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RED RING DISEASE OF COCONUTS IN TRINIDAD AND TOBAGO

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SUMMARY

A short account is given of the origin of red ring disease of coconuts in Trinidad, its distribution elsewhere, and early investigations of the disease. Reference is made to serious losses caused in recent years. The symptoms of the disease are described and shown to be associated with the production of a strongly reducing substance in the periphery of the cortex of young palms invaded by the nematode *Aphelenchoides cocophilus.*

Experiments on the inoculation of stems and roots are described. These showed penetration via the leaf axils to be the normal means of entry of the parasite, root infections, though successfully carried out artificially, being of no account under natural conditions. The coconut weevil, *Rhynehophorus palmarum*, and by inference *Rhina barbirostris*, also was shown to be able to transmit the disease by burrowing in diseased debris in the cortex of affected palms, emerging with legs and body covered with this debris, and transferring it to wounds or to leaf axils in adjacent palms.

Reference is made to reports of natural and artificial alternative hosts of the parasite, and it is concluded that under natural conditions the disease is confined to the coconut palm, at least in the Lesser Antilles.

Control of the disease is shown to be possible by the removal of all infected palms and complete destruction of diseased tissues by fire.

INTRODUCTION

Red ring disease of coconuts, due to the colonisation of the periphery of the cortex of young palms by the nematode *Aphelenchoides coeophilus* (Cobb), is an endemic disease of South and Central America. It is known in Brazil, Venezuela, Colombia, Panama, and British Honduras, but its once reported presence in British Guiana is incorrect. The disease has also, in course of time, found its way from the mainland to Trinidad, Tobago, Grenada, and St. Vincent in the Lesser Antilles.

Red ring was known in Trinidad and Tobago fifty years ago as ‘root disease’, under which name it was studied by several mycologists, until in 1918 Nowell, investigating the disease in Grenada, realised the significance of the eelworms found so plentifully in the affected tissues, and showed them to be the cause of it. The nematode concerned was examined and named by Cobb (1919), and further experimental work by Nowell and Ashby (1919-1924) threw more light on the aetiology of the disease. Though failing to discover its means of spread, they stressed the importance of complete and effective destruction of affected palms by fire, and also suggested trenching to contain the nematodes; there the matter remained for some thirty years.

Apparently, when the Trinidad coconut industry was expanding in the second and third decades of the present century, the disease did not cause excessive damage in the new plantations, doubtless because it was absent in most of the newly planted areas to begin with, and did not have time to build up a large source of potential infection before the plants passed the most susceptible age—four to seven years old. The subsequent supplying of these plantations was generally carried out haphazardly, either by casual planting in gaps that arose, or by leaving these to be filled by ‘drop nuts’ conveniently germinating near the right place. The result was that the older plantations always contained a number of young palms of varying age, scattered, and not all at the age of greatest susceptibility. Losses from the disease were sometimes quite extensive, but on the whole the deaths did not seriously affect output and were accepted as inevitable.

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In some cases planters took phytosanitary measures to check the rate of spread.

In recent years, however, coconut planters on the East coast of Trinidad, after felling the original palms, have started replanting whole fields with seedlings, raised in nurseries from selected nuts. In such plantings, all the young palms in a field reach the age of maximum susceptibility at the same time, and the disease has been causing such serious losses (in some cases over 60 per cent. by the fourth or fifth year) that rehabilitation of the plantations in this manner seemed impossible to achieve. Consequently the planters concerned asked for further investigation of the disease, and this was carried out at Nariva-Cocal, where heavy loss had been sustained.

DESCRIPTION OF THE DISEASE

The appearance of the disease was well described by Nowell (1923), his account being quoted in most subsequent references. The initial yellowing and subsequent drying out and browning, of the leaves can, however, occur in palms affected by other adverse factors. The leaf colour changes generally start with the oldest leaves, the occasions when younger leaves are first affected being due no doubt to primary infection higher up the stem. The age and size of palms attacked varies somewhat in different accounts of the disease; but, in general, coconuts are most susceptible from the time they first form a clearly defined stem with a cortex of soft tissue till the time when this cortical tissue hardens. This period, of course, varies with the conditions under which the palms grow, but in Trinidad is generally from the fourth to the seventh year. In Brazil the disease is recorded on palms up to ten years of age (Joffily, 1948).

