RING-BARKING OF TREES, AND ROOT DISEASES

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In Ceylon, Armillaria root disease of tea [1] is not common, but in Nyasaland where it is primarily a disease of jungle clearings it has caused serious losses. In Ceylon, it has occasionally been found in old tea not known to have been attacked previously by this disease, and in only one instance is it known to have caused serious loss in a jungle clearing. The latter case demonstrated how destructive the disease can be under favourable conditions.

In all cases investigated, the disease has been found to be closely associated with old tree stumps and their roots; often, the root causing infection has been located many feet below the soil surface. One method of minimising the risk of subsequent infection of tea on newly opened forest land is by thorough stumping and root clearing. There is, however, an economic limit to this process and it has been found, in Nyasaland, that although this extra cost of opening reduced the incidence of the disease, it by no means ensured complete protection. The losses, even when stumping and root clearing were employed as far as was practicable and economic, forced Leach [5] to the conclusion that such control measures were far from satisfactory.

Observations made while studying this disease suggested to him a new method of control. Briefly, it was that the incidence of Armillaria in tea clearings would be reduced if the jungle trees were killed by ring-barking before felling. The connection between ring-barking of jungle trees and the incidence of root disease in the crop grown later on the jungle site may not be immediately apparent, so a short consideration of the evidence on which his idea was founded is necessary.

Armillaria mellea requires media containing easily available carbohydrates for its satisfactory development in culture. Examinations of infected tea seedling roots showed that the invading hyphae grew most freely towards the wood and pith where the starch reserve is stored, whereas the cortex (bark) is devoid of starch. It followed, therefore, that if the starch reserves of the roots could be depleted before the trees are felled, the roots would form a less favourable

medium for the growth of the fungus, and consequently, the incidence of the disease would diminish. The most obvious method of depleting the reserves of food in the roots is by ring-barking, for reasons given later.

The roots of 'Muula' trees (*Parinarium mobola*) are considered to be the commonest source of Armillaria infection to tea on newly cleared forest land in Nyasaland. Healthy "Muula" roots contain abundant starch but when such trees become defoliated as a result of ringing, their roots are devoid of starch.

To test his hypothesis, Leach examined the roots of 24 dead stumps of 'Muula' trees which had been felled without ringing. Only three of those stumps were found to have roots free of infection by Armillaria. A similar examination of the roots of 12 stumps of 'Muula' trees which had been killed by ringing before felling disclosed no root infected by Armillaria, though he entertained some doubt about one. These observations demonstrated beyond doubt that by ringing the trees before felling, later infections of the roots by *Armillaria mellea* could be materially reduced, if not eliminated entirely.

The roots which were not attacked by Armillaria were almost invariably invaded by other fungi, the identity of all of which could not be ascertained. These roots Leach termed 'dry rotted' to distinguish them from the 'Armillaria rotted' roots. Of course, amongst the fungi causing dry rot of the 'Muula' roots might be some which could themselves become active parasites of tea, but his attempts to cause infection of tea seedlings by means of such roots all failed. He therefore concluded that the roots of forest trees killed by ringing for the control of Armillaria cannot be considered a danger to the health of the subsequent economic crop.

Ring-barking entails the cutting off of a wide strip of bark down to the wood in a complete ring round the trunk. The removal of this strip of bark in no way interferes with the upward movement, from roots to leaves, of water containing raw food materials in solution, but it completely breaks the channels down which the elaborated foods are passed from the leaves to the roots. The position immediately after ring-barking, is that the leaves are being supplied with water and other requirements from the roots but the food supply to the roots has been cut off. The roots, therefore, are forced to exist on their reserves, which includes starch, and when these are exhausted, the roots die of starvation. When this happens, the roots no longer absorb water and pass it to the leaves, so the leaves and the branches then die of water shortage as during drought.

It is imperative when attempting to kill a tree by ring-barking to suppress rigorously all growth arising below the ring and carrying leaves. Also, if the tree tends to regenerate the bark over the ringed area the new growth must be removed. To prevent this regeneration it may be necessary with some species, to cut a little way into the sap wood. The cut, however, must not be deep, otherwise the water channels from the root to the leaves will be severed and the crown will die before the roots as though the tree had been felled. The objects of ring-barking must be kept in mind. They are to deplete the roots of food reserves and to hasten the death of the root system relative to the death of the crown.

