# Physiological Principles

for Determining the
Value of the various

# RUBBER TAPPING METHODS.

BY

PROFESSOR DR. HANS FITTING,
STRASSBURG i. E.

*WITH FOUR DIAGRAMS.*

[Translated by J. H. RENTON.]

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Founded on some Experiments made on Hevea Brasiliensis.

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*Translated from the German by J. H. Renton, and Published by kind permission of the Editors of the "Tropenpflanzer," Berlin.*



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# TRANSLATOR'S PREFACE.

The great importance which the Rubber Planting Industry in the East has attained during the past few years must be my excuse for offering to my fellow planters an English translation of Professor Fitting's treatise on Rubber Tapping Methods, which appeared as a supplement in this year's February number of the "Tropenpflanzer."

Professor Fitting is one of Germany's first physiological botanists and I feel sure that his views will be of interest to and carry weight with those engaged in producing rubber in Ceylon and Malaya.

I hope that his advice will be followed, and that serious endeavours will be made to find out by further research and experiments on a larger scale the very best method for harvesting rubber.

I think I have succeeded in giving the exact sense of Professor Fitting's very instructive treatise, but it is not possible to translate a German scientific work literally without rendering the translation heavy and un-English, though I have endeavoured to adhere as closely as possible to the German text.

I wish to take this opportunity of expressing my very sincere thanks to Professor Fitting and to the Editors of the "Tropenpflanzer" for allowing the publication of an English version. Mr. F. Crosbie Roles, of Ceylon, has kindly helped me to see this pamphlet through the press.

J. H. RENTON.

Christmas, 1909.

# PREFACE.

When I went to Java in the Autumn of 1907, having obtained the German so-called Buitenzorg grant, it was, amongst other things, my intention, by studying rubber plants in the tropics, to

## ERRATA.

Page 11, line 5—read *organic* instead of *inorganic*.
Page 14, footnote—read *Vol. 94* instead of *Vol. I. 94*.
Page 22, footnote—read *levulose* instead of *cevulose*.
Page 45, line 20—read *bark* instead of *latex*.
Page 48, line 16—read *distribution of substances* instead of *sap distribution*.

[illegible] are imperative in order, by introducing rational tapping methods, to protect rubber plantations against very unpleasant earlier or later injuries. It is extraordinary, that the opinions on the advantages of the various tapping methods so far recommended, are not based on experiments, such as our general physio-botanical knowledge suggests, and which have a definite object in view. It is likewise strange, that there is an utter lack of effort, by minute scientific research, to clear up the points on which the experiences of planters are at variance. Consequently a great uncertainty of opinion still prevails, which can only prejudice the cultivation of rubber. Recognized authorities in the field of rubber investigation have not been able to shut their eyes to this fact. From the literature on the subject

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# PREFACE.

When I went to Java in the Autumn of 1907, having obtained the German so-called Buitenzorg grant, it was, amongst other things, my intention, by studying rubber plants in the tropics, to help to extend our knowledge of the utility and advantages of the various tapping methods that had been described already. This object can be obtained by research in two directions: firstly, on anatomical lines, by studying the process of development of the laticiferous system, the expansion of this system during the diameter growth of the trees, and the renewal of the latex ducts after the infliction of large wounds on the bark, such as those made for the purpose of obtaining rubber; and secondly, on physiological lines, by ascertaining and investigating all the various influences which tapping has on the vitality of the tree and its component parts, as well as on the renewal of its latex and rubber. Every physiological botanist, who has taken the trouble to wade through the existing voluminous literature on the subject of rubber cultivation, must arrive at the conclusion that all these investigations, especially the physiological ones, are imperative in order, by introducing rational tapping methods, to protect rubber plantations against very unpleasant earlier or later injuries. It is extraordinary, that the opinions on the advantages of the various tapping methods so far recommended, are not based on experiments, such as our general physio-botanical knowledge suggests, and which have a definite object in view. It is likewise strange, that there is an utter lack of effort, by minute scientific research, to clear up the points on which the experiences of planters are at variance. Consequently a great uncertainty of opinion still prevails, which can only prejudice the cultivation of rubber. Recognized authorities in the field of rubber investigation have not been able to shut their eyes to this fact. From the literature on the subject it would almost appear, as if in this connection it was not yet sufficiently recognized, how important it is that theoretical and practical research should go hand in hand. If from the very first an endeavour had been made to keep in close touch with scientific botany, I feel sure that many mistakes in the cultivation of rubber would have been avoided, mistakes, the consequences of which may for many years injuriously affect many plantations. Rubber, more than any other cultivation, stands in need of being constantly supported by science, because in rubber planting many very complicated scientific problems of various sorts have to be considered, which cannot in any way be solved without due regard to theoretical botany, and in practise very important demands are made, the fulfilment of which must greatly depend on the solution of these problems. For the more the world's production of rubber increases, and the price drops, the more necessary it is for producers, by rational methods, to get the most out of their plantations.

As a whole series of questions for investigation actually force themselves on any physiological botanist, who wishes to decide on the suitability of the various tapping methods that have been recommended, it seemed to me a profitable task, to determine, whether research carried out from scientific points of view might not promote our knowledge of the practicability of the tapping systems considerably, and should this supposition prove correct, to show the way we should follow in investigating the tapping methods with regard to their utility.

Before beginning my investigations, I inspected a number of old rubber plantations, noted for their excellence and productiveness, and in conversation with planters, obtained a certain amount of insight into their methods, experiences and results. A stay in Ceylon offered the best opportunity for this.

Hevea offered itself, so to speak, of its own accord as a fitting object for my experiments. Firstly, it still occupies the first place amongst rubber plants. With regard to no other tree, therefore, is it of such pressing importance to increase our knowledge of the utility of the various tapping systems. Secondly, Hevea was the only rubber plant, of which at Buitenzorg in Java, I was able to obtain some specimens for my experiments. I should not like to miss this opportunity of expressing my warmest thanks to the highly esteemed Director of Agriculture, Professor Dr.

Treub, for the kind way in which he met my requests. In the same way I owe grateful thanks to the Directors of the Large and Small Botanic Gardens, Mr. Pit and Dr. Tromp de Haas. Both these gentlemen were constantly ready to assist me. Mr. Pit had also the great kindness to let several older Hevea trees be tapped according to my directions for some months, and to sacrifice them afterwards for an examination. Dr. Tromp de Haas with equal kindness, caused the incisions in some plants to be covered with soil and coconut fibre. It is conceivable that the number of old Hevea trees that could be placed at my disposal in Buitenzorg was not sufficiently large to enable me to solve the tapping problem completely. Too much must, therefore, not be expected from my experiments. They can do no more than point out a way, which by experiments on a larger number of trees, might lead us in a comparatively short time to a comclusion as to which of the tapping systems must be condemned as harmful.

But anyhow, my experiments will supply many valuable data, on which it will be possible to base decisions with regard to the various tapping methods, at least as far as Hevea is concerned. How far the conclusions at which we have arrived in the case of Hevea are also applicable to other rubber plants, future experiments alone can decide.

## PART I.

# PHYSIOLOGICAL STARTING POINTS FOR THE INVESTIGATION.

If a physiological botanist wants to form a right decision on the suitability of this or that tapping method, he will above all find it necessary to decide—and this at first apart from all practical questions—in what way the tapping cuts affect the vitality of the tree, and therefore, also the renewal of latex, and whether they will not sooner or later hinder the further development of the tree. For if they injure the tree, its growth must after a certain time be retarded, and the latex, on account of insufficient renewal, must gradually deteriorate and become poorer in caoutchouc.

## A. Influence of Incisions in the Bark on the Life of the Tree.

I think we can take it for granted that *every* tapping system will have at least some injurious effect on the tree. For every tapping incision wounds in no small degree a living part of the tree, namely the bark. But how can such an interference injure the tree? In order to answer this question, which is a very complicated one, certainly more complicated than may be imagined in planting circles, it will first of all be necessary to refer to the general nutritive relations, which must exist between the various parts of the tree, in order to insure its normal existence and growth. We are lucky in being able to make well-founded statements about these relations, and to ignore everything hypothetical, and can thus base our decisions on a sure foundation.

Two parts of the tree co-operate in providing it with the nourishment that is absolutely necessary to make it live and grow: the root system and the crown of the tree.

The r o o t - s y s t e m supplies simultaneously the indispensable water as well as the inorganic nutrient salts of the soil, which are chiefly required for the formation in the plant of the organic combinations containing nitrogen, sulphur and phosphorus. In order, however, to fulfil their chief function, the absorption of water and salts in a profitable and sufficient manner, it is necessary for the root-system to be well developed and healthy. It is likewise necessary that the development of the root-system should keep pace with the growth of the other parts of the tree, so that it can satisfy the constantly increasing demands for the supply of water and nutrient salts made on the roots by the continuous development of the crown.

The crown, on the other hand, provides the tree, that is the whole tree in all its parts, and thus also the roots, with the organic products formed from the organic substances employed in the construction and nutrition of the tree, in that the leaves, with the aid of sun-light, extract carbon from the carbon dioxide of the air and convert it into sugar. It is immaterial to us, in what part of the plant the organic combinations containing nitrogen, sulphur and phosphorus, necessary for the construction of *all* the organs of the tree, are formed from this product of assimilation and the nutrient salts of the soil. We will therefore only mention the fact that a great number of these substances appear to be produced in the leaves, and this during the presence of sunshine. However that may be, it is necessary under all circumstances, that the water and salts from the soil should be transported upwards from the roots into the other parts of the tree, especially into that part above the soil, which grows most extensively and vigorously, namely the crown; and that, on the other hand, the products of assimilation, sugar and other complicated organic substances from the crown, be conveyed to the other parts of the tree, and down to the vigorously growing roots.

The sole connecting link between the root-system and the leafy head is the stem. It must therefore contain the means of transport for the organic and inorganic substances. The transport of substances in the stem can take place in sufficient volume only if the channels work normally and suffer no interruption. It would, however, be a mistake to assume that the inorganic salts and the water of the soil are transported in the same channels as the organic substances. We are aware that four different principal parts can be distinguished in the stem: the pith, the wood, the bast and the cortex, with its suberous tissue, or bark. Careful physiological investigations have shown that the ascending movement of the salts and water of the soil takes place chiefly in the wood, while on the other hand, the descending movement of the inorganic substances towards the roots takes place chiefly in the bast, and possibly also in the cortex. Only in the case of a very few plants does the pith participate largely in this transport, namely in the case of those trees, where the pith contains a so-called inner bast.

