TECHNICAL BULLETIN NO. 5.

THE COCONUT ROOT (WILT) DISEASE

A STATE OF THE ART REPORT

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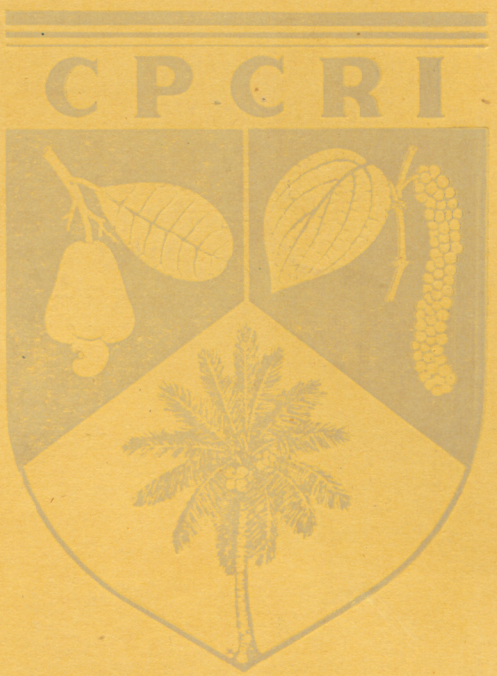

CENTRAL PLANTATION CROPS RESEARCH INSTITUTE
KASARAGOD - 670 124 — KERALA
INDIA.

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THE COCONUT ROOT (WILT) DISEASE: A STATE OF THE ART REPORT

I. Historical background

It is not known as to when the coconut root (wilt) disease was first observed in the erstwhile Travancore State (presently, southern Kerala and Kanyakumari district of Tamil Nadu). However, it has been speculated that the disease became prevalent in the Erattupetta area of Meenachil Taluk (Kottayam district) sometime between 1868 and 1878. The malady was first brought to the notice of the erstwhile Travancore Government in April 1897 by the ryots of Kaviyoor and Kallooppara (Tiruvalla Taluk, Alleppey District). By 1880, the disease was prevalent between Shertallai and Quilon on the western side and the foot hills of Erattupetta on the eastern side.

The Travancore Government responded to the appeal of the farmers of Kaviyoor and Kallooppara in 1900 by asking Mr. B.S. Narayanaswamy Iyer, then Superintendent of the Government Agricultural Farm, Karamana (near Trivandrum) to enquire into the incidence of the disease. He identified two causes, a predisposing one in the impoverishment of the soil and a possible attack by an insect or a fungus. In 1906, the problem was referred to the then Conservator of Forests, Mr. T.F. Bourdillon, who furnished a detailed report in 1907. It concluded that the "disease was fungoid, identical probably with the Bud rot of Ceylon (now Sri Lanka) and the Pythium rot of palmyra and coconut groves in Godavari". The disease was observed to spread from palm to palm and the predisposing causes were suggested as either mineral deficiency or improper drainage.

In 1908 Mr. E.J. Butler, then Imperial Mycologist at Pusa surveyed the area extensively and drew up a report of

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of his findings. This was subsequently published as a bulletin of the Agricultural Research Institute, Pusa (No. 9 of 1908). Butler described foliar symptoms correctly as is known today and he differentiated the disease from bud rot. He believed that the infected palms had rotten roots, and he isolated from these roots a fungus Botryodiplodia. He did not make any attempts to prove the Koch's postulates, but concluded that "the roots of diseased palms are rotten by the attacks of a parasitic fungus, that this fungus appears to be a Botryodiplodia and that probably the root rot caused by it is sufficient to produce the disease".

With the creation of a separate Mycology Section in the Travancore State Agriculture Department in 1929, fresh investigations were started on the cause of the disease. Earlier in 1924, Mr. M.K. Varghese had been appointed as the Mycologist. He identified about 4 sq. miles (over 10.5 sq. km) of one of the worst affected areas around Kayangulam for the studies and examined every palm in the area numbering 60,545 palms. Of these, 59.4% palms showed root (wilt) disease and 69.9% palms were bearing. Of palms of the bearing age 55.3% were diseased. Among the diseased ones, 31.1% palms were hardly yielding any nuts, 65.4% palms gave good yields and 3.5% palms showed exceptionally good yields. The report of Mr. Varghese concluded "that the cause of the disease is not definitely known, but it need not always stand in the way of devising some measures atleast to keep the disease under control". He recommended a system of good management to improve the general health of the palms for reviving them in spite of the disease. These included systematic cultivation, judicious drainage and proper manuring. Eradication of the disease by destroying the infected palms was yet another measure suggested by him.

