OBSERVATIONS ON ROOT DECAY IN COCONUTS, ITS CAUSE AND ITS RELATION TO THE FOLIAR SYMPTOMS OF DISEASE IN THE DISEASE BELT OF TRAVANCORE-COCHIN

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ROOT decay has been associated with some of the diseases of coconuts in different parts of the world and in some cases it is considered to be the cause of disease. Butler in 1906 reported that *Ganoderma lucidum* was parasitic on coconut roots and since then it has been reported on coconuts from Mysore, Ceylon, West Indies, etc., (Briton-Jones, 1940). The root disease of coconuts in Ceylon, was attributed to *Fomes lucidus* by Petch (1910); but Small (1927) considered *Rhizoctonia bataticola* to be the causal organisms. Ocfemia (1937) observed the association of certain fungi and bacteria with roots of coconut trees affected with the cadang-cadang disease, their relation to the host being similar to what it is in the bunchy top of abaca, a virus disease. Dwyer (1937) has reported a root disease from New Guinea. In the case of the bronze-leaf wilt in Trindad, Briton-Jones (1940) found that a large proportion of the root system of affected palms was in various stages of decay; but he could not associate any root-invading organism with the disease which he considered to be a nonparasitic wilt. Martyn (1949) noticed that even in palms recently infected with the unknown disease in Jamaica, the roots were becoming rapidly moribund; but in the early stages of disease he could not detect any parasitic organism in the roots. His observations indicated that the disease was probably infectious and he suspected it to be of virus origin. Leach (1946) isolated a *Rhizoctonia* sp. from decaying roots of palms affected with this disease, but on inoculation the fungus remained confined to a zone around the area of inoculation. Other fungi such as *Fomes* sp., *F. noxius*, etc., have been claimed by various workers to be causes of root diseases in coconuts (Briton-Jones, 1940). The parasitic nematode *Aphelenchus cocophilus* is the cause of the red ring disease of coconuts in Trindad and is known to infect the roots also (Briton-Jones, 1940).

In India, Butler (1906) isolated *Botryodiplodia theobromae* from roots of palms affected with the wilt (root) disease of coconuts in Travancore and considered this to be the probable cause of disease. Menon and Nair (1949, 1951) found that in addition to *B. theobromae*, *Rhizoctonia solani* and *R. bataticola* were also constantly associated with the roots of diseased palms.

From the above review it is found that root decay has been associated with many

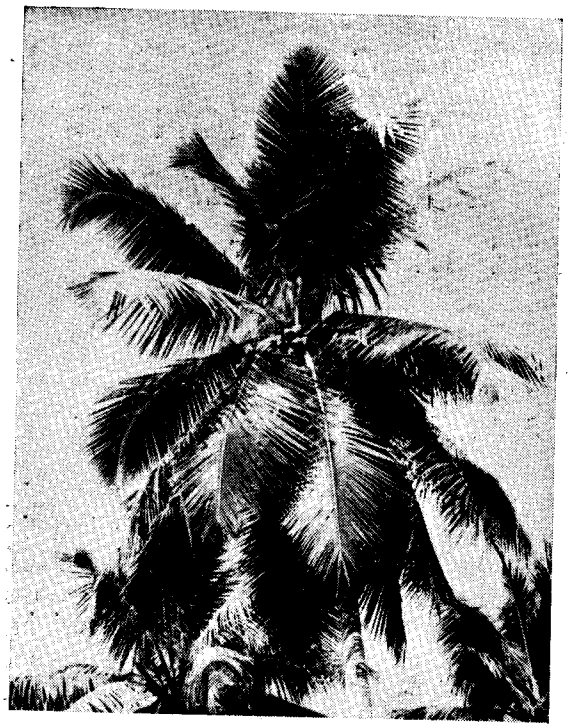

Plate I a—A healthy palm

diseases of coconuts; some of these may be fungal or virus diseases, some may be deficiency diseases and one is caused by a nematode. Root decay may be the cause of disease in some cases and in others it may be a secondary symptom. In the disease belt of Travancore, apart from the symptoms of wilt disease, symptoms such as tapering stem, general chlorosis, etc., are also noticeable. The study reported herein was conducted to determine which type or types of foliar symptoms were consistently associated with a high percentage of root decay and to examine the causes of the latter.

