DISEASES OF THE TEA BUSH—I.

DISEASES IN GENERAL AND FUNGI IN PARTICULAR

C. H. GADD.

The object of agriculture is the production of a commercial product of satisfactory quality and quantity, but the achievement of that objective is frustrated more frequently by disease than by faulty agricultural practice. A knowledge of plant diseases and the methods of their control are, therefore, as essential to the study of crop production as are such subjects as soil tillage and plant nutrition. Apart from such disastrous epidemics as those caused by the potato blight of 1845 in Ireland, the coffee leaf disease in Ceylon in the latter half of the 19th century, the chestnut tree blight in the United States of America which, since about 1906, has threatened to exterminate the American chestnut, the blister rust of white pine which has spread to an alarming extent through the north-eastern United States, and banana wilt which has seriously threatened the banana industry in several countries, the annual loss from plant diseases throughout the world is immeasurable. Russell* has estimated that in Great Britain alone "it is probably at least 10 per cent of the total value of the crops, and the loss is probably some £12,000,000 sterling per annum".

*Presidential Address, British Association, Section M, 1924.

No very strict definition can be given of the word disease, but in its broadest sense it implies any departure from a state of health, in which each organ fully performs its normal functions. In plants, a derangement of the physiological activities of an organ is usually accompanied by structural changes or the premature death of a part or of the whole plant. Usually there is no difficulty in recognising the existence of disease, though its causation may be obscure. Rational means of control, however, can only arise after the cause is known.

Plant diseases can be grouped into three great categories according to the nature of the causal agents :—

(1) *Non-parasitic diseases.*—These result from some inherent quality in the plant, improper environmental condition of soil or climate, or from mechanical injuries. In this category are included such injuries as are caused by drought, water-logging of the soil, frost, hail, excessive heat or shade, deficient nutrition, lightning and other non-parasitic agencies. The injuries may be so insignificant as hardly to merit the name disease, but on the other hand they may materially affect the whole plant and even cause death. Diseases of this type are frequently more difficult to study than are those of parasitic origin, and very little is understood of many of them.

(2) *Virus diseases*—are due to an infective principle, or *virus*, which is transmitted from one plant to another, usually by specific insects. These diseases are highly infectious and constitute some of the most serious that affeet plants. As yet, none has been found on tea.

(3) *Parasitic diseases.*—These result from the attacks of organisms, termed *parasites.* The attacked plants are usually referred to as *"hosts"*, and as the word in this usage has not the socially accepted meaning, the term *"suscepts"* is sometimes used instead. Among the parasites are found representatives from the whole range of the animal and vegetable kingdoms. The animal parasites, or pests, belong mainly to the *mammals*, *arthropods*, which include the mites and insects, *molluscs*, represented by snails, and

vermes or worms, of which the eelworms or nematodes constitute an important group. The plant parasites, with which alone we shall be concerned, are mainly to be found amongst the *flowering plants*, *e.g.*, loranthus and mistletoe, *algae*, *fungi*, and *bacteria*.

There are no very strict divisions between these three classes of diseases. The virus diseases could well be included in the parasitic class on the grounds, as is sometimes considered, that they are caused by organisms too small to be seen even with the aid of a high-powered microscope. Even the division between parasitic and non-parasitic is not always clear. Amongst the parasitic diseases are usually included cases in which the invasion of the parasite is dependent upon a previous weakening of the plant by climatic or other environmental condition. In such cases the initial cause is non-parasitic, though the later entry of the parasite may increase the extent of the injury. Moreover the bringing together of a host and its parasite does not necessarily result in disease ; climatic or other environmental conditions must be favourable. It may thus be argued that the non-parasitic factor plays a part equal in importance to that of the parasitic agent in causing the disease.

It sometimes happens that a disease originally considered to be of parasitic origin is later shown to have a non-parasitic causation. The "bitten off" disease of tea seedlings and the "Diplodia" disease of tea bushes in Ceylon are two such examples. In other cases the reverse is true. But it is a safe rule to regard any disease of unknown origin as of parasitic causation, particularly if its occurrence in any way suggests that it is transmissible.

Among plant parasites the fungi stand pre-eminent, and, following the publication in 1853 of Anton de Bary's classical work on "Die Brand Pilze" which established their parasitism, the science of plant pathology has been built mainly on the study of their characteristics. For this reason, plant pathology and economic mycology (study of fungi) are almost synonymous terms.