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In the report on the coconut enquiry in South India submitted by Dr. J.S. Patel (then Oilseeds Specialist, Madras Presidency) in 1934, he summed up the situation by stating that systematic cultivation and regular manuring could keep the disease under control.

A move in this direction came out in the Conference held during 27-29 March 1935 at the Agricultural Research Laboratory, Quilon. One of the committees constituted by the Conference was for initiating a scheme of propaganda and research for restoration of coconut industry. Recognizing that none of the then existing coconut farms at Karamana (near Trivandrum), Ochira (near Kayangulam) and Alleppey had the required facilities for carrying out scientific studies, it recommended the establishment of a Central Coconut Farm of 100 acres (40 ha) in extent at one place where the different soil types of the State would be available. This Committee also recommended to the Travancore Government to move the then Imperial Council of Agricultural Research in India to set up an Indian Central Coconut Committee on the model of Indian Central Cotton Committee.

Subsequently, a decision to constitute such a committee was taken with the passing of the Travancore Coconut Committee Act in 1944. As a consequence, the erstwhile Central Coconut Research Station (the present CPCRI, Regional Station) was established in 1949 at Kayangulam to work on the pests and diseases of coconut, particularly the root (wilt) disease. Initially, the strength of scientists and technical staff was 12. The abolition of the Commodity Committees in 1966 and the taking over of the Kayangulam Station by the Indian Council of Agricultural Research was the first major step taken for strengthening the research efforts on root (wilt) disease.

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These efforts received better direction and newer dimensions after the Central Plantation Crops Research Institute was formed in 1970 by merging the two Central Coconut Research Stations at Kayangulam and Kasaragod and the Central Arecanut Research Station at Vittal. The number of scientists working on the disease was 16 in 1970.

At present, the CPCRI Regional Station at Kayangulam has a strength of 50 scientists, with about 35 scientists working full time on this complex problem. The research is being carried out under 29 ongoing research projects dealing with all aspects of the disease (Table I). The laboratories are well equipped by Indian standards with ultramicrotome, ultracentrifuge, refrigerated centrifuge, spectrophotometer, scintillation counter, gas chromatograph, lyophiliser, laminar flow, colorimeters, pH meters, research microscopes and a cold room. An electron microscope is expected to be installed in 1981.

II. The Present Research and Development Strategy

Over a period of decades, considerable information has been gathered on the nature and properties of this disease. A review of the research carried out so far has been compiled (Tech. Bull. No. 5, CPCRI, 1981). These have been recently assessed and a four pronged strategy for the management of the problem has been worked out. These consist of: (i) contain the disease within the present geographical limits; (ii) to rehabilitate the affected plantations by adopting of package of practices developed for improving the productivity of affected gardens; (iii) eliminate gradually the intensity of the disease by selective eradication and replanting and (iv) continue more intensively the investigations on aetiology and control of the malady. These are now discussed below:-

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(i) Containing the Disease

In 1978, after a series of discussions with the Directorate of Coconut Development and the Kerala Agricultural University, the Kerala Agriculture Department and the CPCRI have jointly launched a programme to see if the northward spread of the disease could be checked. Accordingly, the Kerala Agriculture Department has uprooted about 28,000 wilt affected palms occurring between Chalakudi river in the south and Karuvanoor river and Amballoor-Varandarappally road in the north. The farmers were paid Rs. 75/- per palm as compensation, and in addition, a substitute seedling and fertilizer for the first three years are given at 50% subsidy. The operation cost the Kerala Government over Rs. 2 million. The CPCRI has taken up a more intensive operation in the area north of Karuvannoor river and Ambailoor-Varandarappally road, which consist of uprooting about 2000 palms and practicing intensive soil disinfective operations. For this, a Field Station has been functioning at Irinjalakuda since the last three years. The Field Station will keep a vigil north of Chalakudi river for the appearance of diseased palms.

Since CPCRI researches have shown that adoption of sound management practices (consisting of manuring, plant protection and wherever possible irrigation) are known to keep both the percentage and intensity of the disease low and also that they ensure better levels of productivity the CPCRI has initiated efforts to take up a development programme in the nine villages covering the northern border areas, from where the diseased palms have been removed, to induce all the coconut farmers in the area to adopt the management practices developed by the CPCRI. A universal adoption of a package of practices comprising of scientific management of coconut plantations and constant eradication of diseased palms should control the northward spread of the disease.

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In the southern borders, the rate of spread has been somewhat slower, but about 1200 diseased palms have been recorded in two villages bordering Kerala in Kanyakumari District (of Tamil Nadu). The CPCRI has initiated efforts to establish a disease-free border zone in the south also as has been done in Trichur District in Kerala.

(ii) Adopting Sound Management Practices

The second prong in the R&D strategy consists of transferring to the field all the developed know-how to rehabilitate the diseased plantations.

