AND NEW GUINEA.
DISEASES OF COCONUTS (COCOS NUCIFERA) IN PAPUA

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INTRODUCTION.

This article is intended to present a preliminary account of the important fungus and physiological diseases affecting the coconut palms in the Territory of Papua and New Guinea. Several investigations were made previously pre-war by officers of this Department when a suitable well-equipped laboratory (later destroyed during the war) was available. It is considered, however, that sufficient data and recorded observations, although incomplete, are on hand to be of sound practical value to the local coconut planters; these may prove of general interest to investigators and others interested in the coconut and copra industry. A good deal of the information presented has been gleaned from unpublished departmental reports. Further, a study of the literature available from other countries proves most illuminating when their findings are compared with what obtains on plantations in this Territory.

It is pointed out that, although the diseases here are associated with fungi, physiological causes and soil deficiencies have not been investigated to any great extent up to the present time. This work is gradually being expanded by the Department of Agriculture. The aggregate losses due to these causes may not be so noticeable as those due to insect pests, particularly the leaf-eating types, but their effects are always present. It is certain that the physiological effects due to soil deficiencies and such diseases as "lightning strike" causing "False bud-rot" are amongst the most serious conditions affecting coconut palms in this Territory. It is known that coconut palms with reduced vigour, due to any causes whatsoever, become more liable to fungus attack, hence soil condition, drainage, cultural conditions and general health of the palms are usually intimately associated. It must be remembered that injuries and wounds caused by insects often open the way for severe fungus infection thus aggravating any damage already done. Some diseases as yet unrecorded here are listed and described:

LIST OF COCONUT DISEASES RECORDED IN THE TERRITORY OF PAPUA AND NEW GUINEA TO THE PRESENT TIME.

Bud Rot.

Epidemic Bud-rot **(Phytopthora faberi)**.—Suspected and described by Bryce and others; in view of recent findings this is present but not widespread.
False Bud-rot.—Primarily due to lightning strike, or, in some cases, fire.
Sporadic Bud-rot.—Mainly due to injuries. Numerous cases recorded from all parts of New Guinea.
Tapering Steam (see below).—Leading to collapse of the cabbage.

Root Rots.

Fomes Lignosus (probably East Indian type)—**Rigidoporus microporus.**
Fomes lucidus—Ganoderma lucidum.
Brown Root-rot—**Fomes noxious.**
Rhizoctonia bataticola—Macrophomina phaseoli.—So far seen only on other plants here; recorded on coconuts in other countries.

Stem Diseases.

Stem Bleeding—Thielaviopsis **(Ceratostomella paradoxa).**—Often associated with Lightning Strike.
Marasmius palmivorus, Polyporus spp.

Leaf Diseases.

Thread Blight—**Corticium penicillatum.**
Grey Blight—**Pestalozzia palmarum.**
Leaf Spotting.—Due to **Helminthosporium spp.** (probably **H. incurratum)** or an **Acrothecium.**
Sooty Mould—**Capnodium** or **Meliola spp.; Anthostoma Cocois** (recorded by Rechinger).
Silver Leaf.—Cause not known, thrips may assist, fungus present.
Leaf-droop—Soil deficiency and various fungi.
Leaf-break.—Soil deficiency. **Botryo-diplodia Fusaria,** etc.
Tip-wither.—Probably similar to above; **Nectria** stage present.
Bittern Leaf—**Thielaviopsis spp.**

Leaf Blight—Bacterial.

Diseases of the Nut.

Ring Disease—**Botryo-diplodia spp.** (identified by R. J. Noble).
Nut-fall.—Associated with environmental and soil conditions, insects and various fungi.

Leathery Copra.—Associated with soil deficiency.

Physiological Disorders.

Chlorosis and Die-Back.—Due to soil exhaustion. Often leads to collapse of the cabbage.
Frond Choke.—Probably also hereditary. Believed that it may be due to soil disorders.
Drought Wilt.—Common in times of drought. Some forms of Tip Wither may belong to this category.
Obscure physiological disease in New Ireland, causing wilting of central fronds of young palms.

Suspected Virus Diseases.

Head Droop (also known as Cabbage Droop, Corkscrew or Cabbaging).
Genital Abnormalities (possible Mutations and Strain Effect). Yellowing of the palms.—May be genetical, as well as due to disease.
Female Palms.—Male flowers suppressed; nuts often without embryos or with very little copra.
Particular palms produce soft copra, which will not cure; might be hereditary in some cases.
Branching and twin palms.
Leaf bases remaining attached to the palms, either on the whole or portion of the trunk.

Some Serious Diseases Recorded Overseas But Not Here.

"Cadang Cadang." — Disease of coconuts in Philippines — suspected virus disease.
Red Ring Disease—Nematode **Patho-aphelenchus cocophilus** (Cobb).
Root Disease **Diaporthe perniciosa**—Marshall.
Bronze Leaf Wilt—Suspected physiological (or Virus) in West Indies.

Bud-rot.