Foliar Symptoms

The common foliar symptoms met with in these areas fall into four main categories and are described below :—

A. Wilt disease :—The palms in this category show clear symptoms of flaccidity and ribbing of leaflets (plate I b) generally commencing from the outer whorl of leaves, abnormal curvature or bending of leaf rachis, drooping and wilting of outer whorl of leaves, and a gradual reduction in the number and size of leaves. The vitality of the affected trees is greatly reduced, the nut production is adversely affected and in advanced stages entirely inhibited. These symptoms may sometimes be accompanied by a varying degree of yellowing; shedding of buttons and immature nuts is an early indication of disease in some cases. A small percentage of palms in this category exhibit a necrosis of younger leaves in addition to the other wilt symptoms described above. The necrotic symptoms are first manifest in the youngest unfolding leaf, the subsequent leaves showing similar or more severe symptoms. The leaflets become necrotic from the tip downwards, become greyish black in

Plate I b—A palm affected by wilt disease

Plate II—Palm affected by wilt disease showing necrosis

colour and curl downwards. The dead portions remain hanging for a long time (plate II). These necrotic symptoms in all cases observed, were found associated with the other wilt symptoms. Many palms which have been showing only flaccidity and wilt symptoms for a long time have recently developed necrosis. The wilt disease appears to be infectious and is gradually spreading.

B. Tapering Stem:—The symptoms consist of a gradual reduction in the size and number of leaves and nuts. The crown becomes small, bearing very few or no nuts and the stem tapers at the apex (plate III). These symptoms are associated with old age, senility or unfavourable soil conditions. Recent infections are few. No case of a healthy and vigorous young palm suddenly developing tapering stem symptoms has been noticed.

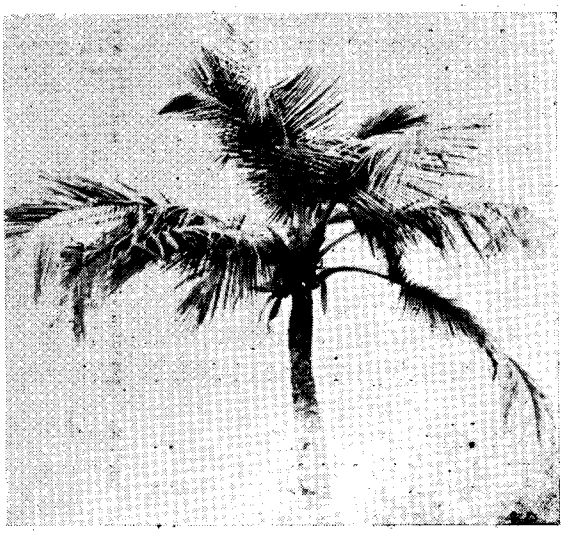

Plate III—Tapering stem of a palm

The disease does not appear to be infectious.

C. Yellowing of outer leaves accompanied by nutfall:—The yellowing might start from the tips of the outer whorl of leaves. The nuts and buttons are prematurely shed in quick succession and the inflorescences, especially the older ones become discoloured. There is no flaccidity of leaflets and the tree does not exhibit a wilted appearance. Some healthy, vigorous and heavily bearing palms have suddenly developed these symptoms. The disease may be infectious but is not serious.

D. General Chlorosis:—Palms in this category exhibit a general yellowing or chlorosis of the entire foliage. The chlorosis persists throughout the year. When young, palms affected might continue to bear normally, but palms in which the yellowing has persisted for years, have very few or no nuts.