Early studies carried out in the CPCRI had shown a high correlation between the incidence of root (wilt) disease and leaf rot disease, which is caused by the fungus Bipolaris halodes, and that 2-3 sprayings of a copper fungicide could control leaf rot disease, incfease nut yield by 2-7 nuts/palm annually, and possibly help indirectly to stem the intensification of root (wilt) disease symptoms. Earlier efforts of the Kerala Agriculture Department to control the northward and southward spread of root (wilt) disease by taking up copper fungicidal spraying in the two borders were not successful. However, following the confirmation by the CPCRI of the beneficial effects of copper fungicidal spraying in controlling leaf rot disease, the Kerala Agriculture Department has now launched an ambitious scheme costing Rs. 64 million a year to carry out spraying operations in the entire wilt affected areas.

(iii) Eradication and Replanting Programme

A survey carried out by the CPCRI in 1975 had shown that the disease is present in varying intensities in the seven southern districts of Kerala covering about 250,000 ha out of a total of 700,000 ha. In atleast 13 taluqs, 40% and more of the palms are infected. Since the disease is primarily

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debilitating and rarely lethal, and the infecting palms show a progressive decline in yield, the Kerala Government has taken up under advice of the CPCRI and in consultation with the Directorate of Coconut Development and the Kerala Agricultural University, a massive eradication and replanting programme. Under this programme, all the highly diseased, senile and uneconomic palms yielding less than 12 nuts annually will be eradicated after paying a compensation of Rs. 75/- per palm. In their place, farmers will be given quality seedlings. They will receive also financial inducements to take up manuring, apply soil amendments and adopt irrigation. In the first year (1980-81), this was taken up in 55 panchayats at a cost of about Rs. 25 million.

The CPCRI has now prepared a replanting programme for coconuts in Kerala to be completed in 40 years in an area of 600,000 ha (Kerala Coconut Replanting Project - NM Nayar, PK Das and Jacob Mathew; Tech. Bull No. 4, CPCRI, 1981). The State would be divided into 20 blocks of 30,000 ha and replanting would be taken up in two stages. The total outlay of the scheme varies from Rs. 15,000-29,000 million in 40 years. By most conservative estimates, when implemented, it would double coconut production in 20 years provide direct employment for 1,60,000 persons annually and direct revenue of Rs. 5,000 million annually.

However, a recent letter addressed to the Union Minister of Agriculture (A&RR) by the Member(s) Planning Commission has stated that the latter had a discussion with the Minister of Agriculture, Kerala State, who made a request for the following for long term research strategy:-

> "Initiate more intensive research by strengthening the Kayangulam Research Centre and also by implementing the Collaborative Agreements with U.K. and France which are under the consideration of ICAR"

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In the letter of the Member(s) Planning Commission, the three approaches spelled out for the short-term strategy on the Coconut Root (wilt) in Kerala are:-

(a) Restricting the further spread of the disease through monitoring and quarantine precautions;

(b) Taking advantage of the additional production which seems possible through better agronomic management of the wilt affected coconut palms; and

(c) Replanting of very severely affected gardens using suitable hybrid seedlings

For the above programme, the Minister of Agriculture, Kerala State has desired Government of India's assistance by way of the following steps:-

(a) Include coconut in the Central Sector Project on Oil seeds Production, since coconut is a very important source of edible oil;

(b) Include coconut in the NDDB sponsored project for the restructuring of the oilseed economy

(iv) The new Research Thrust

This is the third prong of the R&D strategy. It is being directed to determine the causes of the malady and develop cure for the same. Two experiments have been just started to monitor the development of the disease after seedlings are inoculated with all suspected pathogens in various combinations. A number of chemicals like tetracycline, certain phenolic compounds, ascorbic acid, hormones like NAA and selected nematicides and fungicides are being tested to study their effect on reducing the disease or even curing it. Studies have been taken on hand also on water relations, biological interactions in the soil, especially in the rhizosphere, and on the effects of various intercropping systems.

III. Present status of the Disease

A survey concluded in 1972 indicated that 2.5 lakhs ha of coconut gardens in Kerala and two villages of Kanyakumari district, Tamil Nadu are affected by the disease (Table II).

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In general, the disease is present in varying intensities in almost all the taluks in Trivandrum, Quilon, Alleppey, Kottayam, Idukky and Ernakulam districts and the southern taluks of Trichur district. However, as has been pointed out earlier all the diseased palms occurring in Trichur district are being got eradicated. Thus nearly 193 million palms, out of a total of 713 million palms are affected by the disease in the six southern-most districts of Kerala. A survey of this area to determine the change in the intensity and extent of the malady is contemplated during 1980-81.