It has been my experience that in all tissues suitable for sap-transport, the descent takes place chiefly, and quickest, in a straight direction parallel to the axis of the tree. It appears that those rows of cells take the chief part in the transport which run in an upward verticle direction in the stem, and the cells of which inter-communicate. If the organic substances are forced to descend in an oblique instead of a straight direction, the progress of sap circulation will become markedly slower.

But the parts of the stem not only perform the function of *channels* for the constructive substances, they also form excellent reservoirs for the temporary storage of those organic constructive substances, which cannot be utilized at once, and which have been produced in excess. It is also of great importance to know, that not only the channels which most rapidly transport the organic substances, namely the bast and the cortex, form such reservoirs, but so do all other parts of the stem, including the pith and the wood, with its medullary rays, as long as they contain living cells. The large quantity of carbohydrates, particularly starch, which in many trees is found in the living cells of the pith and wood are nothing else but stored reserve material. As soon as they are required, they can be conveyed from the reservoirs and used for the growth of the stem or of other parts of the tree. The reservoirs, at least those contained in the wood, are filled from the leaves by means of the normal channels which exist in the tree for the transport of organic substances: namely the bast and the cortex. The most important subsidiary channels are the medullary rays, which penetrate deep into the wood. They also transport the reserve material from the wood back again into the chief channels.

It is easy to see how highly advantageous it is for the vitality of a tree, that the stem is not only a channel for nutrient material, but also a reservoir for reserve material. If by some influence or other the channels for the organic substances become interrupted, it will through this arrangement be possible for the roots and the stem to continue their growth for a long time in quite a normal manner, by bringing the reserve material into action. They will possibly be able to do this sufficiently long until by reason of the tree's activity, the continuity of the channels has been restored and the damage repaired.

A very simple experiment will give us a clear idea of the functions of the various parts of the stem as channels for the organic and inorganic nutritive substances, and as reservoirs for the reserve material. It is the well-known experiment of girdling the tree. If we interrupt somewhere on the tree the continuity of the cortex and bast, by cutting two circular incisions round the stem, some centimetres or so apart, and if we remove the strip of cortex and bast between the two incisions down to the wood, the leaves do not wither (provided that the wood thus exposed is protected against desiccation), the crown continues to grow undisturbed, and produces new organic matter, and there is a continuous increase in the ash-constituents of the crown; all this proves that the channels in the wood for the transport of water and salts have not been interrupted by this interference. Also the downward transport of the assimilated organic substances from the leaves continues as before. But these organic substances can no longer be conveyed in sufficient quantity as far as the roots, as on account of the girdling the corresponding channels have lost their connection; an accumulation takes place above the ring and there all available reservoirs in the wood, pith, bast and cortex will be crowded with reserve material. As the after-flow of nutritive matter from the leaves into the parts of the tree below the girdle has entirely stopped, the tree will in time be obliged to draw here on all its reserve material in order to supply the matter required for the further growth and sustenance of this part of the stem and for the root-system. While thus in all parts of the stem above the girdle more and more reserve material (for instance starch) is being accumulated, it is on the other hand, noticeable that below the girdle starch gradually disappears from all parts of the stem. Evidently the wood can no longer obtain any appreciable fresh supply of organic substances.

What will be the fate of such a girdled tree? That must depend entirely on whether the connection between the portions of bark will after some time be re-established or not. Soon after the operation of girdling, a process of growth of a peculiar kind that tends to close up the wound, is noticeable on the girdle. On the two incisions, chiefly through the activity of the cambium, protruding pads of cortex are formed, that are termed wound-calli. These pads grow upwards and downwards towards each other across the exposed wood, till they touch and at last coalesce. When coalescence has been accomplished, the connection in the bark has been re-established, and the organic nutritive matter can be conveyed again into the basal parts of the tree and into the roots. But if, for some reason or other, the union between the wound calli is not completed, possibly because through too frequent girdling the wound-calli have repeatedly been removed, the available constructive substances below the girdle will sooner or later become exhausted. The tree will become sickly; the roots will no longer find the nourishment required for their existence; consequently they can no longer absorb nor convey upwards an adequate supply of water and salts for the wants of the tree. The crown consequently suffers, and finally the tree will die. Under such conditions, at what period the tree will begin to sicken, must obviously depend entirely on the rapidity of its growth, on the size of the reservoirs in its stem, and on the quantity of reserve material accumulated in them. For that reason, young trees will as a rule suffer sooner than old ones.

The experiment of girdling has a different result when carried out on plants that contain medullary bast in the pith. They will not suffer so easily, as by means of the bast in the pith, a continuous transport of food substances to the base of the tree can be maintained.

It requires but little imagination to see, that in trees *without bast* in the pith, the transport of material to the base of the tree will be disturbed by circular incisions, even though they have not penetrated right through the cortex and the bast down to the wood. The normal sap transport will be disturbed, even if only *some* of the channels—for instance, those in the cortex and in the *outer* layer of bast—have been severed. How far such an interruption of *some* of the conducting channels will disturb the vitality of the tree depends on various factors: *firstly*, on the amount of matter required by the root-system and the base of the tree; *secondly*, on the quantity of available reserve material; *thirdly*, on the quantity of organic matter, which can still be transported downwards through the unsevered channels; and *fourthly*, on the rapidity with which the reproductive activity of the cambium can provide a substitute for the severed channels on the spot operated upon. Consequently it is impossible to predict off-hand the number of channels in the bast and the cortex, the severance of which will sooner or later kill the tree. This can be ascertained only by experiments suitable to each species of tree.

From the foregoing remarks, it is evident why, at the commencement of this chapter, I expressed the opinion that tapping incisions on rubber plants will result in a certain amount of injury to the trees.

## B. The Applicability of the Facts Enumerated to Rubber Trees.

Is it, however, at all possible that these conclusions founded on observations made on totally different species of trees, are applicable to rubber plants? May not their sap-circulation be subject to totally different rules? Do we not find in them quite a special system of tissues, which is lacking in most other trees, and which is diffused throughout the whole tree: the system of latex ducts? Is it not possible that this system takes an active part in the sap-transport, and that the latex itself contains many important transportable nutritive substances? This theory is still very universally adopted by many practical men. Botanical research has of course often been occupied with the question. The results have been very lucidly summed up by *Kniep* in a very excellent treatise, which appeared not long ago,[1] and in which also a number of new and critical experiments on different kinds of laticiferous plants have been communicated. On the basis of his own experiments and those of his predecessors, *Kniep* arrives rightly at the conclusion, that in all probability, latex is not a nutrient juice, and that it is consequently of no importance as regards the circulation of sap. What mostly interests us is the conclusion at which *Kniep* has arrived by experiments in girdling the branches

[1] Kniep, Hans. "Ueber die Bedeutung des Milchsafts der Pflanzen. Flora." Vol. 1, 94, 1905. Pp. 129, ff.

of a rubber tree—*Ficus Elastica*—that it is not possible by means of those laticiferous vessels which are situated in pith devoid of bast to effect a sap-transport across portions of branches, which have been girdled down to the wood. However we must bear in mind, that not all laticiferous plants need necessarily follow the same rule. It will therefore be necessary to submit all the various kinds of rubber plants to a series of special experiments. I take this opportunity to mention that on *Hevea* my experiments of girdling have had the same negative result, that Kniep obtained by his own on *Ficus*. They will prove, that at least in the case of Hevea, all the same rules for the transport and storage of sap in the stem hold good as in the case of other trees.

## C. Influence of Incisions on the Production of Latex in the Bark.

In order to form a correct estimate of the suitability of any tapping method, it is important to ascertain not only—as I pointed out at the commencement of this chapter —to what extent tapping will injure the vitality of the tree, but it is also necessary to find out in what way it affects the renewal of bark and of latex. The answer to the latter question will for the present depend entirely on the solution of the former, and therefore the solution of the first problem, being the fundamental one, is the one which we must endeavour to obtain. We shall have no difficulty in comprehending this, if we again make the experiment of girdling the basis of our deliberations. Let us, therefore, suppose, that cutting down to the wood, we have made a complete girdle round a rubber tree, the pith of which is devoid of bast, and that during this operation there has been an abundant flow of latex from the parts of the stem below the girdle. The important questions for us to solve are, whether and in what manner girdling will affect the re-filling of the partly drained laticiferous vessels in the parts of the stem below the ring. Whether or no such an influence will make itself felt, will depend solely on the distribution of these vessels in the tissues of the tree. If the vessels only, or chiefly, occur in the cortex and the bast, the influence is a matter of course; if they are also to any extent situated in the pith, an influence on the formation of latex in the tubes of the cortex and of the bast below the girdle is only then a matter of course if these laticiferous vessels do not communicate right through the wood into those of the pith. As, for instance, the laticiferous vessels of tappable Hevea trees are diffused throughout the cortex and the bast (compare the anatomical statements further on), we can with regard to Hevea answer the first question in the affirmative, and must admit, that girdling *has* an influence on the refilling of the vessels below the girdle.

I now turn to the second question: In what way can girdling affect the renewal of latex? It is not difficult to answer. If latex be produced only in the leaves, the descending current of the newly formed latex cannot flow across the girdle towards the base of the tree. But if latex is produced in the stem, then, as we have already seen, the downward transport of food supplies becomes entirely suspended by the girdling. In the former case, a refilling of the latex tubes below the girdle will be practically impossible, as long as the girdle has not been bridged over by callus.

