The Papua and New Guinea

Agricultural Journal

Vol. 10 July, 1955 No. 1

THE ROOT DISEASES OF CACAO IN PAPUA AND NEW GUINEA

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Summary

A GENERAL account is given of the mode of distribution and the action of the fungi which cause root diseases of cacao in Papua and New Guinea. Methods of control are discussed and recommendations are made.

A key is provided for the identification of four root diseases; by means of a second key the fruiting bodies of root-disease fungi and some related saprophytes may be identified. Symptoms of the diseases and representative fructifications are illustrated with photographs.

A short glossary is provided and some terms are explained also by line drawings.

Introduction.—

Most tropical tree crops are subject to attack by several species of root-rotting fungi. These fungi, and the diseases that they cause, have been investigated fairly thoroughly in several parts of the world so that the more important features of their biology are well established. Accounts of this work have been given by Sharples (1936) and Garrett (1944); the root diseases occurring in Papua and New Guinea have been discussed briefly by Henderson (1954).

In addition, a number of related species of fungi are able to grow upon moribund or dead trees and may thus be mistakenly supposed to have caused their death. The object of this article is to present information which will enable planters to distinguish between the two groups of fungi and to identify the commoner species of each; in addition the biology and control of root diseases will be discussed.

Although cacao is the crop with which this account is primarily concerned, some of the pathogens attack rubber and tea as well as shade trees such as *Leucaena glauca.*

Parasites and Saprophytes.—

Unlike green plants, fungi are unable to photosynthesize and so are dependent upon external sources of energy; one such source is living or dead plant material. The organisms that obtain their food from living tissues are called "parasites", while those that live on dead tissues are termed "saprophytes". These two groups are not absolutely distinct from one another, for there are organisms of intermediate type. Thus the following classes can be distinguished :—

(*a*) Obligate parasites: organisms that can exist only on a living host.

(*b*) Facultative saprophytes: organisms which are usually parasitic in habit, but which may exist saprophytically.

(*c*) Facultative parasites: which are normally saprophytic, but which may become parasitic under certain conditions.

(*d*) Obligate saprophytes: which can grow only on dead tissues.

The fungi that cause root diseases of cacao are all members of groups (*b*) and (*c*), whereas the fungi that may be confused with them belong to group (*d*).

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Action of Root-disease Fungi.—

When a fungus invades the tissues of a root, it usually penetrates to the water-conducting elements of the wood. This tissue consists largely of vessels which traverse the length of the tree and are interrupted by relatively few cross walls; the presence of the fungus blocks the vessels and reduces their efficiency in conducting water.

Simultaneously, the fungus secretes substances (enzymes) which destroy the structure of the wood. Wood is composed of two main components: cellulose and lignin. Under the action of the appropriate enzymes, these complex substances are converted into simpler compounds which can be absorbed by the fungus and used as a source of energy; in this way the wood is rotted. The colour of the rotted wood depends upon the type of enzyme that has been secreted. When the wood is rather lighter in colour than healthy tissue ("white rot") the lignin has been destroyed while, in wood that is darker than normal ("brown rot") the cellulose has been attacked.

Because the development of the parasite occurs internally to the host and below ground-level its presence is often not noticed until the fungus is thoroughly established, and the tree displays obvious symptoms.

Root Diseases of Cacao.—

Four important root diseases have been recorded on cacao in this Territory. The common names of these diseases and the names of the fungi associated with them are as follows:—

(*a*) White root disease—*Fomes lignosus*, Klotz.

(*b*) Brown root disease—*Fomes noxius*, Corn.

(*c*) Wet root disease—*Ganoderma pseudoferreum* (Wakef.) Ov. et Stein.

(*d*) Collar rot or dry root disease—*Ustilina deusta* (Hoffm. ex Fr.) Petr. [Syn. *U. zonata* (Lev.) Sacc].

These four root diseases may be divided into two groups depending upon the behaviour of the casual fungus: the Fomes group, comprising the first three members of the list, and Ustilina. Members of the Fomes group possess a pored fruiting body which produces spores in immense numbers. However, infection by means of wind-borne spores is probably a rare occurrence. Usually a cacao tree becomes infected by the fungus spreading underground from the stump of a forest tree or from pieces of wood in the soil. Fungi of this group are normally present among the roots of the forest trees and, when the jungle is cleared, they establish themselves in stumps or logs at the expense of which they derive their energy. However, unless they quickly invade the newly-felled tree, it will be colonized by saprophytic fungi so that the root-disease fungi are unable to establish themselves.