Artificial infection of the stem resulted, as a rule, in the appearance of external symptoms about six weeks later, though occasionally, they appeared before and sometimes were delayed for eight weeks or so. The rate of growth of the palm and prevailing weather conditions are relevant factors in the rapidity with which the symptoms develop.

The red ring forms about two inches from the periphery of the stem, starting as a faint but quite distinguishable line around it, and soon developing into a band some one to one and a half inches in width, often red-brown to brown rather than red in colour. The nematodes are massed in this area, to which they are almost entirely confined, and where they apparently encounter optimum conditions. Aeration and water supply are probably the determining factors that account for their absence nearer the centre of the stem, and the harder tissues confine them on the outside, so defining the limits of the ring. After the cortical tissues harden they are apparently not favourable for the existence of the nematodes, which no doubt accounts for the general absence of the disease in older palms. In addition to the red ring area of the trunk, nematodes may be found generally distributed in the ground tissues of infected petioles.

The discolouration of the tissues is associated with the presence of a high nematode population, and in the orange-brown zone strongly reducing conditions are found. The destruction of this zone of tissue is apparently the direct cause of the external leaf symptoms and subsequent death of the palms, which may be due to the toxic substances formed, but the actual mechanism of the destructive process is obscure.* Leaf symptoms probably depend to some extent on whether direct infection of the petiole or secondary infection from the stem occurs. Growth of the palm sometimes continues for a week or so after external leaf symptomis are evident, or may cease rather sooner.

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*The writer is indebted to Mr. K. W. do Witt. of the Imperial College of Tropical Agriculture for kindly investigating this matter. He reported as follows :—

" In the course of a chemical examination of the tissues of Coconut palms affected by red ring disease it was observed that in an advanced state of the disease the red ring area of the cortex exhibited highly reducing properties towards ammoniacal silver nitrate solution. A drop of the reagent applied to the red ring was blackened within 10-15 seconds, whereas in all other parts of the cross section of the trunk several minutes elapsed before darkening was noted. In healthy palms, and in those in very early stages of the disease, no such effect was obtained.

The reducing material present in the reddened tissue was water soluble, and was estimated by titration against 2-6-dichlorphenol indophonol (Harris & 011iver, Biochem J. 36, 155, 1942). Results, expressed as ascorbic acid, are given in the following table:—

Distance from periphery of trunk (c.m.)		
0-4	4-6.5 (red ring area)	7-30
Reducing material (mg. ascorbic acid/ 100 gm tissue)		
3.2	63.0	1.2

Thus the reducing power of the tissue in the red ring is 20-60 times greater than in other parts of the trunk."

The red ring is the surest symptom of the presence of the disease. A brace and inch bit, the latter penetrating to a depth of three inches, withdraws tissue in which the typical discolouration can be noted and the disease recognised, two or three weeks before external symptoms appear, and without the necessity of felling the palm. Such borings are readily repaired with a wooden plug and a covering of plasticine, to prevent the attraction of weevils.

STEM INOCULATION EXPERIMENTS

(a) Very young plants

Attempts were made to infect young palms (about two years old) in which the leaves were just becoming pinnate, growing in tubs. As in subsequent experiments, pieces of red ring tissue were placed in water in a funnel, and allowed to stand for a while, after which the water, containing large numbers of nematodes, was drawn off from the stem of the funnel for use as inoculum, either as it was, or after dilution. Water containing nematodes was poured over the plants, the petioles of which had in some cases been nicked with a scalpel. In other experiments, with similar palms, pieces of red ring tissue were inserted in wounds in the petioles, or placed in the leaf axils. In no instance was infection obtained. (Ashby (1921 b) claimed to have once artificially infected an eleven-month-old palm in the field, though failing with similar plants in pots.)