We have every reason to assume that latex is produced, not only in the leaves, but also, or almost entirely, in the stem.[2] Some extremely important and interesting observations made in Ceylon and Singapore with regard to the renewal of latex in repeatedly tapped leafless trunks of old Hevea trees, for instance, admit of no other interpretation.[3] But if latex is produced in the stem, which is undoubtedly the case, the nutritive substances required for this purpose must exist in the stem in sufficient quantities. If there is a deficiency of them, the renewal of latex must necessarily suffer, the laticiferous vessels cannot be completely re-filled with latex, and the supplementary latex may possibly deteriorate in quality as compared with the original. We have already seen, that after a complete girdling of a tree a deficiency of nutritive substances must sooner or later make itself felt in the stem below the girdle. The universal injury which

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[2] None of the observations can force us to acquiesce in the supposition, occasionally laid down, that latex is produced only in the leaves.

[3] Compare for instance, J. C. Willis, M. K. Bamber, E. B. Denham. "Rubber in the East." Peradeniya Manuals of Botany, etc., No. 1. Colombo 1906. Pages 25, ff.

H. N. Ridley and R. Derry. Second Annual report on the experimental tapping of Para rubber trees in the Botanic Gardens, Singapore, for the year 1905 (1907) Pages 24 ff.

the tree thus suffers, must *necessarily* extend to the quantity and quality of the supplementary latex.

I have already pointed out, that under certain circumstances, even incomplete girdling incisions, which only interrupt the continuity of the cortex and of the outer layer of bast, may sooner or later have a deleterious effect on the tree, on account of the partial interruption of the circulation of nutritive substances. If such an injury occurs, it is obvious, for reasons given above, that it will not be without great influence on the renewal of latex below the spot operated upon. It will have an influence on the reproduction, all the greater the more latex has exuded, and will therefore have to be replaced. A sufficient re-flow of latex through the few vessels that may possibly still remain intact in the inner bast, will be all the more impossible the younger and more undeveloped are these laticiferous vessels.

In summing up all we have been considering in this chapter, based as it is on well-known physiological data, I think we can form the following conclusion, that in rubber trees (as in other trees), cuts made very deep in the cortex and in the bast, are apt, sooner or later, to disturb greatly some very important vital functions of the tree, and consequently retard below the girdle the renewal of cortex and of the latex that has exuded; all the more the deeper and more extensive these cuts are, and the longer the period is, which will be required for the restoration of the severed parts, because the reservoirs below the girdle will become exhausted and a scarcity of food must occur in some parts of the tree. The younger the tree, the sooner the injury will be noticeable.

## D. Problems for my Experiments.

How can we utilise this conclusion, in order to determine the value of the various tapping methods? Does tapping really interfere with the vitality of the tree so much as, sooner or later, to damage it seriously, and hinder the renewal of latex of good quality? In order to decide these questions, it will be necessary firstly to glance at the anatomical structure of the Hevea tree, and secondly, to consider the demands made in actual practice on the tapping cuts, so that a sufficiently remunerative yield of latex can be obtained.

As regards the anatomy of the stem of Hevea, it will be sufficient to draw attention to the following facts observed by myself: if young trees are examined, one to three years old, it will be found that the interior of the stem contains pith *consisting of thin-walled cells.* Fibres of bast are completely wanting in the pith. Some isolated, inter-communicating laticiferous vessels run through the *periphery of the pith.*[4] The pith, rich in starch, is surrounded by dense wood. The living cells of the wood are so rich in starch, that a solution of iodine in diluted alcohol will colour the whole body of wood an intensely dark blue. On the outer surface of the wood, the creative tissue, the cambium, is found, through the activity of which the tree grows in girth. By division, it forms cells towards the interior, that enlarge the wooden ring, and others towards the exterior, that thicken the bast. Outside the cambium the bast is situated. In this a number of laticiferous vessels are diffused, which like those in the pith, are parallel to the axis of the tree and united by numerous cross-connections. They, as well as the other cellular tissues of the bast, are continuously reproduced by the cambium. Outside the bast, last of all is the cortex. In it as well isolated laticiferous vessels occur. The greatest amount of latex, however, is contained in the laticiferous vessels, which are situated in the parts of the bast, that adjoin the wood, and are still young. If we examine the young green twigs of these trees, in which lignification has not yet begun, we perceive that the medullary and cortical laticiferous tissues, as well as those of the bast, are here and there united by cross-connections, especially in all those places where a leaf or a side branch emerges, namely at the nodes. But these connections are not found in those branches, in which an unbroken ring of wood surrounds the pith.

Older trees, which are what we have to consider for tapping, do not differ much anatomically from younger ones. However, I have made one significant observation, namely, that medullary laticiferous vessels seem to have lost all importance, and have become quite valueless in older trees. Their walls are of a brownish colour, so are their contents; in many cases the vessels have been compressed by the adjoining pith-cells. Naturally all

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[4] Miss A. Calvert has already described correctly the distribution of laticiferous vessels in the stem of Hevea trees. Vide her short treatise: "The laticiferous tissue in the stem of Hevea Brasiliensis. Annals of Botany." Vol. I. 1887-88. Page 75.

transverse connections between the medullary laticiferous vessels and those of the bast are non-existent in trees of such dimensions. This anatomical discovery of the obliteration of the medullary laticiferous vessels, accords with the observation, that if green unlignified branches are cut through, there will be a small flow of milk from the pith, but not in well-lignified stems. It is noteworthy from an anatomical point of view, that in older trees the layer of bast has been greatly thickened through the activity of the cambium, and consequently the laticiferous system contained in the bast has also greatly increased in size.

Therefore, as the laticiferous vessels are situated chiefly in the bast of the tree, and as the yield of latex is the greater the younger the parts of the bast are in which they occur, it is surely right to demand in practise, that tapping should penetrate to the inner parts of the bast in order to ensure a sufficient flow of latex. However, it must neither reach nor cut through the cambium, as then the creative activity of the cambium would be too much affected. In order to satisfy all these demands, a large variety of tapping knives have, as we know, been invented. The labourer, who uses one of these instruments, can without difficulty make his incisions sufficiently deep, and yet not so deep as to injure the cambium. Though it is true, that from even a small incision a certain quantity of milk will exude, on account of the pressure on the latex in the vessels, the quantity would be much too small to be turned to account. Consequently we are induced to make deep cuts into the stem, and not only one, but several cuts simultaneously and at some distance apart, above and also alongside of one another. These cuts are made on the stem in an oblique direction, not vertically, as by such incisions only a few of those laticiferous vessels would be severed, that run in a longitudinal direction; nor horizontally, as in that case the latex, as it exudes, would not flow well, nor be easy to collect. It is further necessary to make repeated fresh incisions after intervals of one or two days, and these in close proximity to the old ones, in order to draw from the tree the desired quantity of latex. It is a very strange fact, the nature of which is not yet clearly understood,[5] and which seems to have been first discovered by

[5] To me it seems very probable that this so-called wound-response is based on the same principle as the so-called bleeding pressure, which is noticeable as the result of wounds on a stem. But it is not the

*Willis* and *Parkin*, that the latex will only begin to flow freely from incisions that are made one or a few days after the first incisions.

The following process seems to be the basis for all tapping methods at present in use. A number of shorter or longer oblique incisions are made in the stem of the tree, each a fair distance above the other, and at intervals of one or more days, small strips of bark are pared off with the tapping knife from the lower edge of all the tapping incisions and along their whole length. This process is repeated, till eventually the whole of the cortex and almost all the bast has been pared off down to each next lower incision. It is regarded as a matter of great importance, that each time a very narrow strip of bark only should be removed, so that it should take as long as possible to complete the entire removal of the cortex, and for the tapping period to come to an end. In order to prolong the time, and to spare and preserve as much bark as possible, a favourable view has been taken of a suggestion, which has been adopted in practice on many estates. to make the incisions with the knife less deep, and at repeated tappings, not to use the knife each time, but alternately the knife and another instrument invented for the purpose, the pricker. This pricker is a small star-shaped wheel with sharp teeth. It is applied on the inner edge of the last incision made by the knife. By moving it with an appreciable pressure along the whole length of the tapping surface, those laticiferous vessels are severed that are situated in the inner parts of the bast, and which have become exposed by the last incision; and by this process the greatest possible drainage of all vessels is obtained. The pricker should penetrate as far as the cambium, but must not cause any injury to this creative tissue. It seems that there is still a great diversity of opinion as regards the advantages of the use of the pricker. I shall refer to it again.

Two facts are thus characteristic of almost all tapping methods in vogue: firstly, the entire severance by oblique cuts of extensive areas of cortex and bast. The result of this severance is an interruption in the stem of numerous channels for organic substances. Secondly, the gradual removal of very large surfaces

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question here of root-pressure, but of fluid secretions of living cells in the neighbourhood of the wound. Compare L. Jost, Pflanzenphysiologie. G. Fischer, Jena, 2nd ed. Pages 64, ff.

of cortex and bast, together with the extraction of large quantities of latex. This necessitates an extremely extensive renewal of bast and latex in the stem, for which purpose a large extra expenditure of organic substances is required. These substances will have to be obtained all the more exclusively from the reservoirs in the stem, the more the downward current of food supplies from the crown has been checked by tapping the tree. The expenditure of material, as compared with a tree in its normal condition, is all the more increased, in that the intensity of respiration is far greater at any wounded parts of a plant, than at the uninjured ones.

I think all these facts and considerations demonstrate with sufficient clearness the necessity for investigating the influence which the various tapping methods exercise on the distribution of sap in the stem, and for ascertaining how far tapping injures the tree by checking the downward current of sap. It is only by such investigations that we can in time solve the extremely important question, how much nutritive substance must be present in the stem below and within the wound in order to provide not only for the renewal of the removed bast, but also for respiration, for the continuation of the normal growth in girth, for the continued development of the root-system, as well as for the reproduction of latex in its original quantity and quality. It is conceivable and even probable, that a deterioration of the renewed latex begins to show itself even *before* all the reserve material in the reservoirs has been exhausted, in fact as soon as the growing tissues completely absorb and utilise the reserve.

The objection might be raised, whether there is still any need for such investigations, whether the experience gained in practice will not yield sufficient information as to which of the tapping methods injure the tree and will in time cause a deterioration of the latex. The answer to this must be; firstly, that the views of planters on the value of the various tapping methods differ very much and contradict one another; secondly, that the injuries resulting from bad tapping systems need not necessarily be very apparent till after the lapse of several years. I shall discuss this more in detail further on. It is against a fate of this sort that we must as much as possible guard rubber plantations by investigations systematically conducted. For of what use are estates, which perhaps during a period of four to six years yield plentifully, but must then lie fallow from exhaustion for years. Furthermore, it is the duty of scientific research, based on well-established facts, to lend a helping hand, when the experience of practical men is at variance.