Eventually, the food reserves of the log or stump are exhausted and the root disease fungus must find a new source of energy. Migration is achieved by means of rhizomorphs, which are strands of fungal filaments or hyphae. Although capable of penetrating for short distances through root-free soil, the rhizomorphs can grow more readily and for longer distances along a series of solid surfaces such as roots or pieces of buried wood. It is during the migratory phase that the fungus is most likely to attack the roots of cacao trees. Furthermore, the food reserves of a small stump are exhausted more readily than those of a large one so that, generally, small stumps or small pieces of wood represent a more immediate source of infection than do larger ones.

Similarly, spread of the pathogen from a diseased to a healthy cacao tree occurs by the rhizomorphs growing from the roots of the diseased plant and along those of the healthy tree.

In contrast to the situation found among fungi of the Fomes type, Ustilina does not produce well organized rhizomorphs and the fungus can spread underground only when the roots are in contact. The fungus is able to colonize dead logs and stumps upon which its fruiting bodies are sometimes found. Infection of cacao may occur to some degree through the agency of wind-borne spores, but it is likely to occur more frequently by the healthy tree being wounded with an implement carrying spores or other infective material which had been picked up by slashing a fructification of Ustilina or the bark of a diseased tree.

Control of Root Diseases.—

Attention to cultural practices can help to reduce the number of trees which are attacked by root diseases. Such practices include care of drainage and shade manipulation in addition to eradicating all obvious sources of infection, such as logs and stumps, that it is practicable to remove. Despite all precautions some trees will be lost through the agency of root rots, and the number of trees that are attacked will vary with the type of soil and other environmental conditions. However, constant attention to measures of control will decrease the number of trees that are killed and will prevent the loss of large patches of trees.

The essential features of controlling root diseases are the removal of diseased trees and all of the infected material with which they were in contact, thus preventing the disease from spreading to adjacent healthy trees.

In a previous section is was stated that, in young plantations, the stumps and buried wood may act as centres of infection from which pathogenic fungi can attack the cacao trees. Consequently, the only way to eliminate root diseases would appear to be clean clearing including the removal of all roots from the soil; such a practice is not feasible.

Instead, attention should be given only to the areas of the plantation where root disease is definitely present. If a tree dies in an immature plantation it should be dug out promptly and the cause of its death determined. The root system should be traced out and the source of infection, together with all other buried timber, should be removed. All of this infected material should be burnt in the hole. Simultaneously, a check should be made to find whether the roots or surrounding cacao or shade trees may have become infected. If this has occurred, a trench about two feet deep should be dug to surround a complete row of healthy trees, the soil being thrown inward on to the infected area. The trench may be filled in again fairly promptly but should be reopened at intervals of twelve to eighteen months in order to cut the roots which would have grown through the soil to reestablish contact with the clean part of the plantation; simultaneously, these roots can be inspected for fungal infection. This practice should be continued until the area has been free from disease for six months. It will be seen that the basis of this procedure is to use the young cacao trees to locate foci of infection and to concentrate attention upon these areas. Logs and stumps that have been colonized by purely saprophytic fungi are not a source of danger, and may be left to rot.

In mature plantations, the root system of adjacent trees probably form a fairly continuous network. Thus, when a tree dies from a root disease it is advisable to dig a trench enclosing a ring of apparently healthy trees. During this process the cut roots should be examined for signs of infection and, if necessary, the trench extended to enclose another row of trees. Removal of the diseased tree and other operations should be carried out as described above.

Where isolated trees have been killed by members of the Fomes group of root-disease fungi replanting should be delayed for about six months. Where infection is more extensive and had to be limited by means of a trench, replanting should not be attempted until the area has been free from disease for a similar period.

With respect to replacement of trees killed by collar rot there seems to be little reason why immediate replanting should not be practised provided that no infected wood is left in the hole when the soil is replaced. Experiments are in progress to obtain more information on this topic, but, meanwhile, it would be well to follow the procedure advised for trees killed by the other root diseases.

Identification.—

The identity of the fungus causing a root disease can be determined by the symptoms that it causes in the host, or by its fructification. However, the fruiting bodies of root-rotting fungi are found more frequently on dead stumps than upon the standing host. Thus it is nearly always necessary to dig up the affected tree in order to discover the identity of the pathogen that killed it; simultaneously an important source of infection is removed from the plantation.

Accordingly, a key is given by means of which the identity of root diseases may be determined; it is based on the appearance of the diseased root system. A second key, which depends upon the type of fruiting

body, includes several of the commoner saprophytes that could be confused with the parasites. The method of using the latter key is simply to choose the particular alternative that fits the specimen at hand, always starting from the beginning, then proceed until the name of a fungus is reached. In Figure 1 are illustrated some of the terms used in the key. It will be noted that most of the fructifications described in the second key have a pored layer. When such a fungus is cut across it will be seen that the upper layer is solid and usually homogeneous, while the lower layer consists of closely-packed tubes within which the spores are produced. A hand lens giving a magnification of about ten times would be found useful for the examining of these fructifications.

