Canker of Cacao

BY

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With 3 Plates.

This disease had been observed in Suriname for years. In 1891 it was noticed at Dordrecht and since then on several other estates, but up to the present it has only been sporadic.

In the summer of 1907 however, the canker became epidemic on some estates in the Saramacca district. In consequence, an investigation into the disease was undertaken, the results of which are recorded here.

It appeared to be caused by a parasite, which may certainly attack *healthy* trees, but the serious character which the disease assumed here so suddenly, must be ascribed to the unfavourable state of the trees, and may be accounted for by the following observations of Mr. Drost, Agricultural Assistant at the Agricultural Experimental Station, during a visit to the Saramaccadistrict.

During the excessively heavy rainy season of 1907 the Saramacca river rose so high that in many places it overflowed its banks and flooded the cacaofields, so that the trees were standing in water. On the estate Johanna Catharina on the right bank of the river, the backdam broke, so that bushwater came in; at „De Morgenster" it oozed through the backdam. On both estates and on

Frederici's gift, a little higher up the river, part of the fields are on a very low level.

On these three estates thousands of trees were diseased and dying of canker, especially in the low fields, while in the higher parts the disease occurred only sporadically.

In other places where the trees did not appear to have suffered from the water, only rare cases of canker were to be met with.

One must conclude from these facts that the stagnant water rendered the trees susceptible so that they easily fell a victim to the cankerparasite.

Owing to the extent of the disease on these estates, and the absence of sufficient labour, there could be no question of fighting it energetically.

The only thing that could be done was, to remove the dead trees as far as possible. Nevertheless the disease came to a stand in the dry months (October, November) following the rainy season. Diseased trees recovered and no other trees became affected. No damage of any moment has been done since.

Symptoms of the Canker.

Cankered trees are first recognized by the occurrence of moist patches on the bark, caused by a liquid oozing out, sometimes in considerable quantities. Where it has dried on the bark, this assumes a rusty colour. These places are nearly always found on the trunk and thicker branches; sometimes the younger branches of a tree also show them. When the bark is cut off superficially, it appears to have assumed a claret colour (Fig. 1); this claret patch is surrounded by a narrow black border which marks it off sharply from the surrounding healthy tissue which is of a yellowish red colour. These patches occur in large numbers on the tree; they may extend over a large area or even encompass the

stem or branch. Often two patches unite into a single one, or one first appears under the surface and joins itself on to another, in the latter case the infection must have spread from within to the outside. Even in badly affected trees, spots which may penetrate to the wood, are not always a deep claret colour, but often light red. When these lightcoloured patches are exposed to the air after cutting, they become dark red. Where the wood is also affected, it sometimes assumes a red, but generally a blackish brown colour which may penetrate, into the wood for some centimetres; fig. 2 and 3 give an illustration of the more common case, in which only a small border of the wood is discoloured. In fig. 3 the progress of the discolouration in the bark is clearly visible. This dark discolouration of the wood is sometimes continued in narrow stripes far under the healthy bark.

In cutting out pieces where the wood also is diseased, one often finds bark and wood quite separated from each other, even where there is no question of insects having entered. Sometimes a gummy liquid has accumulated between the two.

How long the canker takes to kill a tree I cannot say with certainty. It is probable that no more than a few months is required, for in July many trees were found dead, which partly at least had most likely only been affected in the rainy season, but further observation on this point is necessary. Sometimes a cankerspot can be traced to have spread from a wound, but the roughness of the bark often makes it impossible to ascertain this. In rare cases there is a cankerspot at the foot of dead „krulloten". [1])

1) Krulloten are hypertrophied twigs, due to *Colletotrichum luxificum*. C. J. J. van Hall et A. W. Drost. Les balais de sorcière du cacaoyer provoqués par *Colletotrichum luxificum* n. sp. Recueil des Travaux Botaniques Néerlandais. Vol. IV. 1908. p. 243.

This way of infection is by no means rare as appears from the fact, that canker, which was not uncommon on the estate Suzannasdaal, has not been met with since, two years ago, all the trees on that estate were pruned in order to get rid of the witchbroom disease. By this treatment all infected parts are removed and only the stem and the stumps of the main branches are left. The number of witchbrooms which reappear is very small. [1]

Diseased trees may also be recognized by their foliage becoming thinner, probably when they have been diseased for a long time and are slowly decaying, while dead trees which still bear their leaves, probably suffered a severe attack at once and were soon killed.

All these symptoms quite correspond with those of the disease known in Ceylon and elsewhere as „canker", so that it is doubtless the same disease we have to deal with here.

It was generally called „canker" here in Suriname, until lately the name „red rot" has come into use. The name „canker" is however preferable, because in other countries the disease has for years been known as such.

It may be observed that another disease in Suriname is sometimes called canker. It is characterized by the accumulation of an evil smelling fluid in the wood, through which the stem is sometimes deeply split. When, by making an incision, one causes this liquid to flow out, the tree recovers. To prevent confusion it is better to call this latter disease by the alternative name of *„hartwater"* (literally: „water of the heart").

1) See Van Hall et Drost. Les balais de sorcière etc. Recueil des Travaux botaniques Néerlandais. Vol. IV, 1908, p. 300.

Bibliography.

In Ceylon the canker became wide-spread in 1896, but had been occurring there for some years before. Not until 1898 was it more carefully studied by Carruthers, who in some reports [1]) recorded the results of his investigations; these were written during his investigations and so bear a preliminary character; a more detailed account has however never appeared, so that several points, especially in respect to the cause of the disease, have not been fully elucidated. I shall revert to this after the discussion of my own investigations.

According to Carruthers it is not only the stem and branches of the cacaotrees which are attacked but the fruits as well. In the diseased tissues he found the mycelium of a fungus and on the bark the perithecia of a *Nectria*, which he regarded as the cause of the disease.