Palms of all ages are susceptible to the disease, but disease-free gardens occur in the midst of diseased areas and apparently healthy palms also in heavily infected gardens. The spread is either contiguous or sporadic, but it is more frequent along the banks of rivers and waterways subject to inundation and waterlogging. It is important to note that the disease is not lethal, but only debilitating.

Observations recorded for a period of seven years in selected garden of approximately one ha in extent, and having low percentage of disease incidence revealed rapid and indiscriminate spread of the disease in coastal sand and alluvial soils. An increase in the percentage of infection from 2.3-18.2 was noticed, as about 5 palms contracted the disease every year. The rate of spread was comparatively slower in laterite soils. However, the disease is found in all soil types. The rate of spread has been 1-4 KM each year from the nearest source of infection.

The epidemiology of the disease is not consistent with nutritional disorders. The major and minor nutrient status of soil and palms in the healthy and diseased areas exclude any major nutritional factors as the sole cause of the disease.

In the 1972 survey, the disease was estimated to cause an annual loss of over 340 million nuts. In terms of loss of

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goods and services, this adds upto an annual loss of Rs.765 million (if cost of one nut is computed at Rs. 1.50).

IV. The Present Research Work

Since 1948, the ICAR/CPCRI has been the only agency researching on this malady, except for some disease resistance trials under way in the Kumarakom Station (Kottayam District) of the Kerala Agricultural University. However, the Kerala Agricultural University has some plans to initiate a research programme on this malady.

The typical symptoms of the disease include (wilting of foliage), flaccidity and ribbing of leaflets (of young leaves) followed by yellowing and marginal necrosis. Abnormal shedding of female flowers and buttons are often noted. Healthy roots of apparently healthy and diseased palms show tylosis, fungal hyphae in metaxylem, and necrosis of phloem tissues. Cell walls in root from diseased palms show poor stainability. It is believed that excessive rotting of roots is also one of the symptoms, but this aspect is under reinvestigation. Earlier reports used to give a higher percentage of root rotting and vascular discolouration of roots in infected palms, but is now known that vascular discolouration of roots is not observed in the presence of an antioxidant. It is well known that all tissues containing high level of tannins turn brown upon cutting and exposure ti air; cut apple is a good example.

For early diagnosis of the disease before the onset of visual symptoms, serodiagnostic and a rapid biochemical tests have been developed, but both these tests require further refinement. Multiple forms of polyphenol oxidase show distinct difference between healthy, symptomless and diseased palms.

The etiology of the malady is still uncertain, as Koch's postulates are yet to be proved with the implicated biotic agents. Likewise, virus and virus-like particles are yet to be located consistently in electron micrographs.

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The fungus Botryodiplodia theobromae was initially suspected as the possible pathogen, but subsequent studies showed the association of two Rhizoctonia species, R. solani and R. bataticola. But, niether of these have been able to produce foliar symptoms in pathogenicity trials. The fungi Fusarium equiseti, Cylindrocarpon effusum and a sterile fungus have been found more recently in palms of disease affected areas. Similarly, the fungus Cylindrocarpon lucidum has been isolated from nematode-induced root lesions.

A bacterium, Enterobacter cloacae has been implicated, but it does not belong to a conventional plant pathogenic genus. Also, it is very widely present in the soil and water; the genus has also been recently implicated in plant diseases. The bacterium, however, elaborates a wilt-inducing toxic principle in growing culture filtrate an aqueous suspension of which produces waving and bending of tender coconut leaflets.

Plant parasitic nematodes belonging to 35 genera have been isolated from the root zone of coconut, which include species of Xiphinema, Longidorus and Trichodorus, all known virus vectors, as well as the burrowing nematode Radopholus similis. Populations of R. similis as high as 4000 nemas per gram of root have been recorded from roots of diseased palms. When inoculated, the nematodes produce elobgated critical lesions on the roots, which coalesce and cause severe root rotting. The burrowing nematode population has been recognised as the Banana race, which parasitises over 40 species of plants.

A positive transmission of the disease in the coconut palm by mechanical inoculation of sap and through an insect vector Stephanitis typica in field conditions and insect proof house suggest a probable viral etiology. Seed transmissible nature of the disease has not been confirmed in limited experimental studies carried out so far, but this is suspected.

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Icosahedral particles of 56 nm size observed in electron micrographs of tender leaf sections and reported as viral particles by Maramorosch recently, have been subsequently identified to be plasmodesmata by Parthasarathy and this reinterpretation has been accepted by Maramorosch. Likewise, mycoplasma-like organisms, typica virus-like particles, viroid like RNA and cadang-cadang specific RNA have not been detected in the palms studied by Randles.

