

THE PARASITISM OF TEA ROOT DISEASE FUNGI.

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Among the commonest root diseases of tea in Ceylon are those caused by *Poria hypolateritia*, *Fomes lamaoensis* (Brown root disease), *Ustulina zonata*, and *Rosellinia arcuata*. *Fomes lignosus*, the well-known cause of the most widely distributed root disease of rubber (Hevea), rarely attacks tea in Ceylon, though one of the most serious outbreaks of *Fomes lignosus* on rubber in Ceylon occurred on an estate where rubber had been planted through tea, and the tea cut off at ground level when the rubber was mature. In that case, *Fomes lignosus* developed on the tea stumps and spread from them to the rubber over about 150 acres.

Some of these diseases have a long history. Brown root disease was first recorded on breadfruit trees in Samoa in 1875, and again from the same country on cacao in 1895 and 1907. Cunningham found it on tea in India in 1887. Zimmermann recorded it from Java in 1904, and it was identified in Ceylon in 1905. Since then it has been recorded from the Federated Malay States, Burma, and West Africa.

In general, Brown root disease has been identified by its mycelium, since, in most countries, the fructification of the fungus has not been found. Consequently, there is a possibility that the name may cover more than one disease, as there must always be a doubt when a fungus from one country is identified as the same as a fungus from another country from mycelium only. The mycelium of Brown root disease has peculiarities, but it is quite possible that the mycelium of some other fungi may have the same peculiarities. A fructification of the Ceylon Brown root disease has been found repeatedly during the last ten years, and there is no doubt that, in this country at least, the most frequent Brown root disease, if there is more than one, is *Fomes lamaoensis*. But until the fructifications of the "Brown root diseases" of other countries have been discovered, there is room for doubt whether they are the same.

One species of *Poria* was recorded as the cause of a root disease of tea by Zimmermann in Java in 1901, a group of one hundred bushes, two and a half years old, being killed, but it is uncertain whether his account refers to *Poria hypolateritia*, the commoner Ceylon species on tea, or to *Poria hypobrunnea* which is rare on tea but fairly common on rubber. The former was first recorded in Ceylon in 1907, though there is a little doubt that it has been the common tea root fungus on new clearings since 1880. It is known to occur also in India.

Rosellinia arcuata was recorded, as the cause of root disease in tea, by Carruthers in 1903. It also causes root disease of tea in India and Java. Species of similar habit occur in the West Indies and other parts of the world, and have long been recognised as the causes of root (or collar) disease in Europe, America, and New Zealand.

Ustulina zonata was first observed to be parasitic in Ceylon in 1907. Since then it has been found to attack numerous species of woody plants in India, Burma, Java, and the Federated Malay States.

Fomes lignosus was first found as a cause of root disease on rubber at Singapore, and was recorded by Ridley in 1904. Since then it has been recorded from all the rubber-growing countries of the eastern tropics, as well as from Africa, and has been universally accepted as the cause of the most serious root disease of rubber in the eastern hemisphere. It is also known to attack many other woody plants.

Proof of the parasitism of *Fomes lignosus* on woody plants was given by Bancroft. Rubber seedlings, three months old, were transplanted into boxes. In four cases, a piece of a root infected with *Fomes lignosus* was placed in contact with the roots of the seedling. Two other plants were left as controls. Of the four plants whose roots were in contact with an infected root, three acquired the disease, the fourth remaining healthy because the mycelium of the fungus failed to grow out from the infective material.

Two other experiments were carried out by Bancroft on similar lines. Attempts were made to infect fourteen plants, and of these ten were successful.

As regards Brown root disease, Anstead has recorded an experiment in South India in which a root attacked by Brown root disease was buried in contact with the roots of a healthy rubber tree, with the result that the latter was infected and died.

In Ceylon, tea roots bearing the mycelium of *Poria hypolateritia* have been buried in contact with the roots of tea bushes, and the mycelium has spread to the latter and killed them.

Anyone who has any doubt about the parasitism of these fungi can repeat these experiments in the field. In the case of rubber (*Hevea*) the diseased roots should be buried in contact with healthy roots an inch or two in diameter.

