Shanghai jar or tank. It dissolves slowly in cold water but is readily soluble in boiling water. Half a gallon of boiling water is sufficient for 6½ ounces. The hot solution is poured into the jar containing the bulk of the water, being strained through muslin to remove the black sediment which remains undissolved.

The sheets do not require washing before soaking, provided that the sheeting rollers are fitted with water sprays. If no water spray is fitted the sheets should first receive the ordinary washing.

The sheets should be placed in the jar of solution singly, each sheet being pushed well under the surface of the liquid before the next sheet is placed on top of it. The object of this is to ensure that the whole surface of each sheet comes in contact with the chemical. If a mass of sheet is placed in the solution, the solution will not be absorbed by the sheets in the centre of the pile.

The sheets are allowed to soak for half an hour and are then removed and hung to drain before removal to the smoke-house.

Another method of treatment which ensures better soaking but involves more labour is to have 2 jars of solution. The sheets are placed one by one into the first jar. When the jar is full (60 to 70 sheets) the sheets are transferred one by one to the second jar. This is repeated 5 times and occupies about half an hour.

Soaking in P. N. P. gives complete immunity against mould if carried out efficiently, but this is not always done on estates. It is for this reason that, if possible, a small proportion of P. N. P. should be incorporated in the latex.

40 gallons of P. N. P. solution is sufficient for treatment of approximately 400 lbs. of rubber.

Black Streaks, Spots or Patches. The origin of these is not difficult to trace. They are caused by drippings from the roof, and contain condensation products from smoke plus moisture. The ventilation of the roof ridge should receive attention, and if the trouble persists it will be necessary to place some absorbent screen below the sloping roof. Sack-cloth is sometimes used, but leads to a worse state of affairs unless changed frequently. In most modern smoke-houses having an iron roof there is an inner lining of soft timber. Sometimes the fault could be traced to an iron roof which has become perforated by the corrosive action of smoke, in which case the roof should be repaired forthwith.

Whitish or Grey Streaks. This is a very uncommon defect, and is generally to be traced to a building in which fairly new galvanised sheets have been installed. The zinc surface becomes oxidised and the whitish powder which is formed flakes or is carried away by drops of moisture condensing on the surface of the iron sheets.

Rust. Sometimes if a sheet is stretched forcibly and allowed to retract quickly, the hitherto clear surface will be seen to be marred by a "rusty," deposit. The rubber is then described as "stretching, rusty", and its value is depreciated. Experimental work on "rust" formation by H. J. Hellendoorn has shown that "rustiness" is caused by the decomposition of serum substances under the aerobic micro-organisms. The following points quoted from "the Cause of Rustiness in sheet-rubber" H. J. Hellendoorn, Archief voor de Rubbercultuur are worthy of note:

1. Rustiness could apparently be produced at any time merely by keeping freshly rolled sheets for periods varying from 24 to 48 hours in a moist atmosphere.
2. Sheets placed immediately in a temperature of, say, 110° to 130° F. never showed "rust", but if air-dried at ordinary room temperature, "rust" might appear.
3. "Rust" can be prevented by soaking freshly prepared sheets in dilute solutions of disinfectants such as formalin, sodium bisulphite.

If subsequently the sheets are hung for any length of time in a moist atmosphere, the protective effect of the disinfectant gradually vanishes and " rustiness " may be produced.

The same disinfecting effect may be obtained by the use of steam or hot water. It was found that there was less liability to the formation of " rust " when sheets were immersed in water at a temperature of 95° to 120° F., whilst steeping at 140°F gave complete freedom.

4. It was shown that the micro-organisms which cause decomposition of the serum products flourish only in the presence of air — i.e., they are aerobic in character. It is not uncommon to find therefore that "rust" may be incident only on those parts of a sheet which have been exposed for some time to air and moisture before being placed in a warm smoke-room.

5. The optimal temperature for development of the particular organisms appeared to be about 100°F., in a moist atmosphere.

6. Soaking the sheets in water (except the short immersion in hot water, which is recommended), even for a period extending over a week, does not hinder the formation of " rust ".

7. Rustiness may be prevented by placing the sheets in a sufficiently warmed smoke-house as long as there is adequate ventilation and a moist atmosphere does not persist.

   The simplest means of prevention is to soak the sheets first for a short period in water, and then to hang them to drip for a few hours in a well-ventilated place, outside the factory preferably in the open without shade or cover.

The prevention of " rust " by the use of para-nitrophenol in two ways has already been discusssed earlier in this chapter.

Occurrence of Bubbles in Sheet Rubber. The contributory causes of this defect are many and varied. The underlying reason for bubbles appearing is that certain gases, either those of the atmosphere, oxygen and nitrogen, but mainly of carbon di-oxide, which are originally dissolved or combined in the latex subsequently become liberated at a time when their free access to the air is prevented, i.e., during or after coagulation, and thus are compelled to remain embedded in the rubber.

To show how this may happen it will be convenient to follow through the various processes of the preparation of rubber and to point out under what conditions at each stage bubble development may occur.

On adding the coagulant to the latex there is usually a brisk effervescence and escape of gas. This is due to the interaction of the acid with bicarbonates of magnesium which are contained in the latex, the gas evoloved being carbon di-oxide. Obviously, then, if excess of acid is used and coagulation sets in rapidly, part of this gas will be imprisoned and form bubbles, as becomes evident after drying the rubber.

A too rapid coagulation therefore is the first cause, taking them in order leading to bubble formation.

On the other hand, if too little acid is used, bubbles—and in particular "coagulation marks", the pocked appearance caused by bubbles forming and bursting on the under surface of the sheet-will again almost certainly be obtained.

The cause in this case is less obvious, but may be due either to a gradual decomposition of the bicarbonates or to the setting in of putrefactive alterations. That too little acid is being used is indicated by an excessive surface darkening and oxidation taking place during and after coagulation.

If, on the other hand, the employment of more acid affects coagulation too quickly then an unduly diluted latex is probably being dealt with and less water should be added in the field.

However, assuming that the correct quantity of coagulant has been used and that the mixture has been transferred to the dishes, it is now saturated with carbon di-oxide at the prevailing atmospheric temperature. The solubility of this gas in water and in such solutions as that we are dealing with however decreases as the temperature rises, any increase in the temperature causing a further portion to be expelled from the solution.

If then, owing perhaps to the factory getting more sun in the afternoon than in the morning, the coagulum gets warmer, this carbon di-oxide will be evolved and must form bubbles in endeavouring to escape.

This is the next point to observe therefore if trouble of the nature under discussion is being experienced, that the temperature of the room in which the dishes are standing should not be higher afterwards than at the time of coagulation. If it does get higher better ventilation is called for.

The safe passage of the sheet to and through the rolling stage must not however, as might perhaps be thought, be the signal for the cessation of vigilance. It still contains up to 35% of the solution, saturated with gas that may yet cause trouble.

If the rolling has been tight, especially if differential rollers have been used, further risk is small as the greater part of the solution will drain out in the course of a few hours, carrying the gas with it. If, on the other hand, the rubber has been evenly rolled, and not very tightly, the rate of drainage is very slow and a large amount of water will be still remaining when the sheet is placed in the smoke-house.

Whilst in this state any appreciable rise in temperature, such as may be caused by having too large a fire or to the sheet being hung too near it will produce a luxuriant crop of bubbles.

Other causes of the formation of bubbles may be traced to some decomposition of substances, other than rubber, contained either in the coagulum or in the serum. In a general way, if this decomposition is evidenced by an unpleasant odour, it is described under the the term of "putrefaction". As far as field operations influence the result, the decomposition is generally to be attributed to the work of mirco-organisms. Conditions favourable to the incidence and development of these are to be found where absolute cleanliness in all details is not maintained. Broadly, causes of the formation of bubbles may be grouped into two:

(i) Those originating in field operations, and

(ii) Those which arise after the arrival of the latex at the factory.

Contributory Causes in the field are:

1. Spouts, buckets and cups being dirty. Regular cleaning is essential. If the buckets are allowed to be taken to the lines by tappers, trouble may ensue due to use of these utensils for the preparation of food.

2. Delay in commencing work. This means similar delay in collecting latex which is exposed to greater heat than under ordinary circumstances.

3. Exposure to the sun's rays. The heating of the latex may provide improved conditions favourable to the development and action of mirco-oragnisms.

4. Allowing latex to stand too long before collection. This usually is the result of giving tappers too great a task.

5. The addition of water to the latex, either purposely or accidentally, in the form of rain. The water may be slightly acid in character, or it may carry micro-organisms from the bark into the latex.

6. Tapping trees at too great a height. The latex generally has an abnormal distance to travel before reaching the cup.

7. Sometimes the latex from old trees, or from trees after wintering (just prior to full renewal of leaf), contains more than the usual proportion of substances such as sugars which are capable of effecting flocculation or coagulation.

8. Too great a distance for transport. The trouble arising from this cause is likely to be much increased if the journey has to be made over bad roads. In such case the physical action augments the effect likely to be produced by long standing.

The foregoing does not include all possible causes, but serves to indicate the direction from which trouble may be mainly anticipated. It will be plain that any latex which exhibits symptoms of premature coagulation or minute flocculation should be regarded as a potential source of bubbles in sheet rubber.

Contributory causes in the factory. These are :

1. Lack of cleanliness of utensils, particularly of coagulating dishes or tanks. The trouble becomes acute sometimes where wooden tanks are employed. Unless the tank and the partitions are thoroughly and regularly cleansed, the wood may become coated with a bacterial slime, which is capable of causing what may be termed "fermentation" of the latex layers in contact.

   The tank should be thoroughly cleaned occasionally with a weak 5% solution of sodium bisulphite. The partitions should be scrubbed and placed in the sun twice or three times a week.

2. Allowing latex to stand too long before treatment.

3. The use of a latex of too high a rubber content. Such latices are difficult to handle in order to secure uniform mixture with the coagulant.

4. The use of too concentrated a solution of coagulant. In conjuction with (3) there may be a rapid and irregular coagulation, giving rise not only to decomposition in parts and subsequent formation of gas, but also to the formation of true " air bubbles " by inclusion of air during stirring.

The use of insufficient coagulant. Coagulation is slow and incomplete.

Defective straining and skimming. Small flocculated particles of rubber may pass, or be rubbed through, the strainer. If allowed to remain they act as local points of danger.

7. The proximity of the coagulating latex to some source of heat, or exposure to sunlight.

8. Any delay of drying in the preliminary stages, either, before or after the rubber enters the smoke-house.

In practice, it is more often found that bubbles and cloudy patches in sheets are caused by imperfect cleansing and sterilising of dishes, in which minute particles of old coagulum remain and set up fermentations or yeast like action in fresh latex, resulting in bubbles and blotches. Thorough cleansing and scalding of dishes are the safest remedies.

Blisters. This description aptly fits the case in which sheet rubber in the smoke-house exhibits large bubbles of gas which distend the surface of the rubber. When subjected to pressure, small "balloons" are formed, which burst with a perceptible report. It was formerly believed that this defect was caused solely by an abnormally high temperature. That such is not the case can be shown by the experience of estates which have had only the rubber of a particular day or short period affected under normal factory conditions. At the same time the heat of the smoke house exerts an influence causing expansion and distension but it is advanced that the gases had begun to form before the rubber entered the smoke-house. The view held is that decomposition had supervened or was taking place probably from one or more of the causes enumerated in the preceding paragraphs. The heat of the smoke house only serves to exaggerate the effect. It is acknowledged that the degree of decomposition must be initially greater than in the ordinary incidence of "bubbles".

This defect is comparatively rare, and seldom appears on estates which employ anti-coagulants in the field. Investigations have shown that blisters appear on the rubber of some estates after wintering, and during the period of new leaf development, and that the defect has been noted on other estates during a period when there were frequent but not heavy rains, and when there was a comparatively low average temperature.

Support Marks. It frequently occurs that one sees across the middle of smoked sheets a wide mark. This is where the wooden support in the smoking chamber has been. As a rule, even in the most careful cases a faint mark may always be seen, but in many instances this mark is exaggerated to such an extent as to point to lack of care on the part of smoke-house supervision. If bays of racks remain empty overnight, they may possibly become covered with a light sprinkling of fine wood ash and tarry deposit. Wet rubber placed upon these racks will pick up and retain the impurities, and more often than not they cannot be washed out. It is essential therefore to see that empty racks are thoroughly cleansed before placing wet rubber upon them. The better plan is to arrange that the bars can be removed easily from sockets. There should be in stock sufficient "spares" for say, two days' rubber. When the dry rubber is removed, the bars should likewise be taken away, to be cleansed and kept in the factory until again required. This will ensure that fresh rubber always rests upon a clean support. On some estates, in order to guard against a pronounced " bar-mark ", sheets are moved and turned daily. In other smoke-houses the upper surface of the bar is chiselled in concave form, so as to admit of the passage of smoke below the surface resting on the bar.

Stickiness. This is not to be confused with "tackiness" from which the rubber does not recover. Stickiness is only temporary, and may be remedied. As a general rule, it is due to packing sheets, which have not a good raised "ribbing" and which may have been coated with light tarry deposits. This surface film or glaze may be removed by washing the sheets, or scrubbing them, with cold water. Usually a further two days' air-drying will make the rubber fit for packing; and if the smoke-curing has been efficient, there should be no need to anticipate trouble from mildew. Some estates adopt this practice daily with success as a form of insurance against complaints of surface deposits.

Ribbing Surface Pattern. While the passing of sheets of rubber between rolls, causing a particular raised pattern to appear, has no effect upon the actual quality of the rubber, there is a great deal of practical advantage gained. The practice ensures an increase of superficial area which is an aid in drying, improves the appearance of the rubber for selling purposes, and is of distinct advantage in enabling the rubber when packed to travel in better condition. Sheets do not become so closely packed and sampling and general handling are easier on delivery.

As long as the surfaces are sufficiently and regularly distorted, there would seem to be no limits to the type of pattern or "mark" which may be placed upon the rubber. But in actual practice the variety is small. The most popular effect is produced by a pair of rolls cut with closely placed narrow grooves running spirally. The spirals travel in the same direction on both rolls, producing close-cut ribbing running in opposite directions on the surfaces of the sheet. On sheets of standard thickness, the result approaches a diamond effect.

A few other patterns are employed, notably that producing longitudinal stripes of varying thickness. On the whole, the type of pattern would seem to be immaterial if the points already indicated are achieved.

It is seldom one encounters a case nowadays in which the "marking" is unsuitable, but a few estates may be using an old type of patterned roll on which the full diamond grooving is cut. As this appears on both sides of the sheets of rubber, and as the ribbing does not coincide, a blurred effect is seen when the sheet is viewed against the light.

Thick Ends, "Sheet Clippings". It rarely happens, even with good equipment and average supervision, that the preparation of smoked sheet is unaccompanied by slight defects. For instance, in spite of rules and regulations regarding manipulations of the coagulum, it is not uncommon to find that some sheets after rolling, have slightly thickened ends. In the ordinary course of events these might delay drying considerably. It is the practice on some estates to cut off these thickened ends while the rubber is still wet. The pieces are then machined into crepe form, but as no sodium bisulphite may have been used, the resulting rubber cannot be classed as No. 1 Standard Crepe.

The other alternative is to trim the ends when the bulk of the rubber is thoroughly smoke-dried. The moisture containing portions are then returned to the smoke-house until dry, and are subsequently packed without further treatment as "smoked-sheet clippings". It will be plain that, except, in the particularity of form, these clippings differ in no degree from the original sheets; and, owing to extra smoke-curing, may arrive in even better condition. One must be prepared, however, to find that a slightly lower price is offered. Whether the price obtained would be comparable with that commanded by the crepe made from wet sheet clippings would depend upon general ruling market conditions, and the degree of care exercised in guarding against the inclusion of any inferior pieces of rubber. In ordinary factory practice, there could be no room for abuse under the latter clause.

Other Defects. This chapter will be closed with a reference to other small defects which, although infrequent, cannot be classed as minor complaints. In point of fact, when they occur, they assume an importance, in the eyes of the consumer, which is not perhaps sufficiently appreciated by producers.

Dirt. Trouble from this source should be absent, but carelessness on the part of packing coolies may be responsible for occasional complaints. How the dirt is incident may remain a mystery, but it has been noted that sheets have at times been thrown on a cement floor, and a certain amount of loose dust may thus adhere to the rubber.

Ash. The source of this surface deposit scarcely needs indication. Where open-hearth furnaces are employed and wire mesh floor screens are not perfectly sound, fine ash may find its way into the upper chamber. If this trouble is persistent in spite of precautions the sheets should be surface washed and air-dried before packing.

Bark. Complaints of the presence of particles of bark in sheet rubber used to be fairly frequent, but are now less common. The trouble may be traced to the use of defective straining sieves when the latex is being strained..

Oil Streaks. These are produced by dirty rollers, the use of too much lubricating oil or worn bearings.

Cotton Fluff This is caused by using cotton waste for cleaning the machines. A clean cloth should be used instead.

"Short" or Brittle Sheets. Shortness is caused by the use of Formalin to prevent premature coagulation or by too high a temperature in the smoke-house.

Specification of Standard Quality Sheet Rubber.

The following specification was adopted by the Rubber Manufacturers Association, Inc. and endorsed by the Rubber Trade Association of New York, Inc.,with effect from July 1st,1952.

Rubber Manufacturers Association Types Ribbed Smoked Sheet.

Nothing but ribbed smoked sheets of rubber can be used in marking these grades. Cuttings, block or frothy sheets, or other scrap, air-dried sheets or smooth sheets are not permissible.

No. 1 X R. S. S. *Superior Quality Ribbed Smoked Sheets.* This grade must be produced under conditions where all processes are carefully and uniformly controlled. Each bale must be packed free of mould but very slight traces of dry mould on wrappers or bale surfaces adjacent to wrapper found at time of delivery will not be objected to provided there is no penetration of mould inside the bale.

The rubber must be dry, clean, strong, sound and free from blemishes, rust, blisters, and any foreign substances, except slight specks as shown in type sample. Small pin-head bubbles, if scattered, will not be objected to.

No. 1 R. S. S. *Standard Quality Ribbed Smoked Sheets.* Each bale must be packed free of mould but very slight traces of dry mould on wappers or bale surfaces adjacent to wrapper found at time of delivery will not be objected to provided there is no penetration of mould inside the bale. The rubber must be dry, clean, strong, sound and free from blemishes, rust blisters, and any foreign substance, except slight specks as shown in type sample. Small pin-head bubbles, if scattered, will not be objected to.

No. 2 R. S. S. *Good Fair Average Quality Ribbed Smoked Sheets.* Slight rust and slight amounts of dry mould on wrappers, bale surfaces and interior sheets, found at time of delivery will not be objected to, provided these conditions, either singly or in combination, do not exist to an objectionable extent on and in more than 5% of the number of bales included in the delivery, lot or tender as determined by the number of bales inspected. Small bubbles and slight specks of bark, if scattered, will not be objected.

Rubber must be dry, clean, strong, sound and free of blemishes, blisters and all foreign substances other than those specified above as permissible.

No. 3 R. S. S. *Fair Average Quality Ribbed Smoked Sheets.*

Rust and dry mould on wrappers, bale surface and interior sheets, found at time of delivery will not be objected to, provided these conditions either singly or in combination, do not exist to an objectionble extent on and in more than 10% of the number of bales included in the delivery lot or tender as determined by the number of bales inspected.

Slight blemishes in colour, small bubbles and small specks of bark permissible.

Rubber must be dry, strong and free of blemishes, blisters and all foreign substances other than those specified above as permissible.

No. 4 R. S. S. *Low Fair Average Quality Ribbed Smoked Sheets.*

Rust and dry mould on wrappers, bale surfaces and interior sheets, found at time of delivery, will not be objected to provided these conditions, either singly or in combination, do not exist on and in more than 20% of the number of bales included in the delivery, lot or tender as determined by the number of bales inspected.

Translucent stains, medium size bark particles of the size shown in the type sample, bubbles, slightly sticky, over-smoked rubber permissible. Weak rubber, under-cured rubber, heated or oxidised spots or streak not permissible. Rubber must be dry, firm and free of blemishes, sticky blisters, and all foreign substances other than those specified above as permissible.

No. 5 R. S. S. *Inferior Fair Average Quality Ribbed Smoked Sheets.*

Dry mould on wrappers, bale surfaces and interior sheets, found at time of delivery will not be objected to provided this condition does not exist to an objectionable extent on and in more than 20% of the number of bales included in the delivery, lot or tender as determined by the number of bales inspected.

Rust, stains large bark particles of the size shown tn the type sample, bubbles, over-smoked, slightly sticky under cured rubber permissible. Weak rubber, heated or oxidised spots or streaks not permissible. Rubber must be free of blemishes and all foreign substances other than those specified as permissible.

CHAPTER XIX

PREPARATION OF CREPE RUBBER

PALE CREPE

Preliminary Operations. Operations connected with receiving, weighing and measuring and straining the latex are the same as described in smoked sheet manufacture. The best grade of crepe is known as No.1 or Fine Pale Crepe. In this pale rubber minor blemishes are plainly apparent and defects which would escape notice in smoked rubber assumes marked prominence in pale crepes. However, the observance of a few elementary rules with care to avoid all likely sources of contamination will enable the manufacture of the finest pale crepes.

Bulking of Latex. In order to ensure uniformity in appearance and inner properties of the rubber it is very desirable to have a large tiled receiving tank so that the latex from large areas and different fields can be efficiently bulked and mixed together,

Standardisation of Latex. In order to maintain uniformity in the appearance and quality of the finished crepe, it is recommended that the latex should be diluted to a standard dry rubber content of 2 lbs. per gallon. Unless the dry rubber content is invariable, and the quantities of chemicals fixed, the colour of the crepe will vary appreciably. Higher dry rubber content than 2 lbs. is not advised for the reason that a fairly soft coagulum means easier working on the machines, less labour and proportionately cheaper costs.

Sodium Bisulphite. Sodium Bisulphite must be added to the bulk before adding the acid to ensure uniform pale colour. It prevents oxidation or surface discoloration, delays too rapid coagulation, and should be used in the proportion of 5 to 8 oz sodium bisulphite diluted with 3 gallons water per 50 gallons of coagulum, or each Shanghai jar. Both acid and Sodium Bisulphite should be thoroughly well mixed with the latex by means of a broad wooden paddle, and it must be kept in mind that Sodium Bisulphite is heavier than latex and inclined to sink to the bottom of the vessel. Defective mixing of sodium Bisulphite will cause whitish streaks in the pale yellow crepe. Taking an average of 8 oz. per 50 gallons latex diluted to 2 lb. dry rubber content per gallon, 1 lb. sodium will be sufficient for 200 lbs. of rubber, and this is the maximum amount of sodium bisulphite which should be necessary.

Deterioration of Sodium Bisulphite. It must be borne in mind that Sodium Bisulphite rapidly decomposes when exposed to air at tropical temperatures. For this reason the solution should be freshly made for each application, and unless this is done it is of doubtful efficacy.

The caution must again be given that the employment of an excess of sodium bisulphite will] lead to the production of an over pale rubber, and a prolongation of the drying period. If thick crepes are made, an excess of the chemical is sometimes made visible by a greyish powder deposited on the edges of the strips of dry rubber.

Differentiation of Sodium Bisulphite and Sodium Sulphite. Sodium bisulphite and sodium sulphite are both bought in the form of a fine crystalline powder, and on analysis good specimens should contain over 90% pure substance when packed in well sealed vessels. It often happens that through inadvertence one chemical is supplied in place of the other and results in detriment to the rubber and considerable discomfiture to estates managers. The error as a srule is not detected for some time until complaints are received. To the layman it is not a simple matter to distinguish between them without special knowledge. There are certain elementary tests, however which can be applied on all estates serving to make the distinction, but these tests will not afford any information regarding the actual quality of the chemicals which must be ascertained by laboratory tests. Distinctive characteristics of the two chemicals are given below.