Several experiments are in progress at Regional Station, Kayangulam, and also in cultivators' gardens on the possible control of the disease using fungicides, bactericides, nematicides, as plant growth regulators. An integrated chemical control trial is also in progress in a garden of about 3 hectares in extent consisting of 600 palms of different ages and intensity of the disease in the Krishnapuram village. Here, on the basis of the yield, age and disease severity, 135 palms have been selected for the integrated chemical control trials. A favourable response to terramycin tree formulation, a research product containing oxytetracycline as active ingredient, and to ascorbic acid and naphthalene acetic acid have been indicated in farmers' gardens.

A varietal screening programme to study the yield and reaction to the disease has been taken up in 163 cultivators' gardens. So far, 49 out of the 100 cultivars/hybrids have developed the symptoms of the disease. In the Regional Station, 98 palms in a total of 474 palms, belonging to 38 cultivars/hybrids have so far developed the symptoms of the disease.

Performance of healthy palms & their progenies in diseased area

The northern belt of the root (wilt) disease has been tentatively identified in the nine villages, viz. Varandarapally, Amballur, Kallur, Keezhpallikkara, Kurimbilavu, Inchamudi, Oorakam and Arattupuzha on the northern side of the Karuvannur river and Amballur-Pulpally road in Trichur District. After detailed surveys, about 400 diseased palms were

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identified in these villages. These were uprooted and removed after spraying with Carbaryl (0.05%) to destroy any possible vectors present on them. The boles and roots of the diseased palms were dug out and burned. The nematicide Temik 10G and the fungicide Bavistin were applied in the soil at the base of palms surrounding (15 m^2 around) the palms removed. The farmers were paid a compensation of Rs. 75.00 per palm and DxT or TxD seedlings were supplied for replacing the eradicated ones. A more thorough survey of the area upto Bharatapuzha river is proposed to be taken up shortly.

Physiological derangements have been observed consequent on the incidence of the disease. Water economy is upset which results in reduced uptake and upward transport of water, increased rate of transpiration, higher moisture content and more number of stomata in the leaves. Loss of permeability of the root and leaf cells and an increased rate of respiration, higher moisture content and more number of stomata in the leaves. Loss of permeability of the root and leaf cells and an increased rate of respiration are also observed in the diseased palms. Accumulation of nonprotein nitrogen in the leaves reduced rate of photosynthesis, lower chlorophyll content and reduced activity of carbonic anhydrase are yet other derangements. Carbohydrate metabolism is impaired, suggesting a possible block in the translocation and distribution of sugars.

A mixed farming experiment carried out in the Kayangulam Station in the early 70's involved the growing of forage crops under rainfed conditions in a severely infected garden, raising milch cattle and recycling organic matter. This resulted in raising the yield from 31 nuts to 41 nuts/palm/year during five years. It also showed an increase in colonisation of nitrogen-fixing and phosphorus-solubilizing organisms in the root region of coconut. Encouraged by these results, a series

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of new studies have been initiated in intercropping and mixed cropping systems of coconut mostly in farmers' fields.

A survey of healthy and disease-affected soils indicate a possible deficiency of zinc and molybdenum. A new field experiment to study the effect of micronutrients on disease incidence is being laid out during the year.

In 1970 and 1972, two field experiments have been laid out in the Institute using West Coast Tall (WCT) (with 648 palms) and DxT hybrids (324 palms) to study the effect of varying doses of N, P, K, Ca and Mg on the development of the disease and nut yield under rainfed conditions. The rate of development of the disease and nut yield obtained in the two experiments (as an average of all the treatments) is given in Table III.

The interesting aspect of these studies are (1) that this has been planted in one of the most severely infected areas; (2) the effect of Mg has been very marked; (3) the data obtained so far show that even if the palms contract the disease, they are able to give very high yields under good management conditions. Incidentally, these trials are being carried out in sandy soils and under rainfed conditions after cutting down all the diseased palms.

The results obtained in these and other experiments were discussed in a group meeting held in Kayangulam early in 1980, that was attended by representatives of the Kerala Agricultural University, Kerala Agricultural Department, Directorate of Coconut Development and the CPCRI. This meeting recommended a package of practice for the root (wilt) affected tracts (Table IV).

Under rainfed conditions, the fertilisers are applied in two split doses, one-third before South-West monsoon and the remaining two-third before North-East monsoon. Under irrigated conditions, the fertilisers are applied best in

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four split doses in April-May, August-September, December and February. In addition, 1 kg each of slaked lime and magnesium sulphate are also to be applied.

Irrigating the palms in summer is strongly recommended, approximately once 3-5 days in coastal sandy loam soils and in 7-10 days in laterite soils.

Other components of the package of practices include application of organic manures and silt, crop mixing with cacao combined with irrigation and mixed farming with milch cows and fodder crops. Uneconomical palms are to be replanted and fungicides should be sprayed at least twice in a year.