According to investigators, but-rot is generally regarded as a serious disease in most tropical countries. Ocfemia (48) states that bud-rot has been recorded in Portuguese East Africa, Ceylon, India, Malabar, Florida, U.S.A.,

Trinidad, Jamaica, British Guiana, The Philippine Islands and several other countries.

One of the first records of an epidemic disease of coconuts was from the West Indies in 1934. Heavy losses occurred in Jamaica from 1891 to 1910 and at about the same period in Trinidad.

In the Philippines the disease spread very rapidly and the coconut planters became alarmed because their plantations were threatened with destruction. Through the efforts of Dr. Copeland (24) in Laguna (1908) an act was passed requiring that all coconut trees infected with bud-rot be cut down and burned. The disease has been considered serious in the Territory of New Guinea and is the subject of legislation, hence it is believed worthy of detailed discussion.

Bud-rot was proclaimed under the "Plantation Diseases and Pests Ordinance of 1916" in the Laws of this Territory (33) as a disease subject to inspection by qualified officers of the Department of Agriculture. Remedial measures were laid down, and penalties provided for in case of non-compliance with the provisions of the Ordinance. In the Ordinance the indications of bud-rot were stated as follows:

"Withering and turning brown of the central shoot (which can then be easily pulled out by hand) followed (or occasionally preceded) by the decay of the other fronds, and a soft, vile, putrid, brown rot in the heart, followed by the whole top falling off, leaving only the bare trunk."

Approved combative measures cited were: Immediate felling, cutting up and burning of affected palms, together with spraying of all palms and ground within a radius of 150 feet with Bordeaux mixture.

It is now generally recognised that bud-rot may be due to a variety of causes, hence evidence of the power to infect is necessary to establish the existence of any specific bud disease in a particular country or locality. It also appears necessary to differentiate between the rotting of palm buds and true bud-rot diseases. As bud-rot may be brought about by so many causes it represents a condition resulting from a number of such causes rather than a specific disease.

There have been several individual records of bud-rotted palms occurring in this Territory, not including those now known to be associated with lightning-struck areas. The incidence of these bud-rotted palms led Dr. Bryce (13-18) (late Director of Agriculture in New Guinea) to suspect that true bud-rot was present in this Territory. So far as one can gather from the records, no actual fungi or bacteria which could be held responsible for the disease were isolated. He described the condition of bud-rot (13) in a departmental leaflet and mentioned that in New Guinea this disease had been reported from New Ireland, New Hanover and the Witu Islands, and was no doubt generally distributed in the Territory.

Phytopthora faberi, which several authors consider to be identical with **Phytopthora palmivora,** was described by the same author (17) as being present on cocoa here, causing purple canker and pod rot. This was significant, as bud-rot in India (19) Philippines (56) and other countries is usually attributed to the fungus **Phytopthora palmivora.** Thus it was legitimately considered that where Phytopthora was present on cocoa it would most likely be found on coconuts.

Ashby, S.S. (6) stated that, although the Phytopthora of pod-rot of cacao in the West Indies appear to be the same species as that on the coconut, it is not believed to be the same strain, since the form from the palm has not been found able to rot cacao pods.

The Bud-rot Position in Other Countries.

The position in New Guinea, however, is, in the author's opinion, analagous with what occurs in Malaya, where **Phytopthora spp.** (59-61-62) is found attacking many plants, but was seldom seen on coconuts. When it does occur under specific conditions it can be serious. As an illustration, Thomson, Malaya (78) inoculated 40 coconut palms just above the bud with different strains of Phytopthora isolated from coconut, cotton, rubber and cacao, but only one positive result was obtained with **Phytopthora palmivora** from a coconut derived from India. Dr. Muller(44) stated personally that bud-rot due to **Phytopthora faberi** was practically of no importance in Java or the Moluccas and that only a couple of cases of probable infection had been reported.

The present author has only in one area so far seen this fungus on coconuts here; one case of spear die-back of oil palms at Keravat was due to a fungus thought to be **Phytopthora spp.** as seen under the microscope.

Stockdale 1906(75) pointed out that a proportion of the bud-rot occurring in Trinidad was purely secondary in its nature, being a consequence of the failure of the palms brought about by so-called root disease. This was later proved to be red ring disease (46) due to infestation with a nematode worm.

Johnson 1912(37) came to the conclusion that **Bacillus coli** (Esch. Mig.) or an organism indistinguishable from it, was believed to be capable of causing rot of soft tissue of the coconut plant and perhaps responsible for coconut bud-rot in the Philippines. This was due to **Phytopthora faberi,** and that the bacterium coli was not the cause of epidemic diseases there. He found that infection could be obtained through the growing point with cultures of this bacteria, but only in the case of severe injury, or excessive dampness. Bryce 1924(13) stated that it was rather an open question as to whether **Bacillus coli** is in this instance more than secondary, i.e., follows the Phytopthora attack and completes the ruin of the palm.

Ashby 1924(4) expressed the opinion that there were two bud-rots in the West Indies, one fungoid caused by Phytopthora and one bacterial caused by a bacillus, probably a strain of **Bacillus coli,** but there is some doubt as to definite proof. (See also discussion by Elliott(27)).