Sodium Bisulphite	Sodium Sulphite
1. If in good condition it has a powerful odour of sulphur dioxide. High-grade sodium bisulphite has very little odour, but by the time it reaches the estate and as a result of short exposure to the moist atmosphere of the tropics, a little decomposition sets in and a strong odour of sulphur dioxide gas is noticeable.	1. It has no perceptible odour.
2. In solution it should turn a blue litmus -paper red.	2. In solution it should turn a red litmus-paper blue.
3. It exhibits amarked tendencny to "cake" if the drum is allowed to remain open.	3. The tendency to "cake" and form lumps is less marked than in the case of the bisulphite.

Sodium sulphite under normal conditions gives off a gas when exposed to the atmosphere, and it deteriorates in quality continuously. It is the potential presence of this gas which makes the powder effective as an anti-oxidant and disinfectant. It is within the experience of all accustomed to the handling o this chemical that, in addition to the loss of gas, the powder cakes into a hard mass on exposure. If only the top layer is caked, the remainder may be in fair condition; but no caked portions should be used, as they cannot be of good quality. They may, however, be used for the treatment of scrap rubber.

The ready tendency of sodium bisulphite to deteriorate on exposure should give sufficient indication regarding its treatment in storage. It should be purchased only in air-tight containers or drums and should be stored in a dry place. No drum should be opened until required and the practice of keeping an open drum on the floor of the factory should be avoided. It will be always preferable to purchase sodium bisulphite in the smaller size drums of ¼ cwt. capacity. Although the initial cost of the larger capacity drums may be cheaper, the smaller drums are to be preferred as the loss on exposure will be less. Where the quantity used per diem is small, it is advised that precautions should be taken to preserve the quality of the chemical when a drum is opened. It might be of advantage to place the contents of the drum in smaller sealed tins or to have a special container made with a closely fitting lid into which the powder can be placed as soon as the drum has been opened.

Mixing Sodium Bisulphite Solution with Latex. The importance and necessity for care in the preparation of the solution has been emphasised earlier in a preceding chapter. Now equal regard must be given to the mixture of the solution with the latex. Adding the powder to the solution of acid will lead to aggregate loss of efficiency owing to the rapid escape of the gas evolved. The satisfactory and correct method is to pour the solution of sodium bisulphite into the latex in as uniform a distribution as possible, and the mixture of solution and latex should be thoroughly stirred. A thorough stirring should again follow the pouring in of the acid.

These elementary rules should be observed scrupulously, otherwise deficiency will most probably be manifested in the dry rubber in the shape of streaks of varying shades of colour. Finally, the use of deteriorated sodium bisulphite should be avoided. In order to obtain an effect, double the quantity may be required, and the residual salts left in the rubber on evaporation of the mixture will be responsible for prolonged drying, surface deposits and other troubles.

Coagulation and Acid. Coagulation may be undertaken without any special arrangement of tanks and is usually effected in Shanghai jars containing about 45 gallons standardised latex. With proper care and the use of the correct quantities of chemicals, no difficulty will be experienced. On a larger scale proper reception tanks for bulking and standardising the latex should be installed. If ordinary jars are used, and the coagulum is left until the following morning, the mass of rubber has to be cut up into pieces of a size suitable for the machines. The knives or saws are sometimes rusty, and the colour of the coagulum is affected. The machines are often fed with lumps which are too large with the result that portions are thrust under the cheek-blocks and become stained. When a sheet-coagulating tank is used all labour of cutting the coagulum is obviated. The long strips are handled and fed into the rolls easily and saves considerable work in machines.

The normal amount of acetic acid for latex diluted to 2 lbs. dry rubber per gallons is 1 lb. of acid (16 fluid ounces) to 200 lbs dry rubber. For a Shanghai jar containing 50 gallons of latex at 2 lbs. per gallon the amount is 8 oz. of acetic acid diluted to not less than 1 gallon. If it is desired to use the acid in the form of a stock solution, this is prepared by mixing 1 part of acid with 19 parts of water and adding this to the latex in the proportion of 1 part stock solution to 50 parts of standardised latex.

It will be understood that if formic acid is to be used, only about one-half the quantities will be required.

It is not possible to lay down an exact figure governing all cases, as so much will depend upon the treatment undergone by the latex before it reaches the store. Some estates use solutions of greater strength, generally 5 per cent., in crepe preparation. While such solutions may be effectively stirred in when the latex is dilute, it is advised that for intimate mixture the solution need not be stronger than 1 per cent.

In estimating the quantities of acid required, much depends upon the interval which is to elapse between the addition of the acid and the time of working of the coagulum. If the rubber is to remain until next morning, the average formulae will be found suitable. If, however, it is required to work the coagulum with an interval of less than three hours, an excess of acid must be employed. The excess need be comparatively small, unless the interval is much reduced. Unless the procedure is strictly unavoidable, it should be discouraged on account of the waste of coagulant involved and the deterioration of the rolls resulting upon the use of strong solutions of acid.

Machinery for Pale Crepe Manufacture. For pale crepe manufacture as well as for other types of crepe manufacture which will be described hereafter, heavy machinery is necessary and adequate engine power must be available. The machines should comprise three types.

(i) Machines with rolls cut in such fashion and run at such different speeds as to have a macerating effect upon the coagulum. These machines are referred to as " macerators ".

(ii) Machines with intermediate rolls, grooved in varying designs and geared differentially. These reduce the thick rough crepe obtained from the macerators into a form suitable for passing to the smooth rolls. These are sometimes called "crepers", but as the term may be applied equally to the macerating rolls, they will be termed the "intermediate" rolls.

(iii) Machines with smooth rolls which are usually run at approximately even speeds and, as their name denotes, are devoid of any grooving. They are called "smooth" rolls or "Finishers".

Without the above equipment it is not possible to prepare the grade which is known as "Fine Pale Crepe". In the common acceptation of this term, No. 1 quality generally connotes fineness and paleness with a thin crepe which has a good, smooth and fairly well-knit texture.

Speed. Taking first the macerating machines, the intermediate gearing between the shaft and the rolls should give a driving speed of about 20 revolutions per minute on the faster travelling roll. This is equivalent with a 15" diameter roll to a peripheral speed of about 60 to 65 feet per minute.

The intermediate and smooth rolls can be arranged to travel more quickly, but the maximum comfortable speed for proper feeding and control would appear to be about 25 revolutions per minute. In view of the fact that the rubber at each successive machine becomes longer and thinner, it will be seen that a smooth roll machine could not cope with the output of a macerator in the same period of time. If, therefore, the macerator is fully occupied for the greater part of the time, an additional smooth roll machine must be installed, even though the existing one has been speeded up to practical limits.

Particulars of a battery of rollers for producing the finest quality of thin pale crepe and lower grades are given below:

Machine	Type of grooving	No. of times Rubber passes through
1. Macerator	Deep horizontal grooves; square- cut 5/16 inch x 5/16 inch x5/8 inch spaces	4
2. Intermediate	Horizontal grooves: 3/16 inch x 3/16 inch x 3/8 inch spaces	3
3. Intermediate	Fine spiral grooves: 1/8 inch x 1/8 inch x 1/4 inch spaces,	2
4. Smooth	Nil	1
	Total	10 times.

The actual rate of output of this installation is the capacity of the last smooth machine which is about 180 lbs. per hour, while the output of the macerator is approximately double this amount. Thus the macerator only works for about half the time. This applies also to the two intermediate machines.

The artificial standard set up by buyers and brokers for "Fine Pale Crepe No. 1" necessitates this thin crepe being of even texture and fairly free from small holes or "looseness". In order to secure the desired effect the coagulum must be passed consecutively through the three types of rolls as above. Owing to the existing differences in equipment and speed of drive, the ordinary practice of one estate may not be suitable for another. It remains, therefore, a matter of study for each estate to discover the minimum number of times which rubber should pass through the machines. In any case it may be assumed that if any factory cannot prepare a good crepe by passing the rubber, say, twelve times through the rolls, there is some deficiency in the machines, or of speed. Also the coagulum may be too hard or the rolls may be badly worn.

Blanket Crepe. Manufacture of Blanket Crepe consists of three operations:

1. The coagulum is passed through the maceratator, the machine with grooved rolls in order to reduce the lumps to a workable strip.

2. The strip is passed through the machine with smooth rolls which reduces it to thin lace crepe for drying.

3. The dried lace is re-rolled, without water, to form thick blanket crepe.

First Step. The coagulum is passed 4 times through the grooved roll machine. The first rolling breaks down the coagulum and gives a long irregular strip. The macerator is fitted with a sprinkler system by which the coagulum is continuously washed by a stream of water coming from above while it passes through the machine. In the second rolling the strip is doubled on itself in feeding and so reduced to a fairly regular shape. In the third rolling the width is reduced by doubling in the edges, and the fourth finally works the strip into good shape with regular, corrugated pattern. The setting of the rollers should not be altered during this operation. Two coolies are needed at the machine with the grooved rolls, one to feed and the other to receive and arrange the rubber at his side ready for the next rolling.

Time and labour can be saved by rolling the rubber in long strips. In many factories the practice is to roll in short strips of about 10 feet each, but it is quite possible for two coolies to handle a strip of 100 lbs. and the longer strip also facilitates work when it comes to the smooth rolls. During rolling it is often found that grease and dirt get on to the rubber from the sides of the rolls and it is then advisable to decrease the width of the hopper in order to keep the strip well in the middle. This is done by placing blocks of wood at either side of the hopper; they should not be screwed in, but left loose so that they can be removed and dirt and grease cleaned out. The blocks used on smooth rollers should be slightly thicker than for the grooved ones to ensure the edges of the thin crepe being straight and even.

Second Step. The crepe is now removed to the machine with smooth rolls and put through once only, which reduces it to thin lace. As it leaves these rolls, the lace is loosely wound on to a wooden drum in quantities sufficient to form a load for each tray of the drier, and while it is being wound the cooly tears off any dirty marks or edges that may have resulted from oil stains. It is very important in this process to guide the strip well into the centre of the rolls in order to prevent further oil marks. Two coolies are required at this machine, one for guiding the strip and one for winding the lace on to the drum. When removing the strip from the drum, it should be cut with a sharp knife along one of the reepers and not torn.

Third Step. After drying each layer of lace crepe is folded in three and then doubled on itself again and set aside on tables with a clean cloth between the layers to prevent the rubber sticking together, ready for the third operation of rolling. This consists in its being passed four times **dry** through the grooved rolls in order to form it into thick blanket crepe. Care must be taken to avoid overheating as the result of setting the rolls too close, also to avoid pulling the strip too hard or the edges will be torn. Scrap crepe should be rolled into blanket form with water which will prevent its becoming overheated and sticky.

SOLE CREPE. The coagulum is macerated as described earlier and rolled to thin crepe as in the preparation of ordinary crepe and hung up to air dry, and thereafter built up into thick sole crepe according to the thickness of the final product required. The usual standards of thickness demanded by the market are in fractions of an inch: 1/16", 1/8", 3/16" and 1/4". These standards are dictated by the purpose for which the rubber is to be used. It is essential that the consolidated layers, built up by a process of squeezing between rolls and technically termed the **process of lamination,** should be of uniform thickness in all parts. It is likewise demanded that the whole of any piece offered for sale should be of uniformly pale colour and free from the slightest blemish.

Machinery for preparing Sole Crepe. The most suitable type of machine for preparing sole crepe is one with (superimposed) smooth rollers 22 or 24 inches wide by 12 inches diameter and the operating speed should not exceed 12 revolutions per minute.

Milling the Sole Crepe. Dry lace crepe is fed evenly into the machine with the rollers set so that the rubber emerges as a fairly uniform sheet about 1/8 inch thick.

Three or four layers of this rubber are then placed together and passed three times through the machine. The rollers are tightened at each rolling and are finally set so that a uniform sheet of rubber slightly over 1/6 inch thick emerges from the machine. The width of the rubber at this stage should be 17 to 18 inches.

These sheets form the plies from which the sole crepe is built up to the required thickness. Two plies are used for 1/8 inch sole crepe, three for 3/16 inch sole crepe and 4 for 1/4 inch sole crepe.

The laminated strips or plies have to be examined most carefully for minute blemishes, and the thickness tested in all parts by means of a gauge. Unless the best equipment of machinery is available, the labour highly skilled and supervision good, the proportion of rejected strips will be very appreciable. The point regarding supervision is important, and it is really necessary that a well experienced and thoroughly reliable person is placed in charge of the work.

Building up the Plies. The procedure for building up the plies is as follows: A sheet of the rubber is laid out on a table which may be thirty feet or more in length. The rubber is stretched slightly and held in position at each end of the table. Another sheet of rubber is carefully placed on top of the first sheet and secured at the ends in the same way. A heavy hand roller (a roll from an old smooth crepe machine is suitable) is passed once over the rubber to bind the plies together. The required number of plies are built up in this way, and the rough edges are then cut off with scissors leaving the rubber with a width of 15 to 16 inches. The rubber is then ready for final rolling. (The cuttings are reworked through the macerating and other rolls and reappear as thin, medium or thick crepe of No. 1 grade and quality.) The long sheet of rubber is passed once through the machine with the rolls set so that it emerges at the exact thickness required.

The output of sole crepe from a machine of the type described will be approximately 100 lbs. per hour.

Sole crepe is always marketed in the form of sheets 36" x 13" and must be cut to this exact size.

Uniformity of Thickness. Great care must be taken to ensure that the rubber is made to the exact thickness specified by the buyer. A small difference in thickness which may be imperceptible to the eye and hardly measurable with calipers will make a considerable difference in the number of sheets of sole crepe per ton. The most satisfactory method of controlling thickness is by the weight of the sheets. The standard number of sheets of sole crepe per ton are as follows:-

	Number of pieces per Ton. (2240 lbs.)	Number of pieces per chest or bale (140 lbs.)
1/8 inch sole crepe	1, 152	72
3/16 ,, ,, ,,	864	54
1/4 ,, ,, ,,	576	36

The above figures should be regarded as the basis for controlling thickness, but at the same time calipers or gauges should be provided for checking the thickness during manufacture.

LOWER GRADES OF CREPE RUBBER.

Naturally Coagulated Lump Rubber. The grade of rubber made from the naturally coagulated lump which forms in buckets and carts is usually of a mixed colour due to that the fact the lumps oxidise very quickly. When they are allowed to remain overnight before being machined, it can be imagined that the colour of the dry crepe would be very dark, or would contain very dark streaks. Such is ordinarily the case unless special precautions are taken.

Providing that the coagulated lump is free from bark, leaves and leaf stems, and certain other precautions taken, the difference in price between coagulated lump crepes and first grade crepes should be very slight. The lump when lifted out of the latex should be allowed to drain for a few minutes and is then placed in a dilute solution of sodium bisulphite. This should be done without squeezing the rubber. It should not be thought that the use of sodium bisulphite will counteract any previous oxidation. This will only check further surface oxidation, and the rubber may be allowed to remain until the next day for working, if it is so desired. On some estates the lump rubber is worked on the machines as it is received, and the resulting crepe is submerged in a weak solution of sodium bisulphite overnight. It is then rinsed in water and hung to drip before weighing and placing in the drying house. Under certain conditions some of the lump rubber darkens rapidly during transport to the store, and any such oxidised portions must be rejected if a uniform colour is to be expected in the crepe. Following the procedure indicated above, some estates find it possible to prepare from naturally coagulated lump rubber a crepe which can be classed as No. 1 grade.

Skimmings and Washings. The skimmings of tanks, as already shown, may be prepared as a second quality of smoked sheet; but generally they are amalgamated with the rinsings of cups and buckets, treated with sodium bisulphite and acid and made into crepe form.

The cup washings, as they arrive at the factory, represent a very dilute latex, the rubber from which is generally of a greyish colour.

Bucket-washings should yield a good type of pale rubber if they are obtained properly. To obtain the maximum quantity of good rubber, the buckets should first be rinsed. A small quantity of water, say a quart, is poured into the first bucket, and this dilute latex used progressively in all the buckets of one gang of tappers. The result is a fair latex which can be added to the bulk of No. 1 latex, provided it is free from dirt. Where sheet rubber is being prepared, carefully strained cup-washings or bucket-washings may be utilised in the dilution of the latex to the required standard, thus increasing slightly the first grade rubber percentage.

Tree Scrap. As tree-scrap is a naturally coagulated rubber, it should be expected to show up well in quality. This is usually the case. But if the trees are not regularly "scrapped" there is a danger that the crepes may be found to contain tacky streaks due to the inclusion of old scrap which has been sun-baked. In hot dry weather, on widely planted areas tapped on alternate days, it has been noticed that scrap remaining for two days often exhibits a resinous appearance and feels sticky to the touch.

Some proportion of the tree-scrap is usually found to be heavily oxidised, and naturally if a crepe of uniform colour is to be obtained, these dark scraps must be rejected, otherwise dark streaks will be formed.

Bark-Shavings. The method of obtaining and collecting bark-shavings varies, and where the scrap is removed from the edge of the bark on each occasion before tapping, the amount of rubber to be extracted from the dry shavings is very small, and when prices are low, it is doubtful whether it pays to collect and work the material.

Where trees are not "scrapped" before tapping, the bark shavings and tree scrap are collected together and the amount of rubber derived from the mixture may be 30 to 40% upon the gross weight depending on the quality of the tapping and the thickness of the paring. Another factor influencing this figure would be the effect of using an anti-coagulant on the cuts. No heaps of bark-shavings should be accumulated, and tanks should be provided in which the shavings should be submerged in water. Otherwise excessive heat will be generated in the heaps and tackiness of rubber will result.

Earth-Scrap. Of all grades of crepe this is the one most liable to become tacky in transit. This tackiness to a large extent cannot be avoided as old pieces of earth scrap may be brought in amongst the bulk. Probably these old pieces have been exposed to the sun for days and have become very resinous. The difficulty does not appear on estates where earth rubber is collected systematically at very frequent intervals.

SCRAP MANUFACTURE. A scrap-washing machine is essential for cleaning Tree scrap and cup scrapings, Ground collected scrap and Bark shavings. These are heavy machines specially devised for the treatment of the lower-grade rubbers. In these the raw rubber is well masticated and freed from impurities, if the machine functions efficiently.

Most of the machines are made in varying sizes to meet the requirements of small, medium or large estates and a scrap-washer should be regarded as an essential item in the machinery of any estate employing engine power. The rate of output of scrap washers will depend mainly upon the speed at which they are driven, and when ordering the equipment it would be advisable to state the ordinary speed of the back-shaft, length of drive etc. It does not follow that the larger the rate of out put, the greater is the efficiency of the washer. The point is not as to what quantity of rubber can be taken out per hour, but what quantity is actually freed from impurities. A thorough knowledge of the general construction and principles of the particular scrap washer employed should acquired.

Hot water at a temperature of approximately 180°F. is very helpful in softening old and dirty scrap, and if the overflow pipe from the engine cooling tanks is made to direct hot water into the machine, the cleaning of scrap rubber will be more expeditiously performed. For each filling a double supply of hot water is required. The outturn of clean dry rubber from the machine is as follows:—

Tree scrap cleaned per hour	-	100 lbs.	dry rubber
Earth scrap cleaned ,, ,,	-	74 ,,	,, ,,
Bark Shavings ,, ,,	-	25 ,,	,, ,,

No difficulty attends the cleaning of either tree scrap or ground collected scrap, but special care has to be exercised in cleaning bark shavings and before being placed in the machine, the scrap rubber may, with advantage, be soaked for some time in a tank filled with hot or cold water to soften and clean it.

Cleaning Good Tree Scrap. Very little foreign matter should be present in this class of scrap – probably only a small percentage of bark and fine sand and a charge of 25 to 30 lbs. or sufficient to fill a 2½ gallon bucket, when put into the machine should form up into a homogeneous sausage-shaped mass quite free from all extraneous matter, within seven minutes. This period can be shortened if the scrap rubber has been previously hand sorted and passed over a No. 4 or 5 mesh to get rid of any small loose stones, sand or bark. During the cleaning operations a good supply of water should be made to flow through the box, keeping the level of the water at the top of the rotor. When cleaning is completed the rubber is transferred to an ordinary creping mill with fluted rollers and passed between the rollers four times. The rubber is thus formed into crepe and is then ready for natural drying, but for quick drying in a heated air machine the thick crepe is passed through a washing mill with smooth rollers to be made into thin lace form and after drying finally through a rough roller with water to make blanket crepe.

Cleaning Earth Scrap. The quantity of foreign matter in this class of scrap varies in the vicinity of 30% and with a charge of 25 to 30 lbs. placed in the machine about 10 to 15 minutes will be required before the rubber forms up into a homogeneous mass free from impurities. A very generous supply of water, heated if possible, should flow through the box while cleaning this class of scrap, the water level being maintained half way up the rotor, and at intervals of five minutes the water should be made to flood over to get rid of bark or other floating substances. The cleeand earth scrap is then removed from the scrap washer in sausage form and is passed to the creping mills for treatment as described earlier.

Cleaning Bark Shavings. The cleaning of this type of scrap is difficult as the 'maximum amount of cleaned rubber obtained will not exceed 15 per cent of the total weight, and more frequently the return will be 8 to 12 per cent. only.

About 40 lbs. bark shavings are placed within the box and a generous flow of water is directed upon the mass. In about 5!

minutes the rubber contents of the mass will have formed up into a roll and much of the bark will have been washed out. At intervals of about five minutes the whole contents of the box should be well flooded to get rid of the bark, and the actual cleaning operation should be completed within 20 minutes. The clean rubber is removed in the form of a sausage and passed to the creping mills as already described. To ensure a continuous flow of water through the machine, the exhaust cock under the box should be kept partly open and a supply of water be allowed to flow into the box to maintain the required level.

DRYING OF RUBBER.

Crepe may be dried either naturally by air drying or artificially by means of a vacuum or hot air drying chamber. Air drying is not recommended for the better calss rubber, as the crepe is liable to moulds or spot disease. Pink spots appear upon the half dried or finished rubber, the result of infection contracted in the field and accelerated by damp conditions in the factory. To prevent moulds coagulum should not be left standing longer than possible before being worked nor should there be any delay between the smooth rolling and drying. Moulds will not appear until the rubber is half dry, because it takes a certain length of time for the fungus to develop.

Upon leaving the smooth rollers to be artificially dried the fine lace can be loosely wound 2-ply up on a wooden drum of a squrrel cage design and of sufficient length and diameter to spread a tray load of 4 lbs. If wound too tightly, the lace rubber shrinks during drying and leaves empty spaces on the trays, thus decreasing the efficiency of the drier and causing white spots to appear, and it is therefore important that the winding should be even. If the driers are conveniently situated to the smooth rollers it is a good plan to bring the trays to a table near the rollers and spread the lace crepe on them direct.

Operation of the Drier. While the chambers are being gradually heated the complement of trays should be retained in each chamber and, if possible, the trays should be charged with rubber. Approximately 4 lbs. of wet rubber in thinnest crepe form should be placed on each tray. Thickness of the rubber at this stage is very important and should be of about the consistency of fine lace. The correct thickness is obtained by passing the strip once through smooth rollers placed together and by exerting some stress or pull on the crepe by hand as it passes between the rollers. Unless the crepe is rolled sufficiently thin the drier will not give anything approaching the maximum output.

Drier Temperature. For drying prime latex a temperature of 180°F. is the general practice, and for drying scrap 140°F. has been found most suitable. With scrap rubber, however, better results are generally obtained by natural air drying. Until the temperature in the chambers has reached approximately 150°F, the inlet valve should be kept 1/3rd open only. When the thermometer registers about 180°F, rubber in correctly thinned crepe form will dry in about 1¼ to 1½ hours, but as the result of varying conditions such as differences in the class of latex, or rubber spread differently on separate trays, it may be found that the load on any one tray is ready for removal 15 minutes before its neighbour.

When to Remove Rubber from Drier. The trays should be removed from the chamber when a few white spots of moisture (not too many) are still present on the layers of rubber. The risk of overdrying the rubber will be avoided by careful attention to this point. It is not necessary to wait for the complete contents of a chamber to be thoroughly dried before any one tray is removed, consequently each tray of rubber may be considered separately, and when the charge is dry it should be removed and another charge of wet rubber substituted, irrespective of the fact that adjoining trays may not be ready. When taking trays of dried rubber from any chamber and replacing with trays of wet rubber, the inlet valve should be closed while the door is opened. If this is not done there will be a waste of hot air. When the final charge of rubber to be dried at the end of any day's working is placed in the chambers the fan can be stopped and all fire withdrawn as the heat retained in the machine partially dries this charge and on the following morning a fully dried lot of rubber is usually secured before the full temperature is reached.