V. Foreign collaboration/Expert Involved

Besides short visits of a number of scientists from India and abroad, which have been going on regularly, there have been so far four consultancy visits from overseas to study the problem at any depth. These are listed below:

1. Dr FO Holmes	(13 October 1964 to 3 December 1964)
2. Dr B Weischer	(22 October 1966 to February1967)
3. Dr JW Randles	(5 February 1979 to 13 February 1979)
4. Dr DJ Raski	(13 May 1979 to 19 June 1979)

Dr Holmes (Rockefeller Institute, New York) assumed that the disease is of viral/virus like etiology, particularly on the strength of the cowpea that was being reported from the Institute as well as his own experience during that period as a diagnostic test. His recommendation was to follow up the rate at which infective soils became noninfective after eradication of the diseased palms and examination of soil samples before recommending the area for planting or replanting

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coconuts. These recommendations are not valid now, as for reasons unknown, the cowpea test has not been reproducible since the past few years. Dr Holme's other recommendations included identification of diseased palms in disease-free areas and eradicating them to prevent the further spread of the disease in such areas. He recommended also the strengthening of the staff and providing better facilities for research at Kayangulam.

Dr Weischer (University of Munster, West Germany) was of the opinion that the low population density of nematodes, their widespread occurrence and the general distribution pattern of the disease indicated that plant parasitic nematodes could be excluded as a primary cause of the disease. However, they could be considered as disease incidence by causing injury to the root tissues and consequently providing entry points for other pathogens. If viruses are involved, the presence of Xiphinema and/or Longidorus in all soil types and places could be of importance. Dr Weischer suggested that host-parasitic relationships between coconut palms and nematodes should be studied. He also proposed that transmission studies with these nematodes should be undertaken if a viral etiology was substantiated at a future date.

Dr Raski (University of California, Davis) recommended that survey sampling should be done for determining the precise association of Radopholus similis with the disease. This could have the same number of samples in the three major soil types (sandy, alluvial and laterite) in both healthy and diseased areas. He further suggested that the other coconut growing States of India should be surveyed to map the incidence of R. similis. Dr Raski's other suggestions include strengthening of taxonomic studies and taking up of pathogenicity trials with priority for the latter.

Dr Randles (University of Adelaide, South Australia) observed in his concluding note that mycoplasma-like organisms,

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virus-like particles, viroid-like RNA and Cadang Cadang-specific RNA were absent in the material. He recommended that efforts might be concentrated on the antiserum to see if virus-specific particles, nucleic acid or protein could be associated with the precipitate. He felt that the electron microscopic results should be regarded as inconclusive rather than negative.

In the past few years, the CPCRI has been making efforts to obtain organized collaborative support for the ongoing research programmes. Accordingly, under the World Bank funded Kerala Agricultural Development Project, which aims to improve the condition of coconut, rubber and black pepper plantations in Kerala, a research component costing Rs. 119 lakhs for five years has been included. This is being executed by the Kerala Agricultural University and the CPCRI. The allocation for the CPCRI is Rs. 64 lakhs and the work under this was started on 1 January, 1978. Out of this, Rs. 41 lakhs is being spent on intensification of research on root (wilt) disease. This provides for appointment of five senior scientists at Kayangulam to strengthen the ongoing research programmes (out of a total of nine scientists and four other categories of staff provided), training of scientists for nine man-months in foreign countries and obtaining consultancies from overseas countries for 18 man-months. One scientist working on Stephanitis, a possible insect vector of root (wilt) disease, has already had the benefit of training under this programme. Dr DJ Raski's (University of California) visit was also arranged with funds from this source. Negotiations are now under way to train more scientists and also obtain some consultants under this programme.

As part of the Indo-UK protocol signed in 1977-78 under the Natural Resources Development Programme, the CPCRI has been identified to "twin" with Rothamsted Experiment Station, the biggest and the most prestigeous agricultural research station in UK, for taking up co-operative research programmes on root (wilt) disease of coconut and yellow leaf disease of arecanut.

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Already, the Chief Agricultural Adviser of the Overseas Development Administration, the Director, Rothamsted Experiment Station, a Senior Virologist of Rothamsted and officials of the British High Commission in India havev visited the Institute for appraising themselves about the work. Under this programme about seven senior British scientists working in Rothamsted and other leading agricultural research laboratories would be identified to maintain an abiding interest in the ongoing research programmes on root (wilt) disease for the next 3-5 years. They themselves and/or their immediate associates would visit this Institute approximately every year. Further, about 12 Indian scientists in six important disciplines where strengthening of research efforts has been sought would spend about 72 man-months in Britain for training and research. A limited quantity of equipments are also expected to be made available under this programme.

