THE ARMILLARIA ROOT DISEASE OF TEA.

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In 1910, Petch[6] described a root disease of *Acacia decurrens* in Ceylon caused by a species of Armillaria, which he had named *A. fuscipes* [5]. At that time the disease had not been recorded on tea. In 1918, Palm [4] published an account of a tea root disease from Java, caused by a similar fungus which, following Rant [8], he ascribed to *Armillaria mellea* (Vahl.) Fr. Armillaria root diseases of tea have since been reported from Uganda [10], Nyasaland [1] and Ceylon [3], but so far there appears to be no record of the disease occurring on tea in India, though the fungus is known to exist in the Himalayan pine forests [1].

There can be little doubt that the Armillaria root diseases of Ceylon, Java and West Africa are the same, and that the fungus which causes them is closely allied to *Armillaria mellea*, a well-known saprophyte and parasite of forest and orchard trees in temperate zones. A number of diverse forms of *A. mellea* are known, and Rea [9] lists ten varieties for Great Britain alone. Whether the tropical form should be regarded as a further variety of *A. mellea* or should be given specific rank under the name *A. fuscipes*, as Petch [7] maintains, is a matter for systematists to decide. At present, the name *A. mellea* is in common usage for the tropical fungus.

A peculiar feature of Armillaria root diseases in the tropics is that the tap root and lower part of the stem frequently split longitudinally. For this reason this tea disease in Java is known as "Split-kanker" [4], and the cacao disease of the Gold Coast as "Collar Crack" [2]. The fissures are usually coated with sheets of somewhat leathery, cream-coloured mycelium, termed xylostroma. This mycelium often extrudes from the split cortex as a narrow, raised ridge running vertically down the root; the ridge is often slightly frilled, and is usually dark brown or black owing to the change in colour of the external layers of the xylostroma. (Plate I, fig. 1.).

The radial fissures result from the formation of mycelial sheets in the medullary rays of the affected parts. It is doubtful, however, whether the pressure exerted by the mycelial sheets alone is sufficient to split the wood in the manner observed. Cases of this disease on old tea in Ceylon rarely exhibit the characteristic fissures at the time the disease is first observed in the field, *i.e.*, at the time the bush dies, but they usually develop as the bush dries out in the laboratory. The fissures so developed are not as a rule coated by definite mycelial sheets, but it is believed that in the field, such cracks would become filled with xylostroma as the fissures slowly form. It seems probable

that the unequal drying out of the variously affected wood, resulting from the interruption of the water current consequent to the death of the roots, sets up strains responsible for the formation of fissures at places prepared by the fungus.