He does not believe that some trees more than others are specially predisposed to the attacks of the canker; an immune variety has not yet been found; vigorous trees as well as unhealthy ones are attacked, when the conditions, necessary for the infection, are present. In the dampness of the air he sees the principal factor for spread of the disease as it facilitates the germinating of the fungus spores. A considerable part of Carruthers' work has been devoted to the combating of the canker. The remedial and preventive measures practised by him will

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1) J. B. Carruthers. The Tropical Agriculturist. Vol. XVII, 1898, p. 851, Vol. XVIII, 1899, p. 359 and p. 505.

J. B. Carruthers. Proceedings of the Linnean Society. Oct 1900, p. 7.

J. B. Carruthers. The Tropical Agriculturist. Vol. XXI 1902, p. 441 and 517.

be mentioned later. His investigations have been carried on by Wright [1]) and Petch. [2])

In the West Indies the canker was first noticed by Hart in Trinidad. Some material of diseased trees was forwarded to Massee [3]), who detected a *Nectria* on it. In 1901 Howard [4]) found the disease to be rather common in Grenada and Dominica. A *Nectria* and a *Calonectria* were recorded from the affected trees. According to Stockdale [5]) the canker in the West Indies is now met with in Trinidad, Grenada, Dominica, St. Lucia and St. Vincent.

In Java it is also known. Zehntner's [6]) observations about its mode of occurrence, so much resemble what we saw in the Saramacca district, that I quote part of it here.

In visiting some estates in 1904 „I found that on one of them the canker had assumed a malignant form. Whereas in 1902 I had not been able to find more than a few cankered spots, so many trees had meanwhile died of the disease, that in some fields large gaps had appeared, although cankerspots had been carefully excised and all measures had been taken to prevent the spread of the disease. The manager had even disinfected the instruments every time a tree had been treated."

„I have not discovered a wholly satisfactory explanation

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1) H. Wright. Circulars of the Royal Botanic Garden, Ceylon. Vol. II, N°. 18. 1904, p. 279. Vol. II, No. 21. 1904. p. 339. Vol. III, N°. 10, 1905. p. 116.

2) T. Petch. The Tropical Agriculturist. Vol. XXIX, 1907, No. 2. Supplement p. 5.

3) G. Massee. The Tropical Agricult. Vol. XIX, 1900, p. 478.

4) A. Howard. West Indian Bulletin. Vol. II, 1901, p. 200.

5) F. A. Stockdale. West Indian Bulletin. Vol. IX, 1908, p. 171.

6) L. Zehntner. Korte Mededeelingen van het Proefstation voor Cacao, No. 11, 1904, p. 4.

of this case." „It seems to me, we have to do with one of those cases, where a disease, when first appearing, takes a very serious aspect and then gradually looses ground, or in other words, where the infection at first is very virulent and so spreads easily, while the virus by and by looses much of its power."

„That the canker is very virulent in the beginning of its appearance, is in my opinion proved by a case, which I noticed this year for the first time and that in a single spot of the plantation. But in this spot every tree was found to be affected, a thing which does not occur on estates where the canker has been present for years." On one estate Zehntner found the fructification of the cankerfungus (probably *Nectria*).

Finally in 1907 von Faber[1]) noticed the disease in the Cameroons, where up till now, it has not caused much damage. There also a *Nectria* has been found on the diseased bark.

Anatomical Investigation.

On microscopical examination every red spot of the diseased bark appears to be surrounded by a corkcambium, several rows of cells thick (Fig. 4). The colour is the result of a red coloured mass in the cells. This is often transparent and fills up the cells completely, but it may be granular or form smaller or larger drops, which sometimes flow together along the cellwalls, forming irregular masses. The cellwalls too are often coloured, and the intercellular spaces filled up with it. In the first celllayers within the corkcambium the colour is not red but brown;

1) F. C. von Faber. Untersuchungen über Krankheiten des Kakaos. Arbeiten aus der Kaiserl. Biolog. Anstalt für Land- und Forstwirtschaft. Band VI. 1908. p. 395.

these cells form the small black border, by which the red spots are surrounded. Where the wood shows the black or brown colour, these same masses occur within the cells, here also coloured from light to dark brown, in the medullary rays and the woodparenchyma as well as in the fibres and the ducts. This mass quite corresponds to that found by Went in petrified fruits [1]), not only in shape but also in its behaviour towards chemical reagents, so that with the same reservation it may be considered as woundgum. Von Faber also mentions it, in his description of the cacaocanker [2]) as well as in that of the witchbrooms [3]) in the Cameroons.

Therefore the secretion of this woundgum is probably not characteristic of a definite disease, but produced in response to the stimulus resulting from a variety of diseases.

The discolouration does not always spread. Often a new healthy tissue forms under the diseased area, in which case the red bark is loosened from its surroundings, dries up, becomes dull brown and may easily be removed. Howard noticed this in Grenada [4]), but only in rare cases and when the wood had not yet been affected. Carruthers [5]) often saw the moist claretcoloured tissue dry up, after which it had quite the appearance of dead wood. In his second report [6]) he says that after having been superficially shaved and exposed to the air, the diseased tissue dries up and „in some cases scales out and drops

1) F. A. F. C. Went. Krulloten en Versteende Vruchten van de Cacao in Suriname. Verhandelingen der Koninkl. Akademie van Wetenschappen te Amsterdam. Tweede Sectie. Deel X. No. 3. 1904, p. 31.

2) See v. Faber. p. 398.

3) See v. Faber. p. 393.

4) See Howard. p. 200.

5) See Carruthers 1898.

6) See Carruthers 1899, p. 359.

away, while the remainder of the bark being relieved from its enemy, forms a healthy callus round the injury, and in course of time completely covers over the shaved part". Though the facts mentioned are the same as those observed here in Suriname, this description of Carruthers is not quite correct, for the callus is formed first and by its agency the diseased patch is loosened.

In this way a tree may recover without excision of the diseased tissue, as it was observed in the dry season of 1907 in the Saramacca district. The diseased patch was often still present as a dry piece of bark, lying loosely on the callus which had formed underneath. I have not yet had an opportunity of examining trees in which the disease had penetrated into the wood and which had nevertheless recovered; therefore I am at present unable to judge as to the way in which this took place.

Mycological Investigation.

