DISEASES OF THE TEA BUSH—II.

ROOT DISEASES.

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Some of the most serious and destructive of the diseases to which the tea bush is subjected are to be found on the roots. As the primary function of roots is to supply the water requirements of the tree, the destruction of root tissues by disease seriously affects the water supply to the leaves. Its complete cessation results in the rapid death of the entire bush. The attacked tissues are below ground and the early stages of attack are consequently unobserved, so the disease usually has reached a very advanced stage before any symptom is visible above ground to suggest that anything is amiss at the roots. Consequently root diseases usually prove fatal.

Symptoms.—As root diseases lead to the stoppage of the water supply to the plant, the symptoms are those of water shortage or drought. The first indication is the wilting or withering of the leaves. The leaves dry rapidly, but frequently remain attached to the branches for some time. Usually the whole crown of the bush is affected simultaneously, though occasionally a part only may wither and die, but it is, of course, only a matter of time before the remainder dies similarly.

Deaths from root diseases appear to occur suddenly; the bushes may appear perfectly healthy one week, yet be completely dead the next. The organisms which cause the disease, however, do not work with that rapidity. As much as two or three years may elapse after the first invasion of the organism into the root and before the death of the bush. Bushes which appear to be perfectly healthy above ground may be found to have the root systems very heavily infected and many roots badly rotted, when uprooted. Examination of the roots is necessary to disclose the presence of disease before death and for the identification of the specific disease involved.

If a bush wilts or dries up as though it has been scorched, and dies with all its leaves attached, it is almost certainly a case of root disease. Root disease should also be suspected if the bush sheds its leaves gradually but fails to recover. If new shoots are produced after the leaves have been shed root disease is very improbable.

The cessation of water supplies to the leaves and branches may be brought about by agencies other than organic diseases of the root tissues. Drought, resulting in a shortage of water in the soil itself, is one such obvious cause. Lightning too is often responsible for the sudden death of bushes, which usually show no sign of scorch or other direct injury attributable to the flash. Lightning usually affects a small area of tea by causing the death of a number of bushes almost simultaneously. Later, more deaths may occur on the perimeter of the dead patch as though a very virulent, rapidly-spreading root disease were active. No fungus, however, is to be found on the roots of the dead bushes, and the spread of the disease ceases as suddenly as it began. Lightning should be suspected where a number of bushes are simultaneously affected in an area with no history of root disease and where there is no evidence of fungus on the roots. Stem disease may also result in the apparent sudden death of a bush if the main stem has been ringed by a canker. The effect in such a case is very similar to that brought about by "ring barking" a tree, *i.e.*, by removing a ring of bark in a circle around the tree near ground level. The existence of the canker or circle of dead bark near the collar affords a ready diagnosis. The shedding of leaves, which in some cases is mistaken as a symptom of root disease, may result from attacks of such leaf diseases as *Cercosporella* or of mites such as the Scarlet mite (*Brevipalpus obovatus*). In such cases large areas are simultaneously affected, but the bushes later put out new shoots. In all cases of doubt the roots should be examined. If they are alive and no fungus is present on them, the cause of wilting or defoliation must be sought elsewhere. But as a general rule the sudden wilting of individual tea bushes is the result of root disease.

Occurrence.—Where root disease fungi are active there is a tendency for the bushes to die out in patches. This is particularly

noticeable in Ceylon when the red (*Poria hypolateritia*) and the black (*Rosellinia arcuata*) root diseases are concerned. The formation of a patch is the result of a gradual extension of the mycelium of the fungus underground in all directions from the original source of infection. So long as the fungus is active, the patch will increase in size owing to further infection of bushes on the perimeter. If by the time the infected bushes are dead, the fungus has already spread to and invaded the roots of other bushes, the fungus causing the disease is ahead of the dead bushes, and the removal of dead and obviously dying bushes does little to stop its progress. The size of a patch affords a rough measure of the time during which the disease has been active, and there can be little doubt that the disease in many of the large bare patches to be seen in Ceylon tea estates has been operative from the time the estates were opened from jungle.

It is very unusual, however, in Ceylon, to find such root diseases as the Brown root disease (*Fomes lamaoensis*) or Charcoal root rot (*Ustulina zonata*) causing ever-enlarging patches. Usually a few adjacent bushes die where there is no evidence of previous deaths having occurred on that site. Such deaths normally occur in the immediate vicinity of a jungle stump or the stump of a felled *Grevillea* or other shade tree. Certain root diseases, of which the two commonest have been mentioned, are normally associated with existing stumps or old buried roots, while others persist long after the original source of infection has disappeared.