Percentage Incidence of Disease

To determine the percentage incidence of each of the categories of symptom

pictures described above, a survey was conducted over an area of 31·49 acres, near Krishnapuram, Travancore. This is one of the worst affected areas in Travancore. A number of palms that were not perfectly healthy (as indicated by the crown) but were not showing clear symptoms of disease, have been placed under the category healthy (doubtful). The 1555 trees surveyed, fall into the different categories as stated below:—

Healthy	..	8·6%
Healthy (doubtful)	..	12·9%
Wilt disease	..	67·9%
Tapering stem	..	2·8%
Yellowing of outer leaves	..	6·5%
General chlorosis	..	1·3%

The distribution of palms in the different categories clearly indicates the importance of wilt disease. The small percentage of palms exhibiting tapering stem symptoms points out the number of very weak and senile palms. Though yellowing of the foliage is very common in these areas it generally accompanies other disorders. The percentage of palms showing only yellowing of the outer leaves or only general chlorosis is hence so small.

Root Decay in Coconuts

The root system of the coconut palm consists of a number of main roots which grow in different directions from the bole. The main roots of mature trees are about 0·4 inch in diameter (Patel, 1938) and may bear numerous branching rootlets. Young roots are cream coloured at the tip. The older roots are harder and darker colour. When the roots are cut, functional and healthy roots are distinguishable from the dead or moribund ones by their glistening cut surface from which droplets of sap may sometimes ooze out. Clear indication as to the living or dead condition of roots is obtained when the root-tips are observed. In the dead roots, the tips lose their shiny appearance and colour, become dry with a warped skin. In a few palms a soft rot of roots was noticeable wherein the root-tips collapsed on pressure and the internal tissues contained a large number of nematodes.

To find out the extent of association of root decay with each of the four categories of symptoms described earlier, the roof systems of a number of palms in each category, as well as those of healthy palms for comparison, were studied. For the wilt disease, the root systems of trees in the early stage, middle stage, and advanced stages of disease were studied ; the trees selected for the other three categories, were all above 25 years old ; all the trees selected for category B were above 40 years old. It was generally found that the diseased condition of a root system was indicated in the horizontal roots which were concentrated between 1—2½′ from the surface. When these were healthy, it was found in all cases examined that the vertical roots also remained healthy, unless there was a hard pan or a persistent high water table. Hence a quadrant of the root system of each tree upto a depth of three feet and a radius of six feet from the bole was exposed and the number of dead or dying, and healthy roots was recorded.

TABLE I

Percentage root-decay in trees showing different types of foliar symptoms

	Healthy		Wilt Disease						Tapering Stem		Yellowing of outer leaves		General Chlorosis	
			Early Stage		Middle Stage		Advanced Stage							
	No.	Percentage of total	No.	Percentage of total	No.	Percentage of total	No.	Percentage of total	No.	Percentage of total	No.	Percentage of total	No.	Percentage of total
Total number of trees exposed ..	45	..	19	..	10	..	12	..	10	..	10	..	10	..
Trees without root-decay ..	12	26·7	6	31·6	..	..	..	..	..	..	..	..	2	20
Trees with root-decay;—														
Root-decay— 1— 10% ..	11	24·4	2	10·5	1	10	..	..	..	..	5	50	..	..
„ 10— 20% ..	1	2·2	3	15·8	1	10	..	..	..	..	..	..	..	..
„ 20— 30% ..	1	2·2	1	5·3	1	10	..	..	..	..	2	20	..	..
„ 30— 40% ..	4	9·0	1	5·3	2	20	..	..	..	..	..	..	..	..
„ 40— 50% ..	3	6·7	1	5·3	..	..	1	8·3	..	..	..	..	..	..
„ 50— 60% ..	3	6·7	2	10·5	2	20	1	8·3	1	10	..	..	2	20
„ 60— 70% ..	3	6·7	..	..	1	10	..	..	..	..	..	..	..	..
„ 70— 80% ..	2	4·4	..	..	2	20	2	16·7	1	10	3	30	2	20
„ 80— 90% ..	3	6·7	1	5·3	..	..	3	25·0	2	20	..	..	1	10
„ 90—100% ..	2	4·4	2	10·5	..	..	5	41·7	6	60	..	..	3	30

Results

The results obtained from the study of root systems of 116 trees are summarised in the table above.