In the discoloured parts of bark and wood I found the mycelium of a fungus. It sometimes is very scarce, at other times it is found without the least difficulty. It may be especially abundant in the youngest part of the wood. Most investigators have also found the mycelium outside of the discoloured patches, I have not been able to find it there myself. The mycelium is intracellular and traverses the ducts, the fibres and the woodparenchyma in a longitudinal direction; it sends out many short sidebranches and is often somewhat sinuous; the sinuosity in the medullary rays becomes so marked, that it is mostly impossible to trace a definite direction (fig. 5 *a* and *b*). By preference it seems to pass from one cell into another through the pits as has already been obser-

ved by v. Faber.[1]) When present in any quantity Carruthers saw the mycelium running in the wood as thin black strands.[2]) Like v. Faber, I am unable to confirm this statement.

In order to make a closer study of the fungus it had to be grown artificially. With a sterile knife small pieces were cut from the wood at the borders of the diseased and the healthy tissues. These were transferred to a culturemedium in a sterilized dish. In a few days the mycelium came forth from these pieces as a pure culture. In this way the parasite could always be easily obtained. Soon a conidial fructification developed; on a septate mycelium appear branched conidiophores, from which oval unicellular conidia are cut off (Fig. 6). I consider the fungus as belonging to the genus *Spicaria*.

The branching of the conidiophores is indeed not purely verticillate; sometimes it is even very irregular (Fig. 7), yet it often is repeatedly trilateral (Fig. 8 at ×) and the conidia form chains.

Fusion of the hyphae is very common; in old cultures the mycelial cells are so rounded off against each other, that the fungus assumes a *Monilia*-like appearance. The breadth of the hyphae depends on the culture-medium on which they develop. The size of the conidia may differ considerably, als old and young conidia are found in the same preparations. They measure from 7,5—10,5 μ by 4 μ. In germinating they put out one or two germ-tubes.

The conidia are developed in the air; in hanging drops none or only a few are produced in the drop, but no sooner has the mycelium grown out of it than they appear in large numbers.

1) See v. Faber, p. 399.
2) See Carruthers, 1902, p. 442.

Very characteristic of this *Spicaria* is its property of imparting a red colour to some culture-media.

I have not studied this property in detail, although I am able to state, that a weakly alkaline medium is coloured violet-red, a weakly acidic medium yellow-red. The mycelium itself may also acquire the red colour. On sterilized cacaowood and bark the mycelium yields an abundant growth, but it also develops luxuriantly on all kinds of artificial media.

In the course of my investigations I found another fructification in a two-months old culture on cacao-bark, namely pustules of Fusarium conidia.

Hanging drop-cultures of these Fusarium-conidia were started, so that the development could be watched under the microscope. This appeared to be only possible in very dilute solutions as otherwise the luxuriant growth of the mycelium interfered with the observation. In water no conidia were produced, but a saccharose-solution of ½ % appeared to be suitable. In it the Fusarium conidia always gave rise to a mycelium which produced conidiophores of *Spicaria*. In Fig. 8 the sown Fusarium conidium is lying at *a*; the *Spicaria* which has developed from it at ×. In the numerous cultures I watched, I always found this same course of development.

The converse question now arose, namely, whether *Spicaria* could produce Fusarium. To study this, I made hanging drop-cultures of *Spicaria*-conidia. These nearly always developed a mycelium which produred the *Spicaria*-fructification, but in rare cases the mycelium formed a conidiophore with Fusarium conidia. (Fig. 9).

Of the external conditions which influence the production of the various fructifications, light seems to be the most important. In dishes with sterilized bark and wood which had been inoculated with *Spicaria*, I nearly always found

the Fusarium pustules after a few days, only however in the light. If of two cultures which had been started at the same time, one was put into the light, and the other wrapped up in black paper, no Fusarium but only *Spicaria* was formed in the latter. When the black-paper was removed, Fusarium developed in a few days in the culture which had previously been darkened.

In several ways I tried to obtain a higher fructification; I made cultures in large flasks and dishes on sterilized bark, wood, bread or liquids; I let some grow very old, put others into the light or kept them in the dark but without any success. In old cultures on cacao-bark I sometimes did find small hollow bodies, from which, when pressed, numerous oildrops escaped. As several species of *Nectria* possess two kinds of conidia: microconidia and a Fusarium, I do not think it unlikely, that in this case too, the higher fructification will prove to be a *Nectria*, of which the little globules perhaps form the first development.

I have named the species *Spicaria colorans*, the diagnosis follows here:

Spicaria colorans, n. sp.

Mycelium hyaline, septate, anastomosing; conidiophores hyaline, septate, tapering towards the ends, where the conidia are produced, branched. The branching is irregular, or dichotomous or repeatedly trichotomous. Conidia hyaline, smooth, oval 6—10,5 × 4—5 μ, formed in long chains at the ends of the conidiophores. The fungus imparts a violet-red colour to an alkaline medium and partly takes up the colour itself. It often produces a Fusarium. In living cacaobark and wood.

Inoculation Experiments.

I have not succeeded in producing canker in cacaotrees by inoculating them with *Spicaria*. I introduced small pieces of sterilized bark or wood, which had been permeated by the fungus, into small wounds, which had been cut in the bark of the trees, or between bark and wood, and kept these places moist; I experimented in the same way with conidia of *Spicaria* or of Fusarium. Nor was infection induced by bringing conidia of *Spicaria* or Fusarium on uninjured bark. Experiments in which pieces of diseased bark were introduced into wounds of healthy trees likewise failed. This failure accordingly does not prove anything against *Spicaria* being the cankerparasite, but leads to the conclusion, that the conditions which rendered the trees susceptible to the disease or which are necessary for securing the infection, were not present.

Attempts to infect fruits likewise failed.

Saprophytes.

After this discussion upon the cankerparasite I think it advisable to deal with some saprophytes, one of which at least very often occurs on cankertrees. It is a *Nectria* which I at first supposed to be the cause of the disease, the more so as in Ceylon and elsewhere a *Nectria* is regarded as such. Moreover nearly always the same form occurred. It was therefore grown in pure cultures. The bicellular spores were sown in hanging drops; they germinated readily and produced a mycelium with Fusarium-conidia. A comparison of this Fusarium with the one produced by *Spicaria* makes it clear at once, that it is a form differing from the above described parasite.