Overdrying will produce a dull orange coloured crepe; and underdrying will produce patches of white raw rubber.

Fuel. The consumption of firewood for a C. C. C. drier will range from one to two yards per day of 10 hours for 2 to 4 chambers.

Drier Output. The output from one chamber should approximate between 25 and 30 lbs. of dry rubber per hour provided the rubber is rolled sufficiently thin and the proper temperature is maintained, or say 250 lbs. per diem per chamber. Work is expedited by placing in front of the driers a long table 16 ft. long x 4 ft wide x 3 ft. high for carrying the trays whilst loading and unloading. 18 additional trays might be provided with a big drier so that there will always be a supply of loaded trays ready to place in the machine as soon as completed trays are removed.

The fire should be kept always at the back of the furnace place as the chimney draught is thereby improved. The rubber lace must be spread well over the trays to get efficient firing and no empty spaces for hot air to pass through should be left. The drier chambers may be clad with wood to prevent loss of heat by radiation which will greatly increase their efficiency.

The C. C. C. Drier. The Drier manufactured by the Colombo Commercial Company consists in principle of a number of small chambers or units in which crepe rubber is placed, and through which hot air is passed. As in the case of vacuum drying which process will be described hereafter, a great deal depends upon the preliminary treatment of the rubber. If the crepe is not rolled thin enough drying will be unduly prolonged, with possibility that the rubber will become tacky. The temperature usually obtained is about 150°F to 180°F, and if the rubber is thin the production of an installation of two chambers should be at the rate of 1 lb. of dry rubber per minute. The usual period of drying is under two hours with low temperature and between 1¼ to 1½ hours at higher temperatures in the region of 180°F. One advantage which this drier has over the vacuum drier is that the chamber can be opened at any time for a short period to withdraw or insert trays. The thin crepe is folded several times, as in the case of vacuum drying. Figures obtained from the actual working of a drier are given below :—

Chamber No. 1 — Temperature 150° — 180°F					Chamber No. 2 Temperature 150°—165°F
No. of Trays	Drying Period		Weight of Wet Rubber	Weight of Dry Rubber	
	Hrs.	Mts.	Lbs.	Lbs.	Worked similarly to Chamber No. 1. Yielded in 2 hrs. 23 mins. 70¾ lbs. dry rubber from 87½ lbs. wet rubber.
1	1	22	7½	6	
2	1	42	7½	6	
3	1	57	7½	6	
4	1	57	7½	6	
5	1	57	7	5¾	
6	1	57	7½	6	
7	2	0	7½	6	
8	2	0	7½	6	
9	2	11	6½	5	
10	2	11	7½	6	
11	2	11	7½	6	
12	2	18	7½	6	
			88½	70¾	

It will be seen from the above figures that from both chambers the output was 141½ lbs. dry rubber in 2 hrs. 23 mts. which is at the rate of 1 lb. dry rubber per minute approximately.

As the rubber leaves the driers it resembles vacuum-dried rubber in being surface-sticky. This stickiness is only temporary, and is got rid of by passing the crepe through wet rolls.

Vacuum Driers. The vacuum drier consists of a chamber heated by steam pipes and capable of having the contained air and moisture withdrawn by a pump. Indicators are fitted which show the vacuum pressure and the pressure of steam in the heating pipes which travel underneath horizontal slabs upon which the trays may be placed. There are two important points to be borne in mind, and if these are adhered to vacuum drying of rubber is a simple operation :—

(1) The rubber must be thin.

(2) The temperature should not be allowed to rise too high; some makers advise 140°F as a maximum, but provided the interval is not prolonged, no harm will result from a temperature of 150° to 160°F.

The machine can be considered efficient only if it can show a vacuum pressure of 28 inches within 15 minutes of starting the pump, and with the pump stopped, there should not be a greater fall in pressure than 1 inch within ten minutes after stopping the pump.

One of the most frequent sources of error is the control of steam pressure which is responsible for the temperature of the drier. It is quite unnecessary to maintain any steam pressure once the drying is well under way. All that is necessary is to heat the chamber well, with a steam pressure of 5 lbs. before inserting the rubber. As soon as the maximum vacuum pressure has been obtained, steam should be shut off from the heating pipes and it will be found that the temperature is well maintained throughout the operation with a rise of ten to twenty degrees at the end.

If the drier is working at a vacuum pressure of 28 inches, and if the crepe has been prepared thin enough, the rubber should be quite dry within two hours. Should the operation have to be extended to $2\frac{1}{2}$ hours at 28 inches vacuum pressure, it is a sign that the crepe is too thick. On such occasions it is often noticed that these thicker crepes are not thoroughly dry, having moist spots enclosed in them. On re-rolling these moist patches become easily visible, and are a source of great annoyance as they take a long time to dry out completely.

As mentioned before, the crepe for vacuum drying should be thin. There is no necessity to give it a superfine finish, and the presence of small holes is quite permissible, as they disappear on subsequent re-rolling. The thin crepe may be folded loosely to the length or breadth of the tray several times.

It is the common practice to screw up the door of the chamber as tightly as possible. As a rule it is found in course of time that the obtainable maximum vacuum pressure decreases. This may be attributed solely to the forcible screwing up of the door. Around the inside edges of the door are strips of rubber compound, the function of which is to form a tight joint. Should the door be screwed up too tightly, these strips of seal become deformed in course of time, and slight leaks occur.

The practice of placing a thermometer through the roof of the chamber does not enable correct determination of the temperature. In the same way, a thermometer suspended behind the observation window cannot indicate the temperature of the rubber as in both of these positions the thermometer must be influenced by radiation from the walls of the chamber. The only position in which the correct temperature could be indicated is between the folds of crepe. This can be arranged easily so as to enable one to read the temperature from the observation window.

CHAPTER XX

DEFECTS IN CREPE RUBBER

SORTING AND GRADING

In this chapter we shall outline the common defects in crepe rubbers and consider how to avoid them.

Grease, Oil and Dirt. It is a difficult matter to keep old machines clean, and unless proper precautions are taken, it is equally difficult to keep the edges of the crepe free from oil and dirt. Where wide crepe is made, the edges of the rubber often pass under the edges of the hopper and so pick up dirt and oil. On such machines only narrow crepe should be made by decreasing the width of the hopper placed above the rolls by means of blocks of heavy wood cut to shape and fastened in position. The use of too much of lubricating oil should be avoided. The whole question resolves itself into one of cleanliness, moderation in lubrication and proper supervision.

The machines should be inspected every day and once a week rolls should be swabbed down with a ten per cent. solution of caustic soda applied by means of a cloth fastened round the end of a stick. Immediately after this operation water should be turned on and the rolls set in motion so that all traces of caustic soda are thoroughly removed. Where possible lubrication by oil should be substituted by grease applied through screw caps.

It sometimes happens, if the "liners" of the bearings are eccentrically worn, that a few drops of dirty oil or a particle of grease are squirted out to some distance. These usually find a resting place in the tray and the contamination may then appear in any part of the rubber. All trays beneath machines, therefore, should be examined as the probable source of danger from contamination by oil and dirt.

Torn Edges and Holes. These are caused by improper folding after removing from the drier in the final rolling, or pulling the strip too tight through the roller. The presence of small holes is most generally an indication that the rubber has received the minimum amount of working on the rolls consistent with good washing. Further working would only be undertaken with the idea of so consolidating the rubber as to get rid of holes in order to meet the market scheme of valuation. This is usually achieved by making a very thin crepe and rolling together two lengths when wet. The resulting crepe may be slightly thicker than ordinary, and the method employed may be usually detected by the appearance of the edges unless these are trimmed.

Overheating. Too high a temperature in the drier or setting of the rolls too close in the final operation will produce a dull orange colour in the crepe. The drier temperature should not exceed 160°F and best results are obtained with even drier temperatures of between 150° and 160°F.

Greenish and Tacky Streaks. This is caused by copper or brass from worn bushes of the rollers. All cuttings containing green stains should be burnt as copper contamination can lead to actual melting of the rubber. Copper may be said to be a "poison" to rubber and every effort should be made to avoid possible sources of contamination, which may take place in two ways:—

(a) By the ejection of actual particles of brass from the bearings of machines due to eccentric grinding of the "standards" of the rolls upon the brass "bushes". These particles are carried by exuded oil or grease into trays, and thence to the rubber.

(b) By the action of an acid lubricant upon the brass, with the formation of a metallic soap which has a decided green colour, unless obscured by the dark colour of the oil or grease. It is transferred to the crepe rubber in the manner indicated above.

When the defect is discovered, the affected portions should be cut out, and the cuttings should be burnt. Mixing them with the

the lowest scrap grades,\ as may be done thoughtlessly or inadvertently will only cause further trouble.

Another source of contamination may be found from the presence in the rubber of small pieces of the brass mesh which is generally used for straining latex.

Iron Stains. This is caused by particles of iron and graphite getting into the rubber when the rollers get worn in the centre, and the screws are tightened up too much causing the rollers to grind at or beyond the edges of the rubber. The rollers should not be allowed to run empty.

Rust Stains. Rust forms upon the rolls when they are at rest and pale crepe must not be passed between the rolls until they have been thoroughly cleaned. Even when apparently clean a piece of lower grade rubber should be passed through several times to remove any trace of rust.

Oxidation Streaks. Defects caused by portions of coagulum becoming oxidised can be traced to insufficient sodium bisulphite. In normal course, without the use of an antiseptic agent such as sodium bisulphite, the freshly coagulated rubber has a surface darkened by oxidation. Unless this dark surface were carefully cut off, there would result a crepe containing dark streaks caused by the mixture of the oxidised surface portion with the bulk of the paler coagulum. The presence of oxidation in No. 1 crepes would imply either that no anti-oxidant substance was in use or that the quantity necessary to prevent this surface oxidation was exceedingly small. Although the price obtained would appear to be influenced by the presence of oxidation streaks, no evidence can be obtained that the actual quality of the rubber suffers to the same degree as does the appearance.

Yellow Latex Streaks. The appearance of "yellow" latex is rare, but when it does occur, it may be accounted for by incomplete mixture of two different latices. It is a fact of common observation that, when a new portion of bark is being tapped for the first time, there is a distinct yellow tinge in the latex exuded. As tapping progresses, this colour vanishes. Usually it may persist for a period varying from two weeks to more than a month. Should this latex be poured into ordinary latex without thorough mixing, it is sometimes found that, when the crepe rubber is dry, there are distinct yellow streaks. It should be remembered that the rubber content of the latex from first tappings is high and therefore mixed latices must be well stirred with a broad paddle to obtain intimate mixture. It would be much better to keep yellow latex apart, and coagulate it separately, if this is possible. In such case the resultant crepe may be of a distinct yellow in colour.

Bisulphite or White Streaks. These again arise from defective mixing. In the dry rubber it is seen that there are streaks of colourless rubber in a general mass, which may be of varying shades of yellow; or a length of exceedingly pale rubber is apparently streaked in patches with a darker shade of colour. A solution of sodium bisulphite is heavier than latex, and there would be a tendency therefore for the chemical to sink in the large mixing jar. Unless stirring is thorough it is possible that portions of the latex would not be in contact with sodium bisulphite while others receive more than a fair share. This effect is particularly marked where coagulation takes place quickly.

Another factor which has some bearing on the point is the strength of the solution in which sodium bisulphite is used. In the ordinary course of working, the acid coagulant is added immediately after sodium bisulphite has been stirred in. Should a strong solution of the bisulphite be used, and if coagulation takes place quickly, it is easy to see that the possibilities of obtaining a uniform and intimate mixture are small. Probably, in no factory is sodium bisulphite added to latex in powder form, but it has been found that if care is not taken to see that all the bisulphite has dissolved before the solution is added to latex, streaks may result in the dry rubber. The undissolved particles sink to the bottom of the coagulating jar or tank, and there slowly dissolve, forming local strong solutions. The effect upon the rubber in the vicinity of these strong solutions is much more marked than in the bulk of the coagulum and hence lighter streaks on patches appear in the dry rubber. In spite of apparently complete mixture by good stirring, it will be seen that it is possible therefore to have failed in this direction if any undissolved powder remains in the solution of sodium bisulphite.

Stickiness. This makes the rubber difficult to separate and causes it to become massed in the package, caused by overheating in the rollers or drier. The layers of rubber should be kept separated with a clean cloth after removing from the driers to prevent their sticking together. The final rolling should not be done when the rubber is hot.

Tackiness. This defect is caused by exposure of the rubber to sun light, or of worn bearings exuding grease and copper. The lower grades are particularly liable to become tacky and should be kept in water before being manufactured. Tackiness implies that some physical and chemical change in the rubber has taken place which renders it no longer rubber, but an oxidation product containing much resinous matter. It does not behave as rubber, and hence its value is much depreciated.

The defect can be avoided by taking a few simple precautions which are briefly enumerated below:-

(1) Any permanent openings through which it is possible for direct sunlight to enter, whether large or small, should either be totally closed or provided with some substance which cuts off the direct effect of the sunlight:- e. g. ruby glass or ruby glazed cloth.

(2) Under no circumstances should rubber be placed near, any source of heat.

(3) No rubber should be hung in a drying-room in such a position adjacent to a window or door that it is possible for sunshine to reach it.

(4) Instruments or vessels of copper or brass should not be used where acids are employed.

Thickened Edges. This defect can be traced to crepe being squeezed out to the edges of the roller which can be prevented by the insertion of wooden blocks of suitable size and shape.

Cotton Fluff in the Rubber. This is caused by the use of cotton waste in cleaning the machines, scraps of it being thrown about after use and working into the rubber, or by its being used as packing at the ends of the rolls to prevent oil squirting from the bearings.

Coloured Spots or "Spot" Disease. This is caused by bacteria, the result of infection in the field or damp in the factory. It is manifested by the appearance of small coloured spots varying in density and colour. The most common colours are black and orange, but "spots" of brick-red, yellow, violet and ruby and green tints have been noted, the last named seldom. Sometimes in place of definite "spots" or colonies, the colour is spread practically over the whole surface of the rubber as a "flush".

These coloured spots, or flushes indicate infection by minute fungi which are present in the latex prior to coagulation. The infection of the latex takes place in the field by means of spores, which are only visible with a microscope.

The condition may be created inadvertently in the factory if Piles of crepe rubber are allowed to remain for any appreciable period before hanging to dry. For this reason batches of wet crepe should always be placed on edge to allow free drainage of surface moisture if the rubber cannot be taken immediately to the drying sheds. Again, the condition is also provided if the thickness of the rubber is excessive.

The chief points connected with this defect are summarised below :-

1. No coagulum should be left without working for longer than the ordinary period. Otherwise, the prevailing conditions are very favourable for the development of the disease.

2. Thin crepe should be made when the disease is prevalent. The quicker the rate of drying the less possibility is there of the coloured spots appearing.

3. Crepe should never be allowed to remain folded overnight, and batches of folded wet crepe should be placed on edge to drain off surface moisture. The rubber should be hung to dry as soon as possible.

4. Several species of fungi causing coloured spots have been recognized, and it has been proved conclusively that it is possible to infect latex and also fresh coagulum.

5. Chiefly it would appear that infection takes place chiefly in the field vessels. It may take place during transport or during coagulation.

6. There is reason to believe that no further infection takes place once the rubber is well into the drying stage, and that dry rubber is not infected even by contact. From this one might infer that, as long as rubber remains dry, infection cannot take place in transit during voyage.

7. Coloured spots do not appear until the rubber is about half dry, because that period is necessary for the development of the fungus to that stage in its life-history when it excretes colouring matter. The fungus in its earlier and colourless stage may have been present from the time the latex entered the cup.

8. The natural habitat of the fungi would appear to be decaying vegetable matter in the field.

9. Having exercised all care and if it is found impossible to be rid of fungoid spot disease, the ordinary air-drying process should be replaced by a system of quick drying such as the hot-air draught system or the vacuum-drying process which enable the rubber to dry so quickly that any possibility of appearance of "spots" is entirely removed.

Surface Moulds or Mildews on Crepe Rubber. The necessary conditions for this defect would be supplied by one or more of the following causes:-

(a) Making the crepe too thick.

(b) Hanging the crepe in a badly ventilated or badly situated building.

(c) Abnormally wet weather.

(d) Allowing piles of crepe to remain too long before hanging.

(e) Using excessive quantities of deteriorated sodium bisulphite. In short, any factor contributing towards a retarded rate of drying may be responsible for the appearance of surface mildews. The last-mentioned cause is of not infrequent occurrence. Knowing the chemical to be of poor quality, relatively more is used to produce the desired anti-oxidant effect. Unless the rubber is particularly well washed on the rolls, there remains within it a residue of sodium *bisulphate* which is an oxidation product of sodium bisulphite. This is hygroscopic to some degree, that is, it takes up moisture from the atmosphere. Hence drying is retarded and delayed, and even should mildews not develop, the chemical may sometimes be seen on the surface of the rubber as a whitish "bloom".

Finally, before packing care should be taken to see that the crepe is thorougly dry.

General Discolouration. This may be caused by one or more of the following and adequate precautions should be taken to avoid them:-

1. Caused by dirt in the coagulum and insufficient straining, or by delay in transport and premature coagulation.
2. Rain water carrying acidic substances from the bark of the tree in wet weather may cause discolouration.

3. Defective mixing of Sodium bisulphite and acid or poor quality of these chemicals causing streaks as described earlier.

4. Rust marks caused by rust on rollers.

5. Grease from sides of rollers or pan at bottom, iron stains and green streaks.

6. Overheating and overdrying producing a dull orange coloured tint.

7. Underdrying and uneven drying, causing patches of raw white rubber. A bright even colour should be maintained and no mottled or cloudy rubber should be included in No. 1 grade.

DEFECTS IN SCRAP CREPE.

A summary of common defects in Scrap Crepe are given below :-

1. *Sand and Dirt.* The scrap should be well picked over and thoroughly washed in the scrap washing machine.

2. *Tackiness.* Earth scrap which has been lying about for some time is [particularly liable to tackiness. There is no cure for tackiness and care must be taken to exclude all direct sun light from the factory by the use of red curtains or other means. Tacky rubber should be packed separately.

3. *Spongey and Loosely Rolled.* Buyers prefer a firm type of scrap crepe. Over-machined and lacerated crepe is liable to become tacky.

4. *Stickiness.* Scrap crepe should be finally rolled with water or it will become overheated and sticky. It should also be air dried and not put through the hot air drier, which is liable to make it too hot resulting in stickiness.

5. *Undried Scrap Crepe* will show white spots, and moisture in the crepe will cause the rubber to become hot and mouldy.

6. *Smoked Crepe.* Scrap crepe should never be smoked or the colour will become too dark.

7. *Cotton Fluff.* This is caused by using cotton waste when cleaning the rollers.

8. *Uneven Sorting.* The different grades should be care fully sorted.

SORTING AND GRADING.

Ceylon. The following is a brief description of sorting and grading crepe rubber as practised in Ceylon :—

1.	*Best Pale Crepe.*	Pale crepe with good bright colour manufactured from pure latex.
2.	*Crepe No. 1.*	This grade is almost similar to above, but rather lower in colour. This must be separated from the *Best Pale Crepe.*
3.	*Crepe No. 2.*	This consists of mottled, palish and dark mixed crepe made from lumps, skimmings, washing and parings. Of these, skimmings will give the best grade, a fair-coloured, somewhat streaky rubber. Washings will be rather darker, and lump will give a dull-coloured streaky rubber.
4.	*No. 1 Scrap Crepe.*	This is made from tree scrap and consists of clean even-coloured light brown crepe.
5.	*No. 2 Scrap Crepe.*	This grade is dark brown in colour, but clean and firm and free from tackiness.

6. *No. 3 Scrap Crepe.* This grade is black and sticky, and is the product from bark shavings, earth rubber and cup scrap.

In grading, uniform quality in each grade should be aimed at, and all tacky rubber must be kept quite separate.

Packing. If packing is carried out in chests, the following points should be observed.

1. All cases should be planed and cleaned inside to prevent intrusion of chips and splinters into the rubber.

2. Care should be taken to see that the chests are not cracked.

3. The chests should be perfectly dry. If local chests are used, they should be well seasoned before use.

4. The chests should be less than 5/8 inch thick.

5. The best size is 18″ x 24″ and 16″ in height, inside measurements. 10 chests of this size will measure 1 shipping ton of 50 cubic ft.

6. 160 to 175 lbs. of sheet and 130 to 140 lbs. of crepe can be packed in each chest provided the package is a strong one. Rubber arrives in better condition in a full chest than when loosely packed. A saving in freight and in transport from the factory will result by observance of this rule.

7. Pack exactly the same amount in each chest and spread evenly and close up to the sides.

8. Nail and hoop iron each chest at each end and in the centre. But too large a nail for the centre band should be avoided or else the rubber will be torn.

9. Crepe rubber should be cut into lengths of 18" and strips of this size can be placed side by side. A patent cutter should be used, but if an ordinary knife is used,

dipping it into water will render the cutting easier. Trimming the edges of crepe would ensure closer packing resulting in perhaps 15 lbs. extra per package.

Marking. Each chest should be stencilled with the following details :—

(a) Nett Weight and Gross Weight on 1 side.

(b) Name of Estate
Invoice Number
Chest Number
Grade
} on the other side.

A chest of the aforementioned size will require 6 to 8 oz. hoop iron, if the centre band is used, 3 to 5 oz. 1½″ nails and 1 oz. of hooping nails.

Malaya.

First Quality Latex. This is crepe made from the true coagulum obtained from the regulated coagulation of strained latex. This is a pale rubber, and may be prepared satisfactorily if the directions for their manufacture are properly carried out. Any defective rubber in this grade for reason of inferior colour, contamination with dirt or traces of oil and grease etc., must be set aside and not included in this grade. When a proper scheme of standardisation of latex and chemicals is followed, there will not arise variety in shades of colour.

Compound Crepe No. 1. This grade includes cup- coagulated lumps, coagulated lumps from transport vessels, skimmings, bucket rinsings, cup washings, and tree scrap. The use of a scrapwasher renders the best results.

On some estates the ingredients of this compound crepe while fresh are placed in a common jar or tank to which a quantity or sodium bisulphite (1 per cent. solution) and acid are added. The resulting mass is cut up for working.

Compound Crepe No 2. This grade includes remaining lower grades, viz. bark shavings, scrap and earth rubber scrap.

The Rubber Growers' Association's Recommendations on this subject contains the following remarks:

"The fewer grades the better, and regularity of each grade is most important. The grading should be as follows:

No, 1. Fine crepe made from the free or liquid latex.

No. 2. Clean Light Brown Crepe made from lumps and skimmings.

No. 3. Scrap Crepe, made from tree scrap.

No. 4. Dark crepe, made from bark shavings, earth rubber and the lower quality of scrap.

All tacky rubber should be packed separately.

Compound Scrap Crepe. Estates using scrap-washers should make a compound crepe of grades Nos. 2 and 3, which will make one compound free from bark and specks. All rubber intended for No. 4 should be most thoroughly washed".

Care in Sorting. Whether dealing with smoked-sheet, pale crepe or lower grades, the strictest care is necessary in sorting and grading. This work must of necessity be relegated to trained workers under responsible supervision. Any pieces showing unmistakable signs of what are regarded as defects should be rejected. In the case of pale crepe, when the defect is confined only to a small area it is permissible to cut out the affected portion. Similarly there can be no objection in the case of smoked sheets to an occasional sheet being treated in this manner.

Samplers have often an uncanny knack of hitting upon the defective specimens which are not true to its grade, and it will be entirely the fault of the estate's sorters if these defective specimens are submitted as being representative of the mass.