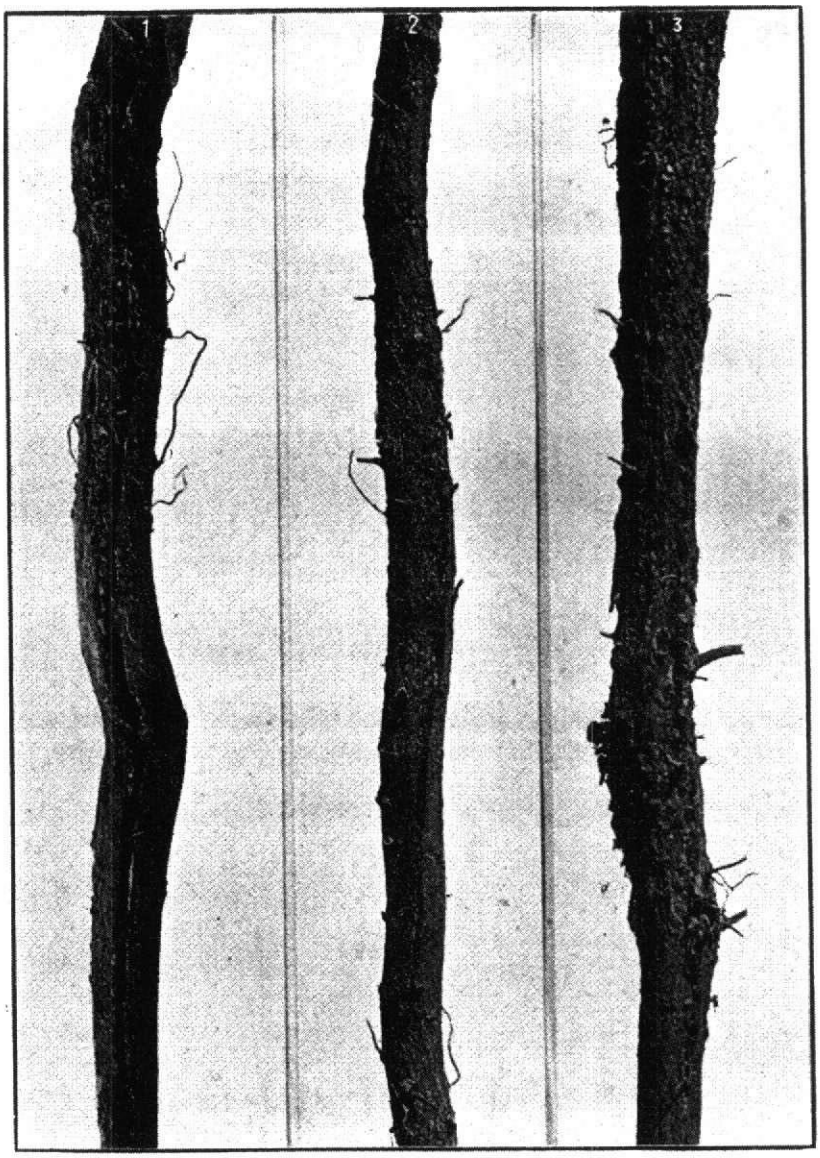
Though the peculiar fissures have not been observed in attacked mature bushes in Ceylon, they have been observed in *Albizzia lopantha* and in young tea plants about half-an-inch in diameter about to be transplanted. In some instances, the tap roots of the latter were split from the tip to the collar as though with a knife. Occasionally the roots were split along more than one plane so that the remains of the tap root had the appearance of having been trimmed to a point. Photographs of such roots were published elsewhere (3). In others, narrow fissures occurred in the cortex, from which exuded frills of xylostroma forming vertical, raised bands down the root. Fissures and frills of xylostroma are shown in Plate I.

Another feature by which this disease can be identified is by the presence of black, somewhat flattened, rhizomorphic strands which resemble black roots about one sixteenth of an inch in diameter (Plate II Figs. 2 and 3). These black cords or rhizomorphs are rather brittle, and are usually broken during uprooting operations. Fragments, however, may usually be found attached to the cortex. The rhizomorphs are not confined to the surface of the bark but run freely for long distances through the soil. Under African conditions, as in Nyasaland on tea and in the Gold Coast on cacao, the formation of definite rhizomorphs appears to be rare in nature though they are readily produced in artificial culture.

In the absence of rhizomorphic strands or extrusions of xylostroma, there is no visible fungus on the exterior of the roots. The bark is much roughened and when shaved away tangentially, sheets and strands of white mycelium running parallel to the surface of the bark may be observed (Plate II. Fig. 5). Frequently, thin but compact fans of mycelium occur between the wood and the bark in the place of the cambium. In this respect the disease resembles that caused by *Ustulina zonata*. In the latter disease, the mycelial fans are larger and are usually confined to the cambial layer. The mycelial fans of Armillaria are thicker, with a reddish brown outer covering, and are also to be found within the cortex. The Ustulina fans are best seen by lifting an area of cortex away from the wood, whereas the Armillaria strands and sheets are most easily found by shaving the cortex, which then has a mottled appearance due to the alternating areas of white mycelium and brown bark.

The wood of Armillaria infested tea roots in Ceylon is typically hard and dry, and is divided into definite areas that differ in appearance and stage of decay (Plate II Fig. 4). These areas are frequently

PLATE I.



Young tea plants attacked by *Armillaria mellea*. x1.