1. The shape is different in several respects:
   a) The Fusarium from *Spicaria* is more curved than the one from *Nectria*;

b) the ends of the former are rather sharply pointed, those of the latter always very obtuse;

c) the former alone often bears a small stalk which is sometimes bent at the place where it was formerly joined;

d) the contents of the former are much more coarsely granulated, than those of the latter.

e) moreover the dimensions of the former are smaller; the Fusarium from *Spicaria* measures 56—90 μ by 6—9 μ (Fig. 11, of which the conidium marked with $\times$ shows the most common size), the Fusarium from *Nectria* is 76—100 μ long by 8—12 μ wide. (Fig. 12).

Both forms are generally 7 septate, but 5—9 septate specimens often occur and germinate as readily.

2. There are other differences besides those of shape. As has already been pointed out, Fusarium-conidia which originate from *Spicaria*, always produce *Spicaria*; Fusariumconidia from *Nectria* on the other hand never yield anything else than Fusarium. (Fig. 13).
3. Their different character is also shown by their mode of growth on nutrient media. On a slightly alkaline medium, colonies developed from *Spicaria*-Fusarium assume a red colour, those from *Nectria*-Fusarium do not. It is evident from the differences enumerated that this *Nectria* is not a fructification of *Spicaria*, the cankerparasite.

Probably we have to do with *Nectria striatospora* Zimmermann [1]) which was found by Zimmermann on cacaotrees at Buitenzorg and which he also considered as probably harmless.

1) A. Zimmermann. Centralblatt für Bakteriologie, etc. Bd. VII. Abt. 2, 1901, p. 105.

The perithecia (Fig. 14) are red, constricted above the middle. Sometimes the constriction is so strong, that the upper part hangs like a cap over the under part; the ostiole is clearly visible, often a little protruding; when ripe the perithecium around it turns black. Paraphyses are present. The ascuswall is very thin; when the spores are nearly ripe, it is often much strained and in consequence but partly visible (Fig. 15) and frequently torn. The ascus contains eight spores; these are bicellular, often slightly constricted at the septum; the wall is striate lengthwise (Fig. 16).

The perithecium is 300—400 μ long; under the constriction it is 210—260 μ wide, over it 160—220 μ. The asci measure 100—120 $\mu \times 12$ μ, the spores 28—32 $\mu \times$ 8—10 μ. The spores are somewhat larger than those of *Nectria striatospora* Zimm.

The perithecia develop from a yellowish white stroma (Fig. 17). It seems probable that this stroma is the continuation of light brown much branched strands of mycelium which are frequently met with on dead trees between the bark and the wood and penetrate into the bark (Fig. 18). As I never found them except in pieces of bark which was already dead and inhabited by different saprophytes, I could not with certainty make out wether *Nectria* and the myceliumstrands belong together. This will perhaps be possible by cultural study of material in an earlier stage.

Another fungus which was isolated from advanced canker-spots and grown in pure culture, produced yellow-brown perithecia, probably identical with *Nectria coffeicola* Zimmermann; both the perithecia and the two kinds of conidia agree with those described by Zimmermann [1]). This form has been rarely found on the bark of dead

1) See Zimmermann, p. 104.

trees and is probably also a saprophyte. Zimmermann found it on old pieces of coffeewood, on dead cacaopods and some other trees and also considers it to be saprophytic. Cultures of *Spicaria* and of Fusarium of *Nectria* have been given to the „Centralstelle für Pilzkulturen" at Amsterdam.

Fungi on cankered trees in Ceylon and elsewhere.

As has alrendy been said, *Nectria* is considered to be the cause of Canker in all countries, where the disease has been observed.

On a number of diseased patches Carruthers found pustules of small, oval, unicellular conidia; after some time larger, multiseptate, crescentshaped conidia appeared, and at last perithecia of *Nectria*. From this he concludes, that *Nectria* is the cankerparasite and that both forms of conidia are stages in its lifehistory.

This conclusion, however would only be warranted if he had grown the fungus in pure cultures, and there seen one form develop from another. As far as can be determined from his publications, he has not done so.

It is true, that Carruthers records a series of infection experiments, where in many cases he produced the disease in stems as well as in pods by inoculating them with one of the three kinds of reproductive organs. But since these inoculations were not made with pure cultures, and since the experiments were conducted on estates on which the disease was prevalent, while no control plants were kept (trees treated in exactly the same way as the inoculated ones, except that no fungus was introduced), these results are not so convincing as to remove the doubt which yet remains on many questions. We may consider some of these questionable points. It is possible

that Carruthers introduced into the wounds other conidia besides those he meant to use, as he himself refers to the difficulty of growing the fungus in pure cultures on account of bacteria and fungi.

Of the *Nectria* perithecia he says: „They are to be found only on dead wood or dead patches of dying branches and stems." [1])

Moreover Petch, who as Carruthers' successor must have known the *Nectria* with which the latter experimented, says: „The *Nectria* on the stem agrees with *Nectria striatospora* Zimm. It is perhaps the commonest Ceylon *Nectria* and has been found on tea, killed by *Massaria theicola*, tea with branchcanker, felled *Albizzia*, etc." [2])

Both these statements make it very likely, that this *Nectria* was not a parasite, but a saprophyte.

Whereas Carruthers [3]) believed the form found by him to be *Nectria ditissima* Tul., according to Petch the perithecia on the bark bear a close resemblance to *Nectria striatospora* Zimm; numerous examples, collected by Thwaites in the Herbarium, have been named by Berkeley either *N. cinnabarina* or *N. sanguinea*.