CHAPTER XXI

MACHINERY AND EQUIPMENT
CREPE RUBBER

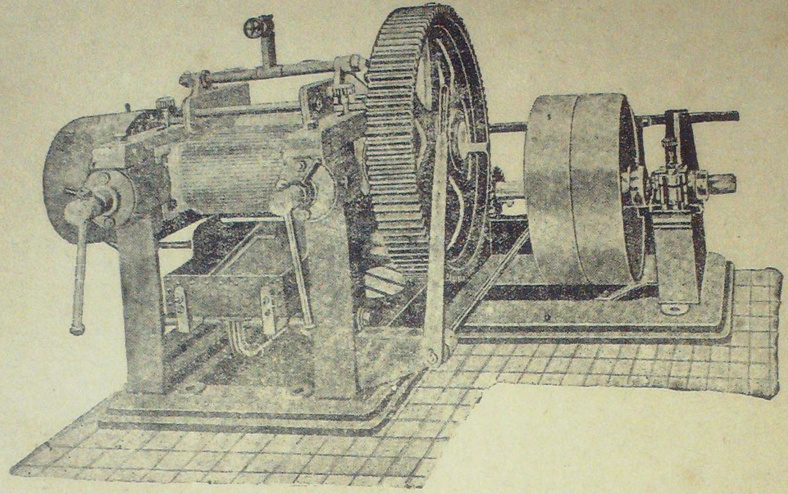
Preamble - Process in brief. The rubber latex is brought from the fields into a certain part of the factory where it is measured and strained to remove impurities and extraneous matter. It is thereafter placed in the bulking tanks and water is added to the latex in sufficient quantities to standardise the product to an average dry rubber content varying from 1½ to 3 lbs. by means of a metrolac.

Acid is then added in sufficient quantities to give complete coagulation of the rubber latex mixture during the night. The coagulated rubber represents a white tough substance which must be cleansed by passing between fluted rolls four or six times forming it into a rough surfaced piece of rubber about ¼ inch thick, termed *wet crepe*. To wash rubber thoroughly it is necessary to bring every particle into contact with water, and to permit the water to carry away all impurities.

The usual way to do this is to pass the rubber between adjustable rollers that force it out into a thin sheet, bringing everything to the surface, and then by means of a flow of water to wash the impurities. It is then passed once between smooth rolls to give a thin sheet of rubber, from which the moisture can be easily extracted in some type of drier or by air drying.

After drying, the rubber is again passed between fluted rolls four to five times to produce the final product known as *dry crepe* rubber.

Rubber Mills. Rubber rolling mills usually consist of two cast iron rolls 12″ diameter by either 15″ or 18″ in length carried by bearings resting on iron side frames, and driven by any type of spur or helical gearing,



FLUTED CREPE RUBBER MILL

The bearings carrying the rolls are made to rest on flat surfaces formed on the side frames. Adjustment of the rolls is obtained by allowing the front roll to slide away from, or towards, the back roll, the position of the bearings carrying the rolls being controlled by two screws working in suitable bushes fixed in the iron side frames. An illustration or a typical rubber mill is given on page 348.

Rolls for Crepe Rubber. The rolls as previously stated are usually 12″ dimater by 15″ or 18″ long to suit the breadth of rubber required to be manufactured, and are of two types, fluted and smooth. The fluted roll should always be of as hard a material as possible, provided the rubber passed between the rolls is free from sand and grit, such as is found in scrap rubber. Sand is *never* present in pure latex rubber.

The flutings on the surface of the rolls are parallel with the rolls and usually about 3/16″ wide by 3/16″ deep and should be slightly tapered. The flutings form the gripping surface required to work up tbe rubber properly and also to allow for an internal movement in the mass of rubber passing between the rolls. A little thought will show that flutings cut with tapered sides will allow the rubber to fill, and extract itself from these flutings easier than would otherwise be the case if they were cut square. It is most important to have the flutings recut when necessary, otherwise the efficiency of the rolls will be greatly decreased. Finished crepe should have a well roughened surface to prevent it from sticking during the packing period, and this can only be obtained with rolls having the flutings in good condition.

Dry Rubber Rolls. Fluted rolls utilised to finish the final dry crepe rubber develop much heat due to the friction of the dry rubber passing between the rolls. In order to keep the rolls fairly cool, it is proposed that they be cast hollow and water passed through them. The majority of rubber rolls made at present are very heavy, and if they were cast hollow, the strength would not be much affected, and benefit will be obtained both by reduced weight and cooling effect when utilised for any rubber creping.

Life of fluted Rolls. The flutings on the rolls may be re-cut several times until a diameter or 10½″ is reached, when the life of the roll may be considered as finished. This period is nine to ten years, provided the rolls are given fair treatment.

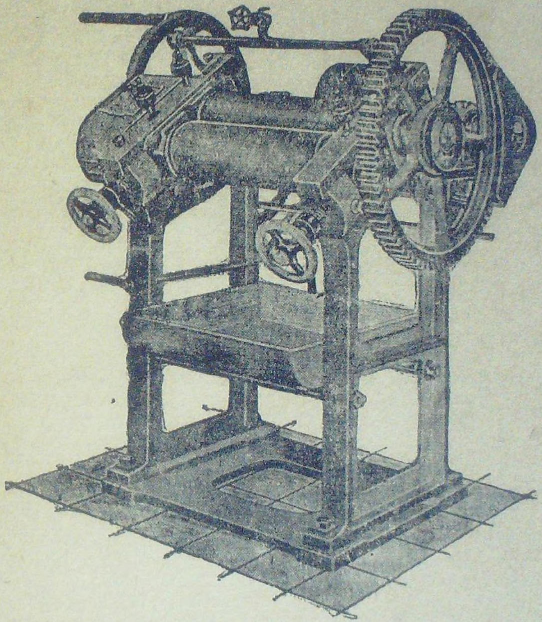
Rolls for Scrap. It is the practice in some factories to extract sand and foreign matter from scrap rubber by passing it between fluted rolls. The scrap requires to be passed twenty six or more times between them to extract the sand and foreign matter, and the strain is most severe on the roll surface and even with hard chilled rolls, will wear out the flutings in a very short time.

The sand should always be extracted from the scrap in a special machine and the cleansed scrap afterwards passed six to seven times between fluted rolls preparatory to thinning between smooth ones.

Working Rolls. Every care should be exercised to keep rubber passing between the fluted rolls. Should the cooly not keep rubber passing between them continually when they are in motion, the flutings on the surface will be apt to catch in each other and destroy their edges, and otherwise place great strain on the bearings of the mill.

Smooth Rolls for Lace Rubber. Smooth rolls are of similar design to those fluted, only differing in their working surfaces, and are utilised to thin down rubber after preparation in fluted rolls. They produce a very thin rubber termed *lace*, from which the moisture can be easily extracted in driers. The rolls are made in two forms, (i) hard chilled and (ii) soft.

Hard Chilled Rolls last longer than soft ones, but the surfaces being so hard and polished, allow a certain amount of slip to take place between the rubber and the roll surfaces. This under certain conditions forms small balls of hard rubber on



HAND OPERATED SMOOTH ROLLER

edges of the lace, and these balls being solid retard the drying of the rubber lace unless picked off by hand. With softer rolls, the surfaces become slightly rough and grip the rubber passing between them, thus having little tendency to form these balls of rubber on the edges which delay the drying process. Therefore in some conditions it may be preferable to choose the softer or semi-chilled smooth roll, although its life is shorter than the hard chilled one.

Rubber Rolls, Idle. — When the rubber mill is stopped for the day the front roll should always be eased away from the back one by slackening the adjusting screws; otherwise, if they are left tight together during the night, a bad rusty mark may form, causing wastage of the roll surface.

Water for Rolls. Various classes of water have different effects on the rollers. It is noticed when the water contains much redish iron deposit, that rolls, especially of the softer type, become pitted and waste more quickly on the working surfaces; hence the necessity for a good pure water supply.

Wear of Rolls. As these wear down, they should be tested to make sure the wear is even, and if not, they should be trued up in a workshop. Attention must also be given to the end gears as afterwards described under the heading "Roller end gears".

Rolls must always be made from a special close grained cast iron and should under working conditions show an even solid surface.

Roll End Gears. The back roll is driven direct from a counter shaft through machine cut gears and has attached to it a toothed wheel, termed an *end gear*, which meshes with a little larger wheel fixed to the front roll. The result being that the rolls work at different speeds elongating the piece of rubber passing through them.

The teeth of these wheels are made longer than usual to allow of the front wheel being adjusted as required. A space of about 3/8" clearance is allowed between the top of one end gear wheel tooth and the bottom of the corresponding wheel tooth when the rolls are new and close together. Great care must be exercised when rolls become worn, as the teeth of the end gears will then "bottom" or come together too closely.

This can easily be noticed by the excessive noise and vibration about the machine under working conditions, and may cause the following faults to appear:—

1. Teeth of end gears may break.
2. Bearings may run hot or wear quickly.
3. Side frame may break or crack.
4. Bush which carries the adjusting screw may break.

Should excessive noise be noticed whilst the rubber mill is working, the end gears should be examined, and if they appear bright on top or bottom of the teeth, they should be taken off and sent to an engineering workshop to have the teeth reduced.

After one or two reductions these gears should be replaced with new ones to suit the reduced diameter of the rolls. It is usually necessary to renew them when the rolls reach $11\frac{1}{4}''$ and $10\frac{3}{4}''$ diameter. End gears should have the following ratio :—

Fluted Rolls }
Smooth rolls } 17 or 18 to 21 teeth or equivalent

In the earlier days of rubber manufacture it was usual to supply rolls (both fluted and smooth) fitted with end gears having teeth ratios of seventeen to thirty four giving to the front roll double surface speed to that of the back one. With fluted rolls this difference of surface speed is probably correct for extracting the sand and foreign matter from scrap rubber. In dealing with latex rubber or cleansed scrap this ratio difference is of no benefit, but is a decided disadvantage for the following reasons :-

Due to the difference in end gear ratios, the rolls will travel at the following speeds :-

Back roll 11 r.p.m. = 33 ft. per min. surface speed.
Front roll 22 r.p.m. = 66 ft. per min. surface speed.

The rubber passing between the rolls is, therefore, subjected to the action of two different fluted roll surface speeds.

With wet latex rubber this difference of speed tears the soft rubber and consumes unnecessary power.

Should *dry* rubber be passed between the rolls, the difference of speed will make different markings on either side of the dry crepe rubber which is not appreciated by buyers; also much unnecessary power is consumed.

With smooth rolls the output of the machine is almost directly in proportion to the speed of the slowest one, especially if the lace is made sufficiently thin to dry quickly.

The faster roll surface only slips on the lace in proportion to the speed difference causing heat and wastage of power.

Both fluted and smooth rolls should only have a ratio difference of the end gears of two to four teeth, which gives sufficient difference of surface speed to pull the rubber between them with the minimum of power. The marking on the finished dry crepe will then be practically similar on both sides, thus giving a rubber of good appearance.

Roll Bearings. Roll end bearings should always be bushed with a brass lining of approximately ½″ thickness. This bush is necessary as the roll journal being of iron requires a brass surface to work upon; brass being softer than iron, any wear which takes place will be on the brass liner which can be replaced, but should both the roll journal and the bearing surface be of iron, then the journal will wear along with the bearing, and when renewals are required the roll journal may be found distorted and smaller in diameter than the standard size of bearing. With brass linings the roll journals will last many years and can be refitted when necessary with new bearings of standard size. If cast iron bearings are used they should be of very soft material, so that any wear will take place on the bearing and not on the journal.

Guide Plates. Two guide plates are usually fitted, one on each end of working surfaces of rolls; the plates are either separate or joined together in one casting. These plates are usually of iron and fit closely to the reduced parts of the roll ends. As the rolls decrease in diameter due to wear the guide plates will become compressed between the roll surfaces they bear upon and may become broken. The plates may be relieved by cutting the edges. The design of these plates might be improved by making them of some softer material such as wood which can be easily cut down in size as the roll surfaces come closer together.

It is a common practice to fix extra wood pieces to the inner sides of the guide plates to reduce the actual length of working surface of the rolls suitable for the breadth of rubber it is required to produce.

Countershaft Bearings. The countershaft with its bearings should not take up any space directly behind the mill rolls, as any obstruction of this kind may transmit dirt to the rubber lace leaving the smooth rolls on its way to the winding drum. If the end bearing is fixed to one frame of the mill no obstruction should exist.

Grease Cups. These should be tested every morning before work is commenced and the grease pipe may be cleared of hard grease with the aid of a piece of wire if necessary.

Driving Gears. The rubber mill is usually driven by a belt running on fast or loose pulleys fixed to a countershaft which carries a pinion wheel which drives a large wheel attached to the back roll. The pinion and large wheel should have machine cut teeth to give silent running and care must be exercised to see that these are kept well greased.

Rubber mills are made in the following sizes and require approximate horse-power as stated:—

Rolls	Smooth	Fluted		Speed of rolls
		Wet	Dry	Wet or Dry
6″ × 12″	4 H.P.	5 H.P.	6 H.P.	22 R.P.M.
9″ × 15″	6 H.P.	8 H.P.	9 H.P.	,,
12″ × 15″	8 H.P.	10 H.P.	12 H.P.	,,
12″ × 18″	9 H.P.	10 H.P.	14 H.P.	,,

The output from rubber mills per hour is as follows :-

Rolls	Smooth	Fluted Wet	Fluted Dry	Speed of Rolls
6″ × 12″	40 lb.	120 lb.	200 lb.	22 R.P.M.
9″ × 15″	60 lb.	210 lb.	300 lb.	,,
12″ × 15″	80 lb.	280 lb.	400 lb.	,,
12″ × 18″	100 lb.	300 lb.	430 lb.	,,

The output of a rubber mill is in proportion to the surface speed of the back roll and will give the highest efficiency with end gear ratio of 17 to 21 or a difference of three to four teeth.

The output and horse-power of the machine will vary according to the speed of back roll, except where end gears are not of correct proportion, the horse-power will be as set out above.

Output of Lace Rubber produced from smooth rolls varies from 70 to 130 lbs. per hour wet weight equivalent to 56 to 104 lbs. dry, the output varying according to the speed of the back roll and the ratio of the end gears.

Best results with 15″ × 12″ smooth rolls appear to be given when the speed of the back roll is 20 r.p.m. and the end gear ratio seventeen to twenty one teeth. The output should then be 70 lbs. to 80 lbs. of wet lace per hour of correct thickness for drying.

Fluted rolls under the same condition should produce 280 lbs. of wet crepe and 400 lbs. dry crepe per hour.

Water Supply to Rolls. It is necessary to spray water on the rolls whilst wet rubber is passing through. The consumption of water varies in different factories, but may be anything between—

60— 80 gallons per hour	—	9″ x 15″	rolls
80—100 ,, ,, ,,	—	12″ x 15″	,,
80—100 ,, ,, ,,	—	12″ x 18″	,,

It is not usual to spray water when dry rubber is passing between the rolls as the dry rubber will absorb part of the water. When rolling dry rubber careful attention must be given to the lubrication of the bearings as the rolls become heated with the friction of dry rubber passing between them.

DRYING OF RUBBER

Drying of Rubber Lace. Rubber lace usually contains about 20% of moisture, which has to be removed naturally by hanging the lace in a large loft supplied with hot air. As this process takes time and in order to accelerate the removal of the moisture rubber driers are usually utilised.

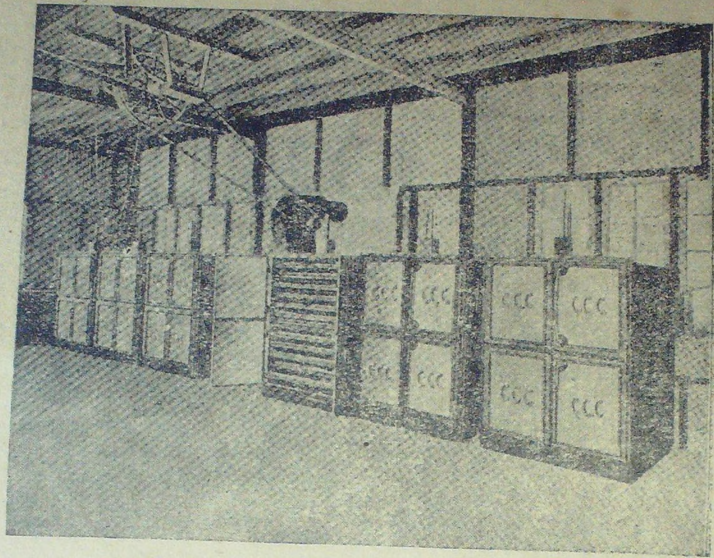
Rubber Driers. To dry rubber effectively, the rubber lace must be very thin, and of a fairly open texture. It must not be hardened too much, as would take place if the rubber were passed twice in place of once through the smooth rolls, or from other causes, such as excessive coagulation. To dry rubber efficiently, the following points must receive proper attention :—

1. The lace should be as thin as possible.
2. The lace should be as open in texture as possible.
3. The lace should not be any harder than actually necessary to allow for handling. If these three points are carefully considered the removal of the moisture is an easy matter.

In all types of rubber driers the rubber lace is laid upon trays in two to three layers. To save unnecessary labour in spreading the trays, the rubber lace is often wound on to a wooden drum as it leaves the smooth rolls. Great care must be taken to see the rubber lace is not wound round the drum too tightly as the layers will then be too close to prevent the moisture being withdrawn freely from the mass of rubber lace.

The wooden drum should have its length equal to the length of the tray and a circumference which is 3 1/7 times the diameter, and equal to the breadth of the tray. As the rubber lace shrinks in drying, it is usual to allow one to one and half inches in excess of the actual tray dimension.

After sufficient lace is wound round the wooden drum, the mass of rubber lace is cut parallel along the drum, and removed in a form equal to the area of the drier tray.



HOT AIR DRIER

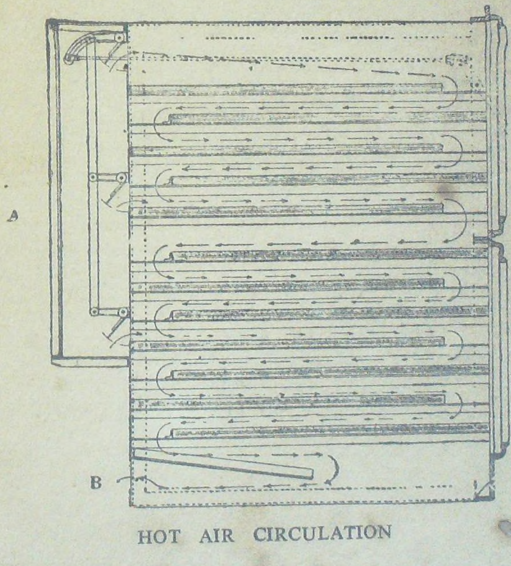
Driers. There are two distinct types of rubber driers:-

(i) Hot pressure air type.

(ii) Vacuum type with heat application.

Hot Pressure Driers. The most successful type of hot air drier consists of an iron heater through which cold air is driven by means of a fan and after heating to 160°F to 180°F. passes through ducts to drier chambers containing usually twelve trays, each tray about 4 ft 0 ins square placed one above the other.

The Hot Air enters the drier chambers, near to the top through controlled flap valves and passes alternately above and below each tray until it escapes near to the bottom of the chamber, as shown in the illustration below by the direction of arrow :—



HOT AIR CIRCULATION

Hot Air Circulation.

A represents the inlet duct for hot air.
B represents the exhaust duct.

The Trays are usually made of angle iron with wire mesh filling, and are passed into the chambers through doors, upon slides fixed to sides of the chamber. On each slide a stopper is fixed and if each tray is pushed against its stoppers, they will be in correct position as shown in the diagram on page 359. The drier may consist of six chambers connected to one heater.

The efficiency of this drier depends upon the position of each tray to give the correct circulation of heated air; therefore each tray must be up against its respective stoppers.

In many cases this is not done, with the result that the drier output falls considerably.

Spreading of Trays. About 3½ to 4 lbs. of rubber lace is spread on each tray; it is most important to see that the rubber lace completely covers the wire mesh of trays. Should this not be the case open spaces are left on the trays, with the result the air will take the easiest course and pass down through these open spaces, resulting in loss of efficiency in the drier.

A little care exercised on these points will make more difference in the rubber output of each chamber than can be realised at first sight.

As will be noticed on trial the hot air enters the drier at, say 160°F to 180°F and leaves by the exhaust duct at a temperature of 100°F to 120°F. This difference in temperature provides the necessary energy to extract about 20% of moisture from the rubber lace; it is therefore necessary to devote this difference of temperature as much as possible to its proper work. If one stands near a drier chamber, a good deal of heat is observed to radiate from the outer surface and this must be looked upon as wastage. To decrease this wastage of heat it is usual to enclose the drier chamber with wood or other heat-resisting medium, and thus prevent heat radiation. If this is done, the heat will be kept inside the drier chamber and be available for extracting further moisture from rubber and thus add to the efficiency of the drier.

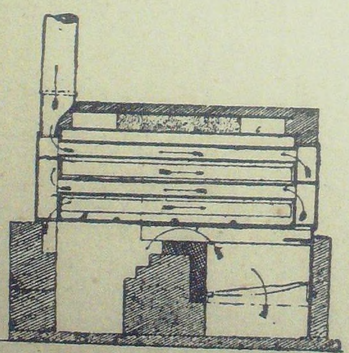
Spare trays. It is well to provide for twelve spare trays and if these are filled with rubber lace they can be placed inside the drier chamber immediately the trays with dried rubber are removed thus saving time.

All trays with dried rubber should always be removed before replacing with trays of wet rubber, otherwise the dry rubber will receive moisture from the wet, especially if they be situated below the wet lace trays.

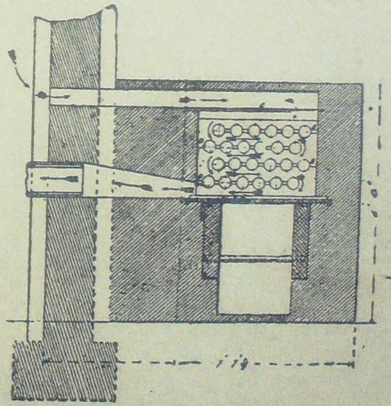
Rubber Drier Heater. An illustration of a hot air Drier Furnace is given on page 362. The furnace is formed of an iron box fitted internally with tubes through which the fire gases pass after travelling along the bottom of the iron box. Parts of the iron box at the fire place are protected with fire bricks; it is important to see these bricks are kept in good repair. Also a firebrick arch is built at back of fire bars with the object of directing the fire gases against the bottom plates of iron box.

The Ash pit under the fire bars should, if possible, be flooded with water or kept regularly cleaned out. An accumulation of red ashes in the ash pit will soon burn out or twist the fire bars, which only remain straight and unburnt so long as they have a supply of cool air fed upwards through them to the fire; it is therefore most important to keep the ash pit as *cool* as possible

Smoke tubes are passed through holes in the end plates and are jointed with asbestos. The fumes after passing under the iron box plates (these plates are renewable), where most of the heat is given up, pass through the smoke tubes on their way towards the chimney. Soot or dirt is a very bad conductor of heat, therefore it is important to clean the smoke tubes every morning if necessary. A deposit of dirt on the tubes means loss of efficiency in the furnace and a larger fuel bill.



Longitudinal Section of Furnace



Cross Section of Furnace showing Air Passages

Firebrick lining shown thus

HOT AIR DRIER FURNACE

Chimney. In most cases it is necessary to fix a cap on top of chimney to prevent sparks escaping and causing damage by fire; this cap has the effect of stopping the free passage of the fumes up the chimney and these more or less condense inside the chimney. When burning rubber wood, a larger percentage of acid fumes are given off than with harder woods and these cause rapid wastage of the chimney. However, as the cap is required in most cases, this wastage cannot be diminshed unless some good class of firewood or liquid fuel be utilised to provide heat in the furnace.