Tucker 1925(80) in Porto Rico isolated an organism resembling **B. coli** from diseased buds, but the results of his inoculations were negative. He reproduced the disease **Phytopthora faberi** with or without wounding.

Dr. Butler, Director of the Imperial Bureau of Mycology, at the Imperial Botanical Conference, July, 1924, (20) indicated that he was of the opinion that **Phytopthora palmivora** was the only vegetable parasitic organism which had been proved to cause the destructive bud-rot of palms and was capable of attacking perfectly healthy palms and inducing severe epidemics of disease.

Stapp 1928(73) stated that it remains to be determined whether coconut bud-rot is due to bacteria ofrungi or both. Alston 1924 and 1925(1) British Guiana, stated that a disease, which was responsible for the dying out of the coconut palm in certain localities, was falsely designated by the name bud-rot for the reason that the bud was, as a general rule, the last portion of the crown to become affected, whereas in true bud-rot a disease caused by a species of Phytopthora, the earliest and most characteristic symptom was infection of the bud followed by collapse of the whole central whorl. A similar condition called "bud-rot disease," practically identical with the above, was described from Trinidad.

At the Imperial Botanical Conference it was suggested that the term "coconut wilt" be applied to these occurrences. Briton Jones 1928(9) distinguishes two forms of the root disease of coconuts recorded by Stockdale (75) and Nowell (46-47) in Trinidad, which he named respectively "bronze

leaf wilt'' and ''yellow leaf'' or ''tapering stem wilt.'' The latter is distinguished by a yellow discolouration of the leaves progressing from the tip backwards while all the leaves, including the central ones, become dwarfed. The latter is a chronic malady and its history and effects have not yet been worked out; its described symptoms are very similar to those described by Park as caused in Ceylon by a root disease associated with **Macrophomina phaseoli.** The symptoms described also resemble the tapering stem and chlorosis which is believed to be due to soil deficiencies present in New Guinea.

Briton Jones, in his book ''Diseases of the Coconut Palm'' 1940(87) described the bud-rot complex and sub-divided the old term ''Bud-rot'' into the following separate diseases: ''Bronze Leaf Wilt,'' ''Phytopthora Bud-rot,'' ''Tapering Stemwilt'' or ''Pencil Point,'' ''Red Ring Disease,'' caused by **Aphelenchus cocophilus.**

The pre-war Director of Agriculture, Mr. G. H. Murray(45) who saw these occurrences in Trinidad, felt certain that the bronze wilt does not exist in Papua and New Guinea; and did not think that the tapering stem disease is the same as the one found in this country.

Smith, 1934(71) Jamaica, states that in Montego Bay area a form of bud-rot in which no fungal pathogens appear to be actively indicated has caused severe damage.

Identification.

The following description of bud-rot is collated from various publications. The first visible indications of the disease are the falling of the young nuts on the palm and the withering of the youngest leaf; there is no known way by which the earliest stage of the infection may be detected as, when the first visible symptom, or the browning of the young leaf, occurs, the growing point is already rotted. The young emerging leaf becomes yellowish brown or light brown and projects upwards sword-like from the crown. The leaf dies because the softer part of its base is completely rotted, and if pulled firmly can be drawn out from the crown or enclosing leaf sheath. At the base will be found a soft grey or brownish mass of rotting material which emits a vile smell. The stench is apparent on merely walking past a diseased palm. If the diseased palm is allowed to stand the youngest leaves become involved and soon die, the oldest leaves being the last to be affected, at which stage the bud or cabbage is completely decayed. The dead central leaf is often first broken by the wind (believed to be more typical in Phytopthora infection) and may fall to the ground. The older leaves may remain green and retain their usual position for several months, but as they die they are not replaced, and finally the trunk is left bare.

Only the soft parts are affected, the hard trunk and the roots remaining healthy, but once the bud is destroyed the whole palm of necessity dies. Often the young spathes are rotted in the same manner as the bud, and often the young racemes of flower heads will be found dead when the spathe opens. A close examination of these dead racemes will show that they are invaded by the fungus at their bases. Sometimes, but not in this case, rows of dark brown spots across the pinnae or leaflets may be seen, due to infection by Phytopthora.

Nowell 1921(46) described bacterial bud-rot and stated that this does not affect the central bud alone, but may commence anywhere in the crown, either at the base of the leaves or inflorescenses or on the tissues between them. It never extends far on the leaf stalk nor does it affect the woody part of the stem. Only in exceptional cases does it travel more than a foot or two into the softer central portion of the stem below the crown. It was pointed

out that typical bud-rot also follows rapidly on the death of healthy trees from poisoning or severance of the stems.

Sharples, Malaya 1924(59) at the Imperial Botanical Conference indicated that some factors associated with severe attacks of bud-rot in Malaya are injuries caused by Black Beetle **(Oryctes rhinoceros)** or Red Strip Weevil **(Ryncophorus schach)** and tidal floodings occurring in fields adjacent to rivers where sufficient protection had not been made to prevent the entry of water. According to reports submitted to the same conference (5-19-25-47-59) swampy conditions of the soil give rise to a condition which results in bud-rot. This has been found to be the case in New Britain. Droughts may give rise to a similar condition, as may ill-defined root troubles. It was also asserted by some that the planting of immature nuts may cause a kind of bud-rot.