The two forms, observed by Howard, were named by Massee *Nectria Theobromae* and *Calonectria flavida*. The description of *Nectria Theobromae* has just been publisted [4]). Howard could infect trees by introducing ascospores of both forms into wounds. In the earlier stages of the disease he observed white pustules in the cracks of the diseased bark, consisting of conidiophores bearing unicellular conidia and Fusariumlike, multicellular conidia. Although he

1) See Carruthers, 1902, p. 443.
2) See Petch, p. 6.
3) Carruthers, 1900, p. 7.
4) Massee. Kew Bulletin. 1908. No. 5. West-Indian Bulletin. Vol. IX 1908 p. 187.

thought it highly probable, that both conidial forms and the ascus form belonged together, he regarded it as uncertain, until he should have proved it by further investigations, which were in progress, when his article was published. Apparently he has not completed his research as Stockdale [1]) observed recently, that an exact knowledge of the lifehistory of *N. Theobromae* and *Cal flavida* was not yet complete and investigations would be continued.

The *Nectria* noted by Hart on cankerspots of cacao trees appeared also to be *Nectria Theobromae* [2]). Von Faber also found a *Nectria* on bark from cankertrees in the Cameroons. To judge from his figures and description [3]) this form is different from *N. Theobromae* and certainly distinct from the one observed as a saprophyte in Suriname. v. Faber had no opportunity of making infectionexperiments and could only study fixed material, so that he could not cultivate the fungus. Therefore it is a mere supposition, that this *Nectria* is parasitic on cacao.

From the foregoing it is evident, that although several forms of *Nectria* have been considered to be the higher fructification of the cankerfungus, none has been definitely proved to be so by experiments to which no objection can be taken. The confusion on this point is the greater for want of accurate descriptions of these different forms. They have only been given for *Nectria Theobromae* and the *Nectria* found by von Faber in the Cameroons.

We must put another important question which has not yet been solved: What is the cause of the pod-disease?

With conidia, ascospores or pieces of cankered bark, Carruthers could produce the disease in pods. It also spread to the pod from a diseased spot in the bark, and

1) Stockdale. West-Indian Bulletin. Vol. IX, 1908, p. 172.
2) Stockdale. West-Indian Bulletin. Vol. IX, 1908, p. 170.
3) See v. Faber. p. 400.

reverted from a pod to the stem. By placing pieces of diseased pods in the bark, canker could be produced in it. [1])

Now in his two first reports [2]) [3]) Carruthers discusses his observations on diseased pods. The mycelium he found in them, was different from that in the stem; in cultures made of them a *Peronospora* developed (in a later report he calls it *Phytophtora* [4]), which also was observed on pods in the field. He therefore made this fungus responsible for the disease. In his third report [5]) however, he came to quite a different conclusion. On further examination he had found the small cankerconidia between the large masses of *Peronospora*-(*Phytophtora*-) sporangia; the first were sometimes found alone, but yet nearly always speedily associated with *Peronospora*; hence he supposed, that *Peronospora* lived as a saprophyte on the tissues killed by the canker.

In my opinion he is not entitled to this conclusion, for the following reasons: The symptons of the disease in pods, as was also noted by v. Faber, correspond closely to those, caused by *Phytophtora*; Carruthers' own observations regarding the occurrence of the fungus in the pods, makes it highly probable, that the disease is due to *Phytophtora*; besides, according to Petch [6]) the *Nectria* on cacaopods in Ceylon is not the same as that on the stem. He says: „If the stem- and pod-diseases are the same they cannot be due to *Nectria*."

Nor is it proved by the observations made in other countries. Howard [7]) does not mention a *Nectria* on pods,

1) See Carruthers, 1902, p. 444.
2) and 3) See Carruthers, 1898 and 1899.
4) See Carruthers, 1902, p. 444.
5) See Carruthers, 1899, p. 505.
6) Petch, p. 7.
7) Howard, p. 196 and p. 198.

except the one found by Hart [1]) on Trinidad and described by Massee as *Nectria Bainii* and the pod-disease on Ceylon which after Carruthers reports may be caused by *Nectria* or one of the Peronosporeae or by both. Nearly all pods, forwarded to Kew on that occasion, appeared to be attacked by *Phytophtora.*

Zehntner [2]) speaks of „the rare cases where a canker-patch appears at the junction of a pod with the stem and the cankerfungus spreads along the stalk to the pod itself".

In the Cameroons v. Faber [3]) never observed an infection of pods by *Nectria.*

Here in Suriname I have never found a *Nectria* as a cause of disease in pods, neither have I seen the canker-fungus (*Spicaria, Fusarium*) as a parasite on pods.

From this survey it is evident, that Carruthers' infection-experiments and the few observations of Zehntner are the only foundations for the belief, that canker is a pod-disease; on the contrary, everything seems to show that Carruthers was concerned with the „black rot" (blackening of pods), due to *Phytophtora,* which is known to attack pods in Ceylon, Java, the West Indies, the Cameroons and Suriname and to cause a great deal of damage in all these countries, except in Java. [4]) Petch asserts that in cases where the disease had spread from pod to stem, in sterile chambers *Phytophtora* developed from pieces of bark, peduncle and pod; if this statement should prove to be correct, it would show, that *Phytophtora* can attack the stem as well as the pods.

1) J. H. Hart. West Indian Bulletin. Vol. I 1900, p. 423.
2) Zehntner, p. 1.
3) V. Faber, p. 403.
4) Zehntner, p. 4.

Barrett [1]) attributes to one and the same fungus (*Lasiodiplodia*) the „brown rot" of the pods and the canker (red rot) of the stem (as appears from his description of the symptoms.) This statement can hardly be correct; it is true, that *Lasiodiplodia* (most probably identical with Howard's *Diplodia* and perhaps with v. Hall's *Chaetodiplodia*) does cause the „brown rot" of the pods and also a stem-disease; but this stem-disease is the so-called „die-back", which is quite different from the Ceylon canker, induced by *Spicaria*-Fusarium. I mention this because this mistake may give rise to confusion. For the same reason Barrett's use of the term „canker in its broad sense to include the destruction of woody tissues by any parasitic fungus", is not to be recommended, now, that the name canker has already been given to a definite disease.

Treatment of the Disease.