These were the ideas that guided me in my experiments. I had to begin with an investigation of the influence exercised by ordinary girdling on the transport of sap in the stem of Hevea, and in connection with this, I had to compare the changes in the distribution of sap in the stem after the tree had been tapped in accordance with the various tapping systems in vogue. For my purpose it was sufficient to ascertain the distribution of starch, formed from organic material assimilated in the leaves and transported in the form of reducing sugar[6] through the channels of the stem, and which chiefly fills the stem reservoirs. It requires very little trouble to prove its existence. It is well-known that the so-called iodine test is sufficient. When treated with a solution of iodine in diluted alcohol the starch-grains rapidly turn blue. If during these experiments, the starch has disappeared from tissues, in which its existence had been already proved, there are two alternatives, either it has become soluble and in this condition has remained in the tissues, or it has been conveyed where it was required and has been utilized. If starch has been dissolved, it is easy to prove the product of solution, reducing sugar, by a treatment with Fehling's Solution. Other substances besides starch and reducing sugar were not taken into consideration at the investigation. Whether it is desirable, or not, to include other substances, such as albumen and ammides, in our research for the purpose of determining the value of the various tapping systems, time alone will enable us to decide.

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[6] *Reduzierende Zucker* must be translated "reducing sugar." It is a more comprehensive term than glucose. It includes glucose, cevulose, grape sugar, and fruit sugar, but not cane sugar—in fact any sugar that reduces Fehling's solution.—Tr.

## PART II.

# MY EXPERIMENTS.

## A. Influence of Girdling on the Distribution and Circulation of Sap in the Stem of Hevea.

I considered it sufficient to make these experiments on young trees. More mature ones I could and would not sacrifice for the purpose, had I done so, I am sure that the results obtained would not have been different. My sole purpose was to ascertain whether girdling has the same effect on the Hevea tree as it has on other trees. As we know by frequent experiments, that other kinds of trees are affected by this operation, no matter whether they are old or young, we are surely right in assuming, that this is also the case with old Hevea trees, if young Hevea trees are affected.

In my first experiments I made use of three yearling plants, the height of which was 1,8 m., and which had been raised from seed in the Large Botanic Garden. They were girdled in the lower lignified part of the stem, 50 cm. above the ground. The length of the removed ring of bark was 3 to 4 cm. Before girdling them, the saplings were 3,5 to 4 cm. in girth just below the girdle. The experiment commenced on December 22nd, 1907. One of the plants was cut down for examination on February 11th, 1908, that is after 51 days. The leaves were fresh, the crown had continued to grow, but no new branches had been formed below the girdle. The circumference of the stem above the girdle was now 5,2 to 5,8 cm.; below it was the same as before, 3,5 to 4 cm. On the upper edge of the wound, pointing downwards, a thin pad of callus had been formed. Above the girdle, as far as the crown, I found much starch in wood, pith and bark. It was especially abundant in the tissues above the incision. Only the pad of callus on the upper edge of the wound, was, curiously enough, completely free from starch. Of reducing sugar, I found no greater quantity here than elsewhere in the bark. Below the upper cut, however, down to the base of the tree, starch was completely absent in all the tissues of the stem. Reducing sugar also was almost completely absent.

The second plant was cut down eight days later. Its condition with regard to the distribution of starch, corresponded completely with that of the first specimen, though 2,5 below the girdle, two young branches, with four leaves each had developed.

The third plant was left till the middle of March. Its examination gave similar results.

It is evident from this experiment, that in consequence of girdling, the circulation of sap in the stem had been completely or almost completely checked, and that after a short time only, the reservoirs in the stem were completely emptied. Outwardly no damage to the trees was visible. Probably they would for quite a long time have kept up in growth with the other trees, because a long period must elapse before the want of food in the root-system, and the retardation in its growth, show themselves in the condition of the crown. Had, however, the latex been extracted from the basal parts of the stem, I feel convinced, that it would not have been renewed in its original quality and quantity, if the tree had been left growing.

A plant, kept for comparison, which had not been girdled, but was under observation, contained an abundant quantity of starch in all parts of the stem down to its base.

The experiment was repeated in the following manner on three bigger and thicker plants, two or three years old, their height being about 2 to 3 m. I had one of these doubly girdled, the rings were cut in the middle of the stem, at a distance of about 50 to 75 cm. from each other. In the case of the other two trees, I did not have circular incisions made on the upper wound, but incisions extending only over half the circumference of the tree. A square of bark from half to two-thirds of the circumference of the plant was then removed, so that on the upper wound, a bridge of bark was preserved. The lower girdling was complete. On all three plants I had the wound embedded in soil and coconut fibre, by which the wood was fairly well protected against desiccation. The plants were girdled on December 30th,

1907. I purposely made the examination very late, that is, as late as April 16th, 1908. The doubly girdled tree contained an abundance of starch in all parts of the stem above the upper ring; the callus only was, again, free from starch. Below the upper ring, however, down to the base of the tree, reducing sugar and starch were wanting, save in the innermost layers of wood. Here was still a considerable quantity of starch. Above the upper edge of the incision, a large number of roots had been formed on the upper and lower wounds, but a greater number and longer ones on the upper than on the lower, apparently because there was not so much food available for the lower one. This plant is of special interest as compared with the younger experimental plants, previously under our observation, because it shows that the process of draining the reservoirs in the stem will be the slower, the more extensive they are. While in the case of the slender yearling, all starch disappeared from the stem after a period of only 51 days, the thicker, three-year-old plant, after three-and-a-half months, still contained starch in the innermost zones of its wood. From this it is also evident, that the drain of starch evidently starts from the bark.

The two plants with the bridge of bark on the upper wound, presented the same appearance below the lower incision as No. I., and also above the upper incision. But it stands to reason, that the conditions between the two wounds were somewhat different. For by means of the bridge of bark on the upper one, it had been possible to continue the downward current of sap. On the upper wound itself, starch and reducing sugar were almost completely absent from the wood, that had been formed prior to the operation. On the other hand, starch was abundant in the newly formed wood inside the bridge of bark. And from the ligneous part of this bridge, some starch, though but a small quantity, had penetrated into the immediately adjacent old wood. Below the upper wound down to the lower one, starch was again present in all layers of the stem. It is impossible to draw any conclusions from this circumstance with regard to the quantity of sap that can be transported across the bridge of bark in a basal direction, as in every case, the lower girdling had caused an accumulation. Roots had been formed chiefly on the upper wound, only very few on the lower one.

The conclusions to be drawn from all these experiments can be summed up as follows: Corresponding with the absence of medullary *bast*, a severance of the bast and the cortex will completely interrupt the downward current of organic food material, so that the reservoirs in the stem below the place of severance will, in the case of young trees, be very soon emptied, in that of older ones, more slowly. The result of this will be that a deficiency of food will sooner or later occur in the base of the tree.

It would have been of great interest, not only for our immediate purpose, but also in its relation to the tapping problem, to ascertain by experiment, how rapidly the reservoirs which had been emptied completely by girdling, would be refilled, when the connections between the severed portions of the bark have been re-established, as for instance, by the joining together of the wound-calli. Such experiments would, however, have required more trees for experimental purposes and more time than I had at my disposal.

## B. Influence of the Tapping Incisions on the Distribution and Circulation of Sap in the Stem of Hevea.

In order to be able to compare in the easiest possible manner, the influence exercised on the circulation of sap by the various tapping cuts, with that of complete girdling, we must first consider those tapping systems in which the rectilinear connection of the channels for the organic substances is interrupted round the whole girth of the stem, as in the case of girdling. These systems only differ essentially from the ordinary method of girdling by permitting a circulation of sap in an oblique direction, and also because possibly the innermost channels in the bast, the youngest and those nearest the cambium, can still be utilised for conveying food. Probably the simplest of these systems is the English full spiral system. It was very much in vogue some time ago, and probably is still very popular. [The full-spiral system was recommended in Ceylon at one time, and experiments were made at the Heneratgoda Government plantation; but the recommendation was never widely adopted, either in Ceylon or the Malay Peninsula, and was speedily abandoned.—*Tr.*] A spiral curve is cut in a slanting direction in the bark, beginning at about the height of a man, and continuing down to the base of the stem. The incision is carried one and a half to three times or more round the stem. Naturally its direction is less sloping the more often it envelopes the stem. By enlarging the wound at intervals of a few days in the manner above indicated, the whole bark of the stem will in time be removed. Of course it was desirable in my experiments to have the tapping operation performed in the customary manner by trained workmen.

Mr. Pit was kind enough to instruct his men accordingly. In the first instance he put at my disposal a Hevea tree, eight years old, that had never been tapped. At the height of, say a man's chest, the girth of the tree was 50 cm. Tapping began on November 8th, 1907. From the height of 1,28 cm, the incision was carried one and a half times round the tree in a basal direction. A distance of 50 to 52 cm. was left between the spiral curves. Details of the manner of tapping can be seen on the accompanying diagram. (Compare diagram 2.) It represents the bark of the tree, as it would appear to the eye, reduced to one-tenth of its size, if the cylinder of bark were cut open longitudinally and spread out flat. Tapping was performed daily, alternately with the Bowman parer and the Bowman pricker. Of course I ascertained frequently, that the tapping cuts were properly executed. Tapping was continued up to February 10th, 1908. On February 11th, the tree was cut down for examination.

Before I communicate the result, I must refer briefly to the examination of small pieces of wood and bark, made at various times during the tapping period. For we derive from it some interesting information with regard to the changes in the distribution of organic substances occasioned by tapping.

On December 15th, bits of bark, 5 cm long, were excised from the tree for the first time, that is, 36 to 37 days after the beginning of tapping, one bit (a), from just above the incision, 10 cm from its upper end, another (b), in a vertical line below (a), just under the wound (Compare diagram 1), a third, (c), from the bark on the opposite side of the stem, 100 cm above the incision. Starch was found only in (c), but not in (a) or (b). By treating with Fehling's Solution, no difference in the quantity of reducing sugar contained in (a), (b) and (c) was apparent.