Emphasis was placed on the fact that growers of coconuts must not rush to the conclusion that cases of bud-rot on their estates may be caused solely by parasitic organisms. Good cultivation, good drainage and satisfactory manuring are likely to result in a reduced number of cases of bud-rot in palms. Correct agricultural methods would result in smaller losses from pests and diseases, although some epidemics are bound to occur.

Bud-rot in Fiji.

Simmonds, in 1921 and 1922(63-64-65) describes an outbreak of bud-rot in Fiji which he considered to be true bud-rot, and as this is one of the South Sea Islands, it is of more than usual interest to New Guinea planters. He stated that the disease seems to have been present in Fiji for at least ten years, but did not cause much anxiety until the years mentioned, when a large number of palms were destroyed on account of it. The disease was almost confined to the wetter portions of the group, where it was commonly found on the back parts of the estates along the foothills. The central heart rotted, leaving the outer leaves and ring of nuts apparently healthy. A similar bud-rot outbreak occurred in Pondo, New Britain, in 1941.

When an affected palm was cut down and the outer leaves removed separately, a greenish brown or yellow spot was seen and this communicated with the central portion of the tree, the whole of which was found to be rotten and in a very foul-smelling condition.

The investigations largely dealt with an outbreak at Taviuni, from which Dr. Garment(32) conducted microscopical examinations of the diseased specimens. He found bacteria associated with each, but believed the occurrence to be secondary. In a culture of diseased tissue he found a fungus which appeared to resemble closely **Phytopthora palmivora.** The Imperial Bureau of Mycology, in reporting on a similar specimen, could only identify the fungus as an introcellular Phycomycete (fungus group) whose mycelial characters may be similar to Phytopthora as no fruiting bodies were present.

Both Simmonds (2-65) and their Inspector of Plantations commented that the older coconuts growing near the sea shore are attacked very slightly, but that the disease was most prevalent on young coconuts following a strip of land at the bases of the foothills. This was a region of continuous rainfall and frequently of poor drainage, thus the coconuts were growing under unfavourable soil and climatic conditions. This indicates a more potent cause of apparent bud-rotting, and it is believed by the present author that this is comparable with some of the areas seen in the heavier soils of New Ireland some distance from the Beach.

Some Examples of Reported Bud-rot Infected Palms in New Guinea.

In May, 1921, at Talasea, New Britain, a plantation inspector stated that he noticed six trees suffering from what he considered was bud-rot

although no microscopical examination was made, and that many more palms had been destroyed previously.

An inspector for the Expropriation Board, in September, 1921, sent in a specimen from New Ireland from a palm which had earlier been attacked by Rhinoceros beetle; this was not considered sufficient to destroy the palms, which undoubtedly died from cabbage rotting. Several palms were affected in the same way and were within a few yards of one another. The symptoms appeared to be the same as bud-rot except that the smell, although very pronounced and persistent, may not have been typical. (The author believes that this was probably a case of lightning strike).

It was also stated that, although palms with rotten cabbage had previously been observed, it was thought that most of the cases were caused by beetles entering the cabbage. The soft tissues had been exposed to infection from bacteria and other sources, which set up a rot.

Over 600 palms, most of which were destroyed, were reported to have been affected by beetles and red palm weevil on one plantation and a fair number of these showed rotting of the cabbage.

At Talasea in March, 1922, the District Officer cut down a two-year-old palm, because when standing near this palm a powerful and peculiar odour was plainly discernable. No trace of beetle or weevil was seen, although the heart leaf was obviously rotting and the outer leaves drying off. On being split open the kernel of the bowl and lower stem was filled with a creamy coloured, pulpy and rotten mass of semi-liquid consistency. From the outside the trunk or bowl appeared healthy in appearance and was not punctured. It appeared, however, that the disease did not develop from the cabbage. Newport (then Acting Director of Agriculture), in reporting on this occurrence said that the condition described is occasionally met with in this Archipelago. It may be a kind of bud-rot but does not tally exactly with the recognised bud-rot in other countries, where the older palms are usually attacked.

The characteristic smell of true bud-rot somewhat resembles bad eggs and bad onions, while the smell from this palm resembled the putrid decay of ordinary vegetable matter, together with the sour smell of fermentation. He believed the case to be a local bud-rot (herein classified as sporadic bud-rot) which is not infectious and could be due to accidental causes.

Some isolated cases of what appeared to be true bud-rot were recorded from Namatanai, New Ireland, in the same year. In December, 1924, a plantation inspector reported cases of what were believed to be bud-rot on two plantations in the Witu group and the symptoms were described as follows:

"The disease appears to be a form of bud-rot and the first noticeable sign of the disease on a palm is on the second or third line of fronds, where the tips of one or more fronds die back a distance of two or three feet and hang down (C.f. leaf break).