Carruthers not only tried to combat the disease by treatment of affected trees, but also by removing the conditions which assist in spreading it. As he regarded dampness of the atmosphere as the most dangerous factor on account of the favourable conditions it offers to the fungus, he urged before all things the necessity of removing superfluous shade and of draining the soil, especially in low hollows. Besides this he advised the planters to burn the dead trees and to bury or burn all discoloured pods in order to destroy the infection-material. As suckers were scarcely ever affected, he recommended not to cut them all in the usual way.

The direct treatment of the trees was to consist in the

1) O. W. Barrett. Agricultural Society of Trinidad and Tobago. Society Paper. No. 280, p. 4 and 5.

excising of the discoloured patches with a large margin of the surrounding tissues as the fungus mycelium had been found outside the discolouration, or, if the spots were too large, in superficially shaving them and exposing the parts so treated to the drying effect of the sun. All excised parts were to be burnt.

The fact that after several years of canker-treatment the disease had not diminished as much as he had expected, Carruthers believed to be due to the carelessness of many planters in carrying out the recommendations. On fields of the Experimentalstation of Peradeniya, where the treatment was carried out strenuously, a fall in the percentage of diseased trees was attained from 96 % in May 1902 to 1.9 % at the end of 1903. [1] [2]

Meanwhile Wright had made the experiment of spraying the pods with a mixture of sulphates of copper and lime. [3] As it is however highly probable (as has already been pointed out), that the disease of the pods is not canker, but caused by *Phytophtora*, his favourable results do not teach us anything about the treatment of canker, however important they may be in other directions.

In Java and the West Indies Carruthers' advice is also followed. In the West Indies the wounds are, in addition,

1) H. Wright. Circulars of the Royal Botanic Gardens, Ceylon. Vol. II. No. 18, 1904, p. 280.

2) From Zehntners observations in Java and ours in the Saramacca district it does not seem certain that this fall in the percentage is only due to the treatment. In Java Zehntner saw the disease suddenly assume a violent character notwithstanding that the most careful treatment of diseased trees had been applied for two years. Here where nothing at all was done, the disease disappeared almost completely.

3) Circulars of the Royal Botan. Gardens, Ceylon. Vol. II, No. 21, 1904.

treated with tar, as *Nectria* is a woundparasite and the spores should not be given an opportunity of penetrating into the tissues. Carruthers disagreed with the application of tar, as it might prevent the control of the excised spots.

In the West Indies the number of cankercases has also diminished, although the disease has not been eradicated.

In Suriname cankerpatches are generally excised; after this the wound is left uncovered for some days to let it dry, and then tarred. A tree often recovers after this, sometimes it does not. As has already been remarked, trees also recovered in many instances without any treatment at all.

As it is probable that the serious character which the disease assumed in Suriname in 1907, was due to the trees having stood for a long time in stagnant water, the treatment here should in the first place be directed towards the prevention of such conditions, or in other words, the cacaofields must be well drained and the dams so well attended to, that there can be no danger of rupture in case the water should again rise abnormally.

Although it is certain that trees can recover without excision of the diseased tissues, we know as yet too little about this to dare trust to it alone. Therefore the old treatment of carefully looking for diseased spots and excising them and removing trees killed by the disease, must for the present be recommended as being the safest method.

EXPLANATION OF PLATES.

PLATE I.

Fig. 1. Cacaobranch from which the bark has been cut superficially so that the cankerspot is visible.

„ 2. Branch with cankerspot cut across, to show the discolouration penetrating into the wood.

Fig. 1 and 2 have been kindly prepared for this article by Mrs. Sack-Weerman.

PLATE II.

Fig. 3. Transverse section of a branch with a cankerspot; the black parts indicate the extent of the discolouration in bark and wood.

„ 4. Longitudinal section from the barkparenchyma; × corkcambium separating the diseased from the healthy tissue. × 225.

„ 5. Tangential section through the wood, showing the passage of the mycelium in the tracheids and medullary rays, *a* and *b* sinuous mycelium in the medullary rays. × 375.

„ 6. Conidiophore of *Spicaria*. × 560.

„ 7. Irregular branched conidiophore of *Spicaria* × 375.

„ 8. *Spicaria* at ×, formed on the mycelium developed from the Fusarium conidium *a*. × 375.

„ 9. Conidiophore with Fusarium conidia, developed from the *Spicaria* conidium *a*. × 375.

PLATE III.

Fig. 10. Germinated *Nectria* spore forming Fusarium conidia. × 375.

„ 11. Fusarium conidia produced by *Spicaria*. Average size. × 560.

„ 12. Fusarium conidia produced by *Nectria*. × 560.

„ 13. Fusarium conidium produced by *Nectria*; sown in a hanging drop it only forms Fusarium conidia. × 375.

„ 14. *Nectria* perithecia. × 80.

„ 15. Asci with ascospores of *Nectria*. × 375.

„ 16. Striped ascospores of *Nectria*. × 560.

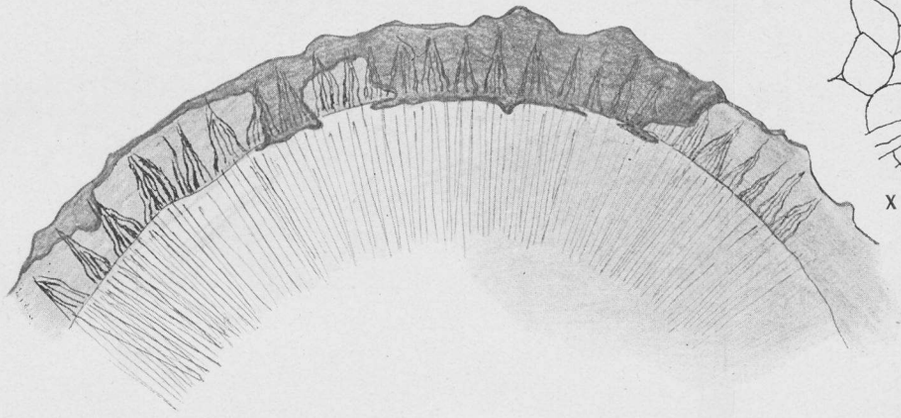
„ 17. Longitudinal section through *Nectria* perithecium on stroma, bursting through the bark of cacao-branch, *a* indicates the perithecium, × the stroma, *b* the cork, *c* the bark. × 80.