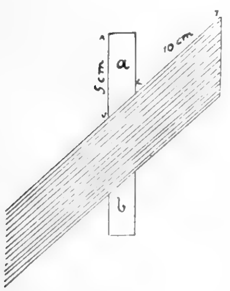

Diagram I.

On December 22nd, pieces of bark, (a) and (c) were again cut from similar places, and also a small piece of bark from the wound near (a). (c) again contained a quantity of starch, but (a), even at a distance of 10 cm from the wound, contained none, nor did the bark on the wound.

I have also taken bits of bark from similar places on another Hevea tree, eight years old, that had been tapped for a fairly long period, and had been thrown down by a storm, on December 12th, 1907, and have examined them for starch. The tapping had been performed on the half spiral system, so Mr. Pit said, and had been continued from April to June, and from August to October, 1907. Starch was completely wanting in (a) and (b), while it was abundant in (c).

From these observations it is evident that soon after the commencement of tapping, starch disappears from those parts of the bark which are next to the cuts, not only below, but also above them, and that after the cessation of tapping, some interval of time must elapse before it can be reproduced even above the incision. In the case of the fallen tree, for instance, one and a half months had not sufficed to reproduce starch above the wound. Evidently the starch in the neighbourhood of the wound is claimed by the vigorous creative activity, which during the period of tapping and for some time after, is at work in the cambium below the wound.

These discoveries prove at the same time, that contrary to my first impression, the examination of small pieces of bark does not enable us to draw conclusions sufficiently as regards the influence of tapping on the distribution and circulation of sap in the stem.

For that purpose, it is on the contrary necessary, to sacrifice the whole tree, at least for the present, till we have more data on which to carry out less disastrous methods of investigation.

For this reason I saw myself faced by the necessity, of having my experimental tree, that had been tapped on the full spiral system, felled on February 11th, that is after 96 days of tapping, and long before the whole bark had been removed. The wound was as yet only 12 cm broad. (Compare diagram 2.) The stem was cut into sections with a saw, after which parings of the bark were systematically examined for starch and reducing sugar. The wood also was at first examined in thin sections under the microscope, till the idea occurred to me to stain the whole transverse section of the wood with a solution of iodine. By this process it was very soon possible to obtain information as to the distribution of starch in the wood: the starch-containing wood turned a blue-black; that containing none, a yellow-brown colour. I can recommend this very simple method to all who feel inclined to continue research in the direction I have indicated.

The result of the examination was most interesting. I begin with the bark.[7] Above the cut, starch was abundant, more so than higher up on the stem. Only quite close to and above the cut in a zone 5 cm wide was it in small quantity. The same was the case beside the upper end of the wound. How starch is otherwise distributed in the basal parts of the stem, will be seen best from the diagram, in which I have set forth my discoveries according to very exact measurements. Wherever the organic substances, uninfluenced by the tapping, had been able to descend vertically, quite as much starch was found as above the upper spiral curve. Below this curve, however, that is, wherever the organic substances had been forced to move sideways or obliquely, a considerable decrease in the quantity of starch, commencing from the upper end of the tapping cut, was very soon noticeable. However, the existence of starch could still be proved in the spiral strip of bark between the wounds, at a distance of half the tree's circumference from the upper end of the incision (measured parallel with the wound). Starch was completely absent from the other parts of cortex and bast at the stem's base. By a treatment with Fehling's Solution there was *no* difference noticeable between the reducing sugar-forming property of the bark that contained starch, and that which contained none.

The distribution of starch in the bark corresponded entirely with that in the outer layers of wood: wherever starch was entirely absent from the bark, or present only in a small quantity the same condition existed in the outer, 2 cm thick, layers of wood. Right at the upper end of the incision in a transverse section marked (a) in diagram 2.), starch, as in the case of the bark,

[7] By bark I mean here as well as on the preceeding page, which I daresay has already been noticed, bark in the ordinary sense of the word, *and* bast.

was absent only from that part of the wood just below the wound. In a transverse section, marked (b), it was not only absent below the tapping spot, but also below a piece of the remaining

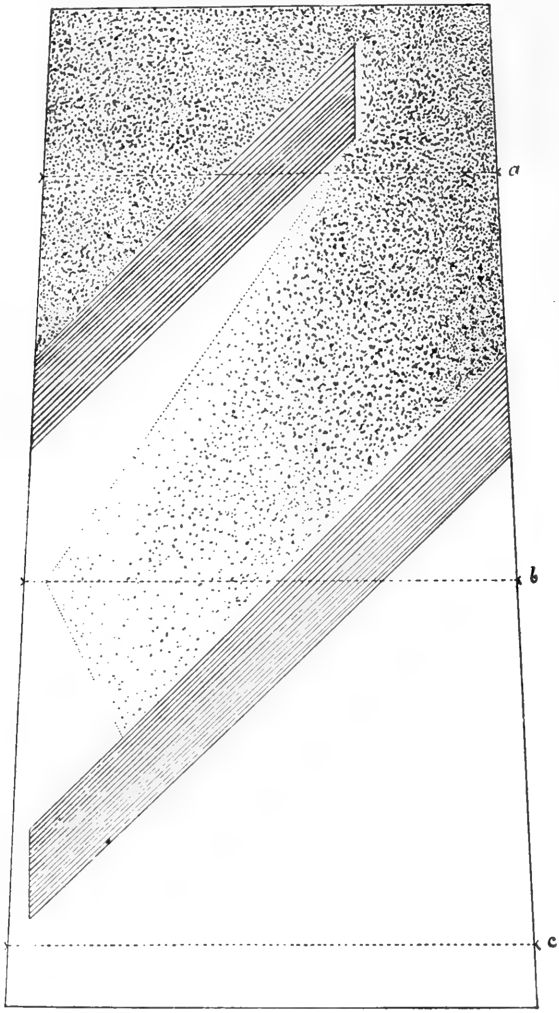


Diagram II.

bark, and finally at (c) in an unbroken ring of wood, 2 cm wide. The inner parts of the wood, however, still contained abundant starch, penetrating into the pith. Nor was it possible, by a treatment with Fehling's Solution, to discover any considerable quantity of reducing sugar in the zones of wood that were free from starch.

It is obvious at the first glance, that this result corresponds almost completely with the one I had previously obtained on girdled trees: the reserve material disappears below the spot operated upon, and accumulates above it. A wound extending over the *entire* circumference of the stem, has therefore the same effect as the girdling, because the rectilinear connection of the conducting channels in the bark has been interrupted and because the circulation of organic nutrient substances in an oblique direction proceeds too slowly to provide the food supply required by the base of the tree.

Speaking generally, however, it seems to me that the conclusion of most practical importance to us in our endeavour to arrive at a decision on the various tapping methods is, that after tapping on the full spiral system, a sufficiency of the organic nutrient substances that are necessary at the base of the tree for the renewal of bark that has been removed, for the renewal of the latex that has been extracted, for the normal growth in girth of the tree, for the longitudinal growth of the roots and for the respiration of the basal parts of the stem, cannot descend there. The tree is therefore obliged to draw on the reserve material from its reservoirs in the bark and wood. Tapping might have been continued for quite a long time, as there was still a sufficient quantity of tappable bark. During that time, the reservoirs in the stem would certainly have been even more completely emptied.

Another point of practical importance for the determination of the value of the various tapping methods is the fact, that a certain amount of sap transport, though a slow one, is quite possible in an oblique direction. I shall refer to this later on.

Before doing so, however, I should like to report on a second and final tapping experiment, which was commenced simultaneously with the first one. In this one, not the full spiral was adopted, but the half herring-bone system, which consists in a number (six) of oblique cuts, one above the other. The age of the tree was identical with that of the other one, its girth was 50 cm. at the height of 1,60 m. The tapping cuts extended only over a quarter of the stem's circumference. Their position on the tree, the distance between them, etc., can be seen on diagram 3 (one-tenth of actual size).

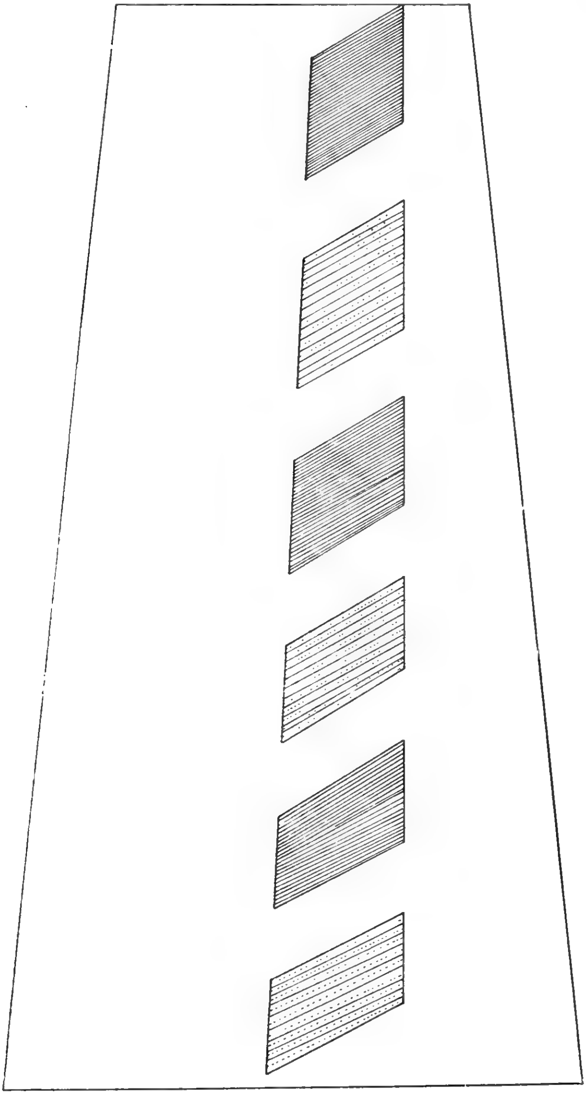

Diagram III.