In addition, under the recently concluded Indo-French agreement, some cooperative research programmes are expected to be taken up on certain specific aspects, particularly those relating to nutritional aspects and screening of genetic material for reaction to root (wilt) disease.

Efforts are also under way to obtain the support of the FAO and other international agencies to arrange an International Conference in 1982/1983 covering all the Coconut Diseases of Uncertain Aetiology, numbering about 23. About 30 scientists from overseas working specifically on these diseases and a few leading plant pathologists from outside India are expected to participate in this programme. Negotiations have also been started to see if some collaborative link could be established with the ongoing international research efforts on the other two important coconut diseases of uncertain aetiology, namely, the Cadang-Cadang disease of the Philippines and Lethal Yellowing of West Indies.

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VI. Summing up

In the foregoing pages an attempt has been made to give an overview of the disease, the magnitude of the problem, a summary of the work done and in progress and a report on the ongoing development efforts to bring the problem under control. The CPCRI scientists are confident that if the full knowledge that has been so far developed on the management and rejuvenation of affected palms is transferred to the field, it would then be possible not only to check the present decline in the yields of the infected palms but also bring about a marked and progressive improvement in the productivity of the gardens within the next 5-6 years. The Institute scientists are also modestly confident that within this period, that is, within 5-6 years, they would be able to obtain a clearer idea about the causes and nature of the disease.

It is well known that man, domestic animals and cultivated plants are all afflicted by several diseases whose aetiology has not been clearly determined. This is obvious in the case of even several common human ailments even in spite of the most intensive research efforts under way. Several perennial crops are also afflicted by similar diseases of uncertain aetiology. The replant disease of apples and similar other diseases of temperature fruit plants, citrus decline etc. are good examples of these. The coconut root (wilt) disease may also perhaps be one such disease.

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Table I. ONGOING RESEARCH PROJECTS ON COCONUT ROOT (WILT) DISEASE

1. Path. I.3(231)	Etiology of the disease a) Monitoring changes in the palm b) Pathogenicity trials (NP Jayasankar, NG Pillai, VG Lily, MP Govindankutty, Mathew George, M Sasikala, S Robert Cecil, Chacko Mathew KV Joseph, K Mathen, Chandy Kurian, B Sathiamma)
2. Path. I.4(231)	Diagnosis of root (wilt) disease (M Sasikala)
3. Path. I.5(231)	Transmission of coconut root (wilt) disease (K Mathen)
4. Path. I.6(231)	Control of root (wilt) disease a) Field evaluation studies on root (wilt) disease (KJ Thommen, P Chidambaram, Thomas Joseph)
5. Path. I.7(231)	Association of virus/mycoplasma with root (wilt) disease
6. Path. I.8(231)	Studies on the role of fungi (VG Lily)
7. Path. I.9(231)	Studies on the epidemiology of coconut root (wilt) disease (N Gopinathan Pillai)
8. Path. I.10(231)	Histopathological studies on coconut in relation to root (wilt) disease (Work suspended)
9. Path.I.11(231)	Virus diseases of weeds in coconut gardens (M Sasikala, N Gopinathan Pillai, K Mathen)
10. Micro.I(231)	Microbiological activities in the root region of coconut palms (GV Thomas, J Antony, Maria Florence)

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11. Micro.II(231)	Host parasite interactions with reference to polyphenols in coconut roots (KV Joseph, VG Lily)
12. Micro.III(231)	Association of bacteria in the etiology of root (wilt) disease (M George, NP Jayasankar)
13. Nema.II(231)	Studies on Radopholus similis (PK Koshy, Sosamma Varghese)
14. Nema.III(231)	Studies on population build up of Radopholus similis in coconut (Sosamma Varghese)
15. SSc.IV(231)	Nutritional status of coconut tissues and soils in relation to foliar yellowing and rubbery kernel of nuts (NG Pillai, S Robert Cecil, VG Lily)
16. SSc.V.1(231)	Effect of N, P, K, Ca and Mg on the incidence of root (wilt) disease (S Robert Cecil, NG Pillai, PG Kamalakshy Amma, AS Mathew)
17. SSc.V.2(231)	Role of micronutrients on the incidence and control of root (wilt) disease (AS Mathew, NG Pillai)
18. Phy. III(231)	Physiological and biochemical changes in dry matter production in wilt diseased palms (Thomas Varkey)
19. Phy.VIII(231)	Metallo-enzymes and biologically active nutrients in relation to root (wilt) disease (PK Ray, B Sumathykutty Amma)
20. Phy. IX(231)	Distribution, absorption and translocation pattern of radioactive P and Rb in healthy and root (wilt) affected palms (PK Ray, KD Patil)
21. Phy. X(231)	Studies on water relations of coconut in relation to root (wilt) disease (Chacko Mathew, Thomas Varkey, V Rajagopal)