Fig. 1.

Fig. 2.

Driekleurendruk van F. E. Macdonald, Nijmegen.

Fig. 3.



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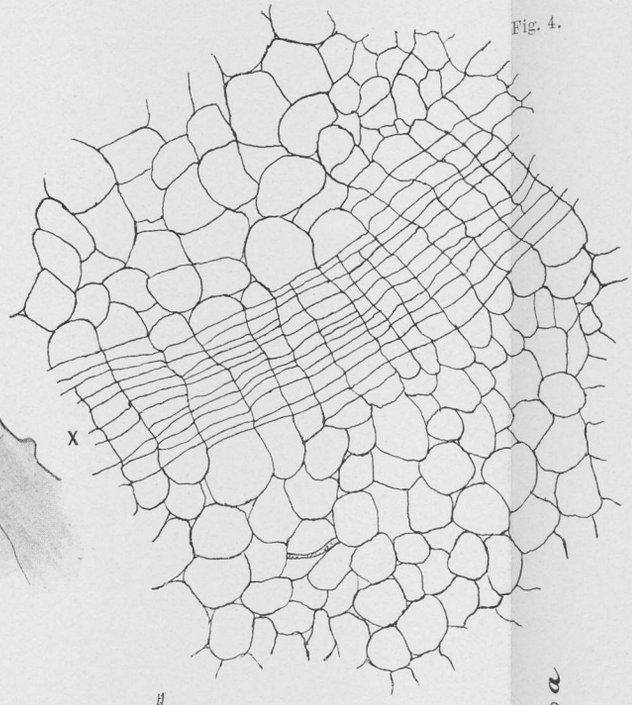

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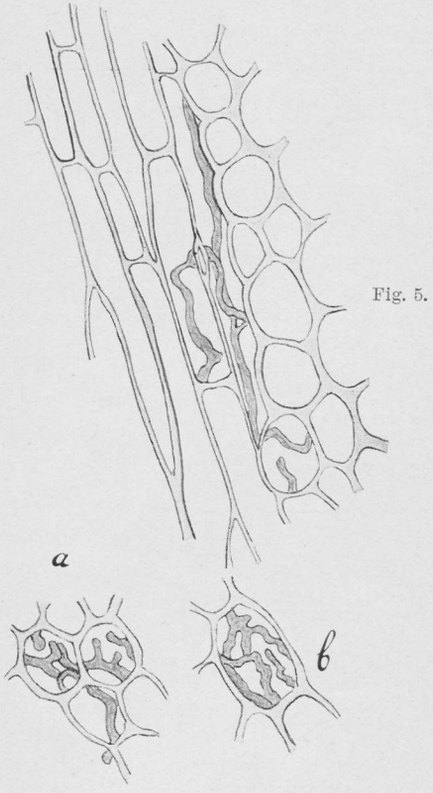
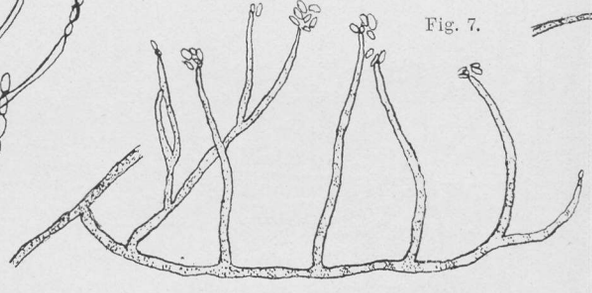


Fig. 6.

Fig. 7.



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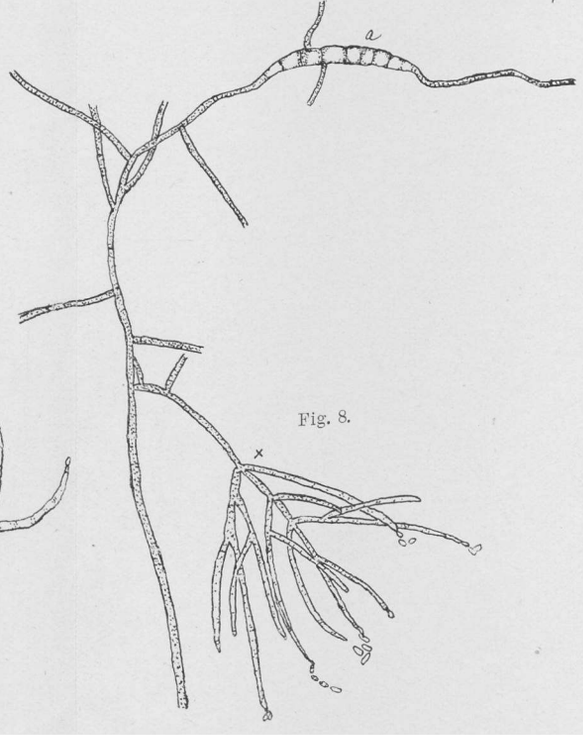

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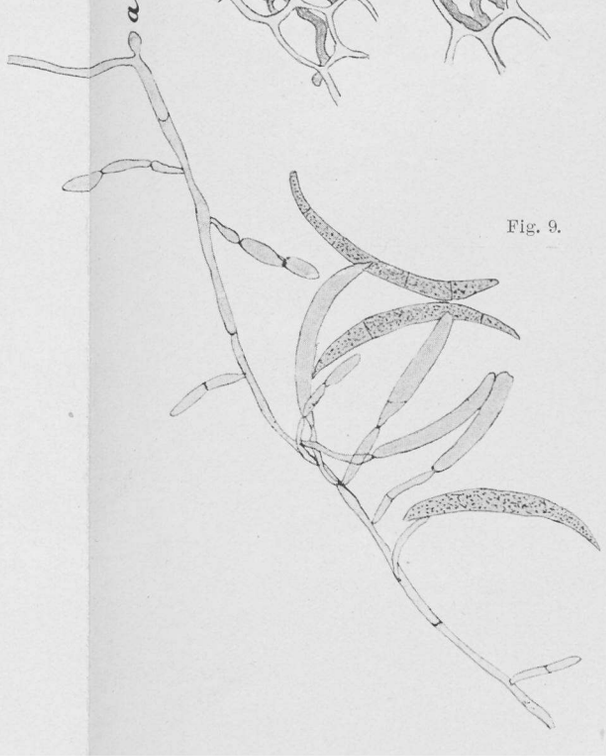