The operation of tapping was performed in the same manner as on the other tree. On three spots, the Bowman parer alone was used (on the diagram evenly shaded), on the other three, the

Bowman parer and the Bowman pricker were used alternately (on the diagram shaded by alternate lines and dotted lines). The tapping period extended from November 8th to April 11th. The tree was then cut down and examined for starch and reducing sugar with the following result: above the uppermost incision, both bark and wood were very rich in starch. But there was no trace of either reducing sugar or starch in a zone of bark 5 cm wide, immediately adjacent to the top end and the sides of the tapping cut. Nor was starch or reducing sugar found in the bridges of bark between the incisions; on the other hand, starch was everywhere present in the wood. Below the last and lowest tapping spot, the presence of starch could be proved only in the bark at a distance of 15 cm. from the last tapping wound. On the incisions themselves, starch and reducing sugar were absent both from the bark and from the outermost zones of wood, 1,5 to 2 cm thick. In all other parts of the tree there was abundance of starch.

That starch was completely wanting in the bridges of bark between the tapping spots, was probably due to the fact, that owing to the transport in an oblique direction, not enough could be substituted to replace the amount used up in this region.

This experiment teaches, that tapping cuts of this description can at most have only a local influence on the descent of organic food substances towards the base.

PART III.

# INFERENCES AND FRESH PROBLEMS RESULTING FROM MY EXPERIMENTS.

Having now obtained the proof, that in the case of some tapping systems, namely, those which involve the extension of cuts over the whole of the tree's circumference, an adequate supply of organic food material for the wants of the base of the tree, cannot be conveyed in a downward direction across the incisions, we must now face the important question, whether the cuts will not in time injure the tree seriously. As I have explained already, injury is certain when the reservoirs at the base of the tree are emptied. and cannot be replaced by a sufficient quantity of material from the crown. It is quite impossible to obtain this fresh supply, at least so long as the food channels are repeatedly severed down to the cambium by repetitional tapping incisions, that is, not before the end of each tapping period. If the tapping period is a long one, and the tree comparatively young and therefore still in the stage of rapid growth, it may be possible that the reserve material will be completely exhausted even during the first tapping period and that injury to the tree will be manifest, for instance, in the deterioration in quality of the renewed latex. Moreover, as I have already pointed out, we are at present still quite ignorant, whether or not, the supplementary latex will be poorer in quality, after a *certain* lack of food has really set in, even though the reservoirs in the wood have been by no means *completely* emptied. These problems, which are of the greatest importance, in rubber cultivation, will at some future time require thorough investigation on the lines I have indicated.

But even when the tapping period has come to an end, a long time will elapse, and this we can maintain with certainty, before a fresh supply of organic material can be conveyed across the tapping spot, because a sufficient number of channels will have to be reproduced by the cambium for this purpose. Judging from observation, Hevea requires quite a long time for this to be effected. Without special experiments, it is impossible to determine, how long a period must elapse before the food deficiency at the base of the tree can be made good by a fresh supply.

This extremely important question arose only after I had ascertained the effect of incisions on the transport of nutrient sap, and it was therefore only at the end of my stay in the tropics, that I might have been able to investigate this subject had I had some trees at my disposal which had been tapped for some time previously. I feel sure that, on the lines I have indicated, I could easily and rapidly have solved this question. It is certainly important to strive to solve it as soon as possible.

Finally, it is important, not only to ascertain *how soon* the transport of a certain amount of food material across the tapping surface can again be proved to exist, but also, and chiefly, how soon after the end of one tapping period it is possible to transport a large enough quantity of material towards the base of the tree to satisfy the probable very great need of food, which has arisen in the bark during and after the tapping period, in consequence of the necessary renewal of bark and latex, and also, *how soon the reservoirs of the tree can be refilled.* I feel sure, that a long time must elapse before the latter will be possible, and probably this may not be till the reproductive activity has all but ceased its work. This question, too, could be solved very rapidly by an investigation of trees which had been tapped some length of time previously. It is evident how necessary the refilling of the reservoirs is, for the maintenance of the tree's life after a repetition of the tapping operation. If the reservoirs have not been refilled completely, the tree will enter the second tapping period with a much smaller quantity of reserve material than at the first one. The result will necessarily be, that at a second, third, or subsequent tapping, the reserve material will have been completely exhausted, that the tree will be injured severely, and that the latex will deteriorate considerably. I do not think it at all unlikely, on the contrary it is very probable, that in this manner, many bad results can be accounted for, that planters have had, with regard to the falling off in quantity and quality of latex, after repeated tapping operations, performed by very extensive incisions.

And lastly there is another question to which I must draw attention, and which cropped up during my experiments, namely: How long a time will elapse before starch can again be stored in the bark that has been renewed on the tapping wounds. I have *never* in my experiments noticed a storage of starch in bark that had been renewed on the tapping spots, not even when a sufficient quantity of food material had been procurable from the neighbourhood, even when, after tapping operations, the bark had had four to five months time to ripen. This accords with the extraordinary fact, that starch is *not* stored in the calli formed as the result of girdling, not even on the upper edge of the incision, where organic material accumulates largely in the bark next to the callus. The result of an examination of a very old callus, is of great interest in this connection, because it proved that a long period of time can elapse without any storage of starch taking place in calli of this description. In the Large Botanic Garden at Buitenzorg, I came across an 18-year-old Hevea tree, the circumference of which was 75 cm, at the height of a man's chest, and which had been tapped in February, 1907, by a spiral curve cutting down to the wood. On the upper and lower edges of the wound, calli had been formed. In a piece of callus which I excised on December 22nd, I found no starch, neither was there any in the new wood formed just beneath it, while a quantity of starch was contained in the old bark just above it. Nor did I find any special quantities of reducing sugar in the callus. In order, therefore, to find out the condition of the tree at the time when a second tapping period is to succeed the first one, it would certainly be very important to ascertain whether the newly-formed bark has regained its power of storing starch or not.

It is evident that there are many important questions which arise in connection with my experiments, and all of them questions to which an answer can be found as rapidly and easily as possible by an investigation of the distribution of material (of starch especially), if only there are sufficient plants at one's disposal. That was not so in my case. But I should imagine that in a country, rich in rubber plantations, it ought not to be difficult to induce planters to devote some trees to experimental purposes of this kind. After all, it is in their own interest to find out which of the tapping systems are advantageous, and which are not. I feel convinced that more minute investigations in the directions given, if entrusted to the right people, will very shortly increase greatly our knowledge of the merits of the various tapping methods. These investigations possess one advantage over many others, in that they do not require new experiments, which might take up years, but that they can be made on any plantations, where tapping has been carried on for a longer or shorter period, so long as the planter is in a position to furnish exact particulars as to the dates of tapping, and the length and duration of the tapping periods.

## PART IV.

# COMPARISONS BETWEEN MY OBSERVATIONS & THE EXPERIENCES OF PRACTICAL PLANTERS.

All that now remains for me to do, is to investigate the question, whether the results of my experiments—by no means numerous and very incomplete as they are—cannot explain some of the experiences of planters, and whether they cannot throw light on points on which these experiences are at variance. It is certain that tapping methods are frequently adopted on estates, by which, by means of spiral or other incisions, the rectilinear connection of all fully developed channels in the cortex and in the bast are severed. In Ceylon particularly, the full spiral system was, at least some time ago, a very favourite one. (See my previous note on page 26. It is evident that Dr. Fitting obtained his Ceylon information just when the full-spiral system was being advocated by a local authority who shortly after abandoned it.—*Tr.*) It is a very remarkable fact, that more than once, complaints have been made in the market about the inferiority of the rubber, which had been collected during a second or later tapping period. It appears that these yields are richer in resin and poorer in caoutchouc than those of the first tapping. This deterioration of rubber, which naturally planters either do not like to admit, or refuse to admit at all, may arise from various causes. It may be that the extracted latex has been mixed with milk from trees that are too young; another cause may be, that the planter has allowed one tapping to follow too closely upon another. I am sure it would be worth one's while to watch more carefully, whether tappings on the above-named systems will not, *in course of time*, cause a deterioration of latex, even if as long a time has been allowed to elapse between each separate tapping period, as is deemed in theory sufficiently long. That this supposition is not without foundation, is pointed out by a statement made by Etherington,[8] according to which the

[8] I Etherington. Experimental rubber tapping in Singapore Botanic Gardens. Tropical Agriculturist. New ser. Vol. 28, 1907. Page 340. Vide also Ridley, Second Annual Report on the experimental tapping of Para rubber trees in the Botanic Gardens, Singapore, for the year 1905 (1907) Page 25.

yield of latex of trees tapped on the spiral system, in course of time, actually becomes poorer in caoutchouc. Likewise it has been noticed by many planters, who commenced tapping young trees which had attained the necessary maturity, that the full spiral system injures the trees in other ways. They have therefore, adopted other methods. From a conversation I had with a planter in the Southern Province of Ceylon, and in which we thoroughly entered into all details, I gained the impression, that the damage to the tree is chiefly noticeable in the growth of the crown and foliage. But I did not gain a clear impression as to whether a deterioration of latex had also been noticed.

In strange contrast to these observations, however, are the experiences of other planters. For instance, I inspected a plantation of old trees of large girth, the proprietor of which told me, that on a system corresponding with the full spiral one, he had for years gained abundant and excellent yields, without noticing any damage to the trees, or deterioration of latex. I was able to see for myself, that his biscuits were distinguished by great resiliency and fine colour. Possibly this contradiction may be explained by the fact, that in this case, the system was adopted on old and not on young trees. Or the reason may be, that on this estate, the intervals of rest between the tapping periods are unusually prolonged. I regret not to have been sufficiently informed on this point. As far as I could judge by the bark-scars, this method had only commenced a few years previously, when the trees were already well-established, while prior to that, the incisions had not embraced so large an area. It would therefore be important to ascertain, whether older trees of larger girth are not much less easily affected by tapping methods that interrupt the food channels on the whole circumference of the stem, because they possess more extensive starch reservoirs in the wood, and because their growth proceeds at a slower rate. Perhaps a fresh supply of substances can be more rapidly obtained from wide-spreading crowns. An investigation into this subject is all the more advisable, because in this way some indication may be gained, that a tapping method, which must in the case of young trees be rejected as injurious, may without disadvantage be adopted for older trees.