The objection may be raised that in these proofs the infecting material was a root which had acquired the disease naturally, and in such circumstances more than one fungus may have been present in the diseased root. It is well-known that, in general, when a plant is attacked by a disease, other fungi may subsequently develop on the dead tissues. But if any fungus which it is suspected might have been present in the infecting material has been proved incapable of

passing to healthy roots from diseased roots in contact with them, that fungus is definitely excluded as a possible cause of the disease.

A further objection that might be brought forward is that these proots do not conform to modern standards in that the infections were not made from pure cultures. As will be admitted by most mycologists, that is not a disproof of their validity.

The earlier determinations of the causes of plant diseases were based on field observations, together with infection experiments with diseased material, such as those described above, or with spores produced in nature,—to which the same objection applies. That method is still employed in very many cases, as it is not always possible, in the present state of our knowledge, to grow a particular fungus in pure culture.

It is worth noting that the majority of these old determinations still stand. Modern technique has only resulted in confirming them. Where this modern technique has added to the number of fungi which are known to cause diseases of plants is chiefly in cases in which no cause could be assigned by the older methods of investigation.

Following on the development of bacteriological technique, it was found that fungi could be grown on artificial or sterilised media in test tubes or flasks, with the assurance that only one fungus was present; and during the current century it has become customary to confirm, or to attempt to confirm, field observations, by infections from such "pure cultures." This, however, is not always successful, as it is not always possible to reproduce, by laboratory methods, what actually occurs in nature.

Our root disease fungi afford a case in point. Our common root disease fungi belong to the group known as facultative parasites, that is, they are not always parasitic, but can either live as saprophytes on dead plant tissue or can attack healthy plants. In general, the fungi of our root diseases begin to grow, on estates, as saprophytes on jungle stumps or the stumps of trees which have been planted as green manure or shade trees and felled when it was desired to get rid of them. The infection of these stumps is brought about by spores of the fungus which are carried by wind.

After the fungus has grown in the stump for some time,—it may be a few months or even years,—and has reduced it to a state of decay, it spreads to the cultivated plants, sometimes by means of free strands of mycelium, sometimes by contact of the roots of the cultivated plants with the lateral roots of the stump. Frequently, it forms strands or masses of mycelium on the exterior of the root of the cultivated plant before penetrating it. It is for the latter reason that it is sometimes possible to deal with early cases of *Fomes lignosus* on Hevea by scraping off the mycelium and painting the root with a fungicide.

[It may be observed, to avoid misunderstanding, that although infection by way of stumps is certainly the more general mode of occurrence of our root diseases it is not the only one. Fungi are propagated by spores, and there is no reason why these spores should not infect plants directly. Occurrences of root disease on isolated bushes, not in the neighbourhood of stumps, are no doubt due to infection by spores.]

The point to be particularly noted is that when the fungus begins to spread from the stump, it has an accumulated reserve behind it, and it is for that reason that it is able to spread through the soil free, not in contact with anything from which it can obtain food, and can develop its mycelium over the root of its victim before it penetrates it.

It is not possible to imitate those conditions from pure culture. If the fungus is grown in pure culture on agar, the amount of mycelium which can be used for inoculation is small, and the agar substratum usually soon disappears. If, on the other hand, the fungus is grown in pure culture on sterilised wood blocks, a similar difficulty is encountered. The volume of a block of wood which can be sterilised with certainty is small; about one cubic inch is usual. Moreover, although a vigorous growth of mycelium may occur, it will be found that this is chiefly external, and unless the cultures are allowed to develop for a long period, there will be little penetration of the wood block.

Consequently the conditions which obtain when infections with our root disease fungi are attempted from pure cultures, when the mass of infecting material is comparatively small, are quite different from those which occur in nature, where the advancing fungus has behind it a stump which may weigh anything up to several hundred-weights. Hence one should not be surprised if attempts to infect our estate plants from pure cultures of such fungi as *Fomes lignosus*, *Poria hypolateritia*, etc., are unsuccessful, in spite of the fact that these diseases are readily communicated by diseased roots.

It is not intended to maintain that these diseases cannot be communicated from pure cultures, but merely to point out some of the difficulties in the way. The use of pure cultures is to confirm field observations. But the failure of the pure culture method does not necessarily refute field observations.