(b) Older palms

Inoculation of older palms was carried out in the field, in areas where the disease had not yet appeared, so that natural infection was unlikely to occur. Palms of about four years old were successfully inoculated by repeating Nowell's methods, i.e. placing pieces of diseased tissue in wounds in stems and petioles, or in unwounded leaf axils. In these cases, however, there was the possibility that some fungal or bacterial organism in the diseased tissue, and not the nematodes, might have caused the infection. Other palms were therefore inoculated simply by introducing the nematodes in water to the leaf bases with a pipette. Nine palms were inoculated in this manner, and infection was obtained in every case, in some instances during the dry season. It is not only apparent, therefore, that the nematode alone causes the disease, but that it can readily gain entry via the leaf bases, as Nowell believed, and this, as will be shown, is no doubt the normal way of infection.

An attempt to inoculate a palm of some 20 years of age by boring holes in the trunk and inserting pieces of red ring tissue—a certain means of infecting younger palms—failed to cause infection.

Attempts were made to establish the eelworms in portions of trunk about two feet long, cut from the stem of a young, healthy palm and trimmed of leaf bases. These were brought to the laboratory, stood upright in trays of water, and the cut surface at the top kept covered with moist filter paper. These pieces were kept thus for 10 days, the cortical tissues remaining apparently fresh throughout this period. A number of borings were made with brace and bit, into which were introduced nematodes in water, or pieces of red ring tissue, and the holes were then plugged. In no case did the nematodes establish themselves in the cortical tissues, and it seems evident, therefore, that for their well-being and multiplication the natural movement of solutes in the tissues of the living plant is necessary. The removal of staling products is no doubt essential.

ROOT INOCULATION EXPERIMENTS

Examination of roots of diseased palms showed nematodes to be present in the cortex of older hard, brown anchoring roots that emerge directly from the base of the trunk; but they were not found in the younger, lighter coloured feeding roots, nor in washings from soil taken from around diseased palms.

As in other cases when the presence of eelworms was looked for in soil or tissues, the material was allowed to stand in water in a funnel, if need be overnight, a sample of the water being then run off and examined for nematodes.

(a) Very young palms

Attempts were made to inoculate the roots of three two-year-old palms just forming pinnate leaves, and growing in tubs, by burying pieces of diseased tissue among the roots. One palm was dug up after a week, another after two weeks and the third, still apparently healthy, after a lapse of five months. The roots were washed and examined, but in no case were eelworms found in them.

In another experiment, six germinated dwarf coconut seedlings with shoots three to four feet high and roots about one foot in length were stood in glass jars in the laboratory, the roots being submerged. The roots of three of these were damaged by cutting off portions, particularly of the larger ones, with scissors. Water containing nematodes was then added, and in addition pieces of infected tissue were placed in the jars, so that they floated among the roots. After a week the roots were examined, but no nematodes were found in the tissues.

(b) Older palm

Inoculations of four-year-old palms were carried out in the field by burying large pieces of red ring tissue among the roots near their bases. Three palms so treated on May 27th showed no red ring tissue when bored on July 15th, but by August 19th they showed early leaf symptoms and the presence of red ring was confirmed by boring. This experiment was then repeated, three more palms having diseased tissue buried among their roots on August 19th. Again, on September 2nd, three more palms were inoculated by pouring water containing nematodes into a shallow trench dug around the base of the trunks. On October 7th, though no external symptoms had appeared, roots from one palm of each of these two latter sets of inoculations were dug up. Some of them were obviously discoloured and eelworms were plentiful in them. On October 21st all six palms were bored, and although no external symptoms were yet visible, one of each set of three was found to contain red ring tissue.

On the same day samples of soil, containing portions of the finer roots, were dug up from near the base of the two palms showing red ring tissue, and the soil (a very sandy loam) was sifted, separating the roots and lumps of soil from the bulk of the finer soil. In the case of the palm around which water with nematodes had been poured, a few individuals of *A. cocophilus* were found in the fine soil separated from roots, and also in the siftings containing pieces of fine root, but other species of nematodes were more prevalent. In samples of soil in which pieces of diseased tissue had been buried, *A. cocophilus* could not be found, though other species of nematodes were plentiful.

All but one of these root-inoculated palms subsequently developed external symptoms, at varying times during November, showing that infection by this route is slower than through the leaf arils or stem. One of the last series (eelworms in water added to the soil) did not become infected and was still healthy on December 16th.