Petch [1] in his book published in 1923 wrote of *Ustulina zonata*: "This is the commonest root disease of tea in Ceylon, and it is in a great measure preventable. Its prevalence is due to the practice of growing *Grevillea* for shade or as a windbreak among tea, and cutting it out either for firewood, or when it has grown too big, leaving the stump to decay *in situ*. It is not uncommon to see three or four dead tea bushes round each *Grevillea* stump over a large area". Since that was written far more attention has been paid to the removal of stumps with a consequent diminution of such diseases as *Ustulina*, which no longer ranks as the commonest root disease of tea in Ceylon today.

The close connection between the presence of stumps and root disease cannot be too strongly emphasised. It was well illustrated on one estate where a large number of *Grevilleas* had been felled. Within two years tea bushes in the immediate vicinity of the felled trees began to die of the Brown root disease. No deaths occurred near the standing living trees nor at any distance from the felled trees. The association of the dead bushes with the felled trees was so very close that it could not possibly be overlooked. Not every felled tree gave rise to disease but in certain areas it was estimated fifty per cent of them did.

Spread.—Tree stumps do not give rise to disease spontaneously; they must first become infected before the infection can spread to the tea. The most obvious means of infection is by spores (the equivalent of seeds) carried in the wind. All fungi which are known to cause root diseases of tea are also known to produce spores, usually in large numbers. These spores are so extremely minute that they can be carried long distances in air currents, but ultimately they come to earth. Should they fall on a suitable medium and the environmental conditions be favourable they begin to grow.

What constitutes a suitable medium for the growth of such spores ? The best natural medium for the cultivation of tea root fungi is undoubtedly wood. They all cause a rot of some form of the woody core of the root, and many reduce such hard tissues to a punky mass. Spores which fall on the cut surface of a felled tree, given suitable climatic conditions, are favourably situated for vigorous growth. The wood becomes permeated by the fungus which grows down into the roots and thence to the living roots of adjacent healthy tea. Soil is a favourable medium for the propagation of many micro-organisms, but soil alone must be considered unfavourable for the maintenance of the tea root disease fungi. Otherwise, the existence of large areas of healthy tea would be difficult to explain. Large numbers of spores of pathogenic fungi must find their way directly to tea soils yet cases of root disease in the absence of stumps or previous history of disease at the site are extremely rare. If the mycelium from a spore which had germinated on the soil surface were capable of attacking and infecting healthy tea roots, root diseases would be far more prevalent and widely dispersed.

Direct infection of living tea bushes from spores of root disease fungi except *Ustulina zonata* are extremely rare. Above ground infections by *Ustulina* are sometimes met with on tea bushes, but in all cases examined the fungus had gained entry through an exposed wood surface, frequently a pruning cut. Above ground infections of Hevea by *Ustulina* are also well known. These are undoubtedly direct invasions of the hyphae produced by germinating spores.

The available evidence points clearly to the fact that, as a general rule, germinating spores of tea root disease fungi must first become established on a food base, usually wood, before a successful invasion of living tea roots can be made. It is probable that leaf mould may form a suitable food base for certain fungi, particularly *Rosellinia arcuata*, but normally wood is the usual medium. For this reason tree stumps are the usual natural sources of infections of root diseases in tea.

The attack by a pathogenic root fungus may be regarded as a mass attack. The fungus requires a food base on which it can grow vigorously and from which it can reach and establish itself upon the root to be invaded. When established within the root the fungus then permeates the whole root system of the attacked bush which in turn serves as a food base for further attacks on nearby bushes. Diseased roots are therefore highly infectious and a source of danger to other bushes. The careless disposal of roots of bushes, uprooted because they have died of a root disease, has resulted in the spread of disease on many estates. A labourer carrying a diseased bush to his room for fuel, or to a central spot for destruction by fire, is likely to drop loose roots which, even if they fall on a path, will probably be kicked under a tea bush. The fungus on such a root is already established on a food base and given favourable opportunity will attack a living root direct.

The normal mode of spread of the major root diseases of tea is from root to root. New centres of infection arise naturally from the infection of tree stumps or other suitable food bases by wind-borne spores or through the agency of man in his dispersal of diseased roots.

General Observations.—The root diseases of tea are a direct legacy from the original jungle. Tea on original patna lands or on jungle soil previously cultivated with other crops is relatively free from this trouble. As a consequence of felling and burning, the root parasites existing on the jungle trees are threatened with extinction. But when a woody susceptible crop like tea is established in the clearing, the threat of extinction ceases to become operative because new root sysetms are developed on which the parasites can subsist. Tea plants placed on the site of an *infected* root system of a jungle plant are themselves certain to become infected and ultimately to die. The amount of root disease in a jungle clearing is therefore a reflection of the amount of disease which occurred in the original jungle.