Fungi are plants of relatively simple structure. In their simplest form, as in the yeasts, they may be merely rounded cells, but more typically they consist of delicate branched threads or *hyphae*, which individually are barely visible to the naked eye.

Collectively they form an interlaced tangle of cobwebby or woolly appearance, and this is termed the *mycelium*. A mycelium is, therefore, the vegetative body of a fungus, and its chief functions are the absorption of food and the nutrition of the reproductive system. As a general rule the mycelia of parasitic fungi are embedded within the tissues of the host plants, but their presence is made evident by lesions in the form of spots, cankers, rots or other symptoms of varied character. In some cases the hyphae are compacted to form cord-like strands termed *rhizomorphs*, which when running through the soil closely resemble roots; they afford a means by which the fungus can grow from one place to another. Such cords are not confined underground; they may occur on aerial parts, *e. g.*. "Horse hair blight", the cords of which closely resemble horse hair.

Like other plants, fungi pass through two phases in their life cycle, the vegetative and reproductive. Fungi reproduce themselves vegetatively very readily. Fragments of the mycelium when detached and placed in new situations, will continue to grow if conditions are suitable, and for that reason care has to be taken of disposal of diseased material. Some fungi also produce special aggregates of mycelium termed *sclerotia*. These vary very considerably in size and shape; they are hard, usually dark coloured, and well stored with food. They can withstand adverse conditions which would prove fatal to ordinary mycelia, and their function is purely reproductive. All fungi, with few exceptions, however, have special reproductive bodies, termed *spores*, which are of microscopic size. They have various names such as conidiospores, ascospores, basidiospores, etc., depending upon their method of formation, but in function they are alike, serving the same purpose for fungi as seeds do for the flowering plants. Owing to their minute size they are readily dispersed by air currents, though insects, birds and other animals, not excluding man, assist in their dispersal. The dissemination of minute spores of parasitic fungi, owing to their adherence to clothing, agricultural implements, planting material and merchandise, constitutes a real danger. The probabilities of a spore finding a suitable medium in which to grow is very small, but that is compensated for by the prolific numbers produced.

Fungi differ from most other members of the vegetable world in that they do not possess chlorophyll, a green colouring matter essential for the production of the world's food supply. The absence of chlorophyll affords a ready means of distinguishing the fungi from other filamentous plants such as the algae; also, it supplies the reason for the great economic importance of fungi. Being unable to manufacture their essential nutritional requirements from simple inorganic materials, owing to the absence of chlorophyll, the fungi are dependent on extraneous sources of organic food. That food supply can only be obtained from animals or plants, alive or dead.

The natural habitat of fungi is the soil. Were it not for the food requirements of fungi and bacteria, an even simpler group of organisms also without chlorophyll, there would be a great accumulation of fallen leaves, stems, fruits and animal remains on the soil surface. This litter, however, contains organic substances which the fungi and bacteria cannot themselves elaborate but which can be used for their nourishment. The complex organic substances are split into simpler compounds, some of which ultimately become again available to the living plant. The degeneration or decay of organic litter resulting from the activities of fungi and bacteria is not unrelated with soil fertility, though the full importance of fungi is possibly not yet fully recognised. By initiating decay, fungi may, however, cause heavy losses when such commodities as stored food or timber become the centres of their activities.

Organisms which live solely on *dead* organic material are termed *saprophytes*; those able to obtain their nutriment at the expense of *living* animals or plants are *parasites*. The majority of fungi are saprophytes, fulfilling a function as scavengers, but a few are *obligate parasites*, unable to live on dead matter even of their own killing and so are dependent upon the continuance of life of the host for their own support. Between these extreme classes are many gradations. There are fungi which normally live a saprophytic existence but are able at times to invade a living plant when the latter is weakened by age, mechanical injury or other cause. Others

can successfully invade, even when their hosts are vigorous, and then live saprophytically on the killed tissues. Some can attack only specific hosts, of one order, genus or even species while others can parasitise almost any plant with which they come into contact.

The intimate association of a fungus with a green plant is not necessarily one of parasitism. The association may be *symbiotic* and to the mutual benefit of both organisms. A well-known example of symbiosis is to be seen amongst the leguminous plants wherein the bacteria of the root nodules obtain their carbohydrates from the plant, and in return supply the green plant with nitrogenous materials. A fungus in symbiotic association with an alga (a green plant of simple structure) commonly forms a lichen; in association with plant roots, fungi form what are known as *mycorrhiza*. Mycorrhiza are essential for the healthy growth of many orchids, but little is known of their value to other plants, such as tea, with which they are commonly associated.