Running down the midrib of these affected fronds, a dry rot, brownish in colour, was noticed and this rot extended down the midrib a foot or eighteen inches past the point from which the tip is hanging. On one plantation, three palms, killed by this disease, were cut down and carefully examined. At the base of the cabbage a circular mass of cream coloured rotted tissue, about 6 inches in diameter, was found which, when cut open, gave off a very offensive smell. It was noticed particularly that only the terminal shoot and the surrounding undeveloped leaves were absolutely dead and dry, while the lower fronds still remained green. Extending down the trunk from the base of the cabbage a dry brown rot was found which, in one instance, extended to a distance of twelve feet, while the trunk below

this area was exceedingly dry. The roots appeared quite healthy and no traces of beetles were found. The whole area where these palms were discovered was isolated and kept under observation.

The Plantation Disease and Pest Inspector, from the Department of Agriculture, was then sent to Witu to describe the disease and reported as follows:

"The disease is similar to that which was seen on one plantation in the Bainings district of New Guinea in 1922. The first indication of the disease is odd fronds broken in the centre, otherwise the palm appears to be perfectly healthy; the central frond was found to be dead but still standing upright. The palm has a very sickly appearance, about half of the fronds being broken in the centre and the **whole cabbage leaning over**, becoming gradually worse until the whole of the cabbage collapses (C.f. head droop or lightning strike). The fronds have a dark brown colouring running through the central stem to the point of fracture. The centre of the cabbage is full of a creamy rot or substance which gives off an offensive odour. The rot can be traced down the centre of the trunk for from 6 feet to 9 feet and occasionally up to 12 feet from the cabbage. This rotted area takes the form of a funnel, tapering off from about 6 inches in diameter at the top to a very fine point as it travels down the stem. The trunk below this is practically devoid of sap and is very tough. Palms which are newly affected appear to be very dry when the stem is cut. The affected area is on low-lying ground about 20 feet above the sea—odd affected palms being located on swampy ground near the beach."

Bryce 1925(18) wrote regarding this disease at Witu Island and stated that from the description the disease is undoubtedly bud-rot. He also said that the danger of rapid spread of this disease is great and that preventative measures should be undertaken immediately and drastically applied. The diseased or dead palms should be cut out and burnt, particular attention being paid to the destruction of the bud and corm.

It should be noted that it is not clear from the records whether the terminal shoots died first, further that the occurrence was confined to particular areas. No causal organisms were seen and in view of recent findings it is likely that this was a case of Phytopthora Bud-rot. Nevertheless this conclusion must be open to doubt when expressed by one who did not investigate the occurrence. The macroscopic (visible) characters were suggestive of true bud-rot, though the fact that no further spread was reported seems to discount this possibility. According to the description it appears that some "Head Droop" may have been present, also the low-lying soil conditions described would have been unhealthy for palms. It is clear that such records of bud-rotted palms led to the conclusion that epidemic bud-rot was probably present in New Guinea. The bud-rot position here has been found to be exactly the same as described by Simmonds (Loc.cit.) in Fiji.

Definition of the "Bud-rot" Problem.

Sharples 1928(61) in defining the coconut disease position stated that up to 1918 the coconut disease position was largely influenced by the results published by Johnson(37) in his work relating to bud-rot. The uncritical acceptance of Johnson's inoculation results has led to much confusion as, according to Nowell(47) and Briton Jones (9) the technique of inoculation was faulty as the infection stands were made in holes 45 cms. deep bored into the tender tissues at the crown of young coconut palms grown under glass. Thus it is evident that not much else was needed to cause their death.

The results of Sharples' 1924(59) inoculation experiments proved that numerous widely separated organisms other than members of the genus Phytopthora were capable of producing typical "bud-rot" symptoms when stab-inoculated directly into the cabbage or bud, hence wound inoculation may be unsatisfactory in elucidating the causes of bud-rot.

It is evident from a study of the literature that the investigations on the bud-rot position have been very complex and difficult to follow even in other countries. It is thought essential that the true position regarding the occurrence of bud-rot in New Guinea be expressed.

Although suspected at various times, as far as is known few authentic occurrences of true infections of epidemic bud-rot have been recorded in Papua and New Guinea. It seems that the records from the Bainings and Witu Island were due to **Phytopthora species.** The coconut palms here which have been believed to be bud-rotted and recorded as such fall into five groups as far as can be determined.

1. Phytopthora bud-rot in scattered areas as described.
2. False bud-rot due to lightning strike or fires, which is described elsewhere.
3. Palms which suffer from tapering stem, presumably due to soil exhaustion, leading to eventual collapse and dying back of the cabbage. This may be associated with root disease but no proof seen. (See discussion on deficiency diseases).
4. Sporadic bud-rotted palms, where the disease is, in most cases, secondary to injury by animals such as rats, mechanical injury, insect injury, etc.
5. Maturation and mature palm wilt leading to bud-rot will be discussed elsewhere.

There have been isolated cases of bud-rot due to fungi or bacteria, but these are very scattered where present at all, and in 1940-41 fungi were isolated from bud-rotted tissues, from Pondo, New Britain. After a recent severe attack of **Promecotheca antiqua** on one plantation in New Britain, many palms withered up and lost their cabbage, leading to death of the palms. It has been demonstrated that when bacteria of the **Bacterium coli** group are introduced into very young buds through injuries or insect punctures, they can develop in the soft nutritive tissue and cause a destructive rot.

