THE INFLUENCE OF THE SOIL ON THE DEVELOPMENT OF PLANT DISEASES AND PESTS

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The development of plant diseases and pests depends not only on the plant, the parasite, and the climate, but also on the soil. The soil is not merely an inert material containing minerals that feed the plant; it is itself very complex and it carries a community of very varied organisms.

The basis of life for the micro-organisms in the soil is the organic matter that is produced by plants through the process of photosynthesis. Photosynthesis is the process by which green plants (with the pigment chlorophyll) use the energy of sunlight to transform carbon dioxide and water into simple sugars, which are then, together with mineral nutrients from the soil, transformed into complex assimilation products which the plant can use or store. Thus the plant needs minerals from the soil and also water.

Decaying plant material serves as food for a large number of bacteria, saprophytic fungi, and eelworms, upon which certain other species prey.

The microflora and microfauna of the soil are of such complexity, and the number of species of organisms involved is so big, that a complete analysis of life in the soil is practically impossible. One thing, however, is clear, namely that just as in communities above the soil surface, most organisms live at the expense of other organisms and rely for their food on the presence of those other species; the only exceptions are the green plants, which eventually provide for all the other species. All organisms in the soil affect each other in some way or other; either by competing for minerals and water, or by devouring each other, or by hindering each other in their growth by secreting substances in the soil that are harmful to other organisms. By these means all micro-organisms in the soil are kept in check and cannot monopolise food sources. Thus, in natural soil, a balanced life of different micro-organisms is established. Any change in the vegetation also causes a change in these balances. With a decrease in vegetagion due to cultivation the amount of organic matter in the top soil decreases, and the numbers of saprophytic organisms, which live on this dead organic matter decrease to the advantage of plant parasitic organisms that were earlier hindered in their growth by saprophytes. If we apply these principles of soil microbiology to the cultivation of tea then we find that the composition of the soil can affect, among others, the following processes:

(1) root diseases and their spread are influenced by the antagonistic action of antibiotics produced by saprophytic fungi;

(2) the number of plant-parasitic eelworms can be influenced by the presence of predatory fungi and predatory eelworms;

(3) leaf spot diseases can be influenced by certain antagonistic organic compounds, produced by organisms in the soil and taken up by the roots, which hinder the development of the parasite in the leaf;

(4) the growth of the fungus, which serves as food for the larvae of the Shot-hole Borer, may possibly be influenced by the antagonistic action of antibiotic products of saprophytic fungi in the soil, if these products are absorbed by the wood on which the fungus lives. This is not proven but may well be so.

These four processes will be markedly affected by the organic-matter content and the microflora of the soil.

Plants can be very roughly divided into two groups, the extremes of which are those which can grow on virgin soil and have pioneer characteristics, and those which normally flourish in a well developed general vegetation, preferably a forest, so that they grow in a rich organic soil with a fully developed microflora. The latter group is probably dependant for healthy development on a soil rich in organic matter. The natural habitat of the tea plant is in the shade of a sub-tropical forest, so it belongs to the latter group.

The soil of a well-tended tea estate up country contains as much organic matter as the soil of the nearby jungle, but in the mid-country, the organic matter is less (Tolhurst 1956; Ramaswamy 1960). The effects of this change in environment have never been studied, but from what we know about other crops and other soils certain things can be deduced, and conclusions drawn as to the probable effects.

1. Root diseases caused by parasitic fungi

The parasitic fungus spreads from a diseased root to a healthy root by growing through the soil. During this growth through the soil it is influenced by the substances present in the soil water, particularly by substances secreted by saprophytic fungi as products of their metabolism, which can have an inhibiting influence. One of these saprophytic fungi is *Trichoderma viride* (Weindling and Emerson, 1936). It has been found in the laboratory that the secretion products of this fungus have a marked inhibitory effect on the growth of *Poria* in the soil (Mulder, 1960).