Wet Firewood. It is not usually recognized that wet fire wood represents a great loss in fuel consumption. For instance fire wood stacked outside may have 25 to 30% of moisture in it; 25% of moisture represents 25 lbs. of water per 100 lbs. of firewood, or two and half gallons by measure, and has all to be evaporated in the fire. Fairly dry firewood will have a moisture content of about 7% which leaves a difference of 25 - 7 or 18 lbs. representing the excess of moisture between wet and dry firewood. Considering that 3 to 3½ lbs. of firewood, would be required to evaporate 1 lb. of water, then 18 x 3 = 54 lbs. of fairly dry firewood will be required to be added to the wet firewood to evaporate its moisture. This example will be sufficient to show why there is an urgent need for a good firewood shed on every estate using firewood as fuel.

Operation. Before placing fire in the furnace the blast fan should be started and the control flap doors on chambers opened just a little; should this not be done the furnace will become overheated and may be distorted with the sudden rush of cold air when the blast fan is started.

While the chambers are being heated gradually, the rubber lfet over from the previous day's last charge (preferably scrap rubber) can be gradually dried off, and removed before the chambers have reached their full temperature of 170°F to 180° F. The best temperature for treating scrap rubber is between 140°F to 150°F.

This type of drier has received many improvements and it is now generally found that the twelve trays can be removed at the same time and a fresh lot placed in the chamber. However, should any trouble be found with the lower two or three trays taking longer to dry, they should be placed on top position before fresh trays are inserted; it will usually be found they will dry off in a few moments and can then be replaced with wet trays. Each chamber should give an output of 40 lbs. dry rubber per hour.

The consumption of firewood required by the heater will vary between one and two yards per day.

Vacuum Rubber Driers.

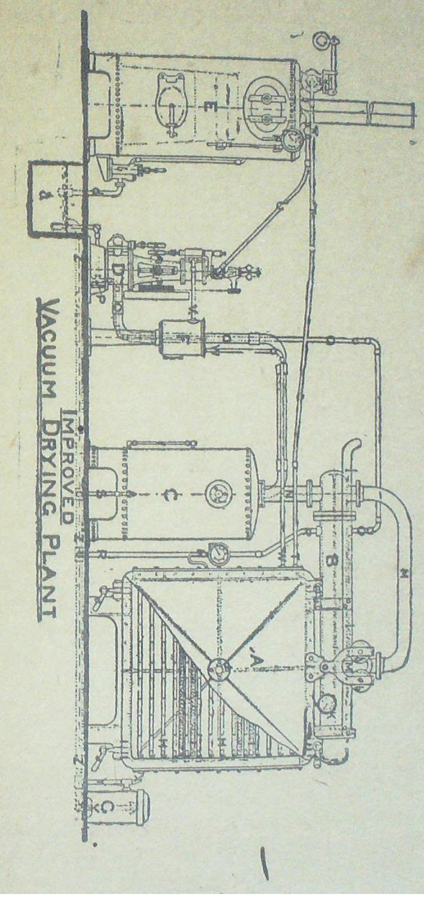
A sketch of a Vacuum Rubber Drier installation is shown on page 365. The unit consists of a large cast iron chamber fitted with steam heated platens which carry the rubber drying trays. A heavy cast iron door closes the chamber and is made air tight by means of a rubber joint.

An air pump, either belt or steam driven, exhausts the air and moisture from the above chamber, the exhaust air passing through a water cooled chamber called a condenser before reaching the pump, the effect being to increase the efficiency of the pump due to the cooling of the gases.

Any moist material heated under the influence of a vacuum should give up its moiture more quickly than if heated in atmospheric conditions, but a comparison of actual working output will show that the hot air system is more economical.

Vacuum Drier.	Hot Air Drier.
1 chamber with 16 trays including condenser, pump and boiler gives an output of 107 lbs. of dry rubber per hour.	3 chambers with 36 trays including fan and furnace give an output of 120 lbs. dry rubber per hour.

Vacuum Drier Chamber. As already stated the chamber consists of a large cast iron box having a swing door on front



IMPROVED VACUUM DRYING PLANT

fitted with a rubber face joint. This joint is partly sunk into the faces and can be easily renewed when worn.

The rubber joint requires attention and must be kept clean; otherwise it will stick and be damaged when the door is opened. Should it become damaged or worn at places, there is danger of the door developing a crack owing to the great pressure of several tons force acting on it when a vaccum is created inside the chamber; the joint should, therefore, be renewed before the wear is excessive. Before the vacuum is created the door is held against its rubber face by means of wing bolts, but after the vacuum reaches five inches the bolts may be released.

Steam Platens are bolted inside the chamber to vertical steam ducts and rest upon snugs or projections on the chamber sides. Careful attention should be given to the top and bottom steam platens, as these rust quickly, especially the top one due to moisture falling on to it. Before wastage becomes excessive the top platen might be removed and replaced with one taken from about a central position in the chamber and the wasted tray put back in its place, where it will be safe for a year or so as the wastage is not considerable except on the top and bottom platen. A receptacle might be hung underneath the pipe opening from top of the chamber, thus preventing drips of moisture falling on to the top platen. The joints of steam platens must be kept tight.

Pipes between chamber and condenser rust very quickly and must be examined each year and replaced if necessary.

Condenser is composed of a cylindrical vessel placed vertically, and fitted internally with tubes around which cool water circulates. The heated gases drawn from drier chamber are cooled by passing through these tubes and give up part of their moisture. It is important to have plenty of water flowing through the condenser as the efficiency of the pump depends upon the coolness of the air withdrawn from it. The condenser can be retubed when necessary.

Air Pump. Due to the effects of the damp acid air drawn rom the condenser, wear about the air pump parts is very rapid, especially about the piston rings and slide valve. The pump is usually worked from a steam cylinder, but it is sometimes more economical to drive the air pump by belt from factory shaft and develop steam at only 4 to 5 lbs. per sq. inch pressure.

Vacuum. A complete vacuum is represented by a minus quantity equal to the Barometric pressure of the air, and is in practise about 27 inches with the pump in good condition.

Should the vacuum decrease to twelve or fifteen inches the following defects should be looked for :—

1. Leaks about chamber door joint.
2. Leaks about drain pipe under chamber.
3. Leaks about steam platen joints.
4. Leaks about pipes between chamber and condenser.
5. Leaks about condenser and its valves.
6. Leaks about pipes between condenser and pump.
7. Leaks about or caused by wear on piston rings of cylinder or slide valve, or glands about pump.

Should much trouble be caused by leakages it is better to consult an engineer at once.

Rubber lace need not be rolled quite so thin for the vacuum drier as for the hot air drier, and 9 to 10 lbs. of lace may be spread on each tray, the time usually taken to dry a complete charge of rubber lace is about 1½ hours, but will increase if the vacuum is defective.

MACHINERY FOR TREATMENT OF SCRAP RUBBER

Scrap Washers. Scrap rubber as picked from the tree, and especially earth rubber, contains a more or less quantity of foreign matter such as sand, earth, etc., which must be removed from the scrap before the rubber can be formed into the final product.

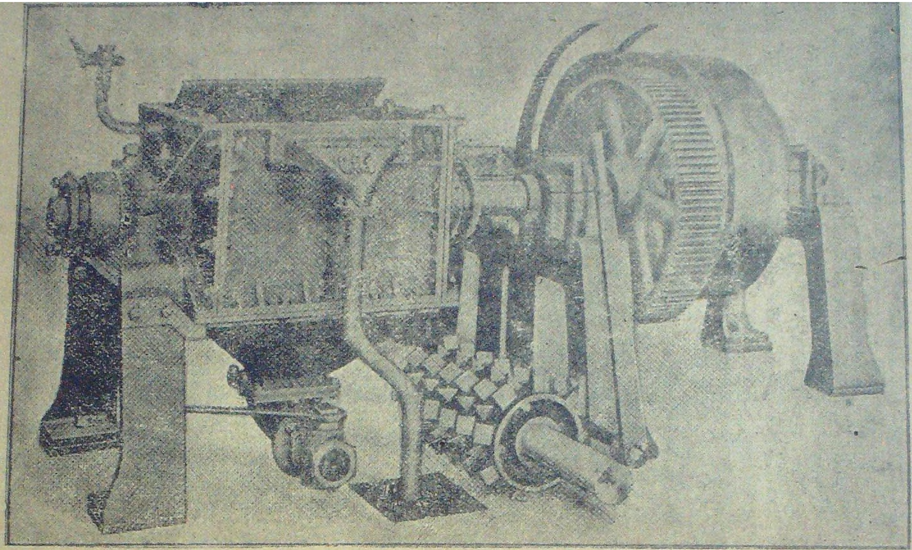
In former times, it was a general practice to cleanse the scrap rubber by passing it between fluted rolls causing excessive wear upon them. To clean scrap rubber it is necessary to keep the mass of rubber continually open to allow water to penetrate to all parts of the mass of scrap. For the purpose of washing out sand and other impurities several types of machines are in use, but generally they may be considered as being divided into two main types.

THE C. C. C. TYPE SCRAP WASHER.

An illustration of the above type of machine is shown on page 369. It is composed of an iron box built up in sections having a revolving rotor fixed internally as illustrated. The sides of the box are lined internally with interchangeable plates having projections of special shape cast upon the working surfaces. The rotor has also special projections cast around its periphery or working surfaces.

Under working conditions about 25 to 30 lbs. scrap rubber is fed into the machine and as the rotor revolves, the projection on the rotor and plates penetrate the mass of scrap from both sides, thus opening it up and allowing water supplied to the machine to wash out the impurities. A plentiful supply of water is necessary for this machine especially during the initial cleansing stages when much foreign matter is extracted from the scrap. To remove this the draw-off cock at the bottom of the machine should be opened frequently to allow the dirty water to escape, otherwise the scrap would be worked in dirty water thus hindering the cleansing operations.

Towards the final stages of cleansing, the scrap forms itself into sausage shaped rolls, 25 to 30 lbs. of scrap should form into two rolls. As these sausage shaped rolls form, they gradually become harder and whiter. This should not be allowed to go on too long. When they commence to make a hard rasping noise on nearing the exit, it is time to remove the scrap for further treatment in a fluted rubber mill. A supply of hot water is



C. C. C. SCRAP WASHER

beneficial. Should it be necessary to treat old or very dirty scrap, hot water tends to soften the mass more easily. The hot water may be obtained by utilising the overflow water from the engine cooling tanks. The horse-power required for this machine is approximately 12 h.p., whilst the rotor makes sixteen to twenty revolutions for minute but it would be wise to consult the makers or agents as to the best speed which they advise to suit the power available in any individual factory.

OPERATION

(i) *Clean Scrap.* To commence work the box should be filled with water to approximately half up the rotor, when a charge of 25 to 30 lbs. of scrap can be put into the machine. The water supply should be turned on full, and as the water becomes discoloured the cock at the bottom should be opened frequently and a good quantity of water allowed to escape, and as will be noticed large quantities of sand etc., are discharged with the water. In about 7 minutes, the sand and other impurities should be extracted and the scrap will form up into two sausage shaped rolls which can shortly be taken out.

(ii) *Ground Scrap.* A similar charge of ground scrap is filled into the machine, but as the percentage of foreign matter is greater a longer time will elapse before the water clears itself, and probably fifteen to twenty minutes will elapse before the scrap will form into the sausage rolls.

(iii) *Bark Shavings.* Bark shavings only yield about 8 to 15% of its weight in rubber and cause a large amount of wear to any machine. Three charges of approximately 30 to 40 lbs. each are added to the machine at the rate of one charge every ten minutes. This forms into a wet mass which must have a generous supply of water accompanied with frequent openings of the outlet cock. In about forty minutes, 20 to 25 lbs. of rubber is produced in the form of a sausage roll which can be further treated in the fluted rubber mill.

Output. The average output of the machine is as follows :-

Clean Scrap	—	100 lbs.	dry rubber per hour
Ground Scrap	—	75 lbs.	dry rubber per hour
Bark Shavings	—	30 lbs.	dry rubber per hour

B. **THE "UNIVERSAL" SCRAP WASHER.**

This machine has two deeply corrugated rolls carried in fixed bearings, and a trough shaped at the bottom to follow the peripheries of the rollers and carrying ledges at the back and front. These ledges turn the rubber over and guide it between the rollers as it is brought to the surface by the action of rollers which run towards one another and catch any large impurities such as stones and nails.

Gratings are set in the back and front of the trough to allow the lighter impurities to escape.

The rubber can be freely fed into the machine, and the rollers acting in conjunction with the peculiarly formed trough immediately carry the rubber down, round and up again continuously and automatically. The rollers are never drawn together but are held at a fixed distance; the object in keeping the rollers apart is to obtain very gentle action. By having a certain distance between them, the pressure is always taken up by a cushion of rubber and as all the rubber in the bottom of the trough is being treated simultaneously, it is obvious that the power consumed by the machine is always bound to be spread over the greater part of the charge instead of being concentrated on a narrow and very thin strip as it is in passing through the usual form of open rollers.

Further by having this distance between the rollers, such impurities as new wood and bark are not splintered, nor are pebbles broken, or large particles of sand ground as there is no crushing action.

Sand and other minute impurities heavier than water pass out through slots underneath the rollers, and are conveyed through the sand box to the straining vessel out of which they can easily be shovelled at intervals; pebbles, nails, etc., which are too large to pass the slots under the rollers are caught on the ledges which are on a level with the top of the rollers.

Lighter impurities, including new wood and bark, are floated off by closing the sand box and the valves in surrounding jacket, thus rasing the level of the water either to a point level with that of the rollers or slightly above the top edge of the trough. They are then quickly freed by the action of rollers working in conjunction with the peculiar formation of the bottom of the trough and float off instantaneously on coming to the surface. The flow of water carries them into the surrounding jacket and out through the upper outlets or through the lower outlets by opening the valves, and thus into the straining vessel.

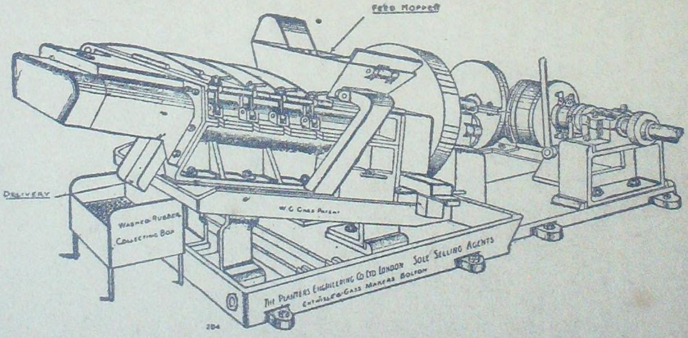
The machine is entirely automatic in its action so that labour is reduced to a minimum, and a uniformly well washed product is obtained.

Capacities and Horse-Power. The patent "Universal" Washing Machine is made in three sizes outputs of which are given below :—

	Small	Medium	Large
Naturally coagulated lump rubber	30 lbs	50 lbs.	80 lbs.
		in 15 minutes	
Tree Scrap	35 lbs.	50 lbs.	100 lbs.
		in 20 minutes	
Bark shavings and Earth Scrap	60 lbs.	80 lbs.	160 lbs.
		in 25 to 30 minutes	

C. THE CONTINUOUS SCRAP WASHER.

This machine is illustrated on page 373 and is claimed to give a quick and thorough wash ng of bark and scrap rubber while preserring the nerve and strength of the rubber. Dirt and sand are



CONTINUOUS SCRAP WASHER.

removed in the process of washing. It is designed for a direct drive through a friction clutch from a main shaft or fitted with fast and loose pulleys for belt drive.

It consists of a main roller specially grooved, revolving in a heavy cast iron casing, accurately bored, and heavily ribbed with a secondary roller which is used as a feed roller. The axes of these rollers are not in the horizontal but inclined, the delivery end being higher than the feed end.

The rubber is fed into the machine and passes round between the main roller and the casing, while at the same time, it is moved along the surface. These two movements give the washing and cleaning effect. The rubber is delivered at the other end in a clean macerated and amalgamated condition, in pieces about one inch diameter by four inches long ready for passing through the creping mills.

POWER

Power. The power required to drive a crepe rubber factory is a very variable one, and the load will naturally vary according to the quantity of rubber to be manufactured, and must be based upon the quantity estimated to be manufactured during the busy months of the year. Figures taken from the principal rubber producing areas in Ceylon point to the following percentages as the average of crop obtained during each month on the one cut alternate day system:—

	For Month.
	%
January	8½
February	3½
March	4
April	8
May	8
June	8
July	8
August	9½
September	8½
October	10½
November	11
December	12½
	100%

If we take for example a Factory which has to deal with 750,000 lbs. of dry rubber during the year, December having the largest crop, averaging 12½% of total crop, is estimated to take in approximately 94,000 lbs. which works out to 3,100 lbs. per day. If the scrap percentage is say, 20%, the day's crop will consist of :-

2480 lbs. of dry latex rubber
620 lbs. of dry scrap rubber

The capacity of the whole factory machinery is based upon the output from the smooth rubber mills which produce rubber lace containing about 20% moisture, thus the capacity of the smooth mills must be as follows :-

2480 + 20%	=	2976 lbs. of latex rubber lace
620 + 20%	=	744 lbs. of scrap rubber lace
Total		3720 lbs. wet rubber lace.

During the busy season the factory machinery might be in commisson from 6 a. m. to 6 p. m. and the smooth mills should be in operation during the full twelve hours.

The capacity of the factory machinery is regulated by the capacity of the smooth rolling mills which may be calculated as follows on the basis that the factory starts work at 6 a. m. and stops at 6 p. m. with one hour stoppage for meals allowing eleven hours clear work, except for the smooth mills which should be worked during the full twelve hours.

Smooth Mills. One mill fitted with 12″ x 15″ smooth rolls will produce 70. lbs. per hour of wet rubber lace sufficiently thin for hot air driers. This figure may be increased by making the wet lace thicker, but this only retards the drying speed.

1 smooth mill per day averages 12 hours' work per day and produces 70 to 80 lbs. of rubber lace having a moisture content of 20%, equivalent to 56 lbs. of dry rubber per hour. On this basis the output of one smooth

mill is 70 x 12 = 840 lbs. rubber lace which is equivalent to 672 lbs. of dry rubber. Therefore 5 smooth mills will be required giving an output of 3600 lbs. dry rubber per day.

Fluted Mills for Coagulated Latex. 1 fluted mill with 12″x 15″ fluted rolls will produce 280 lbs. of wet rubber crepe per hour, equivalent to 192 lbs. dry rubber per hour. 3720 lbs. of rubber lace will usually require about 3900 lbs. wet rubber crepe. Therefore 2 mills having a capacity of 560 lbs. per hour will produce 3900 lbs. of wet crepe in 6½ to 7 hours.

Hot Air Driers will produce 40 lbs. of dry rubber per chamber per hour and should be in commission 10 hours out of the 12 hours per day, giving 400 lbs. per day per chamber capacity. On this basis, 8 chambers will be required to dry 3200 lbs. per day.

Vacuum Drier has a capacity of 107 lbs, of dry rubber per hour and working 10 hours per day will give an output of 1070 lbs. of dry rubber per day.

Scrap Washer. The capacity of a scrap washer might be placed at an average of 80 lbs. of dry rubber per hour on the various grades of scrap manufactured. Therefore it will take 7¾ to 8 hours to handle 620 lbs. of scrap rubber.

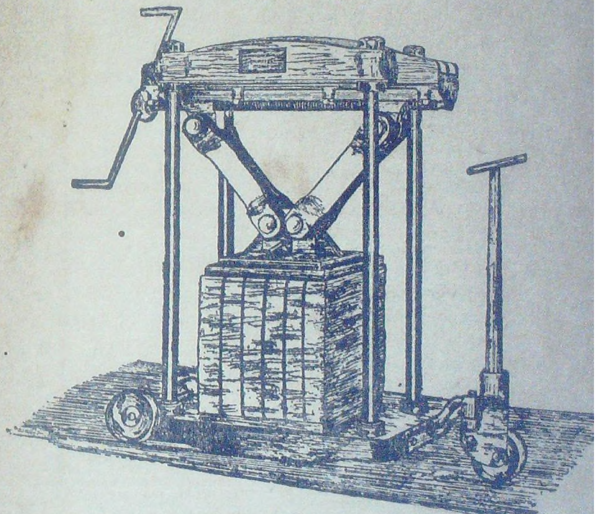
Creping Dry Rubber. A mill fitted with 12″ x 15″ fluted rolls will produce 400 lbs. of dry rubber crepe per hour from dried rubber lace. Therefore one mill will require to work 3100÷400 = 8 hours approximately.

The total H. P. required to drive the above machinery is 120 H. P. It is advantageous to have 1 engine of 120 H. P. to carry the peak load when required and a standby engine of 60 H. P.

Engine Room. The Engine room should be provided with plenty of light and should be maintained clean. Wooden racks should be provided for all tools with a special place prepared for each tool.

Packing of Crepe Rubber.

Much difficulty is often experienced in packing crepe rubber in boxes; a fair amount of pressure is required to compress the rubber so that the proper weight may be placed in each case. The Mobile Press illustrated below will be found very helpful in packing rubber.



MOBILE RUBBER PRESS

The crepe rubber is packed into the chest well above the top of it, and the lid fixed on top of the rubber; the chests are then placed in position in the press, and the flat plate fixed to the arms of the press is forced down until the lid is in correct position. As the flat plate is smaller than the chest lid, the lid can be nailed down and the hoop iron binding fixed before the flat plate of press is released.

Summary of Machinery Equipment

CROP CREPE	ANNUAL EQUIPMENT REQUIRED	
100,000 lbs. ...	Engine, 45 H. P.	1
	Crepeing Mill, Fluted 18″ x 12″	1
	,, ,, Smooth 15″ x 12″	2
	Drier Chambers	2
	Pump if required	1
200,000 lbs. ...	Scrap Washer	1
	Crepeing Mill, Fluted	1
	,, ,, Smooth	1
	Drier Chambers	2
300,000 lbs. ...	Engine, 75 H P.	1
	Crepeing Mill, Smooth	1
	Drier Chambers	2
	(and new drier)	
400,000 lbs. ...	Drier Chambers	2
	Pump	1
500,000 to 600,000 lbs.	Crepeing Mill, Fluted	1
	,, ,, Smooth	1
	Drier Chambers	4

In considering the engine power required for any type of might be included if firewood is scarce and a liquid fuel burner

The mean H. P. needed to operate the above equipments separate figures given for the various machines.

for Crepe Manufacture

EQUIPMENT TO DATE.		App. H. P. req. for Machines	Average Capacity of Machines per hour.
—		—	—
—		10	200 lbs.
—		16	150 ,,
—		3	80 ,,
—		2	500 to 1,000 gls
Engine	1	—	—
Crepeing Mill, Fluted	2	18	400 lbs.
,, ,, Smooth	3	24	225 ,,
Drier Chambers	4	3	120 ,,
Scrap Washer	1	12	80 ,,
Pump	1	2	500 to 1,000 gls
Engines	2	—	—
Crepeing Mill, Fluted	2	18	400 lbs.
,, ,, Smooth	4	32	300 ,,
Drier Chambers	6	6	200 ,,
Scrap Washer	1	12	80 ,,
Pump	1	3	1,500 gals.
Engines	2	—	—
Crepeing Mill, Fluted	2	18	400 lbs.
,, ,, Smooth	4	32	300 ,,
Drier Chambers	8	6	280 ,,
Scrap Washer	1	12	80 ,,
Pumps	1	6	2,000 ,,
Engines	2	—	—
Crepeing Mill, Fluted	3	18	400 lbs.
,, ,, Smooth	5	40	375 ,,
Drier Chambers	12	10	350 ,,
Scrap Washer	1	12	80 ,,
Pumps	2	6	2,500 gals

rubber factory, where a rubber drier is installed, some margin is likely to become necessary.

may be taken at 20 per cent, less than the aggregate of the

CHAPTER XXII

MACHINERY AND EQUIPMENT FOR SHEET RUBBER

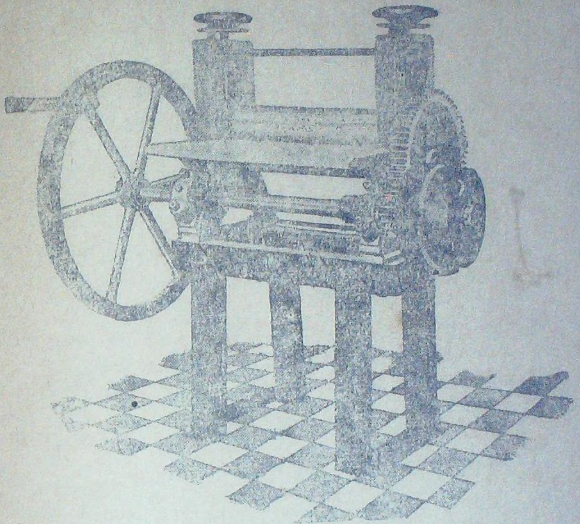
The manufacture of rubber in the form of smoke sheet requires a smaller capital expenditure than that required for crepe rubber, and represents few engineering difficulties.