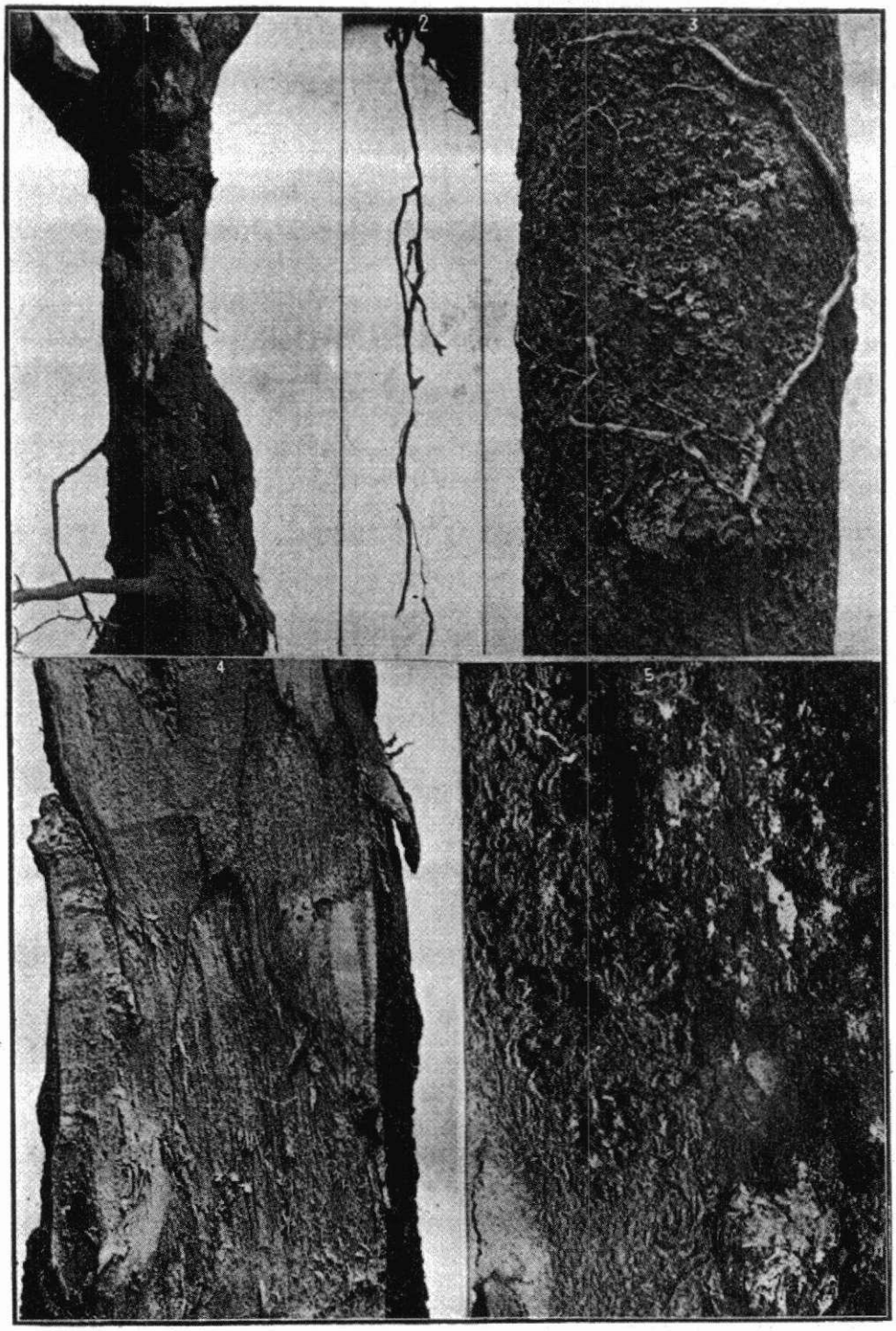


Fig. 1.—Tea bush attacked at the collar by Armillaria showing the fungus on the wood, callus above the region of attack, and rhizomorphs on the root. x1.

2.—A free rhizomorphic stand from a root of *Albizzia lopantha*.

3.—Rhizomorphs on a tea root. x1.

4.—Section through a tea root attacked by Armillaria, showing black lines demarcating areas of different stages of decay. x1.

5.—Tea root attacked by Armillaria showing rough bark on the left and mycelial sheets on the right where the cortex has been shaved away. x2.

demarcated by distinct black lines. In Nyasaland the wood is typically affected by a wet rot—so wet that water can be wrung out of the affected roots. Similar wet rots have been observed in Ceylon in jungle roots infected by this fungus, and in one instance it was reported that when a diseased tea bush was dug out "water or juice poured from the split tap root." Dade (2) considers the wet rot of cacao wood following infection by Armillaria to be the result of the activities of other organisms, possibly bacteria. That the wet rot is due to organisms other than Armillaria is probably correct, as in artificial culture, blocks of tea wood infected by Armillaria show no sign of a wet rot after two years.