(c) Conclusions from root inoculation experiments

It would appear from these experiments that *A. cocophilus* does not build up large concentrations in the soil, as some of the earlier investigators believed; hence their recommendation of isolation trenches. It would seem, moreover, that although root infection can be brought about artificially and might occasionally take place naturally, it is not a normal method of initiation of the disease; for in the ordinary course of events the nematodes would not find their way into the soil or persist there in sufficient numbers to give a reasonable chance of infection. If a persistent source of inoculum is present (e.g. buried red ring tissue, which has been found to remain quite fresh for two weeks after burial), or if a high concentration of *A. cocophilus* is brought about by adding it in water to the soil, the nematode presumably gains entry through damaged or senescent roots. It then multiplies in the tissues, and eventually works its way up into the trunk, producing the usual symptoms. Failure to secure infection of roots of seedling palms in water may have been due to a too short exposure, or to the preference of the nematodes for the water rather than the root tissues. Failure to infect palms in tubs may have been due, in part, to lack of enough senescent larger roots to give entry, and to absence of suitable tissue in these young palms for the nematodes to multiply.

NATURAL TRANSMISSION OF THE DISEASE

It has been suggested that the nematodes travel from one palm to another in continuous films of water during rain, flooding or the presence of heavy dew. At Cocal this was demonstrably not the case. The disease spread with equal rapidity in the dry season when, moreover, owing to the proximity to the sea, there is very little dew, and was if anything more extensive on higher and better drained land near the sea than on swampy land near an adjoining river.

On the other hand. it has always been the opinion of observant planters in Trinidad that the Coconut weevils *Rhynchophorus palmarum* and *Rhina barbirostris* play a part in spreading the disease. They are readily attracted to young palms by the fermentation of small quantities of sap exuded from the slightest injury to the soft tissues. Older, hardened palms do not attract them unless more extensively damaged. Ashby (1924) made reference to the reported transmission of the eelworm on the snouts of coconut weevils in Central America, and it is evident that where these weevils abound the disease is more prevalent than where they are scarce. The East Coast Coconut areas (Nariva, Mayaro, Guayaguayare), where red ring has been so much in evidence, suffered from lack of attention during the war years and the weevils have become very abundant there. On the other hand in the Cedros area, where the disease was originally observed, it is of no account, and apparently caused no serious loss in the areas replanted after the 1933 hurricane; but coconuts there are mostly estate grown and active steps have always been taken to check weevils. Similarly, in Tobago the disease is of little importance on the well managed plantations at the South-East end of the island, but does considerable damage in neglected coconut plantings elsewhere. Finally, it has been remarked (Briton-Jones, 1940) that coconuts established through cane, as opposed to secondary bush, seldom contract the disease. In this environment the necessarily clean surrounding cultivation leaves no breeding place for coconut weevils.

It was therefore considered desirable to investigate the possible action of coconut weevils as vectors of the disease, the moreso as it had been recently stated (Tidman, 1951) that in Brazil infection was spread by R. palmarum feeding on diseased tissue and carrying the nematodes in its intestines and faeces. It subsequently transpired that the report on this means of transmission was based on inaccurate information, but in the meantime experiments were carried out in Trinidad to test the validity of this alleged method of transmission. Firstly, weevils obtained from the leaf bases of diseased palms and then placed in jars with red ring material were subsequently dissected, but no nematodes could be found in them or in their faecal pellets. Large pieces of infected tissue, which would inevitably attract weevils, were left on the ground under young palms, but no infection occurred. Plastic bags were devised to hold wedge—shaped portions of infected tissue and allow access of weevils whilst preventing the direct escape of nematodes in moisture. Three of these bags were placed in leaf axils of each of four palms and left there for two weeks, but though weevils visited the contents, and would then go into the leaf axils, no infection resulted. It is therefore evident that direct transmission by the mouth parts or through the intestinal tract does not take place.