While it is usual in dealing with small crops to coagulate the latex in sufficient quantities to form one rubber sheet weighing from 1 to 1½ lbs. when dry, this method is rather wasteful both in the quantity of dishes required and also in the labour for handling them when dealing with large crops. Details of suitable coagulating tanks and troughs have already been given in an earlier chapter.

When the latex is coagulated it is kneaded by hand or by some suitable means and made ready for handling in the sheet rolling mills.

Rolling Mills for smoke sheet should be of fairly strong construction and it is good policy to utilise a well built machine as the upkeep is less than that required for a lighter type of mill. For small crops, however, where hand power only is required, the general practice is to employ machines of light make similar to the one illustrated on page 381. But when the machines are power driven they should always be of strong construction and should embody the following principles :—

1. Rolls should be made of polished steel, and have ample bearing surfaces termed *journals.*
2. The rolls should be made with a square or rounded groove cut at the ends to prevent oil travelling from the bearing surface to the roll surfaces.
3. Bearings should be of ample size and always fitted with a brass liner to prevent wear on the roll journals.



SMOOTH ROLLING MILL.
FOR HAND OR POWER OPERATION.

Adjustment should be preferably of the independent type as any wear on controlled adjustment often leads to varying thicknesses of the rubber sheet. The adjustment is obtained by the raising or lowering the top roll by means of a screw, which may have an index fitted to show when both adjustments correspond.

4. Driving gears should be machine cut to give smooth running, and a good fly-wheel should always be fitted to the pinion shaft.
5. It is important to see that all parts liable to wear can be easily replaced.

6. **Platforms of wood or glazed iron should be fitted to both sides of the machine to allow the sheets to be easily fed to and taken from the rolls.**

For power operation, the mill used is similar to that shown on page 348 except that the rolls are smooth and not fluted.

Taking for example a factory dealing with a crop having 750,000 lbs. of rubber per year, as already seen in the last chapter, this represents :-

2480 lbs. of dry sheet rubber per day, and
620 lbs. of scrap rubber per day

during the peak month of the year.

Rolling. The kneaded rubber now goes through 3 rollings, twice between smooth rolls, and once between marking rolls. It is thus better to group the machines in sets of 3 mills each :-

1st mill for 1st roll only
2nd mill for 2nd roll only
3rd mill for marking only.

The combined set of the above machines will produce rubber at the following rates :-

Smooth Roll No. 1. is fed with sheet of kneaded rubber about ¾ inch thick, and weighing 13½ lbs. wet or 6 lbs. dry, and produces a sheet about ⅜ inch thick, weighing wet 11 lbs. in 40 secs. Therefore the output per machine will be at the rate of $90 \times 6 = 540$ lbs. dry rubber per hour.

Smooth Roll No. 2. The sheet from No. 1 mill weighing 11 lbs. wet is now passed to No. 2 Mill where it is further rolled and reduced to about ¼ inch thickness and 9 lbs. wet weight in 50 secs. The output per hour is $72 \times 6 =$ 432 lbs. dry rubber.

Marking Roll No. 3 receives the sheet weighing 9 lbs. wet from No. 2 mill and produces a thin diamond or other type of marked sheet weighing 8 lbs. wet in 60 secs. The output of marking machine will be 60 sheets per hour representing $60 \times 6 = 360$ lbs dry rubber per hour.

The above test was made on C.C.C. type sheeting mills running at roll speed of 20 r.p.m. which is the best speed for the first roll.

To bring up the output of No. 2 and 3 mills to approximate that of No. 1 mill, namely 540 lbs. dry rubber per hour, the roll speed might be increased to 24 r.p.m. for No. 2 and 25 r.p.m. for No. 3 and should give good results.

We are now producing sheet ready for marking at the rate of 540 lbs. dry rubber per hour, which will require practically 5 hours to complete the work.

Scrap. The manufacture of scrap is as described in the last chapter and it is therefore not necessary to elaborate the description here. A summary of machinery and equipment for Sheet manufacture is given below :-

Crop @ 100,000 lbs. per Annum.

1 Smooth Sheeting Mill.

1 Marking Mill.

Both machines to be arranged for working by hand or power. Smoke house to accommodate 5000 lbs. or approximately 500 lbs. per day.

Crop @ 200,000 lbs.

1 45 H.P. Engine.

1 2 or 3 throw long stroke pump, unless gravity water supply can be obtained,

And add one sheeting mill with smooth rolls.

1 Crepeing or washing mill with fluted rolls 12″ x 15″		for scrap
1 ,, ,, ,, ,, smooth rolls 12″ x 15″		
1 Scrap machine		

1 Drier, hot air type, with air ducts to distribute the heat within a special room and 2 chambers for drying scrap.

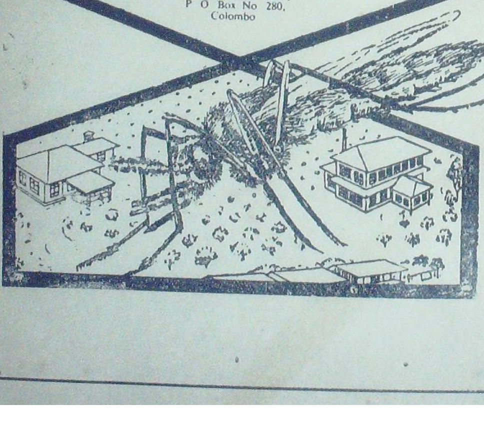
Suitable shafting and gearing, and a smoke-house to accommodate 10,000 lbs.

Crop @ 300,000 lbs. per Annum.

Extend factory a further 50 ft., making a total length 150 ft., increase drying room, add 2 drying chambers and a third sheeting mill with smooth rolls, and provide smoke-house accommodation for 1,500 lbs. a day or to contain 15,000 lbs.

Crop 400,000 lbs. to 600,000 lbs. per Annum.

Increase smoke-houses and add 1 crepeing mill with smooth rolls. With a pre-arranged plan everything as will be seen fits into its place as time goes on, and when the factory is completed a good arrangement with all possible working facilities exists in place of an indiscriminate erection of machinery.



CHAPTER XXIII

FACTORIES & BUILDINGS

Factory Site. The most important point to be considered in choosing a factory site are :—

(a) It should be as central as possible and have roads leading to it from the various parts of the estate, as well as a good exit road.

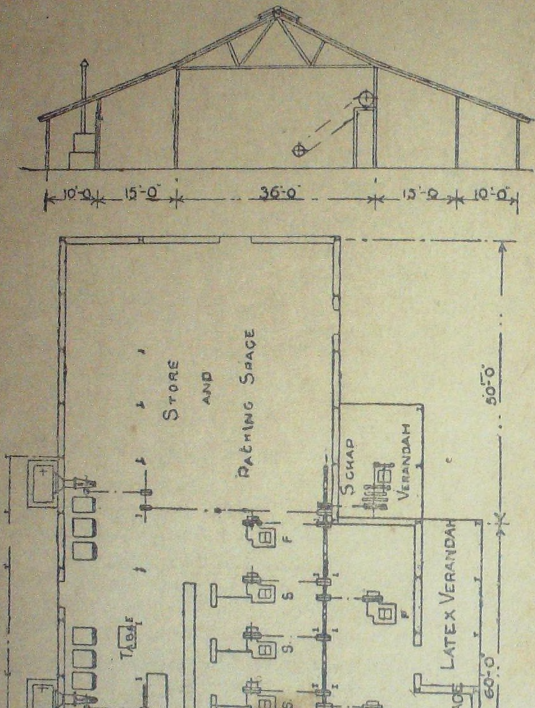
(b) A reliable water supply must be available preferably by gravity, or good well water not lower than 22 feet from the factory floor to the lowest water level.

(c) The building should be arranged with gables east and west, and on solid ground to provide secure foundations, and be situated within a sufficiently clear space to obtain the full benefit of ventilation and light, as well as to give room for outbuildings.

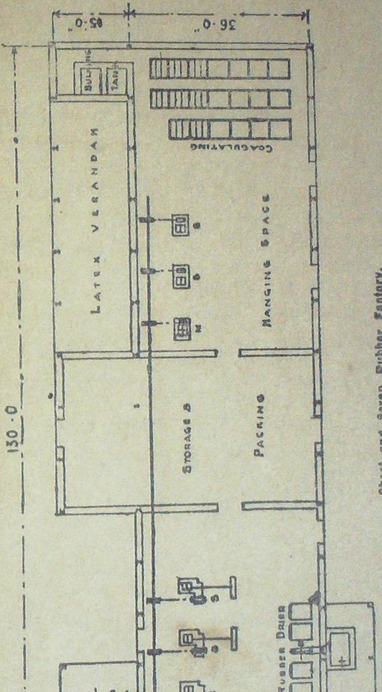
Design of Factory Building The ultimate crop of the estate should be roughly estimated and a complete plan prepared, bearing in mind that the factory building should be so designed as to permit of a part being first erected and equipped with machinery, say for one-third or one-half the maximum anticipated crop and additions to be made as required until the final scheme is completed. Designs of a Crepe Rubber Factory and Sheet Rubber Factory are shown pages 386 and 387.

Light and Ventilation. In designing a factory, provision should be made for ample light and air. If ventilation is imperfect and window space inadequate, the building is always dark and damp, and rubber of a high standard cannot be producd under such depressing conditions.

The floor. The floor should be of thick concrete, and have a good surface layer of waterproof cement. Preferably the floor should not be flat but should slope slightly from the longitudinal



Crêpe Rubber Factory.



Sheet Rubber.

Scrap Rubber

Sheet and Scrap Rubber Factory.

middle of the building to the sides on either hand. If the floor is level it usually results in accumulation of water, the cement breaks in patches and the factory always appears to be dirty.

Position of Machines. All machines should be arranged adjacent to and parallel with one of the long sides of the building and should be raised about 6 inches above the floor so that water may escape easily. Tanks for the reception of latex, scrap rubber, etc., should be placed along the opposite wall to the machines, and the intermediate length of the building should be entirely free from fixtures.

Position of Engines. The position of the engines might, with advantage, be placed as shown in illustration on page 386 which allows for a good long belt drive. The shafting between the engine drives should be fitted with a clutch preferably of the dog clutch type. This type of clutch is preferable as it has no parts to wear out and requires little attention.

Generous accommodation is advisable for one or more engines to be installed, and if a small engine is to be used during the first stages, it should be so placed that ample room is left for the larger engine that will be finally needed. One can hardly imagine a modern factory in full working being equipped with only one engine, which might possibly have an excess of power necessary to drive all the machines. In the case of breakdown, which happens even in the best supervised factories, it would be small consolation to know that this excess of power was present theoretically.

Number of Storeys. There can be no doubt that, taking all things into consideration, the best type of factory is that consisting only of one floor. The factory should be quite separate from all other buildings, and if attempts are made to conserve ground space by putting a drying-room over the factory, much trouble will ensue, especially if pale crepes are to be made. In the first place, the factory is made darker and hence more difficult to keep clean. Secondly the ventilation of the factory will be seriously interfered with. Thirdly, it is manifestly prejudicing the drying of rubber to place it directly over a room which is always more or less awash with water. At night such a building would reek with a moisture laden atmosphere and little drying could be expected to take place in that interval. From actual experience it has been shown that rubber hung to dry in such a room, situated over a damp factory is very liable to attacks of "spot" diseases since the presence of perpetual moisture is favourable to the development of these diseases. If a double-storey building has to be worked, it will be readily seen that no first grade rubber should be allowed to dry in it. The accommodation over the factory may be restricted to the purpose of receiving lower grade rubber which is not so liable to "spot" disease, and possibly does not take so long to dry as first grade rubber of equal thickness. It is evident therefore that the erection of double storey factories is false economy as separate drying houses have to be built eventually. This conclusion does not apply with the same force to factories worked in conjunction with smoke-houses for preparing sheet rubber, but nevertheless, such a factory should not have another floor above the work-room.

Verandahs. One of the worst features in many factories is the necessity for coolies to bring latex into the factory. As already mentioned, the floors of factories are usually running with water and it can be imagined that the passage to and fro of scores of coolies must bring in a great quantity of dirt, and their presence is a hindrance to the efficient working of the factory, and considerable floor space and time are wasted. To avoid this all that is necessary is the erection of a wide open verandah outside the wall of the factory. Here all latex could be received and strained, scrap rubbers could be received and passed through an opening into tanks placed in convenient position. Water could be laid on in this verandah so that coolies might wash their buckets, and the whole verandah might be enclosed only with expanded metal so as to avoid interference with the lighting of the factory. In this way it would be quite unnecessary for any field coolie to enter the factory proper and this would facilitate cleanliness.

Situation of Tanks. It will be noted that these verandahs are raised from ground level to a height of about 3 feet in order that latex may be gravitated with a slight fall into the coagulating tanks which are within the factory. There exists a real necessity for this practice, inasmuch as otherwise to obtain gravitation of latex (which is quicker and cheaper than handling) the coagulating tanks would have to be either placed on the floor or sunk beneath the level. The risk of contamination of latex or coagulum under such circumstances would be appreciable. Apart from this, it is advisable to have the coagulating tanks raised to a height of between 2 and 3 feet to secure the advantage of ease of working in the processes of coagulation and the handling of coagulum.

Drains. All drains leading from the coagulation and machinery space to main side drains might also with advantage be lined with glazed tiles and should be of generous dimensions. The drains should have an adequate fall for efficient drainage. It is apparent that quite a lot of small pieces of rubber are washed into the drains which should be collected at intervals during the day; but in many instances the quantity collected is only a fraction of what escapes. Wherever possible the draining of a factory should be carried as far as is practicable from the buildings by means of cement drains. Too often these are short, and lead into earthen drains. Even if no pieces of rubber are present, the serum from the coagulum is subject to decomposition, the effluvium from which is objectionable.

Water Supply. It is essential that a good supply of water should be available. This should be distributed by pipes all round the building, so that a hose may be used in every part for the thorough cleansing of the factory at intervals during the hours of working.

Summary. Summing up, it might be said that a good factory should have the following features.

1. Plenty of windows or walls of expanded metal.
2. A jack roof in the ridge, and hence a good system of ventilation.

3. Latex tanks and other fixtures along the wall opposite the machines.

4. A long middle free space, at either end of which a large double door should be placed in the walls.

5. Machines on one side of longitudinal section facing latex tanks.

6. A good concrete and cement floor sloping slightly from the middle towards each long wall.

7. An abundant water supply, and several lengths of hose.

8. The building should be of only one floor and have ample head room.

9. There should be an outside open verandah upon which latex may be received, strained etc., preferably outside the wall which is opposite to the machines.

10. The system of drainage should be thorough and the drains should be adequately screened so that all particles of rubber may be collected.

OTHER BUILDINGS.

Drying-Houses for Crepe. It has already been shown in this chapter that a drying house placed over a factory stands condemned except for the drying of low grade rubbers. Generally speaking, a great advance has been made in the design of crepe drying-houses during recent years. Drying Houses for crepe rubber may be of one floor, two floors or even three floors. Doubtless those built with three floors were designed with a view to economising the available site for factory buildings, and as long as the ventilation is good there can be no very great objection to them. It might be pointed out, however, that even with the best of ventilation the air passing successively through three layers of rubber must be fairly saturated with moisture by the time it leaves the building. The effect of this upon the rate of drying in the uppermost chamber will not be so marked as it will be in the middle floor as the temperature of the top floor must be many degrees higher than that of the other two rooms. It would be expected, therefore, that the rate of drying in the middle storey would be slower than that in either of the other two. In houses of two floors this objection would not have to be met, and drying houses of this type are successful and common.

A great many estates favour drying houses of one storey. These are eminently suitable, provided that the site is suitable and that the relative dimensions of the house are favourable to efficient ventilation. It should be noted that if the height of the building is not considerably in excess of the breadth, ventilation will be defective. For a single-storey drying-house, the maximum height should bear the ratio to the breadth of 3 : 2, and in a house of this type specially long pieces of crepe can be utilised.

Ventilation of Drying-House. No matter, how many floors there may be in a drying house, the greatest attention should be given to the question of ventilation. It is an elementary point in the study of ventilation problems that the best system of natural ventilation is obtained by admitting cool air near or through the floor and providing an exit for the warmer air at the highest point in the building. It is not often that such a rule is infringed in the ventilation of rubber drying-houses. In a good modern house there is a space of about 2 ft. in height all round the base of the walls merely closed with expanded metal. This admits cool air. An exit for warm air is provided in the ridge of the roof by either a ventilation chimney or by a jack-roof. The latter is preferable, as it provides for a more free and uniform escape.

In some drying-houses, besides the ridge openings, the space along the eaves is left open. This would seem to be undesirable, as it provides for the entrance of outer air, which might combat the ascending warm air and so interfere with the natural upward currents. Provided that a jack roof or other suitable openings have been installed, there is therefore, no necessity for the existence of open spaces at the eaves, and they probably do more harm than good.

In the tropics on days of sunshine, there must always be an upward current of air in well designed houses. Temperatures of 105°F. are easily recorded in the ridge space of a building, while the temperature in the lower part of the house may be at least 15°F. lower. On the floor of an upper room a temperature of 90°F. is commonly noted, and in buildings with three storeys the usual day temperature of the top room is about or over 100°F. Even when there is no trace of a breeze, there must be a displacement of air in an upward direction though it may not be detected without tests being applied.

It is often asked whether a temperature of 100°F., such as is obtained in the upper room, is calculated to injure the quality of the rubber. There need be no fear on this ground. The experience of many estates goes to show not only that no harm results, but also that the drying of the rubber is expedited. There would seem to be no reason why crepe rubber should not be dried at a temperature of 100°F. It must be understood, however, that higher temperatures for crepe rubber are not recommended, as it has been proved that the rubber is affected. The fact becomes obvious with continued treatment at temperatures much above 100°F. for the rubber stretches and breaks across the support.

Windows. Concerning the subject of window space in a drying-house, there has been much discussion at various times. In former years, it was common to find windows widely open with the sunshine streaming in. Naturally, tackiness developed in some of the rubber and care was then taken to keep the windows closed. Thus the rooms were darkened and air was excluded. There followed a period in which windows were fitted with ruby-coloured glass to keep out the actinic rays of the sun, which were responsible for tackiness, and excess of light, which was responsible for tackiness and excess oxidation of rubber. Unless special precautions were observed in the process of coagulation and preparation, it was not proved that the exclusion of light prevented or lessened the natural oxidation of crepe rubber. With the use of sodium bisulphite for the prevention of oxidation, there has been no cause to worry as to the possible effect of light, as no perceptible darkening of the rubber takes place. It follows, therefore that no trouble need be taken to exclude light, although every precaution must be taken to exclude *direct sunshine.* Windows may be left open as long as the sun does not reach them and direct sunlight does not fall on the rubber. This can usually be arranged in a drying house by manipulating the windows at intervals during the day so that those on the shady side of a building are always open while those on the sunny side are always closed. If it is thought that this manipulation cannot be entrusted with success to the store coolies, the case may be met by having all windows constructed on the louvre pattern, so that, although the windows are closed all day, air and light are not excluded. Should it be desired to retain the existing type of windows, which open outwards, and to keep them open all day, a simple arrangement of ruby-coloured cloth on an outstanding wooden frame may be placed within the walls of the building, or the shutters of the windows may be hinged at the top to open outwards. Unless there is a pronounced breeze, or it is required to examine the rubber closely, there is no necessity to have windows open except in the case of a house in which the bottom floor is used as a packing room. The windows of this chamber may remain open during the day to facilitate sorting and packing and also to afford proper ventilation of the building. Thus the direct rays of the sun are rendered harmless while air and light are allowed to enter.

Hot Air Drying Houses. Another type of drying house employs a system of drying in which hot air is forced into it by means of a powerful fan. Provided the temperature of the hot air could be so regulated as not to exceed 100°F, there would be merit in the system. Such matter of regulation could be solved by having a duct in the main air passage, through which cool air could be admitted in such proportion as to modify the temperature of the hot air. As the process is worked it is often found that the temperature attained is often well above 100°F., and there is a danger of thin crepe placed in this house overnight being found upon the floor in the morning. Unless crepe is prepared thick and cut into fairly short lengths, it will not bear its own weight at higher temperatures; and if it is made thick, drying is impracticably prolonged. It is probable that with a temperature of 100°F, and a steady current of air, average thin crepe would dry in such a drying house within six or seven days. This would be an improvement upon the usual rate of drying in most factories, although several ordinary drying houses are known in which thin crepe will dry naturally in that period.

SMOKE HOUSES. Smoke houses vary considerably in design, but there are several points essential to all. At first sight it would appear that the best type of smoke-house would be one consisting of a tall building, covering a comparatively small superficial area, and having a number of superimposed chambers in which the rubber could be hung to dry. In practice there are several objections which limit the height and the number of floors. Chief among these is the question of temperature. If smoke-curing is to be effective a certain temperature must be attained and maintained. To obtain such results in a house of excessive height would be difficult under normal conditions. It would be found that the chamber immediately above the furnace room would be overheated if the temperature in the upper rooms was within the desired range etc.

The usual type of smoke-house in general use consists of a building of two storeys, in the lower of which are situated the furnaces, while rubber is hung on racks in the upper room. With a single storey the smoke is generated in the same room with the wet rubber and the air becomes saturated at once. With two storeys the smoke generated in the lower one is more or less free of moisture and particles of ash by the time it reaches the upper chamber, and is consequently a more effective drying and curing agent.

Position of Fire. The position of the fire again has to be considered. Internal fires are, as a rule advocated, as the smoke from them can be more evenly distributed and are conducive to slow combustion which is essential for good smoking. With external fires the smoke is brought in by the draught and only the sheets affected by this current of air get sufficient smoke. Others are over-heated and unevenly smoked. The ground floor is employed exclusively for firing purposes, the combustible material being placed loosely on the ground floor generally at two places, or the fire is placed inside an iron box fixed on wheels, the latter method enabling the fire to be quickly drawn out and replensihed quite clear of the building. The upper floor of a "Kent" type of house generally consists of timber beams covered with flooring boards in the passages and wire mesh or small expanded metal directly under the timber racks which are erected for suspending the sheet, and a curved iron baffle plate is hung directly under the floor joists over the firing places to prevent sparks flying up.

The best firing arrangement for a Kent type of smoke house consists in the provision of square masonry boxes 3 feet x 3 feet sunk in the ground or at ground level, built of ordinary bricks and ant-hill earth and covered with perforated iron sheets. These masonry boxes contain the combustible materials, and as uniform firing is not to be expected from the average cooly, and the fire at times will be big and give off excessive heat, it is intended that the masonry shall absorb much of this excess, so that when the fire has fallen low, the masonry shall give out some of its store of heat and equalise the temperature.

A number of small furnaces evenly distributed will give better results than one large one. Some times a metal drum is used mounted on a carriage which can be drawn in and out of the smoke chamber. This arrangement obviates the necessity of damping the fires with water inside the building when the sheets have to be examined and removed.