The rate at which trees die after ring-barking depends largely upon the amount of foods stored as reserves in the roots. Some trees, such as tea, use the roots as the main storage region; others store most of their reserves in the trunk and branches. Obviously, trees with large reserves in the root will take longer to kill by starvation than those which have little or no reserve. In dealing with trees which die slowly after ring-barking, it may be safe to fell them one year after ringing, because the roots would then be so depleted of carbohydrates that the roots would die rapidly after felling.

In a later paper [6] Leach has also demonstrated that in Nyasaland nearly all species in a mixed forest are susceptible to Armillaria after the roots are severed. Nevertheless, only a few species are usually a source of infection of this disease to tea. The species of trees he considered most dangerous as a source of infection by Armillaria, are those of which the roots die very slowly after felling. The slow-dying roots are rich in food reserves including starch, and so form favourable media for the growth of Armillaria. He, however, puts forward another explanation for the connection between Armillaria and roots of felled trees, which is of greater importance when the value of ring-barking is considered as a means of prevention of other diseases associated with the roots of felled stumps. It is that, once dead and invaded by saprophytes, these quick-dying roots cannot be attacked by Armillaria.

fungal antagonism

That such antagonisms might occur between the fungi which invade the roots of felled trees was suggested by the writer in a previous article.[2] Leach, however, has clearly demonstrated that such antagonism does occur between the saprophytes which invade dead roots and the parasite Armillaria, though he makes no claim that similar antagonisms occur where parasites other than Armillaria are concerned.

As an illustration of the antagonism found to occur between Armillaria and other wood invading fungi, one experiment only need

be described. Leach left a set of woody tea prunings on the top of the soil for a month so that they became invaded by various saprophytes. These dead prunings were then buried in the soil alongside a set of fresh woody prunings. Roots of Gliricidia infected with Armillaria were placed in contact with both sets of prunings as a source of infection. After burial for a month, the fresh prunings were heavily infected by Armillaria while the dead prunings were quite free. The dead prunings had an equal chance of infection, and the inability of Armillaria to enter these prunings can be attributed to the presence of other fungi already in them which prohibited its entry. There was no question of any difference in starch content of the two sets of prunings.

Similar antagonisms between fungi have been noted by other writers. Garrett [4] has used the terms *Soil inhabitants* and *Soil invaders* as a basis of ecological classification of the root infecting fungi. "The *soil inhabitants* are considered to be primitive or unspecialised parasites with a wide host range; these fungi are distributed throughout the soil, and their parasitism appears to be incidental to their saprophytic existence as members of the general soil microflora. The *soil invaders*, to which class the majority of root-infecting fungi seem to belong are more highly specialised parasites; the presence of such fungi in the soil is generally closely associated with that of their host plants. In the continued absence of a host plant, such fungi die out in the soil, owing to their inability to compete with the soil saprophytes for an existence on non-living organic matter. This close association between the *soil invaders* and their host plants thus seems to be enforced by the competition of the general soil microflora."

The problem of unwanted roots, no matter whether they are those left in the ground when jungle is cleared, or are the remains of shade trees felled in old tea, is how to ensure their decay without the intervention of a parasitic fungus liable to attack living tea roots. To use Garrett's terms it is one of getting the soil inhabitants into those roots before the soil invaders can get there. Leach's work has demonstrated that ring-barking of trees favours the entry of the soil inhabitants to the detriment of soil-invaders, in particular *A. mellea*.

The problem of old roots in jungle clearings is not quite the same as the related one of roots left in old tea when shade trees are removed. In a clearing, the soil contains a dense network of old jungle roots, many of which may already be infected by one or more fungi parasitic on tea. There may be very little evidence of this infection when the jungle is cut, as the parasites are in equilibrium with their hosts. In Nyasaland, Leach has found that the percentage of trees killed by Armillaria in virgin forest is very

small, even in a pure stand of susceptible species; yet when the forest is cut down the roots of these species become invaded by Armillaria to an amazing extent. This implies that once the trunk is felled, the high degree of resistance of the roots is broken down, and the fungus spreads along the roots which then form sources of infection for the tea planted later.

In Ceylon, the disease which commonly occurs in jungle clearings is that caused by *Poria hypolateritia*, but a preliminary examination of the standing jungle gives little or no indication of the places where the disease may be expected when tea is planted. In this respect, Ceylon experience with Poria is on par with Leach's statement concerning Armillaria in Nyasaland. Moreover, in Ceylon there is practically no evidence that new centres of Poria infection are started from spores. Evidence is accumulating to show that the diseases which occur in jungle clearings are already there on the jungle roots at the time the trees are felled, and it is from these sources that the subsequent diseased areas of the later planted crop plant orignate. Infection is from the jungle roots.