Authenticated Case of True Phytopthora Bud-rot at Pondo, New Britain, in 1940.

The late Director of Agriculture, Mr. G. H. Murray, and other departmental officers investigated and macroscopically diagnosed true "bud-rot" on crowns of palms from Pondo plantation, New Britain, in 1940.

Microscopic examinations of specimens of diseased tissue was made at the Imperial Mycological Institute which revealed the presence of fungus mycelium and this was considered to be Phytopthora from measurements taken. Further detailed microscopic examination was made by the author in the laboratory at Rabaul from fresh specimens. Large concentrations of unmistakable spores were found without any secondary infection. It was found definitely that the bud-rotting fungus **Phytopthora palmivora** was present. The best microscopic slides were obtained from a naturally isolated almost pure culture of the organism in the central tissue of the lower trunk (a most unusual site for this fungus to occur). The mature spores, "oospores," and resting spores were unmistakable under the microscope as they showed the varying forms and pronounced beaks characterising the spores of this fungus.

What was undoubtedly the same fungus was previously found associated

with a case of "Spear die back" of oil palms at Keravat Lowlands Experiment Station, but only a few oil palms were lost and the condition cleared up.

The bud-rot as described above developed under flat and foothill conditions in a region of heavy rainfall in an abnormal climatic season and even then only in such areas as where the palms were growing on heavy soil liable to water-logging. It was found also that near the focus of infection there was a central lagoon with some water lying around in the dry season but much more under wet conditions. A small river running near by also assisted in keeping up the humidity as did the fact that high tides and beach saltwater backed up the fresh sub-surface water almost to the foothills and created excess humidity both in the soil and in the atmosphere, making the conditions almost like a warm humid incubator. Obviously these are optimum conditions for the development of the bud-rot fungus, **Phytopthora palmivora.** It was ominous that severe wilting became apparent in most palms on the affected areas so that the presence of disease was obvious. The presence of nutfall was such that both large green coconuts and small nuts fell and littered the ground and later on the fronds commenced to wither and die and fall off. It was seen that other fungi such as Botryodiplodia were also thriving under these severe conditions and that the palms had lost their turgidity and become limp in appearance. There was some fear that the disease would spread to other properties but this proved unfounded and the indications were very strong that the disease would only prove serious under comparable soil, soil-water and climatic conditions to those indicated as the fungus can only develop in a moist or saturated atmosphere.

It is now certain that the fungus **Phytopthora palmivora** is widely spread in the Territory of Papua and New Guinea. It is noteworthy that there are other species of Phytopthora present in this country and their relationships need to be determined, e.g., **Phytopthora colocaseae** on taros. Apart from the coconut palm there are plenty of other host plants available (e.g. cacao **(Theobroma cacao)**; betel nut palm **(Areca catechu)**; oil palms, pawpaws, rubber **(Hevea brasiliensis)**; etc.) which plants this fungus is known to attack. It would appear, therefore, that it is only under certain special circumstances that this fungus is liable to cause serious losses of coconut palms and even then probably only when a virulent strain of the fungus is present.

Strong measures were then indicated and taken to control and confine this particular outbreak. Two men were employed in this disease control work and measures taken were to drain the area with the assistance of the owners and their native staff, making numerous drains of considerable depth. All infected palms were cut out, stacked and burnt, palms thought to be in the early stages of infection were painted with Bordeaux paste. Loss of palms spread over about twelve months and the disease was confined to the one property; somewhere around twelve hundred palms were cut down. In some instances they were in close contact and in others scattered. The infection rose as a curve, a few palms being noticed early and later many more became infected, but as draining and cutting out commenced to take effect the losses gradually reduced to nothing. It was found that the rainfall and the incidence of the bud-rot was very closely correlated.

Soil Conditions Associated With Bud-rot and Their Relation to Other Diseases.

Association of unfavourable soil and climatic conditions with the development of true bud-rot, in which the fungus **Phytopthora Palmivora** (Butler) was in evidence, have been recorded from certain New Guinea plantations.

It is not intended that the sporadic occurrences of bud-rot be described in detail in this article. Certain contributory factors found in the situations where an outbreak occurred and which are of decided value in illustrating the conclusions of this present article are described. This is the first undeniable diagnosis of true Phytopthora bud-rot here and this was arrived at from investigations by the Director of the Department of a loss of several hundreds of palms. This fungus was at first definitely suspected from the macroscopic symptoms present (i.e., from the visible appearance and symptoms of the disease). This determination was backed up by the opinion of the Director of Imperial Mycological Institute, based on the presence of fungus mycelium closely resembling Phytopthora, and from the descriptions and specimens forwarded to him. Unmistakable spore forms of **Phytopthora palmivora** were later isolated in Rabaul, from the tissue of a diseased coconut palm.