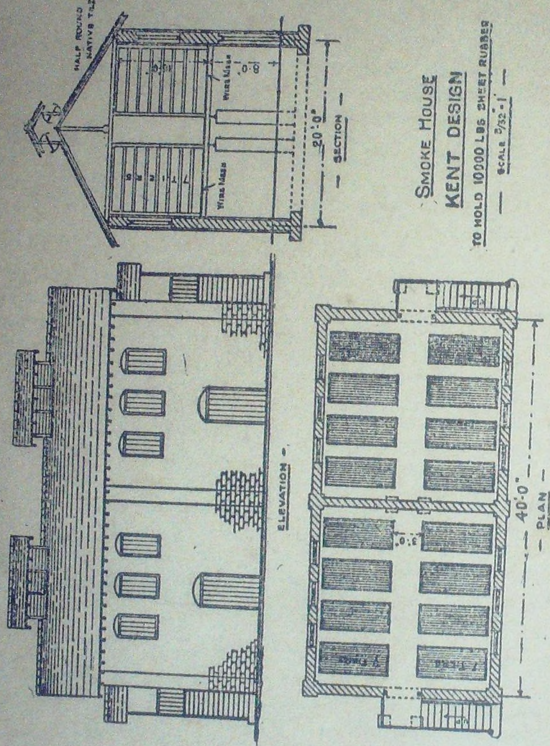
Ventilation. The ordinary rules of ventilation in drying house apply equally to a smoke house. There should be a slow current of air and smoke from the lowest point to the highest point in the building. The rubber contains approximately 25% of moisture given off by the wet rubber. Lack of ventilation greatly delays drying, and is the cause of more defects in smoked sheet than is generally recognised, the chief troubles being :-

1. the atmosphere becomes saturated with moisture; and
2. the sheets sweat and collect surface deposit.

Good ventilation will cause the air to move upwards, and as the moisture laden smoke passes out of the house a fresh supply of hot dry smoke is drawn up from the furnace. To ensure thorough ventilation, the smoke house must be constructed with controlled openings at the ridge of the roof, but the rest of the building must be smoke tight.

Windows. Windows are not strictly necessary, and are only intended to be of service during the time in which coolies are at work within the building. The operation of examing rubber, turning sheets, removing dry rubber, cleaning racks and floors and putting wet rubber into position, usually occupy some hours daily. During this interval the windows should be widely opened if the weather is favourable, and should remain so until the fires have been lighted. It should not be forgotten that during the heat of the day quite an appreciable degree of drying is possible. Advantage can be taken of this, but there is no necessity to exend the interval unduly, and it is of greater advantage to proceed with smoke-curing when the work in the drying chambers has ceased.

Capacity. It is advantageous to confine the capacity of any one smoke-house to hold 10,000 lbs. of sheet rubber, thereby reducing fire risks. For a similar reason it is a wise policy to place smoke-houses some distance apart from each other and from other buildings. By increasing the number of smoke-houses and limiting the capacity of each to 10,000 lbs., more system can be arrived at in the handling of the sheets, and more efficient work will be done than with one building of indefinite area. As the



HALF ROUND NATIVE TILES
WIRE MESH
8'0"
20'0"
SECTION
ELEVATION
40'0"
PLAN
3'0"
SMOKE HOUSE
KENT DESIGN
TO HOLD 10,000 LBS SHEET RUBBER
SCALE 3/32"=1'

curing period should not exceed 10 days, the full output from a smoke-house of this size may be calculated at 1000 lbs. of dry rubber per day, and an illustration of a building of this capacity is shown on the opposite page. If a smoke-house is located on the side of a hill, an excellent arrangement can be made to give direct access to the upper floor by means of a gangway to the hillside and the lower level provides the firing positions.

Racks of Support. In the upper room bays of racks run at right angles to a central passage down the length of the building. Narrow passages run between the bays of the racks to facilitate ease in handling and inspection. The wooden supports may be placed about 3 inches apart horizontally, and 15 or 18 inches apart vertically. A full bay of racks should contain nine or more lines of supports in each of the planes which are 15 or 18 inches apart vertically. The number of these planes is governed only by the height of the room, measured from the floor to the eaves. The supports should be of smooth timber, and need not exceed 1½ inches square in section.

It is usual and advisable to smooth off the rectangular edges of the supports or bars, to avoid the incidence of splinters of wood adhering to the rubber. The bars should not be fixtures, but may either be accommodated in slots, or may rest *between* two nails, so that it is possible to give them a rotary motion by turning the projecting ends. This practice is followed in smoke-houses, the idea being to move the drying sheets slightly each day, with a view to the prevention of a pronounced mark across the sheets.

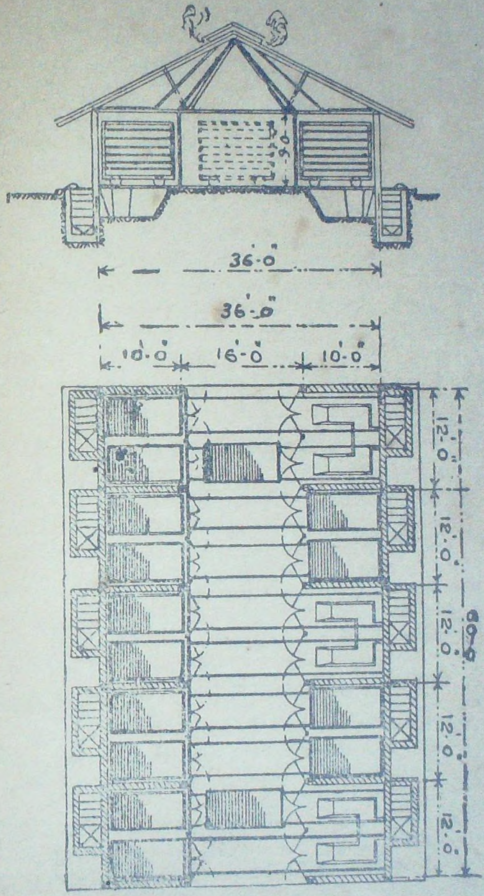
Care should be taken to see that the vacant racks are thoroughly cleaned before fresh rubber is placed upon them, otherwise a distinct dirty mark is caused across the middle of the sheet. This mark usually cannot be removed, even by scrubbing with water. Where this mark occurs regularly in all sheets, attention should be turned to the openings beneath the bays of racks, if open-fire furnaces are employed. It will generally be found that gauze of too wide mesh has been fitted. This should be removed or covered with a finer gauze.

An effective way of dealing with the trouble, provided other precautions have been taken, is to have plenty of spare wooden bars. It should be a rule stringently enforced that as soon as racks are emptied, the bars should be removed to the factory to be cleansed thoroughly. A spare set should enter the smoke house with each batch of fresh rubber. The actual number of spare sets required could be limited to a two days' supply, and the extra cost would be recouped easily.

Trolley Type of Smoke House. This is composed of cubicles 12 ft. x 12 ft. and about 9 ft. high, and each cubicle holds two trolleys side by side of size as shown on the illustration on page 401. Each trolley can be fitted with 210 reepers, each reeper holding four sheets of equivalent weight to 1½ lbs. of dry rubber each. Therefore one trolley holds 210 x 4 x 1½ or 1260 lbs. equivalent of dry rubber. As each cubicle has two trolleys, each cubicle will hold 2520 lbs. equivalent dry rubber.

The above arrangement enables each cubicle to be worked independently of the others, and enables the examination of the sheets of one compartment without disturbing the others. One compartment or cubicle can be used without smoke the first day to hold wet sheets and allow the moisture to drain off after rolling though drip racks are provided in small verandahs. Each cubicle is equipped with a firing pit almost directly underneath the tier of trays, and this close association between the fire and trays enables the rubber sheet to be quicky and thoroughly dried. It will be noted the firing pits are controlled outside the smoke house in small open verandahs which also give space for drip racks.

The entire rack equipment is erected upon four trolley wheels running on rails so that it can be removed from the smoke-house and so enable the sheets to be handled clear of the smoke, or in the unfortunate event of a fire, the rack and rubber can be rapidly drawn out of danger.



TROLLEY TYPE OF SMOKE-HOUSE

General. In the design and erection of smoke-houses of any type, the following points should be borne in mind :—

1. The building must not be hermetically sealed during the curing process, a slight draught must be maintained to circulate the smoke or heated air, and to enable these elements to escape and carry off moisture exuding from the wet sheets.

2. All building materials in close association with the smoke or heated air in circulation should be of an absorbent nature, or be such that the moisture carried off will not be condensed and fall back in drops of water on to the rubber sheets.

3. There is no need for a smoke-house to be dark and dingy. There should be a generous window area with shutters which can be opened to give light to the racks and enable the rubber to be readily seen and examined.

4. Every effort should be made to select a dry position for a smoke-house. Wet or swampy ground is to be avoided or if there is no dry site available, the ground must be well drained, otherwise the fires will be busily evaporating moisture from the site rather than from the rubber.

5. To comply with the rules of Insurance Companies, smoke-houses must be placed at least 100 ft. away from a factory or other buildings. Otherwise these latter buildings will be classed under the same fire risk and rated the same premium as the smoke-houses.

Sorting Room and Packing Room. Sorting and packing should carried out under good conditions, or otherwise consignments of rubber will be marred by the inclusion of defective specimens. Often the only provision made for this important work is the lower room of a drying-shed, which may also contain hanging rubber. Under these conditions, space is cramped, and the light often poor. Small defects may pass unnoticed, and the general surroundings do not conduce to keen work. These considerations, however, do not excuse such instances of gross carelessness as are evidenced by the discovery of extraneous matter among the rubber.

Where for economic reasons, the sorting and packing operations are conducted in the drying-shed, there should be ample space free from hanging rubber, and it should not be possible for wet rubber placed in the upper room to drip upon the dry rubber below or upon packed cases. There should be plenty of light and for this reason windows should be ample. Usually the window frames are fitted with wooden shutters, which are preferably hung on horizontal hinges from the top of the frame. By this device, it is not necessary to close all windows during a shower of rain, and rubber may be stacked near a window with reasonable chance that direct sunlight will not be allowed to fall upon it.

In dealing with smoked sheet, it is advised that the rubber to be examined should be placed upon tables facing the windows so that each piece may be scrutinised in a strong light. Crepe rubber also is best examined in a strong light, but preferably with one's back towards the source of light or at an angle to it. For this work coolies usually are most efficient when sitting on the floor.

It will be clear from the foregoing remarks that the best conditions would be secured in a separate building especially constructed. A single room would be all that is required, at one end of which sorting could be undertaken while packing could be done at the other end. No hanging rubber should be allowed in the room.

The floor should be of hard timber, and raised from the ground to the height approximately of a motor lorry. The boxes or bales of rubber could thus be transported by small hand trucks on a level with the transport vehicle reducing labour to the minimum.

CHAPTER XXIV

VULCANISATION

Raw rubber as produced on the plantations, is almost invariably subjected to the process of vulcanisation in the production of manufactured rubber articles as we know them. Previous to the advent of plantation rubber, the raw material was purchased by the manufacturer in a moist and impure condition. Frequently the rubber was adulterated with sand, dirt and even small stones. Consequently it was the invariable practice of the rubber manufacturer to wash the raw rubber and convert it into crepe which was then hung and air dried before use. The effect on the rubber, if of high grade, was more severe than the washing and crepeing process on the plantation, because the rubber was not a soft coagulum, but generally dried on the surface and semi hard. The power required was considerable, and the resulting crepe was consequently softer and more susceptible to heat than plantation first latex crepe. Much of the raw rubber was soft and tacky and inferior to "earth scrap".

Vulcanising in its simplest aspect consists in mixing the rubber with sulphur and heating the product under regulated conditions. The effect of heat on the inferior grades of rubber is very marked. A soft, sticky and resinous material is transformed into a relatively tough and elastic product. The effect of vulcanising on the better grades is less marked, but immediately apparent. On the other hand, the effect of vulcanising is least apparent on first latex plantation grades, because in these we have a raw rubber prepared in a manner best suited to retain its natural characteristics.

The need of vulcanising in the process of manufacturing rubber goods became an axiom in pre-plantation days, and it is only quite recently that attempts have been made to utilise raw rubber directly, without vulcanisation, particularly for shoe soles. For this purpose a thick dense crepe has been found satisfactory. Smoked sheet rubber is not generally suitable, apparently owing to its microphysical structure. It is possible that the process of rolling in the making of dense crepe compacts the rubber particles, yielding a harder and more resilient product. The rolling must not be carried too far, or the "working" of the rubber will approximate to a preliminary mastication, and the product will be weakened.

Hardness and toughness are actual drawbacks in the utilisation of rubber which is required for vulcanising. When the output of plantation rubber began to increase and to displace the inferior wild sorts, manufacturers complained of the increased power consumption of their machines. The power was required mainly to break down or "mill" the rubber preliminary to the mixing with sulphur and other ingredients. It is obvious that a material such as raw rubber cannot be mixed with powders such as sulphur with a pestle and mortar, or in any simple form of mixing machine. This difficulty was overcome by the earlier experimenters by immersing the rubber in a bath of molten sulphur. The latter was gradually absorbed and "dissolved" in the rubber, and the heat of the bath caused the dissolved sulphur to combine with the rubber to produce vulcanised rubber. The limitations of such a process are apparent. Thus the vulcanised rubber retains the form in which it was originally shaped. Moreover, other ingredients such as mineral matter, cannot be dissolved or absorbed by the rubber in this manner. The method eventually adopted consisted in "breaking down", "milling" or "masticating" the rubber by passing it continuously between differentially geared steam heated rollers. By this means a high-grade rubber is converted into a soft, plastic mass, which will "take up" the sulphur, mineral matter, and other ingredients as desired. The mixing operation may be carried through on the same roller machine as was used for breaking down the rubber or separate machines of other designs may be adopted. Details of the process will be found in "India

Rubber and its Manufacture" by H. L. Terry. It will suffice here to explain that when rubber is kneaded between two hot rollers moving at different speeds the rubber forms a continuous band around the slower moving roller, and if the distance between the rollers be adjusted the excess of rubber held back by the nip of the rollers will form a "bank" or moving wedge-shaped mass on the top of the nip. This closes the space between the rollers, so that sulphur and powder placed on the rubber pass round towards the nip, and are there driven into the rubber. In this manner it is easy to mix, say, 10 per cent. of sulphur into the rubber without a single particle falling through. In technical mixes where large quantities of powders require to be mixed there is always some caking, and part of the powder falls between the rollers into a tray underneath. This is swept up and put back on to the rollers, the process being repeated until the whole of the ingredients have been incorporated.

From this description it follows that, preliminary to mixing, it is necessary to thoroughly masticate or "plasticise" the raw rubber. Much of the "wild" rubber was of so inferior a quality that it very readily broke down, and but little mastication was necessary. It was soft and resinous and readily took up the powders which were to be mixed with it. The better grades of wild rubber such as Fine Para were more difficult to break down, but not so difficult as most plantation rubber, because they had already received a preliminary "working" in the process of washing and crepeing, and we have already explained that such treatment takes more power than the crepeing of the soft moist coagulum on the plantations. The amount of "working" or "plasticising" produced in the rubber is connected with the power expended; the greater the expenditure of power, the greater the working effect on the rubber. Although the manufacturers possessed a relatively soft rubber in the form of washed Fine Para, it was customary in most cases to employ this rubber in conjunction with washed lower grades to produce a soft plastic material for further treatment. Now, however, the manufacturer has a little else but plantation to deal with, and most of it more difficult to break down than washed Para crepe. This is the reason why a hard, tough rubber is no longer a desideratum with manufacturers although orginally taken as an indication of good quality. For the majority of purposes they want something which will break down easily. Hence if a rubber could be produced answering to these requirements, without loss of vulcanising quality, it would be preferred.

Having incorporated sulphur and other ingredients, the plastic mass is sheeted and run between layers of calico to prevent the superimposed sheets from adhering. From this "calendered sheet" the article, whatever it may be, is built up. The calender rollers are heated so as to keep the rubber compound plastic. There is a limit to the thickness of the sheet which can be produced. It is a difficult operation to perform satisfactorily so as to yield a smooth surface and a sheet free from enclosed air. When cool, the rubber hardens and is readily handled. The object to be manufactured is then built up from the calendered sheet. Thus in the manufacture of a motor tyre the tread is built up on the casing or carcase by laying the sheets on the canvas and rolling these with a power operated roller, so that they adhere firmly, the first layer to the canvas of the casing and subsequent layers to one another. This rough description will suffice to illustrate how important it is that the rubber when mixed should be plastic enough to give a smooth sheet, and to allow the sheet to be manipulated in building up the article in process of manufacture. We may, point out here, that the mineral matter is not generally added as an adulterant, but because of certain specific properties it confers on the product.

To proceed with our outline of vulcanisation, we have now arrived at a stage at which the goods are built up and ready for vulcanising. For this purpose they are generally enclosed in some manner, either in metal moulds bolted together, or tightly wrapped, in cloth, as for example, in the manufacture of inner tubes, hose, etc. In the latter case, one can detect the cloth mark on the finished product. Sometimes the rubber is spewed—that is, driven out of a barrel by means of an endless screw revolving in it. In this way rubber tubing, perambulator tyres, and such articles may be made. More recently even tyre treads and the shaped rubber for band tyres (heavy solid tyres) have been extruded in this manner, for the process is much cheaper than building up a tyre from calendered sheet, and then cutting the mass to shape. But for spewing the rubber mass must be very soft and plastic; this condition is not obtainable unless the raw rubber originally used can be made thoroughly plastic without damage. Nor can it be effected with a rubber mass containing much finely divided mineral matter, as this hardens the mixture.

For other purposes the rubber is swollen in a solvent, such as coal-tar naptha, and subsequently masticated. The soft dough is then shaped or spread on cloth, and vulcanised after allowing the solvent to evaporate. Here again the properties of the raw rubber are of immense importance. Thus, the more plastic the dough, the less solvent required, and the less there is to drive off before vulcanising. The plasticity of the dough will depend on the plasticity of the raw rubber and so forth. It is evident that the physical properties of the raw rubber are of great importance. They directly affect the manufacturing operation up to the vulcanising stage, and indirectly affect the results obtained on vulcanising.

The actual vulcanising consists of heating the mass of mixed rubber for a definite time and at a definite temperature, each "heat" being chosen to suit the particular mixture. These data are arrived at empirically, that is, by trying a number of "heats" and choosing that which appears the most suitable. The suitability will depend on the nature of the article, the service to which it is to be put and the time it is intended to last. All vulcanised rubber goods, whatever the process, have a limited life or period during which they can be relied on to give useful service. After a time vulcanised rubber tends to harden, cracks appear on the surface and the article is bent or stretched, and eventually the rubber becomes rotten and "perished". This tendency varies with the quality of the original raw rubber and the conditions of vulcanising. Before plantation rubber was available, the manufacturers were dependent on inferior wild grades for a great part of their output, and consequently, the goods made from these inferior rubbers never showed very good mechanical properties and soon deteriorated. The severest critics of plantation rubber have admitted the advantages to the manufacturers of the replacement of the lower wild grades by plantation rubber. But even the best grades give a vulcanised product which rapidly deteriorates if the vulcanisation is carried too far. This results from too long heating or too high a temperature and the product is termed "overvulcanised". The appearance of the product is deceptive as the physical properties are remarkably good if the overvulcanising is not more than 50 to 100 per cent. in excess of the normal cure. Only in the case of very much overvulcanised rubber do we obtain a product which is brittle from the beginning.

The degree of vulcanising will vary with the type of article to be produced, and where a long life is desired, the tendency will be to "undervulcanise"; but if the best mechanical properties are desired, the tendency will be towards "overvulcanising", or more correctly "fully" vulcanising. These considerations are aptly illustrated by reference to pneumatic tyres. The inner tube need not possess high tensile strength provided that it is easily distensible, for the reason that, during use, it is protected by the casing of the tyre proper, which confines and supports it against the air pressure applied. Inner tubes are therefore cured to give a long life without developing the maximum physical properties. On the other hand, the casing and tread of the tyre are required to withstand severe mechanical conditions - particularly the constant flexing of the cover, and the abrasion of the road surface. Tyres are not stored for any long period, and when put into service have a limited period of useful life. Consequently it is needful to develop maximum properties, and vulcanisation is therefore carried further than in the manufacture of inner tubes.

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For other purposes the rubber is swollen in a solvent, such as coal-tar naptha, and subsequently masticated. The soft dough is then shaped or spread on cloth, and vulcanised after allowing the solvent to evaporate. Here again the properties of the raw rubber are of immense importance. Thus, the more plastic the dough, the less solvent required, and the less there is to drive off before vulcanising. The plasticity of the dough will depend on the plasticity of the raw rubber and so forth. It is evident that the physical properties of the raw rubber are of great importance. They directly affect the manufacturing operation up to the vulcanising stage, and indirectly affect the results obtained on vulcanising.

The actual vulcanising consists of heating the mass of mixed rubber for a definite time and at a definite temperature, each "heat" being chosen to suit the particular mixture. These data are arrived at empirically, that is, by trying a number of "heats" and choosing that which appears the most suitable. The suitability will depend on the nature of the article, the service to which it is to be put and the time it is intended to last. All vulcanised rubber goods, whatever the process, have a limited life or period during which they can be relied on to give useful service. After a time vulcanised rubber tends to harden, cracks appear on the surface and the article is bent or stretched, and eventually the rubber becomes rotten and "perished". This tendency varies with the quality of the original raw rubber and the conditions of vulcanising. Before plantation rubber was available, the manufacturers were dependent on inferior wild grades for a great part of their output, and consequently, the goods made from these inferior rubbers never showed very good mechanical properties and soon deteriorated. The severest critics of plantation rubber have admitted the advantages to the manufacturers of the replacement of the lower wild grades by plantation rubber. But even the best grades give a vulcanised product which rapidly deteriorates if the vulcanisation is carried too far. This results from too long heating or too high a temperature and the product is termed "overvulcanised". The appearance of the product is deceptive as the physical properties are remarkably good if the overvulcanising is not more than 50 to 100 per cent. in excess of the normal cure. Only in the case of very much overvulcanised rubber do we obtain a product which is brittle from the beginning.

The degree of vulcanising will vary with the type of article to be produced, and where a long life is desired, the tendency will be to "undervulcanise"; but if the best mechanical properties are desired, the tendency will be towards "overvulcanising", or more correctly "fully" vulcanising. These considerations are aptly illustrated by reference to pneumatic tyres. The inner tube need not possess high tensile strength provided that it is easily distensible, for the reason that, during use, it is protected by the casing of the tyre proper, which confines and supports it against the air pressure applied. Inner tubes are therefore cured to give a long life without developing the maximum physical properties. On the other hand, the casing and tread of the tyre are required to withstand severe mechanical conditions - particularly the constant flexing of the cover, and the abrasion of the road surface. Tyres are not stored for any long period, and when put into service have a limited period of useful life. Consequently it is needful to develop maximum properties, and vulcanisation is therefore carried further than in the manufacture of inner tubes.

The rate of cure or vulcanisation is controlled by a number of factors in addition to the period of temperature of vulcanisation, in particular by the proportion and nature of the other ingredients, especially sulphur and accelerators, and also by the rubber itself. The main complaint as regards plantation rubber is that it varies excessively in this respect. This matter will not be discussed here, but is only introduced in order to explain the importance of a constant rate of vulcanising to the manufacturer. Plantation rubber should, therefore, be prepared so as to be as uniform as possible in this respect, and the earlier part of this book gives full details of the precautions advised, and which are adopted on plantations. Unfortunately it is impossible to secure uniformity of methods among all producers and hence the importance of branding the rubber whenever possible so that the manufacturer may identify the rubber he purchases.

Latex and Sprayed Rubber. In recent years considerable quantities of rubber have been shipped to the U. S. A. as "liquid latex" for conversion to rubber by the spraying process. For this purpose a small quantity of ammonia up to about 1 per cent. is added to the latex as a preservative. The amount required depends on the time it is desired to keep the latex in good condition. The spraying plant consists of a disc or tube which rotates at a high speed and throws the latex as a fine spray into a chamber surrounding the sprayer. This chamber is supplied with hot air which causes rapid evaporation of the tiny latex droplets so that the rubber falls to the bottom of the chamber and is deposited like snow. It is swept up, compacted in a press, and used in this from by manufacturers in the place of ordinary sheet or crepe. The yield of rubber is some 10 per cent. greater than by ordinary coagulation process, as the whole of the serum is retained. On the other hand such rubber does not contain os much of the actual rubber hydrocarbon as ordinary plantation rubber. The bulk of the serum constituents retained by sprayed rubber are valueless, but a small proportion of them do improve the rubber, particularly as regards rate of cure. It has, moreover, the defect of great hardness and requires more power to break down or mill and render plastic than sheet or crepe. Improvements are being made in this respect and improved sprayers have been designed in recent times.