The fructification is of the toad-stool or mushroom type. In Europe *A. mellea* is known as the honey fungus owing to its pale-yellow or pale-brown colour. In the tropics sporophores are more rarely found than in temperate zones. The writer has found them but once in Ceylon, at the base of a jungle stump adjacent to an infected tea bush, and then they were too old for accurate description, though he had no doubt that it was the same fungus as that described by Petch under the name *A. fuscipes*.

Armillaria mellea almost always begins life as a saprophyte upon decaying tree stumps or jungle roots. From such centres the fungus spreads to adjacent susceptible plants. Infection may occur as a result of direct contact between the living root and the infected stump, or by means of the rhizomorphs which grow out from the infected stump through the soil to healthy roots at a distance. Infections have been observed to occur directly at the collar of tea bushes as shown in Plate II, Fig. 1. Such infections are unlikely to occur from direct contact with diseased wood and are more likely to be the result of infections by rhizomorphs. When infection occurs at the collar, death results when the bush has been ringed. The development of callus above the region of attack indicates the failure of the fungus to extend its activities in that direction, and also affords some indication of the time which elapses between the formation of a definite lesion and the death of the bush.

As with other root diseases of tea, there is no above ground symptom noticeable until the bush is moribund. Then the leaves rapidly wither, turn brown and fall. Frequently, the death of the bush is the first indication that anything is amiss with the bush. In other cases, the bushes die gradually, generally from one side—the side from which the attack is occurring. In Nyasaland (1) this unilateral type of attack is characteristic of spreading patches, but in isolated cases, where patches are starting, deaths appear to be much more rapid. Whether a bush will die suddenly or slowly from one side will depend upon the virulence of the fungus and the position of

infection. An infection at the collar or on the tap root usually results in an apparently sudden death, whereas an infection on a lateral root, particularly when the advance of the fungus is slow, results in the gradual death of the bush beginning with the branches on the side from which the attack has occurred.

Although the fungus has been known in Ceylon since 1908 the disease was not recorded on tea until 1927, since when it has not become of serious economic importance. A few isolated cases have been observed at high elevations, always in close association with decaying jungle stumps, but in no instance has a spreading patch been found comparable with those reported from Nyasaland or with those caused by the Poria root disease in Ceylon. It would appear that under Ceylon conditions, tea is not very susceptible to the disease. The lack of infection does not appear to be due entirely to the rarity of the fungus, because on certain estates, where *Albizzia lopantha* was tried as a shade tree amongst tea, the Albizzias contracted the disease and died, though in no case, in the writer's experience, did the fungus spread to the tea.

In addition to *Acacia decurrens*, *Albizzia lopantha* and tea, the disease has been found in Ceylon on young Grevilleas growing in close proximity to infected jungle stumps and diseased tea.

Treatment.—Two main points should be borne in mind: (1) the fungus originates from decaying stumps and roots; and (2) the fungus spreads underground by means of black, cord-like rhizomorphs. Because of the former, when diseased bushes are being uprooted a search should be made for the stump or root from which the disease originated. The soil should be well dug over to a depth of about 2 feet and all woody material collected. The roots of adjacent, apparently healthy bushes should be examined, and where found to be infected, the bush should be uprooted. All uprooted bushes, stumps and woody matter collected from the soil should be burnt, preferably on the site. If the diseased material has to be transported to a central place for destruction in an incinerator, it should be carried in closed sacks to prevent any diseased roots being dropped amongst healthy tea. In Ceylon these measures alone have proved effective in controlling this disease, and further losses have been eliminated by their prompt and efficient application.

Where there is definite evidence of a centrifugal spread of the disease as is common in Nyasaland, trenching should be resorted to as an extra safeguard. The trench should be sited so that one row of apparently healthy bushes is included within the isolated area after all dead and known infected bushes have been removed. It should be about 3 feet deep and the excavated soil should be thrown on to the

isolated area and not outside it. The depth of the trench is dependent upon the nature of the soil in which the tea is growing; the trench, however, should have a depth greater than that of the lowest lateral roots of the bushes growing in that soil. The trench should be regarded as an extra safeguard, and not as the primary method of control. It can be effective only so long as it is kept open, which on many sites is a laborious matter.

Where the diseased tea abuts on jungle, a deep trench should be constructed to separate the one from the other to prevent continual reinfection from the jungle.

Control measures should be applied as soon as the disease is observed; delay in their application favours the spread of the disease and results in increased losses.

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