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22. Phy.XI(231) Studies on root decay and root regeneration in coconut palm, in relation to root (wilt) disease
(B Sumathykutty Amma, KD Patil)

23. Phy.XII(231) Experiment on the control of root (wilt) disease by chemical treatments
(KD Patil, PK Ray, Chacko Mathew, Thomas Varkey, B Sumathykutty Amma)

KERALA AGRICULTURAL DEVELOPMENT PROJECT (KADP)

1. KADP I. (231)

Electron microscopic and serological studies for the identification of virus-like agents associated with root (wilt) disease of coconut
(J.J. Solomon)

2. KADP II(231)

Screening of coconut germplasm for resistance/tolerance to root (wilt) disease
(KJ Thommen, P Chidambaram)

3. KADP III(231)

Rejuvenation of coconut root (wilt) diseased gardens in heavily infected areas and prevention of its spread to unaffected areas. Expts. I & II
(P Chidambaram, PK Koshy, George V Thomas at Kayangulam, K Radha, P Rethinam, M Kochubabu at Irinjalakuda)

4. KADP IV-VIII (231)

Microbiological studies on coconut root (wilt) disease

a) Role of bacteria in the etiology of root (wilt) disease
b) Bactericidal trials
c) Soil microbial equilibrium in response to inter and mixed cropping trials
d) Soil microbiological studies in response to integrated control trials
e) Mass culturing of microbial antagonists
(M.V. Shantaram)

5. KADP IX(231)

Role of Radopholus similis in coconut root (wilt)
(PK Koshy, Sosamma Varghese)

6. KADP X (231)

Studies on certain phenols, glycosides, growth hormones and the water stress in coconut in relation to root (wilt) disease
(KD Patil, PK Ray, Chacko Mathew, B Sumathykutty Amma, Thomas Varkey)

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Table II. Area under coconuts in Kerala and incidence of root (wilt) disease

Sl. No.	District	Taluk	Area ('000 ha)	Percentage disease incidence
1.	Trivandrum	Neyyattinkara	28	0.1
		Trivandrum	18	0.1
		Nedumangad	17	8.7
		Chirayinkil	37	6.3
		Total	100	3.8
2.	Quilon	Quilon	18	13.8
		Kottarakkara	16	14.9
		Pathanapuram	9	35.7
		Pathanamthitta	8	37.8
		Kunnathur	11	29.9
		Karunagappally	13	55.5
		Total	75	28.7
3.	Alleppey	Karthigappally	6	72.4
		Mavelikkara	14	43.0
		Chengannur	5	36.6
		Thiruvalla	8	43.5
		Kuttanad	4	77.4
		Ambalapuzha	5	22.4
		Sherthalai	18	20.8
		Total	60	39.8
4.	Kottayam	Changanacherry	8	49.5
		Kottayam	15	40.0
		Kanjirapally	6	57.6
		Meenachil	14	55.6
		Vaikom	6	36.2
		Total	49	47.6
5.	Ernakulam	Koothattukulam	5	14.5
		Moovattupuzha	5	14.5
		Cochin	7	35.9
		Kanayannoor	14	52.8
		Alwaye	6	21.0
		Panur	6	30.1
		Kunnathunad	12	16.5
		Total	55	29.9

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Table II. Area under coconuts in Kerala and incidence of root (wilt) disease

6. Idukki	Thodupuzha	16	42.1
	Pirmedu	2	37.8
	Anvikulam	N	Nil
	Udumbanshola	N	Nil
	Total	18	41.2
	GRAND TOTAL	357	27.1

*1978-1979 data

** Data from 1972 survey

Table III. Nut yield and disease incidence in WCT and D x T palms in Kayangulam

Variety	Year	Disease incidence (%)	Nut yield per palm/year
WCT (Planted: October, 1970)	1974	2.2	Nil
	1975	4.3	Nil
	1976	8.8	Nil
	1977	22.5	17
	1978	29.3	40
	1979	35.5	50
DxT (Planted: July, 1972)	1976	1.5	Nil
	1977	3.6	75
	1978	5.0	129
	1979	5.0	90
	1980	6.5	118

Table IV. Recommended package of practices for the root (wilt) disease affected gardens

	N	P	K
	per palm/year		
I. Normal recommendations			
a) Good management	0.34	0.17	0.68
b) Better management	0.50	0.32	1.20
II. Reclaimed clay soils	0.25	0.35	0.90
III. Hybrids and high yielding palms			
a) With irrigation	1.00	0.50	2.00
b) Rainfed conditions	0.57	0.32	1.20