THE END

MISCELLANEOUS NOTES

MENSURATION FORMULÆ.

Area of :—

Circle=3.1416 × radius squared or Square of diameter × 0.7854.

Circle circumscribing square = Square of side × 1.5708.

Circle, Sector of = Length of arc × $\frac{1}{2}$ radius.

Circle, Segment of = Area of Sector minus Area of Triangle.

Ellipse = 0.7854 × long axis × short axis.

Parabola = Base × height × $\frac{2}{3}$.

Parallelogram = Height × Base.

Polygon, regular. Inscribe a circle. Take $\frac{1}{2}$ radius of this circle × number of sides × length of 1 side; or Divide into Triangles, find the area of each and add.

Rhomboid = Base height.

Rhombus = Product of the diagonals ÷ 2, or Base × height.

Right lined figure of 4 or more unequal sides = Divide into triangles, find area of each and add.

Square = Length of 1 side multiplied by itself, or Area of inscribed circle × 1.2732, or Area of circumscribin circle × 0.6366.

Trapezium = Height × (sum of 2 parallel sides÷2).

Triangle = $\frac{1}{2}$ base × perpendicular height.

Triangle, Equilateral = Square of sides × 0.433.

Circumference of:—

Circle = 3·1416 × diameter, or side of equal square × 3.545.

Circle Circumscribing a square = Side of Square × 4.443.

Diameter of:—

Circle equal in area to square = Side of square × 1.1284.

Circle Circumscribing a square = Side of Square × 1.414.

Length of:—

Arc of circle = Degrees in arc × radius × $0.0174\dot{5}$.

Side of:—

Square equal in area to circle = Diameter × 0.8862.
Square inscribed in circle = Diameter of circle × 0.707.

Surface of:—

Cone = $\frac{1}{2}$ (Slant height × perimeter of base) + Area of base.
Cube = Sum of areas of all sides.
Cylinder = (Length × Perimeter) + (Area of 2 ends).
Parallelepipedon = Sum of Area of all sides.
Prism = (Length × perimeter) + (Area of 2 ends)
Pyramid = $\frac{1}{2}$ (Slant Height × Perimeter of base) + Area of base.
Sphere = Square of Diameter × 3.1416.

Volume of:—

Circular Section (Ring) = Mean Diameter of Ring × Square of Diameter Section × 2.47.
Cone = (Area of base × Perpendicular Height) ÷ 3.
Cube = Length × breadth × height.
Cylinder = Area of Base × height.
Paraboloid = Volume of circumscribing cylinder ÷ 2.
Parallelepipedon = Length × breadth × height.
Prism = Area of base × height.
Pyramid = (Area of base × perpendicular height) ÷ 3.
Sphere = Cube of Diamter × 0.5236.

MEASURES OF CAPACITY
APOTHECARIES FLUID MEASURES

60 minims (min.)	= 1 fluid drachm	= 3.552 $cm.^3$
8 fluid drachms	= 1 fluid ounce	=28.41 cm^3
20 fluid ounces	= 1 pint = 568 cm^3	= 0.568 litre
8 pints	= 1 gall. =4546 cm^3	= 4.546 ,,

1 cm^3 (cubic centimetre) =0.061 cu. in. =16.892 min.
1 litre = 1000 cm^3 = 0·22 gall. = 1.7598 pints

BRITISH WEIGHTS AND MEASURES AND METRIC EQUIVALENTS

LINEAR MEASURES

3 barleycorns	= 1 inch	= 2·54 cm.	
4 inches	= 1 hand		
7.92 inches	= 1 link		
9 inches	= 1 span		
12 inches	= 1 foot	= 30·48 cm.	
3 feet	= 1 yard	= 0·9144 m.	
5 feet	= 1 pace		
5½ yards	= 1 rod, pole or perch		= 5·03 m.
4 rods	= 1 chain		= 20·1168 m.
10 chains	= 1 furlong		= 201·17 m.
8 furlongs	= 1 mile		= 1·6093 km.

1 cm. (centimetre) = 0·3937 inches

1 m. (metre) = 39·370113 inches; 3·28084 feet; 1·093614 yards

1 km. (kilometre) = 0·62137 mile

NAUTICAL MILES

1 =6075·6 ft (Admiralty N. Mile 6080 ft.) = 1 minute

3 = 1 League = 3 minutes = 0·05 degree = 3·452 miles of 1760 yards

60 =20 Leagues = 60 minutes = 1 degree = 62·04 yards

607·56 ft. =202·52 yards = 1 cable's length

6080 feet (1 knot) per hour = 1·1515 miles per hour

WINE AND SPIRIT MEASURES

(applied for Wines and Spirits only)

4 gills	= 1 pint	= 0·4732 litre
2 pints	= 1 quart	= 0·9463 ,,
4 quarts	= 1 gallon	= 3·7852 ,,
63 gallons	= 1 hogshead	=238·50 ,,

1 litre (1,000 cm^3) = 1·056 quarts = 2·112 pints

1 hectolitre (100 litre) = 26·4 gallons

SQUARE MEASURES

1	square inch	=	6·4516 cm^2
144	,, inches	=1 square foot	=929·03 cm^2
9	,, feet	=1 square yard	= 0·836126 m^2
30¼	,, yards	=1 sq. rod, pole or perch	= 25·29 m^2
40	,, perches	=1 rood	= 10·117 ares
4	roods	=1 acre	= 0·4047 hectares
640	acres	=1 square mile	=259·0 ,,

1 cm^2 (square centimetre) = 0·155 sq. in.

1 m^2 (square metre) = { 1550·01 sq. in.; 10·7639 sq. ft.; 1·196 sq. yd.

1 are (100 square metres) =119·6 sq. yds.

1 hectare (10,000 sq. metres) = 2·4711 acres

100 hectares (1 square kilometre) = 0·386 sq. mile

CUBIC (SOLID) MEASURES

1	cubic inch	=	16·387 cm^3
1728	,, ins.	= 1 cubic foot	= 0·028317 m^3
27	,, feet	= 1 cubic yard	= 28·317 litres = 0·764553 m^3 = 764·553 litres

1 gallon = 0·1605 cubic feet = 4·545963 litres
=10·0 lbs.

1 cu. ft. of fresh water = 6¼ gall. = 62½ lbs.
1 ,, ,, salt ,, = 6¼ ,, = 63½ ,,
1 ,, ,, clay = 125 ,,
1 ,, ,, loose earth = 95 ,,
35·943 cu. ft. = 224 gallons = 1 ton

1 cm^3 (cubic centimetre) = 0·061 cubic inches
1 cm^3 (cubic metre)= 1,000,000 cm^3 = 1·307954 cu.yd.
= 25·3148 cu. ft.

1 litre (1,000 cm^3)= 0·22 gallon
= 1·7598 pints

1 cm^3 water = 1 gramme
1000 ,, ,, = 1 litre = 1 kilogramme (kg.)
1000 litres =1000 kg. = 1 Metric ton

APPROXIMATE EQUIVALENTS

1 Table Spoon	= ½ fluid ounce approx.			
1 Dessert ,,	= ¼	,,	,,	,,
1 Tea ,,	= ⅛	,,	,,	,,
1 Wineglass	= 2	,,	,,	,,
1 Teacup	= 3	,,	,,	,,

DRY MEASURES (COMMON UNITS ALSO FOR WATER, BENZINE, Etc.)

4 gills	= 1 pint	=34·659 cub. in	=0·568 litre
2 pints	= 1 quart	=69·318 ,,	=1·136 ,,
2 quarts	= 1 bottle		
4 quarts	= 1 gallon	=277·274 ,,	=4·546 ,,
2 gallons	= 1 peck		
4 pecks	= 1 bushel	=1·283 cub. ft.	=36·368 ,,
3 bushels	= 1 sack		
8 bushels	= 1 quarter		
12 sacks	= 1 chaldron		
5 quarters	= 1 wey or load = 51·347 cu. ft.		
10 quarters	= 1 last		

1 litre (1,000 cm^3) = 0·908 quart dry

1 hectolitre (100 litre) = 2·75 bushels = 22·0 gall. dry

1 Imp. Gallon = 1·2 U.S. Gallon.

WEIGHTS

1 grain (avoirdupois and troy)		=	0·0648 g.
24 grains = 1 penny weight		=	1·5552 ,,
1 dram (avoirdupois)		=	1·772 ,,
16 drams ,,	= 1 ounce	=	28·35 ,,
1 ounce (troy and apothecary)		=	31·1035 ,,
16 ounces (avoirdupois)	= 1 lb·	=	453·59 ,,
14 lbs. ,,	= 1 stone	=	6·3503 kg.
28 ,, ,,	= 1 quarter	=	12·7005 ,,
4 quarters ,,	= 1 cwt.	=	50·8 ,,
20 cwt. ,,	= 1 ton	=	1016·0 ,,
1 mg. (milligramme)	= 0.015 grain		
1 g. (gramme)	= 15·432 ,,		

METRIC CONVERSION FORMULÆ

To Convert	Multiply by	Reciprocal Multiply by
Acres into Hectares	0.4047	2.471
Acres into Bouws	0.57	
Bouws into Hectares	1.409147	
Cubic feet into Cubic metres ...	0.02832	35.320
Cubic inches into Cubic cm. ...	16.383	0.06102
,, ,, ,, Litres	0.01639	61.03
Cubic Yards into Cubic metres ...	0.7646	1.308
Feet into metres	0.3048	3.2802
Fluid ounces into Cubic cm	28.42	0.03519
Gallons into Cubic metres	0.00454	220.1
,, ,, Litres	4.546	0.220
Grains into Grammes	0.0648	15.43235
Hundredweights into Kg.	50.802	0.01968
Inches into Centimetres	2.540	0.3937
,, ,, Metres	0.0254	39.3701
,, ,, Millimetres	25.4	0.0394
Miles into Kilometres	1.609	0.6215
,, ,, Metres	1609 3	
,, (nautical) into Km.	1.855	0.540
Minims into Cubic centimetres ...	0.0592	
,, ,, Millilitres	0.0592	
Ounces into Grammes	28.3495	0.03527
,, ,, Kilogrammes	0.02835	35.27
,, (Troy) into Grammes ...	31.104	
Pints into Litres	0.568	1.7598
Pounds into Grammes	453.59	0.002205
,, ,, Kilogrammes	0.45359	2.2046
Square In. into Sq. Millimetres ...	645.1	0.00155
,, Ft. into Sq. Metres ...	0.0929	10.765
,, Miles into Sq. Kilometres ...	2.590	0.3861
,, Yds. into Sq. Metres ...	0.8361	1.196
Tons into Kilogrammes ...	1016.0	0.0009842
Yards into Metres	0.9144	1.0936

METRIC CONVERSION FORMULÆ—*Continued*

To Convert	Multiply by	Reciprocal Multiply by
Compound		
Cu. Ft. per H. P. into M^3 per Ps.	0.0287	35.804
,, ,, hour ,, L. ,, sec.	0.00785	127.3
,, ,, second ,, M^3 ,, hour	101.94	0.0098
Feet ,, ,, ,, cm. ,, sec.	30.47945	0.0327
Foot-pounds into Kg./Metres ...	0.1382	7.233
Foot-tons into Tonne-Metres ...	0.3091	3.23
Grains p. gall into G. p. Litre ...	0.01426	70.153
Gall. p. sq. ft into L. p. M^2	48.93	0.0204
B. Th. U. into Kg.-cal.	0.252	3.968
Heat units p. sq. ft into Kg. cal/m/m^2	2.713	0.369
Horse Power into P. S.	0.0139	0.9863
Inch-tons into Kg. Metres	25.8	0.0387
Lbs. p. cu. ft. into Kg. p. M^3 ...	16.018	0.0624
,, ,, cu. yd. ,, Kg. p. M^3 ...	0.5933	1.685
,, ,, gall. ,, Kg. p. L. ...	0.09983	10.02
,, ,, H. P. ,, Kg. p. P. S. ...	0.447	2.235
,, ,, mile ,, Kg. p. Km. ...	0.2818	3.90348
,, ,, lin. ft. ,, Kg.p.lin.M. ...	1.4882	0.672
,, ,, lin. yd. ,, Kg.p.lin.M. ...	0.496	2.016
,, ,, sq. in. ,, Kg. p. mm.^{2} ...	0.000703	1424.18
,, ,, ,, ,, Kg. p. cm.^{2} ...	0.070308	14.223
,, ,, sq. ft. ,, Kg. p. M^2 ...	4.883	0.2048
Sq. ft. p. H. P. into M^2 per P. S. ...	0.0942	10.913
Tons. cu. yd. ,, T. per M^2 ...	1.329	0.752
,, ,, lin. ft. ,, Kg. p.lin.M ...	3333.3333	0.000333
,, ,, lin. yd. ,, Kg. p.lin.M ...	1111.1111	0.000999
,, ,, sq. in. ,, Kg. p. mm^2 ...	1.5749	0.635
,, ,, ,, ,, Kg. p. cm^2 ...	157.49	0.00635
,, ,, sq. ft. ,, T. p. M^2 ...	10.936	0.0914
,, ,, sq. yd. ,, T. p. M^2 ...	1.215	0.823

VELOCITY

1 ft. per min. =0·01136 mile per hour=0·3048 m per min.
1 ft. per sec. =0·01136 mile per min =18·29 m. per min.
1 mile per hour=88 ft. per min. =1.467 ft. per sec.=26·82 m. per min.
1 knot = 6080 ft. per hour = 1 nautical mile per hour.

FLUID MEASURE

60 minims	=	1 fluid drachm
8 drachms	=	1 fluid ounce
20 ounces	=	1 pint
8 pints	=	1 gallon

VARIOUS WEIGHTS

Average Man	150 lbs.
A crowd per foot super	84 lbs.
Do tightly packed per foot super ...	120 lbs.
Elephant average	three tons.
Small Ox	five cwt.
Large Ox	nine cwt.
One cube of brickwork in lime ...	105 lbs.
1 cubic foot of water	62.32 lbs.

The weight of pure water is to that of sea water as 1 is to 1.026.

HANDY WEIGHTS AND MEASURES

A Tumbler contains 10 ounces or half a pint; a Teacup 3 ounces or 1 gill; a Wineglass 2 ounces; a Table-spoon 4 drachms; a Dessert spoon 2 drachms; A Tea spoon 1 drachm—all approximately only.

BRITISH AND METRIC EQUIVALENTS

Length

1 mil = 0·001 inch = 0·0254 mm.
1 in = 0·083 ft. = 0·0278 yd. = 2·54 cm.
1 foot = 12 in. = 0·333 yd. = 30·4799 cm.
1 yard = 36 in. = 3 ft. = 91·44 cm. = 0·914399 metre.

1 chain = 66 ft. 100 links = 20·1168m. = 0·0201 km.

1 furlong = 220 yd. = 201·168 m. = 0·2012 km.

1 mile = 5280 ft. = 1760 yd. = 80 chains = 1·6093 km.

1 nautical mile = 6080 feet. 1 knot = 6080 ft. per hour.

AREA

1 circular mile = area circle 1 mil diam. = 0·7854 sq. mil = 0·0005067 sq. mm.

1 sq. mile = 1·273 circ. mil = 0·000001 sq. in = 0.000645 sq. m.

1 sq. inch=1273240 circ. mil=0.000694 sq. ft = 6·4516 sq. cm

1 sq. foot = 144 sq. in. = 0.1111 sq. yd. = 929·03 sq. m.

1 sq. yard = 1296 sq. in. = 9 sq. ft. = 0·000207 acre = 0.836126 sq. m.

1 acre=43560 sq. ft.=4840 sq. yd.=10 sq. chains=40.468 ares.

1 sq. mile = 3097600 sq. yd. = 640 acres = 25900 ares = 2.59 sq. km.

VOLUME

1 circular mil foot = 0.000009425 cu. in.

1 cu. inch = 16.387 cu. cm. 1 cu. yard = 0.764553 cu. m.

1 cu. foot = 0.028317 cu. m. 1 cu. yard = 764·553 litres

1 cu. foot = 28.317 litres 1 fluid ounce = 0·0284 litre.

1 pint = 4 gills = 34·67 cu. in. = 0·5682 litre.

1 gallon=8 pints=277·34 cu. in.=0·1605 cu ft.=4·545963 litres.

1 U. S. A. gallon = 231 cu. in. = 0.1337 cu. ft. = 3.785 litres= 0.83254 Imp. gal.

WEIGHT

1 grain = 0·0648 (grams) 1 cwt. (112 lb.) = 50.8 kg.

1 ounce = 28·35 g. 1 cwt. (100 lb.) = 45.36 kg.

1 ounce (troy) = 31·1035 h. 1 ton.(2240 lb.) = 1016 kg.

1 pound = 453.5924 g. 1 ton (2000 lb) = 907·2 kg.

1 Pound = 445000 dynes.

WEIGHT PER UNIT LENGTH

1 lb. per ft. = 5280 lb. per mile = 1488 kg. per km. = 1·488 kg. per m.

1 lb. per yd. = 0.3333 lb. per ft. = 0.496 kg. per m.

BRITISH WEIGHTS AND MEASURES

Linear

Miles	Fur-longs	Chains	Poles	Yards	Feet	Links	Inches
1	8	80	320	1,760	5,280	8,000	63,360
·125	1	10	40	220	660	1,000	7,920
·0125	·1	1	4	22	66	100	792
—	·025	·25	1	5½	16½	25	198
—	—	—	—	1	3	4·545	36
—	—	—	—	—	1	1·515	12
—	·001	·01	·04	·22	·66	1	7·92
—	—	—	—	—	—	—	1

Square

Mile²	Acres	Roods	Chains²	Poles²	Yards²	Feet²	Links²	Inches²
1	640	2,560	6,400	102,400	—	—	—	—
—	1	4	10	160	4,840	43,560	100,000	—
—	—	1	2½	40	1,210	10,890	25,000	—
—	—	—	1	16	484	4,356	10,000	—
—	—	—	—	1	30¼	272¼	625	39,204
—	—	—	—	—	1	9	—	1,296
—	—	—	—	—	—	1	—	144
—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	1

Cubic

Yard³	Quar-ters	Bush-els	Feet³	Pecks	Gallons	Quarts	Pints	Inches³
1	—	—	27	—	—	—	—	46,656
—	1	8	—	32	64	256	512	17,754. 88
—	.125	1	—	4	8	32	64	2,215.360
—	—	—	1	—	6·22882	—	—	1.728
—	—	·25	—	1	2	8	16	554·840
—	—	—	·16054	—	1	4	8	277·420
—	—	—	—	—	—	1	2	69·355
—	—	—	—	—	—	—	1	34·677
—	—	—	—	—	—	—	—	1

WEIGHTS (AVOIRDUPOIS).

Tons	Cwts.	Qrs.	Stones	Lbs.	Ozs.	Drams	Grains
1	20	80	160	2,240	35,840	573,440	—
.05	1	4	8	112	1,792	28,672	784,000
—	·25	1	2	28	448	7,168	196,000
—	·125	·5	1	14	224	3,584	98,000
—	—	—	—	1	16	256	7,000
—	—	—	—	—	1	16	437.5
—	—	—	—	—	—	1	27,344
—	—	—	—	—	—	—	1

MALAYAN WEIGHTS AND MEASURES

WEIGHTS (AVOIRDUPOIS)

10 Tee	= 1 Hoon		Chinese Opium Weights
10 Hoon	= 1 Chee		
10 Chee	= 1 Tahil	= $1\frac{1}{3}$ oz.	
	= 1 Tahil	= $1\frac{1}{2}$ oz.	in general use
16 Tahils	= 1 Kati	= $1\frac{1}{3}$ lbs.	
100 Katis	= 1 Pikul	= $133\frac{1}{3}$,,	
40 Pikuls	= 1 Koyan	= $5333\frac{1}{3}$,,	
12 Saga	= 1 Mayam	= 52 grains	Gold-smith's Weights
16 Mayam	= 1 Bongkal	= 832 ,,	
12 Bongkal	= 1 Kati	= 9984 ,,	

LIQUID AND DRY MEASURES

$\frac{1}{4}$	Chupak	= 1 Pau	= 2 gills
$\frac{1}{2}$	Chupak	= 2 Paus	= 1 pint
1	Chupak	= 1 quart	= 2 pints
1	Gantang	= 4 quarts	= 1 gallon

LONG OR CLOTH MEASURES

General

2 Jenkal	= Hasta	
2 Hasta	= 1 Ela	= 3 feet
2 Ela	= 1 Depa	= 6 feet
2 Kayu(pcs)	= 1 Kodi	= 1 score

Chinese

1 Ts'un	= 1.41 in.
1 Ch'ih	= 1.175 feet
1 Chang	= 11.75 ,,
1 Li	= 2115.0 ,,

LAND MEASURES

12 Inchi (Inches)	= 1 Kaki	= 1 foot
6 Kaki	= 1 Depa	= 6 feet (1 fathom)
4 (square) Depa	= 1 Jemba	= 144 square feet
100 Jemba	= Penjuru	= 14400 ,, ,,
1 Relong	= .711 acre	
1 Lelong	= 2400 square feet	
24 Lelong	= 1 square Oriong (1½ acre approx.)	

CAPACITY OF COAGULATING TANKS

DEPTH	6ft. × 3 ft.	10ft. × 3 ft.	DEPTH	6 ft. × 3 ft.	10 ft. × 3 ft.
in.	gall.	gall.	in.	gall.	gall.
1	9.3	15.6	10	93.0	156·0
2	18·6	31·2	11	102·3	171·6
3	27·9	46·8	12	111·6	187·2
4	37·2	62·4	13	120·9	202·8
5	46·5	78·0	14	130·2	218·4
6	55·8	93·6	15	139·5	234·0
7	65.1	109·2	16	148·8	249·6
8	74.4	124·8	17	158·1	265·2
9	83.7	140·4	18	167·4	280·8

APPROXIMATE WEIGHTS PER SQUARE FOOT OF ALUMINIUM SHEET

Inches	Millimetres	Weight per sq. ft. lbs
1/64	0·40	0·210
1/32	0·79	0·441
0·039	1·00	0·544
1/16	1·59	0·863
0·079	2·00	1·095
1/8	3·17	1·717
0·157	4·00	2·190
3/16	4.75	2·588
¼	6·25	3·473

CEYLON SAWYER'S MEASUREMENT

When the thickness of timber is $1\frac{1}{2}$ inches or less, multiply length in feet by width in inches and divide by 12. When over $1\frac{1}{2}$ inches thick, add width and thickness together and multiply by length, in feet and divide by 12.

SQUARE MEASURE

Sq. inches.					
144 =	1 sq. foot.				
1296 =	9 sq. feet.	= 1 sq. yard.			
39204 =	272.25 ,,	= 30.25 =	1 sq. perch.		
1568160 =	10890 ,,	= 1210 =	40 =	1 sq. rood.	
6272640 =	43560 ,,	= 4840 =	160 =	4 =	sq. acre.

Links.		
625 =	1 perch.	
10000 =	1 chain.	
25000 =	2.5 equals 1 rood.	
100000 =	10 ,, 411	= 1 acre

TO MEASURE METAL

All metal or gravel should be piled in the form adopted by the P. W. D. and the contents calculated as follows:

Length of base ..	18 ft 6 ins	Height of pile ..	2 ft 6 ins.
Breadth of base ..	5 ,,	Length of top ..	13 ,, 6 ,,

$$= \frac{18\frac{1}{2} + 13\frac{1}{2}}{2} \times \frac{5/2 \times 5/1}{2} = \frac{37/2 + 27/2}{2} \times \frac{5/2 \times 5/1}{2}$$

$$= 16 \times 25/4 = 100 \text{ ft (cubic)}$$

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The earliest experiments in budding rubber trees were made in 1917.