We have dealt with this question of pure cultures, as it concerns our root diseases, as briefly as possible. The tendency of much of our present day mycology is to make a fetish of pure cultures and to reject the evidence of field observations,—to believe nothing which cannot be reproduced by laboratory methods.

Infection experiments with *Ustulina zonata* were carried out on Hevea by Brooks and Sharples in Malaya. In one series of experi-

ments, by Brooks, in which seedling rubber plants in pots were used, blocks of wood on which the fungus was growing in pure culture were placed against the root, in three cases after wounding the root and in three others without wounding. Of the former, two plants were successfully infected, but of the latter only one. The experiment was repeated on fourteen four-year-old trees in the field, eight of which were wounded down to the wood, while six were not wounded. All the wounded trees were successfully infected, but there was only one, and that doubtful, infection among the six unwounded trees.

Sharples, using the same method, succeeded in infecting twelve rubber trees out of eighteen inoculated, the inoculations being made on wounds.

According to the foregoing experiments, *Ustulina zonata* is a wound parasite on Hevea, i.e., it can only attack the tree through a wound. But field observations clearly show that that is not the whole truth. Cases have been observed in which it has been quite clear that the Hevea has been infected on the tap root just below the laterals by contact with a diseased root of an Albizzia. This illustrates the point already mentioned,—the difficulty of reproducing, by means of the comparatively small amount of mycelium available from pure cultures, what readily happens in nature by contact with a diseased root.

Similarly as regards tea. *Ustulina zonata* is a wound parasite, when the spores infect the top of the stump,—the exposed wood in the middle of the bush,—and the fungus grows downwards, killing the bush. But *Ustulina* more usually attacks the roots of the tea bush, spreading to them from some neighbouring stump, and there is no doubt that in these cases it does not require that the root shall have been previously wounded. When, twenty years ago, it was a common practice to fell Grevilleas and leave their stumps to decay, it was usual to find lines of dead tea bushes along the decaying lateral roots of the Grevillea, and it was quite easy to determine that the fungus spread from the Grevillea root to the tea root by contact, and that the tea roots had not been previously wounded.

Experiments which demonstrate the parasitism of *Rosellinia arcuata* will be published in a subsequent number of this journal. But to anyone who has watched the spread of this *Rosellinia* in the field, infection experiments must be purely academic.

Almost my first experience of *Rosellinia arcuata* was its occurrence in a Panax hedge round my bungalow garden at Peradeniya. A mango tree which stood on the adjoining estate had been felled and the log left lying with one end near the hedge. The *Rosellinia* began to develop among the dead leaves which had accumulated alongside the log, and then spread to the hedge, where it ran along the surface

of the ground under and among the dead leaves in the hedge bottom. As the mycelium reached each of the closely-planted *Panax* stems, it enveloped it at the base. The cortex of the *Panax* stem rapidly became soft and rotten, and in a very short time that plant was dead. In a few weeks the hedge had been killed for a length of about six feet. It was then considered that sufficient information had been obtained concerning the method of progress of the fungus. The dead plants were dug out, together with two or three healthy plants at each end of the dead zone, all dead leaves raked up, and the whole burnt. About a year later, the gap was filled in the usual way by cuttings, and these, with the remainder of the hedge on either side of the gap, were alive and healthy when I left the bungalow eighteen years later.

A similar account is given of *Rosellinia radiciperda* in New Zealand. "In an orchard it will appear in patches, killing the fern and sorrel, and spreading until it reaches a fruit tree; it then attacks the bark round the stem just under the ground, which speedily rots, presenting the appearance of having been cooked, and has an offensive smell; it then proceeds along the roots, and the tree soon shows withered leaves, which drop off, leaving it bare." (Kew Bulletin, 1896, p. 2).

However, as stated above, proof of the parasitism of *Rosellinia arcuata* has been obtained and will be published at an early date.

The experiments recorded above, with *Fomes lignosus*, Brown root disease, *Poria hypolateritia*, and *Ustilina zonata*, can be repeated by any one who desires. At the present time they are accepted as definite evidence by nearly all mycologists who are acquainted with these fungi in the tropics.