Other fungi that can be inhibited in a similar way are: *Ustulina*, *Fomes* and *Armillaria*. It is less likely that *Rosellinia* will be influenced by *Trichoderma* to the same extent, because *Rosellinia* is able to grow profusely as a saprophyte on leaf litter lying on the soil surface.

Application of this principle of antagonism to practical problems is, however, still rather remote, because it is not easy to increase the quantity of *Trichoderma* in the soil. Injection of *Trichoderma* spores would not help, because they are probably always present and their success depends on soil conditions (mainly the quantity of organic matter present as food for the fungus) and cannot therefore be increased by artificial introduction of the fungus.

2. Eelworm diseases

The eelworm population in the soil consists of saprophagous, predatory and plant parasitic eelworms. In a soil rich in organic matter, the saprophagous eelworms will be numerous, with the parasitic eelworms forming only a minor part of the total population of eelworms.

One group of fungi lives as predators on living eelworms by catching them with special trap devices formed by sticky knobs or rings of mycelium (Duddington, 1955). These fungi can live saprophagously on organic matter and they only develop their trapping equipment where there is a substantial total eelworm population. If eelworms are absent or few, the fungi preying on eelworms do not develop their trapping devices and can consequently not reduce the number of parasitic eelworms. If there is a large total population of saprophagous eelworms due to presence of organic matter, the number of predatory eelworms also tends to increase and these can also reduce the number of parasitic eelworms. There can, therefore, be other reasons why cattle manure has a beneficial effect on plants which suffer from eelworm attack, in addition to the beneficial effect on plant growth.

3. Leaf-spot diseases

For a long time it has been held that the plant takes up only water and mineral salts from the soil through its roots. It is now, however, becoming clear that, together with water and minerals, certain soluble organic substances can penetrate the root surface and enter into the vascular system of the plant.

For instance, antibiotics can be taken up by the roots and be transported to the leaves through the wood (Brian, 1956). These antibiotics can influence the susceptibility of the leaves to certain parasitic diseases (Mitchel, Zaumeyer and Preston, 1953). A number of saprophytic soil fungi produce antibiotic substances and there is no doubt that these antibiotics will be taken up by the plant from the soil (Hamilton and Szkolnik, 1958).

4. Shot-hole Borer

The female beetle carries with her the spores of the fungus *Monacrosporium ambrosium* (ambrosia fungus) (Fernando, 1959) and every gallery which this beetle bores is infected with this fungus. The larvae, which hatch from eggs laid in these galleries, feed on the threads and spores of this fungus. The fungus is essential for the development of the borer. If we could eliminate or reduce the growth of *Monacrosporium* the development of the Shot-hole Borer would be affected. This might be achieved if the wood, on which the fungus feeds, contained substances toxic to the fungus.

The development of systemic fungicides, (*i.e.* fungicides absorbed and translocated by the plant) is still in its infancy; so far, the only ones which show promise are some antibiotic substances produced by Actinomycetes and a few synthetic chemicals.

It may be that antibiotics produced by fungi in the soil are taken up in the wood, and present in the wood in sufficient concentration to impair the growth of the ambrosia fungus. If this is indeed the case then we ought to find a relation between the type of soil and the occurrence of Shot-hole Borer. The speed of growth of the wood should also influence the growth of the fungus, because, the faster the growth, the lower the concentration of the antibiotic substances in the wood may be, and the better the growth of the fungus. The best manured tea is often heavily attacked by Shot-hole Borer.

Reviewing these considerations, we can state a principle that underlies the difference between the circumstances of natural vegetation and modern agricultural cultivation: if we reduce the number of organisms at one point in the chain of biological processes, the balance in the rest of the chain will be upset and outbreaks or epidemics, due to abnormal multiplication of one organism, then called a pest or disease, will develop.

We cannot turn back the developments of intensive agriculture, but we can try to adapt our cultural measures as far as possible to meet the needs of other organisms that play a part in maintaining or restoring the 'balance of nature'. This can be of particular importance on a perennial crop such as tea.

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