In old tea the root position is different. The old jungle roots have almost entirely disappeared. In areas originally planted on grass land (patna) there has never been the problem of jungle roots, yet when shade trees are felled there is liability to root disease orginating at the stump and passing to the tea bushes whose roots are in direct contact with the stump roots. The affected tea bushes often mark out the underground lie of the stump roots.

The writer [3] has recorded some interesting data from an estate which felled about 6,000 Grevillea trees which had been grown as shade for tea. About two years after felling 30 per cent of the stumps had given rise to Brown root disease with the result that over 3,000 tea bushes had to be removed. The source of infection was attributed to wind carried spores which presumably found lodgment on the cut surfaces of the stumps.

Garrett [4] has rightly pointed out that evidence is lacking that *Fomes noxius*, the fungus which causes Brown root disease, is at all a frequent coloniser of cut wood surfaces. The absence of that evidence is held to throw some doubt on the validity of the explanation, viz. spore infection. The writer was aware that his explanation was not entirely satisfactory. He pointed out that an infection of 30 per cent of the stumps implied an immensely heavy spore dispersal which could not be accounted for satisfactorily, as fructifications of *F. noxius* are not common, and that 2 years is a surprisingly short period for the mycelium to permeate the stump and its roots, and to pass to and kill tea roots.

The difficulty of finding a more satisfactory explanation, however, still remains. The trees and the tea bushes were undoubtedly healthy at the time they were cut. The dying tea bushes occurred only around infected stumps and the trees which were not felled remained healthy. There were no old jungle roots on which suspicion might fall. If we are to discard the hypothesis of spore infection in favour of one involving underground infection of the stump roots, then *F. noxius* must have been living freely in the soil or was already established on roots of either Grevillea or tea. But there is no more evidence in favour of those alternatives than there is for spore infection. In time, no doubt, the true explanation will be found.

Because of the risk from spore infections the writer recommended that when shade trees have to be removed from old tea, no exposed wood surfaces should be left for spores to lodge on. This can usually be done by severing the lateral roots and removing the stump by cutting the taproot below ground level. When the stumps are very large their complete removal is not always practicable; then the bark should be removed and the exposed wood painted with tar. These methods are designed to prevent infection from the air, but of course, they do nothing towards prevention of infection from below ground.

Leach's work with Armillaria suggests that a further precaution against infection of tree stumps can be made by ring-barking the trees twelve months before felling. Infections from below ground may thereby be reduced.

A tea estate in an up-country district, in 1930, ring-barked 1,752 Grevillea trees growing along roadsides, over an area of 45 acres. The dead trees were not felled until 1939 when they were cut at a height of 3 to 4 feet, but so far, there has been no case of root disease in the tea associated with these tree roots. These results are not strictly comparable with those quoted above. The estates are situated in different districts and there is no knowledge of what would have occurred in either case had other treatments been applied. For instance, in the area where root disease occurred we do not know whether the amount would have been less had some of the trees been ring-barked before felling; nor do we know whether any disease would have occurred in the other area had the trees been felled without previous ring-barking. The figures quoted were not obtained from scientific experiment but are records kept by estate superintendents of work done in the course of estate management. Nevertheless the figures are not without interest.

It is unusual for as many as 1,750 trees to be felled without that operation being followed by even a small amount of root disease. The trees perhaps have not been felled long enough for the disease to become evident if infection occurs on the cut surface of the tree stump as was suggested from the observations (2 years) made on the estate where Brown root disease occurred. The trees, however, have been standing dead long enough for root infections to have occurred if underground infections of tree stumps is the rule, unless, and this seems to be probable from the foregoing, ring-barking has diminished the risk of infection of the stump roots from all sources.

What, however, is clear is that killing trees by ring-barking before felling does not materially increase the risk of subsequent root diseases. In fact the opposite is more probable; ring-barking before felling diminishes that risk, not only so far as *A. mellea* is concerned as Leach has shown, but where other root parasites, though not necessarily all of them, make their attacks on living bushes from the roots of tree stumps. The method is so simple and inexpensive that it is well worth trial whenever shade trees have to be cut out. It would be well, however, to maintain the practice of eliminating exposed wood surfaces after felling also.

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