Literature Cited.

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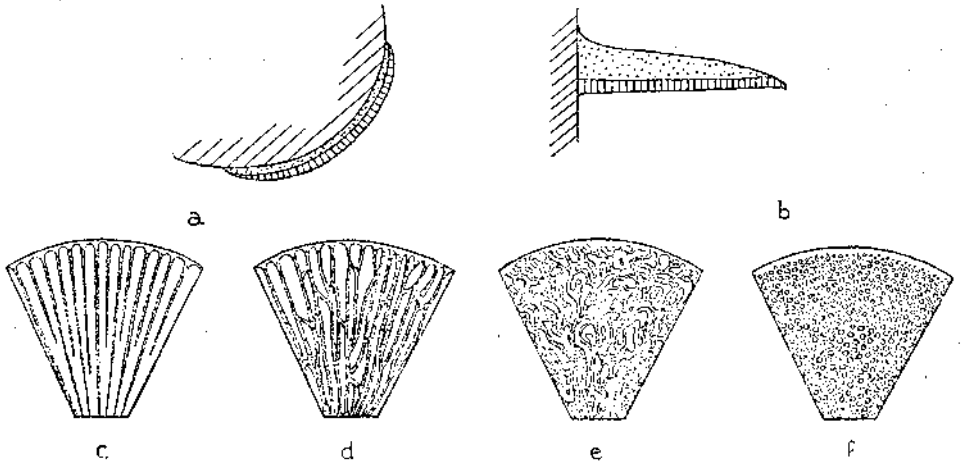

Fig. 1.—Explanation of terms used in the text: (a) and (b)—Type of fruiting body; (a) Resupinate. (b) Bracket-shaped. (c) to (f)—Lower surface of fructifications: (c) Gilled. (d) Lamellate. (e) Daedaloid. (f) Pored.

Glossary.

Collar : The trunk of a tree at the region of ground-level.

Fructification : A fruiting body. The structure in which the spores of a fungus are formed.

Hypha : A thread of fungal material. Fungal structures, including the fruiting bodies, are composed of interwoven hyphae.

Mycelium : A mass of hyphae.

Parasite : An organism living upon and getting its food from another living organism (its host).

Pathogen : A parasite able to be the cause of disease.

Photosynthesis : The process by which green plants synthesize carbohydrates from water and carbon dioxide with the aid of energy absorbed from sunlight.

Rhizomorph : A cord-like structure composed of hyphae.

Saprophyte : An organism using dead organic material as food and causing its decay.

Sessile : Refers to a fructification which does not have a stalk.

Spore : A general name for a reproductive structure in fungi. Conidia are spores which are produced asexually.

KEY TO ROOT DISEASES OF CACAO

Disease	Appearance of Root System	Appearance of Wood of Root	Abundance
White Root Rot	No soil adhering to roots. Rhizomorphs and white fans of mycelium on surface of roots	Wood remains firm. Paler colour than healthy tissue	Common, especially in Popondetta District.
Brown Root Rot	Soil adhering, with inclusion of small stones, to surface of roots. Layer of brown or white mycelium beneath the soil is seen when the root is scraped. Brown crust often formed at the collar of affected trees	Pale colour; soft but dry. Fine brown lines run through the wood in fairly advanced stage of disease	Common. Encrustation at collar is often found in the Gazelle Peninsula.
Wet Root Rot	Tendency for some soil to remain attached to the roots. Redish membrane often present on surface of root beneath layer of soil	Pale colour; soft and spongy so that water can be squeezed from it. Lower surface of laterals usually attacked first	Occasional.
Collar Rot	Often attacks at the collar, where a black, plate-like fructification is formed. Roots may appear healthy for some time	Black lines in the wood when disease is in advanced condition	Occasional.