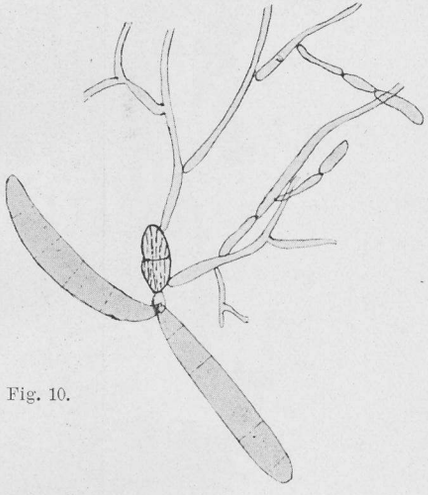
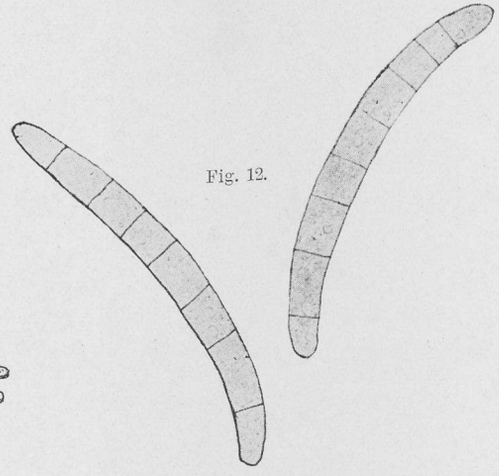


Fig. 10.

Fig. 11.



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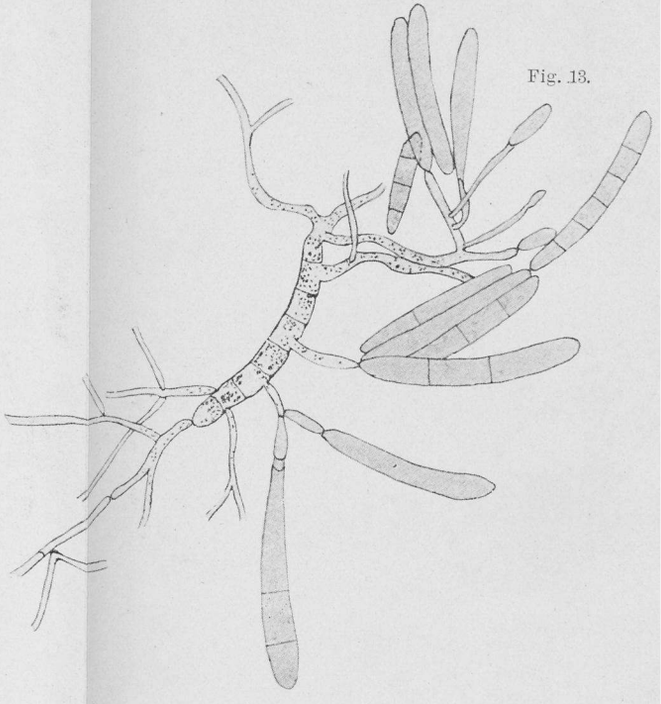

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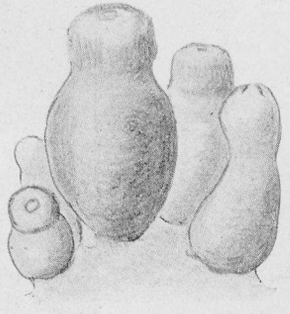

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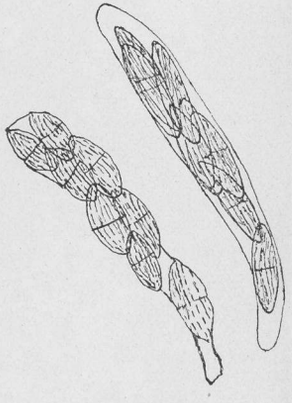

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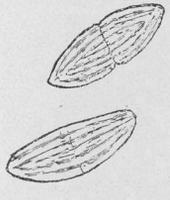

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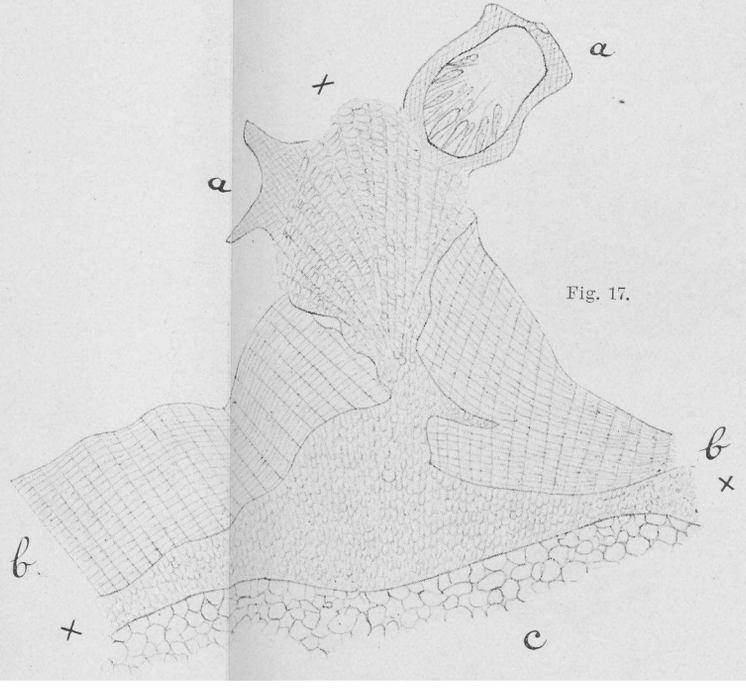

Fig. 17.