A study of the data presented above indicates that even the healthy trees as judged by the appearance of the crown, are not necessarily free from root rotting. 26·7 per cent of the total number of trees studied were free from root decay and 24·4 per cent had less than 10 per cent root decay, while about 28·8 per cent of trees exhibited more than 50 per cent root decay.

The data obtained for the trees in the different stages of wilt disease show that the trees in early stages of disease have similar root systems as the healthy trees, 31·6 per cent of trees being free from root decay and 26·3 per cent of trees showing above 50 per cent root decay. In the middle and advanced stages of wilt disease none of the trees examined were free from root rotting and the percentage of trees showing above 50 per cent root dceay was 50 for the former and 91·7 for the latter.

All the trees showing tapering stem symptoms exhibited above 50 per cent root decay, 80 per cent of the trees having more than 80 per cent of their

roots rotten. All these trees were found surviving on a few healthy vertical roots.

In the category C (Yellowing of outer leaves accompanied by nut-fall) though none of the trees studied were entirely free from root decay, 50 per cent of them showed less than 10 per cent root decay and 30 per cent had above 50 per cent rotten roots.

Among the trees in the last category (general chlorosis) 20 per cent of the trees examined were free from root rotting and the others which had been showing yellowing symptoms since years, had more than 50 per cent of their roots decayed.

Causes of Root Decay

The following experiments were conducted to find out which of the three species of fungi, viz., *R. solani*, *R. bataticola* and *B. theobromae* commonly found associated with roots of coconuts in the disease belt of Travancore-Cochin, could parasitise coconut roots and to find out whether nematodes commonly associated with a soft rot of coconut roots could infect healthy roots.

Fungi:—Seven isolates of three species of fungi, viz., *Rhizoctonia solani*, *R. bataticola* and *Botryodiplodia theobromae* were used in these infection experiments; three isolates were of *R. solani*, two of which were isolated from coconut roots and one from soil; two isolates were of *R. bataticola* from coconut roots; and two isolates were of *B. theobromae* from coconut roots. The fungi were cultured on Richard's agar and 7 to 10 days old cultures were used for inoculations. Tips of young living roots about 3 to 4 feet long, were thoroughly washed with sterile water up to a length of 6" from the tip. These root tips were introduced into tubes containing a pure culture of the isolate that was to be inoculated. The space between the root and the mouth of culture tube was tightly plugged with sterilised cotton wool. Each isolate was inoculated on 30 roots. Roots inserted into tubes containing only the sterilised medium served as controls. These conditions were found to be aseptic and no contamination of the cultures occurred.

Under these conditions it was found that one of the three isolates of *R. solani* (isolated from a coconut root) could infect young living roots. The infected roots stopped growth within two to three days from the date of inoculation. When these roots were cut across on the 7th day from the date of inoculation a browning of the cortex and of the meristem at the root tip region, was noticeable. The rot did not proceed above 4 inches from the root tips. The inoculated fungus was reisolated from surface sterilised tissues (1: 1000 Mercuric chloride for one minute) of these artificially infected roots and on inoculation reproduced root rotting.

The other six isolates (Two isolates of *R. solani*, two of *R. bataticola* and two of *B. theobromae*) did not infect the roots under the experimental conditions. The controls remained healthy and grew normally.

Nematodes:—In the tissues of roots affected with a soft rot, a large number of nematodes was noticed. Bits of these roots containing the nematodes were kept in contact with the thoroughly washed tips of young living roots. These were inserted into sterile tubes, the mouths of which were plugged as reported for the fungal inoculations. Some of these tubes were kept dry and into some others a little quantity of sterile water was added while some were completely filled with water. Under these conditions, the roots remained uninfected and grew normally.

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Discussion

That a good number of healthy trees whose root systems were studied exhibited a varying degree of root decay is an indication that a decayed root system need not necessarily give rise to any foliar symptoms. In fact, some of these healthy trees above 40 years old, and bearing normally, had all their horizontal roots upto a depth of three feet completely decayed, and the trees were able to maintain their normal health with a few healthy vertical roots. This observation lends support to the view (Sampson—1923) that the coconut palm produces roots far more in excess of its needs. However, the effect of such a decayed root system on the trees in the long run, remains to be studied.