KEY TO FRUCTIFICATIONS OF ROOT DISEASE FUNGI AND RELATED FUNGI

1. Fructification smooth on lower surface	Saprophytes and epiphytes.
Fructification with gills	
or Fructification consisting of black or dark brown incrustation	2.
Fructification not corresponding to any of above	3.
2. Fructification consisting of smooth, hemispherical black lumps	*Daldinia concentrica.*
Fructification consisting of flat plates or incrustations, often in the collar region	*Ustilina deusta.*
3. Fructification resupinate and with pores	*Poria* spp.
Fructification bracket-shaped and with pores or some modification of them	4.
4. Lower surface of fructification lamellate	*Lenzites* spp.
Lower surface of fructification daedaloid	*Daedalea* spp.
Lower surface of fructification not so	5.
5. Pores drawn out at lower ends to form "teeth"	*Irpex* spp.
Pores very large and hexagonal or angular	*Hexogona* sp.
Pores simple, circular or angular	6.
6. Fructification woody in texture; upper surface covered with a brown varnish-like crust; lower surface white	7.
Fructification fleshy, leathery or corky in texture	8.
7. Fructification sessile, varnish-like layer extending over almost entire upper surface	*Ganoderma applanatum.*
Fructification sessile, varnish-like layer restricted to margin	*Ganoderma pseudoferreum.*
Fructification with a long, brown, shining stalk	*Ganoderma lucidum.*
8. Pores readily visible to naked eye	9.
Pores minute with a hand lens	10.

Key to Fructifications of Root Disease Fungi and Related Fungi—*continued.*

9. Pores shallow; entire fructification a bright orange-red colour	*Polystictus cinnabarinus.*
Pores shallow. Centre of fructification dark red, with a white margin of variable width	*Trametes corrugata*
Pores deeper (to half thickness of fruiting body). Upper surface bistre and concentrically zoned in yellow-brown shades	*Polystictus occidentalis.*
10. Upper surface of fructification orange-yellow and concentrically zoned. Pores dark orange. When cut, the fructification shows an upper white layer and a bright orange lower layer	*Fomes lignosus.*
Upper surface of fructification dark brown with a yellow margin; pores dark brown, often with a greyish bloom. Woody in texture	*Fomes noxius.*
* Several other genera of zoned fungi also form resupinate fruiting bodies in addition to their normal bracket-shaped fructifications, e.g., *Fomes lignosus.*	

Fig. 2.—Tree killed by root disease. Note that the dead brown leaves remain on the tree and hang vertically.

Fig. 3.—White root rot. The root system is free from encrusting soil. (Compare with Fig. 6 Brown root rot.)

Fig. 4.—White root rot. The infected wood of the tap root is a lighter colour than that of the trunk.

Fig. 5.—Rhizomorphs on the surface of cacao roots; they consist of white cords of mycelium.

Fig. 6.—Brown root rot. Note the crust of soil which adheres closely to the root system; beneath this crust is a layer of brown mycelium.

Fig. 7.—Brown root rot. In the northern Gazelle Peninsula, where the soil is derived from pumice, "Fomes noxius" often forms a brown encrustation at the collar of the affected tree. Sometimes a similar structure may be formed around a wound in the trunk.

Fig. 8.—Wet root rot. Sometimes trees that have been attacked by wet root rot show a marked development of adventitious roots parallel to the tap root. This represents replacement of the diseased tap root by adventitious roots.

Fig. 9.—Collar rot. The conidal stage of "Ustilina deusta", consisting of plates of fungus, each with a grey centre and a white margin. In this example the fructification was situated in an uncommon position, just below the point of ramification.

Fig. 10.—"Black lines" in wood. These are produced by "U." "deusta" and related fungi.

Fig. 11.—Fructification of "Daldinia concentrica", consisting of hard, hemispherical, black structures. When a fructification is cut across, a pattern of concentric circles is seen. Common on dead logs.

Fig. 12.—Fructifications of "Schizophyllum commune". This is a small, grey, gilled fungus which is common on recently-felled timber. In dry weather the fruiting bodies collapse as shown in the photograph, but after rain they revive.

Fig. 13.—Fructification of "Fomes lignosus". A fairly rough, bracket-shaped, pored structure. When fresh, it has zoned, orange-yellow upper surface with a yellowish-white margin. The lower, pored surface is bright orange. (Scale is six inches long.)

Fig. 14.—Fructification of "Fomes noxius". The actively-growing fruiting body has a dark brown upper surface and a very distinct yellow margin. The older fructifications are completely brown and may be two or three inches thick; apparently they can persist for several years.

Fig. 15.—Fructification of "Ganoderma applanatum". A bracket-shaped, woody structure with a zoned, cinnamon-brown upper surface which is partly covered by a varnish-like coating. In young specimens the margin and pored lower surface are white, but become brown when bruised or with age. [Scale is six inches long.]

Fig. 16.—Fructifications of "Polyporus occidentalis". A leathery, bracket-shaped fungus with a felt-like upper layer zoned in shades of brown. Very common on dead logs.

Fig. 17.—Fructification of "Tram
etes corrugata". This structure
thin and leathery in texture; the pore
are shallow and visible to the naked
eye. The upper surface has a whit
margin of very variable width, an
a dark red inner region. (Scale
six inches long.)

Fig. 18.—Fructifications of "Hex-
agona sp.". Note the large, angular
pores. (Scale is six inches long.)