PART V.

## VALUE OF THE VARIOUS TAPPING METHODS IN VOGUE JUDGED FROM THE POINTS OF VIEW ATTAINED.

In a recent book on the cultivation of Hevea, the author advances the following maxim, by which to decide the value of the various tapping methods: "The best method of tapping is that which extracts the maximum amount of latex from the tree with the removal of the minimum quantity of cortical tissue and without damaging the thin layer of cambium cells."[9] But judging from my experimental results, I think the following addition, at least in the case of young trees, should decidedly have been made: And the best tapping method is, furthermore, one that checks the transport of organic material in the bark towards the base of the tree for the minimum length of time, with the minimum degree of intensity, which most confines this interruption to a local area, and which consequently does not in course of time damage the tree, nor injuriously affect the renewal of bark or latex.

From my observations, therefore, I consider it absolutely necessary to condemn quite a number of tapping systems as unsuitable for young plantations, where the trees have only just arrived at tapping maturity. With regard to the future of the plantation, it is necessary when tapping to remember as much as possible, that trees, which at the commencement of the tapping period were by no means large or thick, must become larger, in order that their latex systems may develop and yield continuously remunerative latex in large quantity. The advantages of such a lenient treatment of young trees for the yield of future years, certainly will outweigh greatly the advantages of a quick

[9] H. Wright. "Hevea Brasiliensis or Para Rubber." 3d. edition. London, 1908. Page 89.

yield, which after all, by reason of injury accruing to the tree, may only be of short duration.

Judging from the results of my experiments, I feel bound, in the case of young trees, to warn planters against the use of all those tapping cuts by which the rectilinear connection of the vertical channels for the circulation of organic substances in the cortex and bast suffer a complete, or almost complete, interruption at any spot between the crown and the base of the tree. I would also advise them to abstain from all these methods, at least while we are quite in the dark with regard to the length of time required after the conclusion of the tapping period for the refilling of the reservoirs in the stem below the tapping spot. But even after this point has been cleared up, all those tapping cuts will always be preferable which do not, even temporarily, subject the trees to any extensive injury.

Therefore, in the case of young plantations, the first system to be rejected is the spiral one.[10] Just as impracticable are all other methods which adopt the same principle as the spiral incision: V-cuts, which leave no rectilinear strips of bark of any great size on the tree, the double herring-bone incisions, that cover the whole of the tree's circumference, two half herring-bone incisions, each of which extends over half the tree's circumference. Furthermore, I consider *all* those tapping methods unsuitable, by means of which straight strips of bark are at first left between the incisions, which are, however, in the second tapping period, following on the first one, *completely* removed by a new system of incisions. It is on the contrary, absolutely necessary, by means of old, uninjured bark, or at least by bark that has not been tapped for a long time, to keep up a sufficiently broad rectilinear connection between the crown and the base of the tree, until the necessary number of new channels has been formed in all parts of the bark which is being renewed on the tapping spots, including therefore that beneath the very last tapping incision; until it can be *proved*, that the new bark has

[10] It is a matter of indifference, whether in adopting the spiral cut, the bark of the tree is removed rapidly or slowly. The spiral curve is not to be rejected, because by this method a great quantity of bark is in course of time removed from the tree, but because it completely destroys the food-channels. It seems to me necessary to lay stress on this fact, because several competent authorities still seem undecided on this point. Compare for instance, H. Wright, "Hevea Brasiliensis," London, ed. 3, 1908. Pages 94 and 132.

sufficiently "ripened" to carry on adequately the transport of organic material, and until the reservoirs in the wood beneath it have been refilled with starch. A long time, possibly one to two years, will certainly be required for all these operations. This can be ascertained easily by investigations.

As the flow of organic substances has been checked completely in all those parts of the tree's circumference, in which the vertical channels have been interrupted entirely by tapping cuts, it is furthermore necessary to reject all those tapping methods by which the rectilinear connecting channels between the crown and base of the tree are either *too few in number* or too narrow in width. For, on account of the extensive renewal of bark and latex, the amount of material required in the base of the tree has increased remarkably.

Lastly, it is advisable, judging from the results of my experiments, to avoid all tapping methods, by which, although stress is laid on the preservation of sufficiently large vertical strips of bark, yet the incisions are made of such length, that the organic nutrient and constructive substances within the tapping system must travel too great a distance in an oblique or even horizontal direction. For these substances, as I have previously explained, circulate very slowly in an oblique direction.[11] It might thus happen, that a certain want of food might make itself felt in the portions of bark below the tapping incisions, and that the renewal of latex might be impeded even during the tapping period.

It is most interesting to see how nearly the tapping methods of the natives in the jungles of America, come up to many of these requirements, if they are rationally employed. Tapping is there performed by means of small axes, the blades of which are only 1,5 to 3 cm broad. Oblique cuts are made with them right through the bark. Three or four of these incisions, 1,5 to 3 cm wide, are made simultaneously and at an equal height, at a horizontal distance of 10 to 20 cm, from each other. They begin as high up on the stem as they can reach, and day by day they make new cuts in a vertical line and at some distance below the old ones, down to the base of the tree. Then they begin again at the top, in the spaces that were left in between. It is obvious

[11] In an oblique upward direction the circulation will in all probability be specially slow.

that by these incisions, vertical strips of bark are preserved for quite a long period of time. I have not obtained information as to how long the tree is rested after each tapping period.

For practical reasons, I do not believe that estates will revert to a tapping system based on this procedure. It is not very easy to spare the cambium by a method of this description, neither is it easy to collect the latex, nor does one succeed in deriving the full benefit of the wound response, during the tapping operation, nor, finally, in milking the bark as completely, as in practice one would like to do. I am rather of opinion, that estates will have to keep to a system by which at short intervals narrow strips of bark are again and again removed from the spots of tapping. It will hardly be possible to raise any objections based on physiological facts against this universally adopted method.

If now, after all these considerations, we pass in review the various tapping systems, that in the course of years have been recommended, we come to the conclusion that only very few of them fulfil the requirements I have enumerated, and appear suitable for young plantations. Only those remain for our consideration, by which the last remaining straight strips of bark are not removed sooner than during the third tapping period. If in reviewing the value of the various tapping methods, we also consider the demands made in practice, namely, that the latex should run easily and be easy to collect, and the incisions easy to make, and that the flow of latex from the wound should have full play, we have no difficulty in giving preference to the *herring-bone incision*, as long as it embraces only a small part of the tree's circumference. If the incision be extended over *half* the tree's circumference, too long a time would have to elapse after the end of the first tapping period, before it would be possible to begin with the second. If it be extended over a third of the circumference, the series of incisions would, during the second tapping, hinder on one side the side-flow of organic food material towards the cortical tissues, which have been renewed beneath the incisions made in the first tapping period. Everything, therefore, points to the following: to extend the tapping system only over a quarter of the tree's circumference, to tap a second quarter in the second, and the remaining quarters in the third and fourth tapping periods.

We have still to consider whether preference should be given to the full or half herring-bone incisions, and whether too great an injury will not be caused to the tree, if as is the custom, all oblique cuts are connected by a vertical drainage canal. As regards the first question, the V-shaped, herring-bone incision has probably an advantage over the half herring-bone incision, because in the case of the V-shaped incision, it is possible for the organic food material to flow obliquely from both sides out of the old bark, down into the V-shaped bridges of bark between the incisions, which are disposed one above the other, and because in this case it is only a question of short channels. In the case of the half herring-bone incision, the downward flow can come only from one side and the distance is double. I do not share the doubts that have been expressed with regard to the vertical drainage canal. I do not think that a canal of that description can do much damage to the bark, provided it is not made either too deep or too wide.

And lastly, it will be necessary to discuss the important question, whether or not the pricker should be used. This instrument possesses undoubtedly certain advantages. For one thing, the cuts with the knife need not be made so deep into the inner cortex, and in consequence, a smaller amount of bark will be removed, and secondly, it is not necessary to cut away strips of bark so repeatedly, and the tapping period can therefore be prolonged. But it would be a mistake to imagine, that the pricker does not cut through all channels in the bark down to the cambium on the *entire* tapping surface, just as deeper cuts with the knife would, and that labourers, using this instrument, are not extremely liable to injure the cambium.

But the question, whether the pricker is suitable, must be decided by the way in which its use affects the renewal of bark. If there is no difference in the results as compared with those obtained by the deeper cuts with the knife, the pricker can be used without hesitation. As, strange to say, no investigations on this subject have so far been made, I ordered in the case of the tree tapped on the herring-bone system, the knife only, and the knife and the pricker combined, to be applied alternately to the tapping-spots situated one above the other. I made a minute anatomical examination of the bark, that had been renewed in the course of four to five months. Wherever the pricker had not been used, bark had been produced which did not differ from the normal secondary bark containing laticiferous vessels. But the sections made through the bark, on which the pricker had been used, showed a very different picture. Wherever the teeth of the pricker had penetrated to the neighbourhood of the cambium, the latter had formed a new bark with many stone-cells, but without, or almost without, laticiferous vessels. Where, however, the teeth of the pricker had not penetrated through the inner cortex, new bark had been formed containing laticiferous vessels, that were arranged irregularly, or (as in the case of normal secondary bark), arranged in rows. The entire surface of the bark was uneven; everywhere between the cuts of the pricker the cortical tissue had bulged outwards. From this it would appear that the bark on the tapping spots is renewed much more evenly if the knife is used exclusively, than if knife and pricker are used alternately. In the former case, therefore, the bark ought to be much sooner ready for re-tapping than in the latter. By making further observations and by comparing, under the microscope, sections of the renewed bark after a longer period of time than it was in my power to give, it will, I feel sure, not be difficult to ascertain how much longer the latex takes to ripen after the use of the pricker than after the use of the knife, and whether the greater quantity of latex obtainable by the use of the pricker, compensates for the longer resting-period required before the commencement of another tapping period. For this reason I feel justified in warning planters against the use of the pricker. And this the more, as I have often noticed on estates, that the teeth of the pricker had penetrated into the *wood*. The pricker is evidently an instrument that is out of place in rational estate cultivation. It would be better to make the tapping cuts somewhat deeper and to remove a little more cortex and bast.