It was observed, however, at Nariva-Cocal that R. palmarum was always present in large numbers and was often found in the leaf axils of the palms, especially those of the bottom leaves. The larvae were invariably found tunnelling in the stems of any diseased palms felled and left lying, and sometimes in the stem bases of palms still disease-free, the eggs apparently having been laid by adults attracted by some injury at the base of the stein and entering thereby. Though *Rhina barbirostris* was seldom seen on this plantation, it was quite abundant in the Mayaro area, where planters reported it to be readily attracted even by the slight ooze of sap following the partial or complete removal of a leaf from its stem attachment, either in the course of agricultural operations or otherwise.

At Cocal, two diseased palms were cut down and left lying to attract *B. palmarum*. These were visited on the evening of the day after felling, and it was noted that weevils had by then burrowed into the diseased tissues. When removed they were covered with small pieces of debris, all heavily colonised by *A. cocophilus*. In one experiment, two such weevils were placed in a hole bored in the trunk of a healthy palm, confined there by gauze tacked over the hole, and removed after about 12 hours. In two other experiments, weevils taken from diseased tissue in which they were burrowing were kept overnight in a tin containing pieces of red ring tissue, and the following morning placed in holes bored in healthy palms and left for a day. Within two months all three palms showed red ring symptoms. One was then cut down and the trunk found to contain a number of larval tunnels of *R. palmarum*, caused by the progeny of weevils attracted to the wound made for insertion of the insects at the start of the experiment. Several adults were found burrowing in the debris of these tunnels, which were in the red ring area. Two covered as before with infected debris, were removed and placed in holes bored in the trunks of two healthy palms. The weevils were again confined to the holes by gauze, and in this case left there, the cover being maintained over the holes. These palms were examined four weeks later by borings with brace and bit, and both found to have red ring.

It is evident, therefore, that the disease is spread by the coconut weevil acting as a carrier of infected debris, rather than of individual nematodes. It is to be expected that those carried on the surface of the insect without protecting plant tissue will die from desiccation, and there is no evidence for transmission of nemas on mouth parts or their survival in the faeces. Thus weevils merely feeding on the surface of infected tissue will not act as vectors, but after burrowing in diseased tissue and becoming covered with debris, they do. The debris-covered weevils may enter holes made by other weevils, transmitting the disease in the manner of the experiment, but doubtless more generally they fly to adjacent palms and crawl down into the leaf arils (usually those at the base of the palms, but sometimes higher ones) depositing there pieces of diseased tissue, from which infection can take place. It is noticeable that most new infections arise in palms immediately adjoining those already diseased; weevils taking longer flights probably lose much of the debris when in the air, but the periodic occurrence of new outbreaks in hitherto unaffected areas can be accounted for by the retention of some of it.

Urich and Guppy (1911) made some preliminary observations on R. palmarum in Trinidad, and found that the time from egg laying to moulting of the larvae in two instances was 74 and 128 days respectively, and from formation of the cocoon to emergence of the perfect insect 59 and 33 days respectively, indicating a life cycle of about four to five months. The larvae tunnel in the soft tissues of the cortex, which soon rot in a dead palm, but the cocoons are found near the periphery of the stein, i.e. in the red ring area, and the adult emerges through the outside of the stem. Portions of trunk from a diseased palm, cut down on June 19th and left in the field, were brought to the laboratory on July 10th, by which time they contained many larvae. They were placed in an insect cage in a shaded spot, to see if adults could be obtained. The cage was exposed to rain, and being also shaded, the stem pieces rotted too quickly for completion of the life cycle. Despite this, when a piece of the softened periphery of the stem, in which the cortex had entirely rotted, was cut open on October 9th, traces of red ring were still to be seen, and a few live individuals of *A. cocophilim* were found, although other species of nematode were present in much larger numbers. It is, therefore, evident that in the field, especially in the absence of shade, the life cycle may be completed and adult weevils emerge from the trunks of diseased palms with *A. cocophilus* still present. Therefore the nematode may also be carried in debris on the bodies of emerging adults.

Whether other insects can carry infected debris similarly is a matter for speculation. Ants have been suggested as vectors of the disease in Venezuela (Bain and Fedon, 1951), though the method of transmission was not specified. They do not appear to play such a part in Trinidad.

ALTERNATIVE HOSTS

The literature contains reference (Goodey, 1940) to the disease having been found on a date palm and on oil palm in the Trinidad Botanic Gardens, the reference quoted being the Annual Report of the Trinidad Department of Agriculture for 1925. Search in this and contemporary reports has, however, failed to discover the reference.