One of the first root diseases to appear in a young clearing is that caused by *Poria hypolateritia*, and it seems that one of the last to be eradicated from old tea will be the same disease. Where this disease has not been eradicated from a clearing it has continued to take increasing annual toll of the bushes. The increasing toll is due, not so much to the creation of new centres of infection as to the ever-increasing perimeter of the existing patches. On the other hand, the annual toll taken by such diseases as Brown root disease and *Ustulina* is more the result of new centres of infection than to enlargement of previously infected patches. An instance of new sources of Brown root disease infection has already been cited.

Why then do some root diseases occur in patches of ever-increasing perimeter, despite the uprooting of dead bushes and the destruction of the original source of infection, while others rarely cause a patch of notable area and are normally easily eradicated by the uprooting of diseased bushes and the removal of the stump or roots from which the original infection occurred. To arrive at a satisfactory answer to that question the characteristics of the fungi concerned have to be considered, particularly as regards the rates at which the fungi can kill tea bushes and the distance from which their attack can be made.

Very little is known regarding the time which elapses between the first infection of the root and the subsequent death of the bush, mainly because of the difficulty of fixing the time of first infection.

An ideal parasite would be one which obtained all its requirements from the host without actually killing it. The death of the host plant leads to the death of the parasite unless that parasite can find a new source of food supply before the existing one is exhausted. A parasite which kills slowly is likely to be more difficult to eradicate than another which kills rapidly, given that their rates of growth and extension through the soil are equal. If we imagine an infected bush to be a food centre from which hyphae radiate in search of further food supplies, a slow-killing fungus will have invaded a much larger area of soil than a quick-killing fungus by the time the infected bushes die. In other words, the disease will have advanced further into the surrounding tea in the former case than in the latter.

Reference has already been made to the deaths of tea bushes from Brown root disease within two years of the felling of the adjacent *Grevilleas*. During that period the *Grevillea* stumps had to become infected, the fungus had to grow into the roots and thereby reach the tea roots. It is probable, therefore, that the tea bushes died within a year of their own roots first becoming infected by the pathogenic fungus. Brown root disease would, therefore, be regarded as one which kills quickly. On the other hand, the *Poria* root disease kills more slowly and evidence is available that two or even three years may elapse before the bush dies after the roots are first infected. On this hypothesis therefore, it is to be expected that *Poria* is more likely to cause a large patch than is the Brown root disease because at the time dead bushes are removed the chances of the fungus having reached other bushes are greater in the former case.

Some fungi can grow freely through the soil from a food base, others do not readily do so. This factor materially affects the distance at which fungi can attack living roots. The attacks of a fungus which cannot grow through the soil are restricted to those healthy roots which are in direct contact with the root on which the fungus is established. Both *Fomes lamaoensis* and *Ustulina zonata* belong to this category and consequently Brown root disease and Charcoal root rot are restricted to the root range of the infected tree. *Poria hypolateritia*, *Rosellinia arcuata* and *Armillaria mellea* grow readily through or over the soil and so are able to reach the roots of bushes at a distance. The free mycelium in the soil sometimes takes

the form of distinct strands termed rhizomorphs. This is particularly the case with *Armillaria mellea* whose characteristic black rhizomorphs have given rise to one of its popular names, "Bootlace fungus". Such rhizomorphs grow for considerable distances through the soil but it does not follow that a successful attack can be made from the distant end of a long rhizomorph, nor that a rhizomorph detached from its food base can cause infection. Wallace [2] doubts whether rhizomorphs have an effective range of more than a few feet. The writer has not seen any cases in tea where there was suspicion even that successful invasion had occurred at greater distances than one or two feet from the food base. *Rosellinia arcuata* will grow under and through leaf mould on the surface of the soil for considerable distances and successfully invade tea bushes at the collar. But there is good reason to suspect that the leaf mould itself acts as a food base and so facilitates attack by this fungus. An ability to attack healthy roots separated by a few inches of soil only frequently gives the fungus a great advantage as regards facility of spread. The greater the distance at which successful attack can be initiated the more readily does the fungus having that power spread through an area, the greater is the damage done by it and the more difficult is its eradication.

The distance at which a specific fungus can attack, considered in conjunction with the rate at which it causes the death of infected bushes, affords an explanation of the ease with which certain diseases have been controlled in the past and difficulty experienced in checking the spread of others.

Emphasis has here been made on the importance of food bases from which pathogenic fungi can attack the roots of nearby bushes. Such food bases consist commonly of the stumps of felled trees and the roots of attacked but apparently healthy bushes. Air-borne spores are relatively harmless in the absence of a suitable medium on which they can grow, and it is very doubtful if mycelium in the soil separated from its food base can successfully invade the roots of healthy bushes. Rational methods of control must be based on these principles.

REFERENCES.

(1). Petch, T.—The Diseases of the Tea Bush (1923).
(2). Wallace, G. B.—*East African Agricultural Journal*, 1: 181-192 (1935).