No significant difference could be noticed between healthy trees and trees in the early stages of wilt in the extent and frequency of root decay. This and the observation that a few of the trees in early stages of wilt, did not show any root decay whatsoever, clearly indicate that root decay need not precede the manifestation of foliar symptoms of wilt. This disease (category A) has so far been called root disease or wilt. In the light of the observations reported, it is the authors' opinion that the name 'Wilt' would be more appropriate. The progressive increase in the percentage of root rotting, in the middle and advanced stages of wilt disease might be a secondary effect of the disease.

As regards the symptoms of yellowing of outer leaves with nutfall and general chlorosis, the presence of a very small percentage of decayed roots in 50 per cent of trees in the former category, and the absence of root decay in 20 per cent of trees in latter, indicate that root decay in these cases also may be secondary.

Constant association of a high percentage of root decay with the crown symptoms was noticeable only in trees showing tapering stem symptoms. It is possible that trees that are forced to thrive on a limited number of roots might gradually develop the tapering stem symptoms. Observations continued over a long period on apparently healthy trees having a high percentage of decayed roots, might throw light on this problem. The fact that these symptoms are generally noticed in old palms and those growing under unfavourable soil conditions lends support to this possibility. Similar maladies in different parts of the world have also been ascribed to unfavourable soil conditions (Briton-Jones 1940).

Mechanical injury during cultivation operations might be responsible for the destruction of roots immediately below the surface, but the causes of root decay below 1 to 1½ feet from the surface should be sought elsewhere. Biting marks observed on some root-tips during these studies indicate that biting insects might also contribute towards the death of some roots. Infection experiments conducted with isolates of the three fungi *R. solani*, *R. bataticola* and *B. theobromae* have shown that only *R. solani* could parasitise coconut roots causing a cessation of growth and a brown rot of internal tissues and that there was a difference in pathogenicity between isolates of *R. solani*. *Botryodiplodia theobromae* was suspected by Butler (1906) to be the causal organism of the wilt (root) disease of coconuts in Travancore-Cochin and Small attributed the root disease of coconuts in Ceylon to *R. bataticola*; however, the isolates of these two fungi with which the infection experiments reported herein were conducted, were not pathogenic. Among the vertical roots that go deep into soil, observations indicate that a

hard soil pan or a persistent high water table might pave the way for root decay. The nematodes associated with the soft rot of roots are probably saprophytic since they failed to infect living roots.

Summary

The common foliar symptoms of disease met with in the disease belt of Travancore-Cochin have been classified into four categories, *viz.*, wilt, tapering stem, yellowing of outer leaves accompanied by nut-fall and general chlorosis. The symptoms in each category are described. A comparative study of the root systems of healthy trees and those exhibiting different types of foliar symptoms, showed that only tapering stem symptoms were consistently associated with a high percentage of root decay. Some of the healthy trees had a high percentage of decayed roots, while a few palms in early stages of wilt (root) disease were free from root decay. There was no significant difference in the extent and frequency of root decay, between healthy trees and those in early stages of wilt (root) disease; it is therefore suggested that the name wilt is more appropriate for this disease (category 'A'). Root rotting observed in the middle and advanced stages of wilt disease, and in the other two categories (yellowing of outer leaves, and general chlorosis) might be a secondary effect of disease. In the infection experiments with isolates of three fungi, *R. solani*, *R. bataticola* and *B. theobromae*, only one isolate of *R. solani* parasitised coconut roots causing a brown rot of tissues. There was a difference in pathogenicity between isolates of *R. solani*. The isolates of the other two fungi that were tried, were not pathogenic. Nematodes associated with a soft rot of roots could not infect living coconut roots and are probably saprophytic. Observations have indicated that biting insects might also contribute towards death of coconut roots and that a persistent high water table or a hard soil pan might pave the way for root decay.

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