PART VI.

# SUGGESTIONS FOR RATIONAL TAPPING METHODS.

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According to my observations and the conclusions to be deduced therefrom, and also according to other experiences made to date, I believe that in the case of young plantations and with regard to their future condition, it will be best to perform the tapping operations in the following manner:

Do not begin to tap the trees till they are six to eight years old, that is, till the circumference of the tree is about 50 cm at one metre above the ground. Adopt the half herring-bone incision as your tapping system, or better still, the full herring-bone, the V-shaped incision. The incisions must not be too little vertical, as otherwise the conveyance of sap from the sides is rendered too difficult. An angle of sixty degrees would probably prove the best. The tapping system must only cover a vertical strip of bark, the breadth of which does not exceed a quarter of the tree's circumference. Make the upper incisions at about the height of a man, by no means higher than where the tree attains a circumference of 45 cm.[12] Make the incisions one above the other in vertical distances of 30 to 35 cm. Tap daily, or every alternate day, with the knife only, and early in the morning.[13] Impress on the workmen that the strips of bark they

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[12] Compare J. C. Willis and M. K. Bamber. "Tropical Agriculturist," Vol. 29, 1907. Pages 244, ff.

[13] A circumstance which points to the morning as the best time, is, that the diurnal period of expansion in girth attains its maximum in the morning. The periodicity of expansion in girth in the case of trees belonging to our latitude and to the tropics, has been discovered by Gregor Kraus. (Ueber die tägliche Schwellungsperiode d. Pflanze. Abhandlungen Naturf. Gesellsch. Halle. Vol. 15 and Annales d. jard. bot., Buitenzorg, Vol. XII. 1895. Pages 210, ff.)

remove in tapping with the knife must be as narrow as possible, and that they must not injure the cambium. It is necessary to prolong the tapping period as much as possible, at least to five or six months. During this time the whole of the bark between the incisions may be removed. It is not possible to lay down a general rule as to which season is best for tapping. That will depend on the climate of each district. If the trees go through a wintering stage, that is, if they shed their leaves, do not tap during that particular season, which in the tropics is generally a dry one. The rainy season is the most suitable one, especially the beginning and the end of the rains. Nor is it possible to decide off-hand, whether it is advisable to milk, in each tapping period, all the bark on the strip which is being tapped, without an interval of rest. It will certainly be possible to continue tapping as long as the flow of latex does not appreciably diminish, and its quality does not deteriorate. In order to come to a definite decision on this point one should always only mix and further prepare latex that has been collected from incisions on trees at an equally advanced stage. I am of opinion that the mixing of latex of different quality, for instance, that from young and from old trees, or that from trees at different stages of tapping, should be avoided most carefully. I am sure that a single or repeated greater interval between the tappings of a tapping period, cannot be harmful, but on the contrary, will prove beneficial. Hence I would deem it advantageous to tap for two or three months, and during this time, to remove at most the half of the strips of bark between two incisions; after that to pause for one to two months, and then to finish tapping the remainder of the strips of bark in two to three months.

When the first tapping period is over, allow the tree a rest of several (five to six) months. Begin the second period a year later than the first. Tapping must now be performed on a strip of bark extending over a quarter of the tree's circumference, and situated on the opposite side of the stem and opposite the strip of the first period. The operation is the same as in the first period. In the third period, which commences in the third year, the strip of bark lying between I and II must be tapped, and the last one in the fourth year. Then start again with the first. As strip III immediately adjoins strip II, which has just been tapped, it might be advisable to leave a narrow vertical strip of bark, one to two cm wide intact, between II and III, so that a certain downward sap-transport is still possible from the leaves. If the half herring-bone system is adopted, it would be possible to use the canals of the first and second tapping periods as drainage canals for the latex when tapping the strips of bark III and IV. Therefore only two such canals are required on the stem. In that case it is, however, necessary to make the tapping cuts of periods III and IV in an oblique direction opposite to those of periods I and II. It is impossible to decide off-hand, whether, when tapping the previously tapped strips of bark for a second time, it might not be advisable to make the cuts of the tapping system in a contrary direction to those of the previous one. Whether or not it is feasible with regard to the future life of the tree, to commence the fifth tapping period a year after the initiation of the fourth, should in my opinion be made to depend on an investigation of the sap distribution in the stem. It would be necessary to sacrifice two or three trees for this purpose, and to get an expert botanist (probably at some experimental station) to make an examination for the distribution of starch in wood and bark on the tapping area. If the reservoirs in wood *and* bark have been refilled, there can be no objection to the continuation of tapping, provided that the latex exuding during the fresh tapping period satisfies in quality and quantity all fair demands. If, however, the quantity of reserve material in the reservoirs of the stem proves to be as yet too small, it will be for the expert to decide how long the tree must have complete rest after the fourth tapping period. These examinations ought to be repeated at least every four years, at the end of each fourth tapping period.

If there are any trees on an estate, which for some reason or other are to be removed, there is naturally nothing against milking them as completely as possible on the full spiral system.

After three or four cycles of four tapping periods each have gone by, without causing any deterioration in the latex, or injury to the trees, one might feel inclined to extend the tapping incisions from a strip of bark measuring a fourth of the tree's circumference, to be a broader one measuring a third of or half the tree's circumference. Personally, for scientific reasons, I would unquestionably consider it to be most advantageous, even in the case of mature trees, to keep to the original tapping system, and further for this reason, that every transition to a different tapping system is accompanied by technical difficulties. I would consider it a better idea to try the experiment of allowing the four tapping periods of one cycle to follow each other more closely, so that the whole cycle would not embrace as many as four, but possibly only three or even only two years. But experiments of this kind, or any other experiments with new and other tapping methods, should never be undertaken without having an examination made from time to time as to their effect on the circulation of sap in the stem and on the quantity of reserve material contained in its reservoirs. I look upon this as one of the most important means for arriving in course of time at rational tapping methods.

It is of course not excluded, on the contrary quite possible, that an investigation of all the questions I was able to raise in connection with my experiments, will further substantially increase our knowledge of this very difficult subject, and that we shall then succeed either in modifying my suggestions on this or that point, or in establishing them still more firmly. It is, therefore, a matter of urgency that these investigations should be undertaken without further delay. I have already pointed out, that it is merely a question of sufficient plant material to carry them out in the shortest possible time.

The tapping method (the herring-bone incision on a quarter of the tree's circumference), which I feel justified in recommending on the basis of my experiments, is also the same to which Ridley, in Singapore, recently tried to draw attention. It is a great pleasure to me, that my views coincide unreservedly with the opinions of one who is such an excellent authority in the province of rubber research. This concurrence of views, is all the more gratifying, as we seem to have arrived at our opinions by different ways. Another advantage of this method is, that it gives regular occupation to the labour force year after year, and day by day, without any very great interruptions. It may be possible, at least in many districts, to distribute the time of the tapping periods in such a manner over the different parts of the plantation, that there is no month in the year in which tapping is not carried on.

If anyone should consider it important that during each tapping period, latex should be extracted from *various* parts of the tree's circumference, and not from one continuous strip of bark, extending over a quarter of the circumference, the following method may without hesitation be substituted: Make oblique, or V-shaped incisions along two strips of bark, that are exactly opposite each other on the opposite sides of the stem, and the width of each of which is an eighth of the tree's circumference. Tapping has to be performed in exactly the same manner as in the other method. During the second tapping period, tap two strips of bark, each of which is an eighth of the tree's circumference wide, and which are situated opposite each other and exactly in the centre of the strips of bark that have so far remained intact. In the third tapping period, tap two more strips of bark situated opposite each other, that have before been left untapped; and in the fourth, the remaining two. (Compare diagram 4 for the transverse section of the tree.) In the fifth tapping period, start again with the two strips of bark of the first period. As regards the precautionary measures that must be taken in order to prevent an injury to the trees, especially with reference to the commencement of the fifth tapping period, compare what I have said about the other method. I consider this method a very good one. Probably there are several reasons, on account of which it is even better than that one, by which only one strip of bark, a quarter of the tree's circumference wide, is tapped.[14]

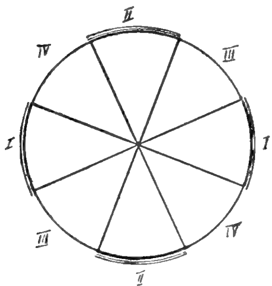

Diagram IV.

But we will have to consider whether this method can be recommended for trees six to eight years old. For in their case we have to reckon with a circumference of only 50 to 60 cm, and each of the two strips that are simultaneously tapped would be only 6 to 7,5 cm wide.

Perhaps some planters will wonder that I do not enter into some of those questions of detail, on the solution of which so much

[14] The yield of latex gained by this method will probably be greater than by the other one. According to Pit, the yield per unit of bark excised is all the greater, the smaller the wound-surface. (Compare Teysmannia, vol. 19, 1908. Pages 479, ff.) From this we would infer, that two small incisions, which are situated on the stem some distance apart, yield more latex, than a continuous one embracing the same area as the two small ones put together.

time and trouble are at present expended, for instance, whether it is of greater advantage to tap daily or only every other day; whether downward incisions made from right to left yield more latex than those from left to right; whether it is better to make the drainage canal in a straight line, or zigzag, etc. I must confess that I do not look on any of these questions as of special importance. It is impossible to decide them scientifically. And a decision based on experiments would only be possible if these experiments were not confined as heretofore to a few trees, but extended to hundreds. It seems to me, however, that the solution of these questions is more or less immaterial for the rational working of an estate. It is much more important to proceed rationally with regard to the larger issues. The small advantages, that might be gained temporarily by the consideration of such minor details, might be counter-balaced by small disadvantages in a lesser yield, which would show themselves later on.

Finally, I should like to mention a point which has been forced on me by the results of my experiments. It refers to the estimate of profits in opening up a new estate. My opinion is, that one should never reckon on average higher yields than can be expected by adopting the tapping methods I have recommended, or similar ones.

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