The essential difference between a saprophyte and a parasite is that the former cannot gain entry into a living host plant, or having gained entry it cannot subsist. The ability or otherwise of a plant to withstand attacks of parasitic organisms are termed *resistance* and *susceptibility*, respectively. The predisposing cause of these conditions constitutes a large, yet fundamental, problem for plant pathology. The characters on which resistance depends are usually obscure, but it is sometimes possible to indicate, in specific instances, an association of certain characters with an ability to resist invasion.

In any case of parasitism not only are there two organisms, the host and the parasite to be considered, but the environmental conditions also, by materially affecting both organisms, constitute an important factor. The effect of environment, particularly climate, on the incidence of certain diseases is very apparent in that some diseases are seasonal. In some cases it may be possible to foretell an outbreak of disease from the meteorological conditions, as definite conditions of moisture and temperature are necessary for the germination of fungus spores and the initiation of a parasitic attack. In general, environmental conditions determine whether a

susceptible plant will become parasitised or not ; they may also, if uncongenial to an otherwise resistant host, so lower its powers of resistance that it becomes susceptible to attack by fungi from which normally it is immune.

Good agricultural methods, by maintaining inherent resistance at a high level, and good plant sanitation, by removing sources of infection and preventing the formation of conditions favourable to infection, as far as is humanly possible, may do much to check disease. But it would be fallacious to conclude that the presence of disease is always indicative of bad agriculture. As is frequently found with root diseases, the very conditions which favour the host also favour the parasite. It is sometimes possible, with annual crops, to evade particular seasonal diseases by growing early maturing varieties, which, though susceptible, are harvested before conditions become suitable, and infecting spores become sufficiently abundant to cause serious harm. Suitable crop rotation is also an important factor in reducing the liability to disease. But neither of these methods are applicable to permanent crops like tea.

Cultivated plants as a rule are more susceptible to fungus diseases than are their wild prototypes. This may be a result of cultivation and a resulting development of more succulent structures, having thinner cell walls which offer less mechanical resistance to penetration by invading fungus hyphae, or, more probably, it is a consequence of interference with natural selection. In nature, the continued existence of a species depends upon its ability to reach maturity ; an inability to reproduce its kind results in extermination. If a species tends to increase, its diseases tend to increase correspondingly and so cause a diminution of productivity. Thus an equilibrium or natural balance is set up. Resistance to a specific disease, however, is a genetic character known in many cases to be inherited in accordance with Mendelian laws. In nature, the more susceptible individuals fail, and selection is directed towards resistance ; but cultivated species are selected mainly for other desirable characters. The possibility of the production of varieties which combine resistance to specific disease with other desirable characters is, however, a subject not overlooked by plant breeders.

When a host and parasite have long been associated, as is the case when both are native of the same country, there is a tendency, as already explained, for the host to build up a power of resistance and for a balance to become established. The introduction of another parasite from abroad may find the host unable to withstand it, and, given suitable conditions, an epidemic may result. Some of the worst epidemics amongst *plants have* been caused in this way. The chestnut tree blight in the United States followed the introduction of a fungus on a resistant species from China and the mildews of the grape vine and gooseberry reached Europe from America. Nearer home, the first occurrence of oidium on rubber in Ceylon coincided in time with the importation of budwood from the Dutch East Indies for grafting purposes, and it is a matter for speculation whether the disastrous coffee leaf disease was not an importation from Africa. The introduction of parasitic fungi on seeds or other planting material is, therefore, a very real danger, and the need for efficient quarantine and inspection of such imports cannot be overrated.

It is, of course, not essential for a new parasite to be imported before an epidemic may occur. Sporadic disease, *i.e.*, those which affect a plant here and there, given favourable conditions which either lower the resistance of the host or increase the vigour of the parasite, may become epidemic. Neglect of certain diseases, thereby allowing the production of infective spores to proceed unchecked, may have serious consequences, particularly where extensive areas are planted with one perennial crop susceptible to the disease, as the risk of a spore meeting a suitable host is much enhanced.

In the foregoing is briefly sketched the economic importance of fungi in the *role* of parasites as a causative factor of plant disease. They may, however, cause disease in animals also, particularly insects, and then their activities may be beneficial to the agriculturist if the parasitised insects are plant pests. The use of fungi for the biological control of insect pests, however, has not met with much success.