Nowell (1924) reported having successfully inoculated the cabbage palm (*Oreodoxa oleracea*) and obtained rapid death, and another successful inoculation of this species has been reported to the writer ; but, on the other hand, this palm, a native of Trinidad, grows plentifully in the Nariva swamp immediately adjoining the plantation where these investigations were carried out, and remains unaffected, presumably because *Rhynchophorus* does not attack it. Nowell also reported successful though slow infection of the gru-gru palm (*Acracomia aculeata*), another common native palm iu Trinidad, but in this case too natural infection is never observed. He also referred (1923) to the natural occurrence of one case of the disease on an unidentified species of Cocos and it seems possible that such might arise from a chance infection due to *Rhynchophorus.*

Red ring would, therefore, appear for all practical purposes to be confined to the Coconut. The nematode appears to have no means of prolonging its existence outside this palm, and no resting stage has been discovered. The origin of the disease on the mainland and the possibility of a wild-palm host there must remain a matter for speculation. Its appearance in the southern islands of the Lesser Antilles can, with reasonable probability, be attributed to its having been seaborne from the mainland by floating stems of diseased palms in which the nematode had remained viable.

CONTROL OF THE DISEASE

This can be effected by removal of sources of infection and reduction in the number of coconut weevils. Proper phytosanitation achieves both ends. The first essential (and it may be noted that this operation was recommended, amongst others, by Nowell in 1920) is the effective destruction of red ring infected tissue by fire, unless it can be conveniently buried where it cannot be a cause of abnormal root infection. However, the trunk of a young coconut palm contains a high percentage of water, and fire applied to the outside scarcely affects the inner tissues. Diseased trunks must be cut down flush with the ground, or, better still, cut off from the roots and removed from the soil entirely, which is not too difficult with young palms on sandy soil. The trunks must be cleaned of the attached leaf bases and cut up into lengths of about two feet, which must then be split lengthwise, so that the axe cuts expose the red ring area. These pieces and the rest of the debris should then be heaped up, on top of the stump if one is left, and burnt. By using coconut husks, with paraffin to start fire, this can be done effectively, though it is generally necessary to burn at least twice to ensure that no infective red ring tissue is left.

This control measure, besides removing the only source of infection, removes the main breeding ground of the weevils. (As has been pointed out above, roots left in the soil are of no consequence.) If it has to be done in an area where the disease has been allowed to become widespread, initial expense is high ; but once the work is completed, it is only necessary to keep a look out for new cases, resulting from infection brought from sources outside the plantation, and deal with them immediately. Just after the initial clearing, of course, a number of infected palms that were symptomless when the others were out may manifest the disease, and the operation of felling and cutting in a badly diseased field with weevils present can, by disturbing them, cause new infections. The danger, once thought to occur, of spreading the disease by chips flying from the axe when felling affected palms, is non-existent, since soil infection does not result. The chips cannot be carried by weevils, and they soon dry out, resulting in the death of the nematodes inside.

The effectiveness of control by proper destruction of diseased palms was indicated in two fields of young palms of susceptible age at Cocal, in which only a few instances of the disease had occurred when the appropriate action was taken. These infected palms were cut and burnt in August and September. One subsequent case appeared in each area late in September, after which no more diseased palms were seen in either field up to the end of December. Complete destruction of diseased trunks has also been reported to give successful control in Brazil (Ferreira Lima and Marques da Cruz, 1945).

The possibility of using a systemic pesticide was considered, and a few experiments were carried out with proprietary substances, which failed, however, to kill the nematodes in the stems of affected palms. The most promising line of attack, if a suitable chemical could be found, would be the prophylactic treatment of palms in the immediate neighbourhood of infected ones. Once a palm shows external symptoms the nematode population in the red ring area is such that destruction of the nemas with concomitant survival of the palm (which will by then have almost ceased growing) seems most unlikely. Moreover, if the nematodes were killed and the palm died, although the immediate source of infection would be removed, the dead palm would become a breeding place for coconut weevils when the pesticide in the tissues had broken down.

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