The only losses of palms from bud-rot recorded here are from regions of heavy rainfall and usually occur under abnormal weather conditions. In the most recent records, it was noted that the first appearance of the disease coincided with a period when the rainfall was much wetter, in the wet season, and much drier, in the dry season, than was usual. This gives a much greater contrast of climatic conditions between the wet and the dry seasons (see graph). The loss of palms occurred on heavy soils under flat and foothill conditions. Significantly, it is under very similar circumstances that the scattered occurrences of bud-rot in Fiji have been recorded by Simmonds (87-88) and others.

The occurrences of this disease have been almost confined to the wetter portions of the Fiji group, being commonly found on the back portions of the estates, along the foothills. This comprises a region of continuous rainfall and frequently of poor drainage, where the coconuts grow under unfavourable soil and climatic conditions which favour fungus development, but reduce the vigour of the palms. Palms growing close to the seashore with optimum water-table conditions are affected slightly as was found in the occurrences here.

The environmental conditions prevailing where bud-rot has been recorded here have many features in common with those obtaining where the other diseased conditions, described in this article, have been recorded, but are more extreme.

The heavy soils present are liable to water-logging in the wet season, and to drying-out and compaction in the dry season. This tendency is increased in areas of heavy rainfall and where poor drainage exists.

In a typical soil-profile of an affected area, it is found that there are proportionately large areas with very compact, almost impermeable hard-pan, or clay layers, present, which hold the water at the surface and restrict root-growth. In certain flat areas, where loss of palms, frond-fall and nut-fall were most in evidence, a stiff clay band was present, usually at a depth of 6 inches to 9 inches, but often almost to the surface. It is seen from water lying about in shallow depressions and from other signs that a superimposed water-table exists in the wet season which disappears in the dry season. The evaporation of this surface water continually adds to the humidity of the surrounding atmosphere.

Below the first clay zone there was, in several places, a sandy sub-soil layer present which was loose and porous and extended to a depth of at least 2 feet. Below this again a second impervious clay band is often met with, which is blue-grey in colour (showing the presence of unoxidised iron) and represents a second zone where depositions of fine particles has taken place.

The root systems of coconut palms growing under these conditions are restricted by the relatively impervious layers near the surface, especially as the water stagnates there in the wet season.

Some root-growth does occur below the first clay layer, but is absolutely prevented where a second clay layer or other hard-pan exists.

In the dry season the loose sand, underneath the clay, is believed to reduce the water supply to the palms, which effect would be greatly increased in the dry season. The clay layers present hinder water movements and the access of the roots to the true water-table. It is obvious, without reference to the bud-rotting and other organisms present, that such conditions are not optimum for the growth of coconut palms, though they do favour most types of fungus development. The Phytopthora bud-rot disease particularly can only be exceedingly destructive in a very moist atmosphere.

Where bud-rotted palms are found on the sides of low foothills, the water-table may not be so close to the surfaces but the soil conditions may still lead to water-logging and restricted root-growth. On one typical area it was seen that the surface soil was a stiff chocolate clay loam, which was stiffer even than those soils found on the flats. The sub-soil was an extremely fine-grained and puggy clay, resting on a compacted layer of weathered parent basaltic rock. This weathered rock formation gradually merges into the unweathered parent rock at a comparatively shallow depth. The soil as described is very puggy in the wet season but sets like a brick in the dry season. Palms growing under these conditions do not flourish. This can be seen from the chlorotic leaves, reduced length and number of fronds, and the grass ground covers present showing a light overhead canopy. It is impossible to think that such climatic conditions and soil and water-table formations, do not have a great deal to do with the development of bud-rot. Obviously, it is no coincidence that the type of bud-rot found here, and in Fiji, occurs under such conditions.

In the Philippine Islands bud-rot only assumes epidemic proportions in one of the most humid districts of the islands, where the soils are heavy and wet.

The late Dr. Sharples(59) in 1924 enumerated several instances of where investigators had recorded outbreaks of bud-rot in various parts of the world which were associated with unfavourable soil and climatic conditions. It was resolved at the Imperial Botanical Conference of 1924(59) that the term "coconut wilt" be applied to such occurrences as were falsely designated bud-rot, for the reason that the bud, as a general rule, was the last portion of the crown to become affected.

It is the author's opinion that, whether the crown is affected first (as in the instances of true bud-rot given) or last, the soil conditions always warrant very close study wherever outbreaks of wilts and bud-rot occur.

It will be mentioned right throughout this article that there are several other diseases and conditions of the palm influenced by related environmental conditions. In this regard it is a significant fact that on some areas where true bud-rot was recorded here, the following series of diseases or symptoms were noted: Leaf-droop, leaf-break, nut-fall (bad), frond fall (bad), leaf scorch, deficiency spotting, taper stem, chlorosis, stem bleeding, **Pestalozzia**, leaf-spotting, thread-blight **(Corticium penicillatum)**, **Botryo-diplodia theobromae** and a condition tentatively named "gummy leaf." It is plain that many of these conditions (especially the first nine listed) are symptomatic of the particular soil conditions prevailing, rather than distinctive diseases.

It is worthy of note that Dynastid beetles (e.g., Rhinoceros beetle **(Oryctes rhinoceros** and **O. curculionidae**; Red Palm beetle **(Rhyncophorus**

ferrugineus; Xylotrupes gideon) had caused considerable damage under these conditions and probably favoured the spread of the disease.

There may be a number of inter-related and inter-acting factors (working both from within and outside the palm) responsible for palms showing a series of pathological derangements such as those described.

It is very clear from the considerations outlined that cultural practices designed to keep up the vigour of the palms and remedy unfavourable environmental circumstances are of the utmost importance in disease control.

This subject will be expanded under separate headings in future contributions of this article.

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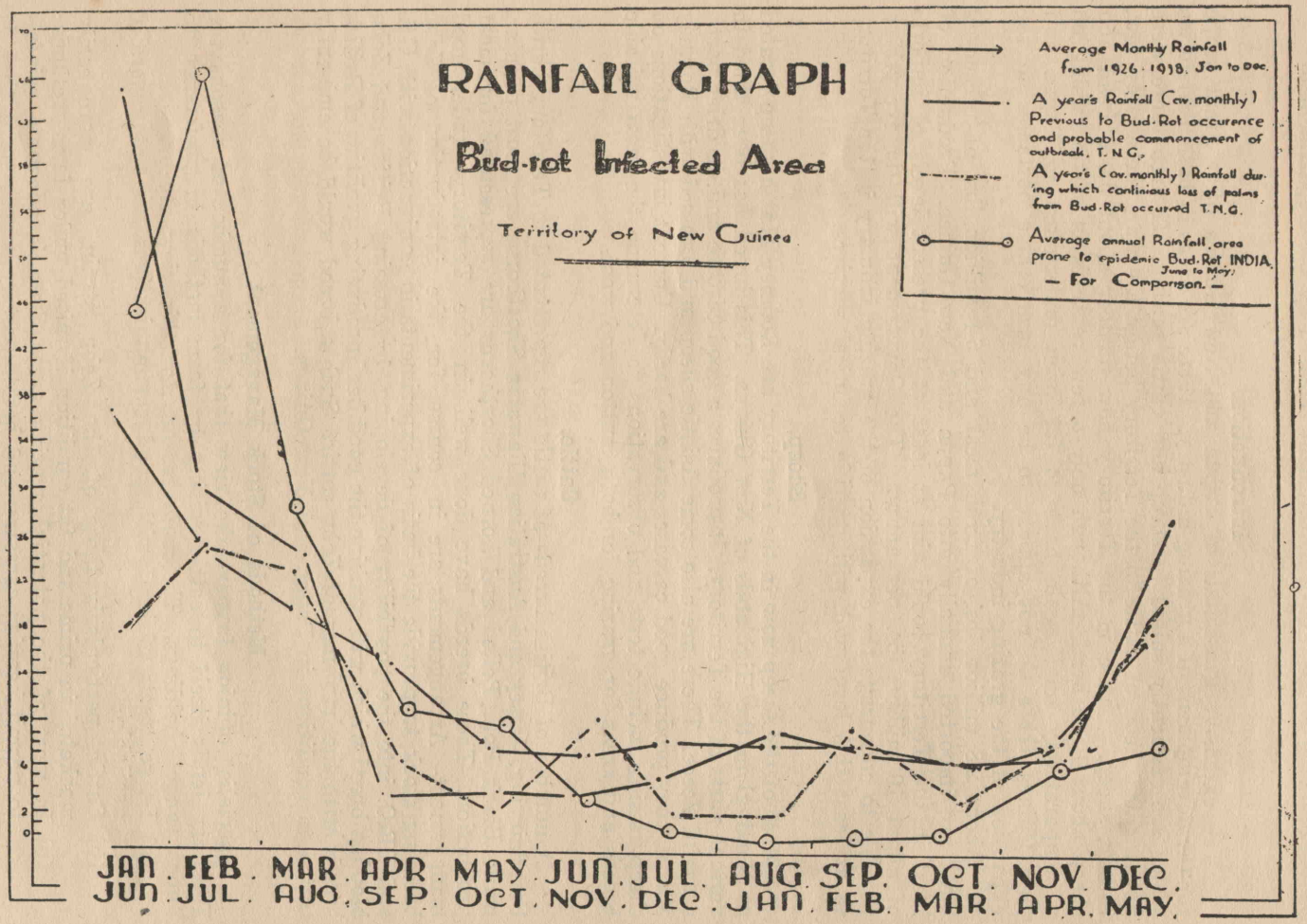
RAINFALL GRAPH
Bud-rot Infected Area
Territory of New Guinea
Average Monthly Rainfall from 1926-1938. Jan to Dec.
A year's Rainfall (Cav. monthly) Previous to Bud-Rot occurence and probable commencement of outbreak. T.N.G.
A year's (Cav. monthly) Rainfall during which continious loss of palms from Bud-Rot occurred T.N.G.
Average annual Rainfall, area prone to epidemic Bud-Rot INDIA. June to May.
— For Comparison. —
JAN. FEB. MAR. APR. MAY. JUN. JUL. AUG. SEP. OCT. NOV. DEC.
JUN. JUL. AUG. SEP. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY.