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Yellow Leaf Disease of Arecanut

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1. INTRODUCTION

Yellow leaf disease of arecanut is the major disease in Kerala and parts of Karnataka states which considerably reduced the production in Kerala. The earliest information on the yellow leaf disease of arecanut (*Areca catechu* L.) is found in the publication Diseases of Coconut palms (Varghese, 1934). He observed that the disease had some similarities with the root and leaf disease of coconut prevalent in Kerala. According to Nambiar (1949), the disease first made its appearance in 1914 in Moovattupuzha, Meenachil and Chalakkudi areas of central Kerala succeeding a heavy flood. The disease was also reported from the coastal regions of Bombay, parts of Karnataka and Tamil Nadu (Menon, 1963). In the malnad areas of Karnataka, the disease is known as 'chandiroga' (Dastagir, 1963).

2. SPREAD OF THE DISEASE

A preliminary survey conducted in 1959-60 showed that the disease had spread to all parts of Kerala with the focus of infection in the Quilon areas where almost 90 per cent of the palms were diseased (Anon., 1960). A comprehensive survey was undertaken in 1976 covering 210 villages in the disease affected areas of Kerala and Karnataka. The survey revealed that the disease is prevalent in almost all the districts of Kerala in varying degrees. Maximum incidence of the disease was recorded from Idukki district where 97 per cent of the area under the crop was affected. In Kerala, 36 percent of the total area under the crop was diseased as against 24.4 percent infected area in Koppa and Sringeri taluks of Karnataka State (Anon., 1977). The data is given in Table 1.

A garden to garden survey conducted during 1987 at Puttur and Sullia taluks of Dakshina Kannada district of Karnataka State has shown that the disease is wide spread in all villages of Sullia taluk. In Puttur, 114 palms from 26 gardens in 6 villages and in Sullia 9188 palms from 184 gardens in 16 villages were diseased (Anon., 1988). A recent statewide survey revealed that the disease had spread to all Malnad districts of Karnataka State.

Thorough and systematic observations were made from 1961 onwards with respect to the pattern of spread of the disease at CPCRI Research Centre, Palode which

Table 1 : Spread of yellow leaf disease of arecanut

District	Area under arecanut (000 ha)	Percentage area affected
Kerala		
Cannanore	16.58	1.20
Kozhikode	8.10	0.70
Malappuram	15.50	N.A.
Palghat	3.70	N.A.
Trichur	15.10	6.30
Idukki	1.70	97.00
Ernakulam	7.80	34.10
Kottayam	5.40	94.30
Alleppy	5.10	N.A.
Quilon	9.20	75.40
Trivandrum	4.50	71.80
Total	92.68	35.80
Karnataka		
Chickmagalore		
(Koppa and Sringeri taluks)	—	24.40

is in a predominantly diseased area. Seedlings planted in 1961 in virgin forest soil took up symptoms by 1968. The pattern of spread of disease from the primary focus was not in a definite manner and it was totally erratic. By 1972, i.e., within period of 4 years from the appearance of the first symptoms, about 80 percent of the palms in the garden showed disease symptoms. This indicates rapidity in the further spread of disease. Usually the seedlings planted in the affected soil manifest the symptoms after 3 years of planting. Fifty percent reduction in yield on account of disease was recorded over a period of 3 years (Anon., 1977). The disease is only debilitating in nature and not lethal.

3. SYMPTOMS

As the name indicates, the disease is characterised by yellowing of the leaves. Nambiar (1949) recorded the symptoms of the disease as yellowing of the leaves and shedding of both mature and immature nuts. According to Menon (1963), the yellowing may appear on any leaf to start with and may be limited to few leaves or it may spread to the remaining leaves in the crown. Subsequent studies have shown that yellowing appears only at the tips of the leaflets from two or three leaves of the outermost whorl. This yellowing gradually extend to the middle lamella and could be easily distinguished from the other sorts of yellowing due to nitrogen deficiency, drought, waterlogging, mite/root grub infestation, etc. The foliar yellowing is characterised by abrupt demarcation between green and yellow region. There will be a clear band of green tissues adjacent to the midrib areas of the leaf as well as the leaflets (Fig. 1). One or two leaflets in any part of the foliage could be affected by the disease. During dry periods, the tips of the chlorotic leaflets become necrotic and eventually dry up. In the advanced stage of the disease, the leaves become reduced in size, stiff and pointed, closely bunched and abnormally puckered (Fig. 2). Menon (1963) recorded translucent spots 1-3 mm in diameter in the growing spindle as the first visible symptom of the disease and also noticed brown necrotic streaks running parallel to the lamina of the unfolding leaves. When the crown is yellowed, the folded spindle become necrotic and collapse. Eventually, the crown topples from the trunk (Nayar and Seliskar, 1978). The final phase occurs 12-18 months after pronounced yellowing of the crown. During the advancement of the disease, the spindle become brittle at the base, necrotic at the tip and fails to open. Spindle leaves break during winds and appear drooping from the crown. Later, normal leaves emerge from the same crown.

Kernel discolouration is a common symptom associated with the disease. The endosperm of the mature and immature nuts show a blackish discolouration mostly towards the calycular region. The whole kernel becomes unfit for consumption. On drying, the chali is shrivelled and of poor quality. Thus, the disease cause qualitative and quantitative loss to the crop. Shedding of fruits in large numbers is also recorded during

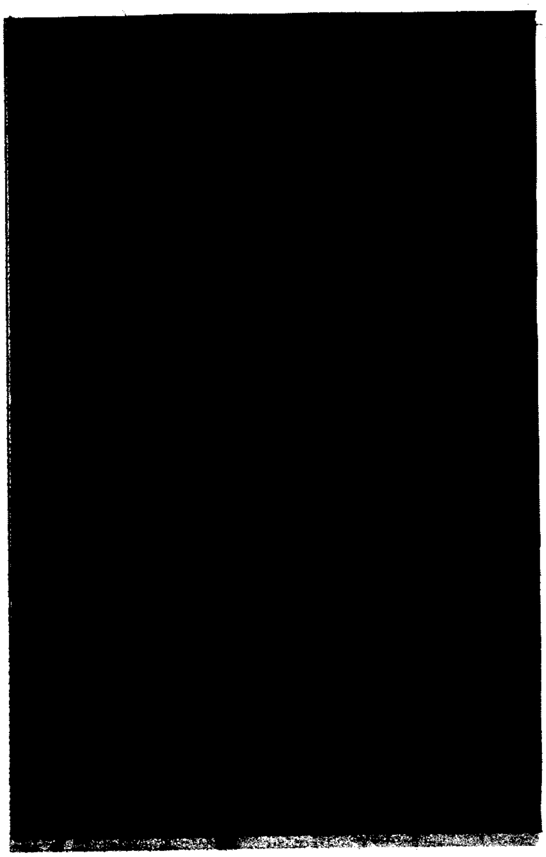

Fig. 1 : Leaf showing yellow gradually extending towards midrib.

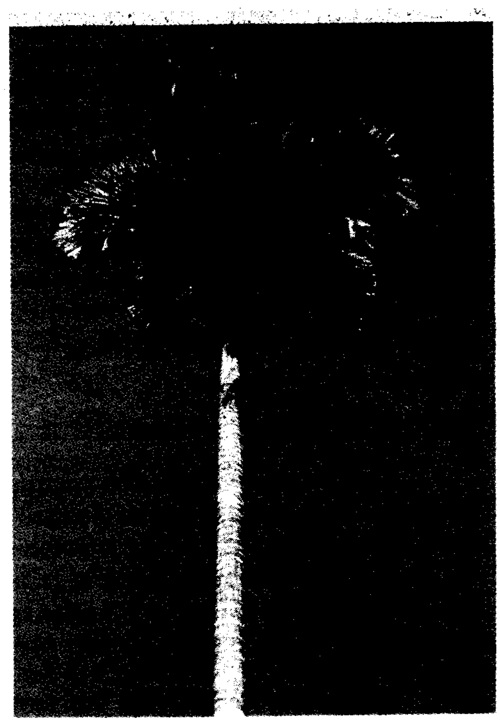

Fig. 2 : Yellow leaf disease affected arecanut palm.

the course of the disease. Rawther (1976) opined that the kernel discolouration is not an essential symptom of the disease since apparently healthy palms in the vicinity of the diseased palms also showed kernel discolouration. Further, all the nuts produced in the diseased bunch may not show the endosperm blackening. Table 2 shows the relationship between kernel discolouration and foliar yellowing.

Table 2 : Relationship between kernel discolouration and foliar yellowing

Foliar condition of the palm	Percentage palms showing kernel discolouration	Percentage of nuts showing kernel discolouration
With foliar yellowing	70	88
Normal foliage	30	60

Roots of affected palms show various stages of decay. The difference in the condition of roots between healthy and diseased palms in the initial stages of infection was not significant. But as the disease progress, the extent of root decay also enhanced. Rotting of root system of palms in the advanced stage of infection is very high (Rawther, 1976). The data is presented in Table 3. It is clear from Table 3 that lateral roots are not produced as profusely as in healthy palms due to the disease. Tips and absorbing regions of young roots turn black and gradually rot. No significant correlation could be obtained between root rot and yellowing during different seasons (Anon., 1977).

Table 3 : Relationship between severity of disease and root decay

Condition of palms	No. of main roots examined	Percentage of healthy main roots	Percentage of decayed roots	Average no. of branch roots
Healthy	134	97.2	2.5	23
Disease early	120	72.8	27.2	12
Disease advanced	130	28.9	71.1	4

The disease affects the normal growth and vigour of the palms. The leaf size is considerably reduced. As the disease advances, the girth of the crown gradually tapers. The internodal distance of the affected stem reduces due to decrease in normal growth. The yield of the affected palms is reduced to the extent of 50 per cent over a period of 3 years. This is mainly due to the reduction in the inflorescence production as well as less nuts in the inflorescences (Anon., 1977). The data is given in Table 4.

A formula for studying the severity of the disease was evolved after studying the associated symptoms in more than 2000 palms (George *et al.*, 1980). Due weightage was given to foliar yellowing, necrosis and reduction in size of the whole crown. According to the formula, the severity of the disease is expressed as

$$\text{Disease index} = \frac{Y + N}{L} + R \times 10$$

Table 4 : Effect of disease on yield and leaf fall (per year per palm)

	Before disease incidence (Mean of 3 years)	After disease incidence due to disease	Percentage reduction
No. of nuts	4433	2138	52.7
Leaf fall	8.0	7.7	4.0
Disease index	0.0	8.8	0.0

Where

Y = total scoring for yellowing of the leaves (0-7),

N = scoring for the necrosis of leaves,

R = scoring for the reduction in size of the crown, and

L = half the number of leaves in the crown.

4. ANATOMICAL CHANGES

Nayar (1968) observed multinucleate cells in the diseased leaf tissues, disturbed tissue differentiation, blocking of palisade cells with brown pigments and degeneration of chloroplasts. Diseased palms possessed smaller epidermal cells, stomata and midrib parenchyma cells, while xylem cells in the midrib tissues were larger. Non-turgidity of midrib phloem and blocking of xylem cells with tyloses to the extent of 35 percent were also recorded (Nair and Aravindakshan, 1970). Epidermal cells from diseased palms were mostly devoid of cell contents and turgidity with deeply stained nuclei. Rapid collapse of stomata and occurrence of tyloses in varying degrees are recorded. Degeneration of inflorescence tissues, phloem bundles of the stems, cortex of roots are also observed. Tyloses occurred on 60 percent of xylem vessels on roots (Nair, 1976).

Significant accumulation of starch grains indicated impaired translocation of food materials and accumulation of products of photosynthesis. Positive colour reactions with tetrazolium salts were also recorded (Menon, 1960).

5. ETIOLOGY

5.1 Mycological and Bacteriological Observations

The association of an organism with the disease was first recorded by Khandige *et al.* (1957). He observed presence of mites associated with yellow leaf disease. Later, Menon (1960) concluded that mites do not have any role with the disease. Anon. (1963) recorded many fungi from diseased leaves. So far, 54 different species of fungi were recorded from various parts of the disease affected palms (Table 5). All the inoculation experiments with frequently occurring fungi yielded only negative results. None of the organisms tried were able to produce the typical disease symptoms (Anon., 1977). Most

Table 5 : List of fungi recorded on YLD affected areca palms

S. No.	Name	Site of isolation	Reference
1.	*Acremonium* sp.	Root	Anon. (1977)
2.	*Alternaria* sp.	Soil	Bopiah (1979)
3.	*Aspergillus fischeri*	Root	Chandramohan (1979)
4.	*Aspergillus flavus*	Root	Chandramohan (1979)
5.	*Aspergillus fumigatus*	Soil	Bopiah (1979)
6.	*Aspergillus niger*	Soil	Bopiah (1979)
7.	*Aspergillus* sp.	Root	Anon. (1963)
8.	*Aspergillus sydowii*	Root	Chandramohan (1979)
9.	*Aspergillus tamari*	Soil	Bopiah (1979)
10.	*Aspergillus terreus*	Root	Chandramohan (1979)
11.	*Botryodiplodia theobromae*	Root	Anon. (1963)
12.	*Cephalosporium* sp.	Leaf	Anon. (1963)
13.	*Cercospora arecae*	Leaf	Anon. (1960)
14.	*Chaetomium indicum*	Root	Chandramohan (1979)
15.	*Chaetomium* sp.	Root	Anon. (1963)
16.	*Colletotrichum crassipes*	Root	Chandramohan (1979)
17.	*Curvularia* sp.	Leaf	Anon. (1963)
18.	*Cylindrocarpon* sp.	Soil	Bopiah (1979)
19.	*Cylindrocladium* sp.	Root	Anon. (1977)
20.	*Didymosphaeria* sp.	Leaf	Anon. (1960)
21.	*Dimerosporina arecae*	Leaf	Anon. (1960)
22.	*Diplodia* sp.	Soil	Anon. (1962)
23.	*Exposporium arecae*	Leaf	Anon. (1962)
24.	*Fusarium solani*	Root	Chandramohan (1979)
25.	*Fusarium* sp.	Root	Anon. (1963)
26.	Gliomastix murorum	Root	Chandramohan (1979)
27.	*Gloeosporium* sp.	Nuts	Anon. (1960)
28.	*Gomerella singulata*	Nuts	Anon. (1960)
29.	*Gongronella butleri*	Root	Chandramohan (1979)
30.	*Guignardia* sp.	Leaf	Anon. (1962)
31.	*Haplotrichum* sp.	Soil	Anon. (1962)
32.	*Leptosphaeria* sp.	Leaf	Anon. (1962)
33.	*Macrophoma* sp.	Soil	Anon. (1962)
34.	*Mucor* sp.	Soil	Anon. (1963)
35.	*Neocosmospora vasinfecta*	Root	Chandramohan (1979)
36.	*Penicillium brefeldianum*	Root	Chandramohan (1979)
37.	*Penicillium* sp.	Root	Anon. (1963)
38.	*Pestalotia* sp.	Leaf	Anon. (1961)
39.	*Phyllachora* sp.	Leaf	Anon. (1960)
40.	*Phyllosticta* sp.	Root	Anon. (1985)

(*Contd.*)

Table 5 : *Contd.*

S. No.	Name	Site of isolation	Reference
41.	*Phytophthora* sp.	Root	Anon. (1985)
42.	*Pythium debaryanum*	Root	Anon. (1985)
43.	*Pythium* sp.	Root	Anon. (1985)
44.	*Pythium vexans*	Root	Anon. (1985)
45.	*Rhizoctonia* sp.	Root	Anon. (1963)
46.	*Rhizopus* sp.	Root	Bopiah (1979)
47.	*Schyzophyllum commune*	Root	Anon. (1962)
48.	*Thermoascus aurantianum*	Root	Chandramohan (1979)
49.	*Thielaviopis* sp.	Root	Anon. (1976)
50.	*Thielaviopsis spirotricha*	Root	Chandramohan (1979)
51.	*Trametes corrugata*	Stem	Anon. (1962)
52.	*Trichoderma harzianum*	Root	Chandramohan (1979)
53.	*Trichoderma koninjii*	Root	Anon. (1963)
54.	*Trichoderma viridae*	Root	Chandramohan (1979)

of the isolates were saprophytes. Similar observations forced to feel that the origin of the disease owes to a different cause other than that of fungi.

The disease caused extensive rotting of the root system (Rawther, 1976). He observed 71.1 percent decay on main roots from disease affected palms as against 2.5 percent on healthy palms. Most of the previous studies on etiological agents were concentrated on root system. Studies on the association of pythiaceous fungi with rotting of roots showed no qualitative difference between healthy and disease affected root system (Anon., 1985).

Fungal association at quarterly intervals on root tips of diseased palms were compared with that of healthy. Fungal infection was more on disease affected roots. The data is given in Table 6.

No qualitative difference on fungal flora between healthy and disease affected root system was observed.

Table 6 : Fungal infection on roots of YLD affected areca palms

Depth in cm	Site of isolation	Percentage infection	
		Healthy	Diseased
0-30	Root tips	20.6	56.6
	Other parts	45.3	66.6
30-60	Root tips	15.3	40.0
	Other parts	29.3	43.3
60-90	Root tips	20.0	38.3
	Other parts	26.6	33.5

Rotting of roots on disease affected palms was more during rainy period. Fungal association with root decay was maximum during December and minimum during June. No qualitative difference in fungal flora between seasons was recorded (Chandramohan, 1979). No correlation could be observed between root decay and yellowing of leaves (Anon., 1977). Stem and crown tissues were completely free from any fungal infection.

Bacterial isolations were made from disease affected leaves, roots and rhizosphere (Anon., 1964). The isolates belonged to *Bacillus* sp. and *Xanthomonas* sp. Srivastava *et al.* (1970) observed prolific bacterial streaming in affected root tissues. The associated bacteria represented two distinct forms, one of which was tentatively identified as *Pseudomonas* sp. Subsequently, a large number of root samples from diseased palms of South Kerala, and healthy palms at Mohitnagar (West Bengal) and Vittal (Karnataka) were examined (Anon., 1972). Seventy percent of the diseased samples showed bacterial streaming while healthy samples from Vittal were devoid of it. However, 20 percent of healthy samples from Mohitnagar also showed bacterial streaming. Pathogenicity trials with the above bacterial isolates yielded only negative results. The root samples of disease affected palms from Sullia yielded only *Bacillus* sp. while healthy roots yielded *Bacillus, Pseudomonas, Enterobacter/Erwinia* (Anon., 1976). The mean percentage of roots showing bacterial oozing were 4.3, 5.9, 7.0, 7.6 and 4.0 for Sullia, Koppa, Thirthalli, Peechi and Vittal respectively (Bopiah, 1979). The low percentage of cloudiness in both diseased and healthy roots were attributed to saprophytic bacteria in the degenerating roots.

A trial using different methods of isolation of phytopathogenic bacteria failed to implicate their involvement with the disease. *Bacillus* sp. were present on both healthy and diseased root tissues while leaf tissues were totally free from any bacterium. Decayed roots showed presence of *Pseudomonas* and *Serratia* sp.

Srinivasan (1982) surveyed large number of areca roots to find bacterial association with the disease. Profuse bacterial streaming was not observed from any part of the healthy, apparently healthy or diseased palms. The shoot tissues of diseased palms revealed no bacterial cloudiness whereas mild cloudiness was encountered from necrotic roots. The frequency of bacterial cloudiness on root tissues of disease affected palms was 50 percent while 17 percent of the healthy roots and 20 percent of the roots from apparently healthy palms showed bacterial cloudiness. He isolated 137 bacterial isolates which included *Bacillus* and *Serratia*. Crude toxin obtained from roots of YLD affected palms resulted in reversible wilting of tomato leaves while sap from healthy roots had no such activity. Margin of leaves became flaccid within 2 minutes with an aqueous solution of 0.5 mg/ml of toxin. This showed that there is an accumulation of toxin like substance in YLD affected roots.

5.2 Microbiology

Qualitative and quantitative characteristics of microorganisms associated with the rhizosphere of both healthy and disease affected areca palms were extensively studied. Healthy soils contained more fungal populations whereas diseased soils contained more bacterial and actinomycetes populations (Anon., 1962). The bacteria included *Bacillus coagulans* and actinomycetes included *Streptomyces* sp. It did not, however, gave any indication on the the specific microflora proliferating or diminishing in the root region. No difference in the distribution of rhizosphere microflora of healthy and disease affected areca palms between various months were recorded (Anon., 1963). Alice *et al.* (1982) recorded maximum bacterial population in August, fungal population in September-October and actinomycetes population in January and minimum during April for all the above organisms. Srinivasan (1982) recorded more bacterial population on rhizosphere of disease affected palms than healthy palm.

Lateral distance of 30-60 cm from base and depth of 0-15 cm was found to be the best region of arecanut for rhizosphere studies (Bopiah, 1979). There was no qualitative and quantitative variation in the microflora with different stages of disease intensity. Young and growing regions of root showed higher population of microbes believed to be due to various root secretions. Total microbial population was more in rhizosphere of disease affected palms. This increased population was attributed to the presence of exudates and sloughed off tissues in the rhizosphere. He opined that there is no specific microorganism proliferating in the root region of YLD affecting palms.

5.3 Virus and Mycoplasma

Earlier studies on paper chromatography indicated that some forms of proteins and their subunits were present only in the sap of disease affected areca palms (Menon, 1960). The total phenols in the diseased palms were more than in healthy palm. Host reaction to pathogen infection indicating serological investigations with crude areca antigen and disease specific rabbit antiserum showed there was precipitation reaction indicating antibody formation (Menon, 1961). These two observations together with negative results obtained with inoculation trials by fungi and bacteria, non-duplication of disease symptoms in sand culture for deficiency of macro and micro nutrients, lack of positive control when soils were amended in field trials in palms sprayed with insecticides and fungicides, suggested the possibility of a virus like organism being involved in the disease (Menon, 1963).

Using partially clarified sap and leaf injections by carborundum technique, the disease was transmitted to test plants *Jatropha curcas, Canavalia ensiformis* and *Vinca rosea* (Menon, 1963). In Jatropha small brown necrotic spots, chlorotic mottling and withering, production of small leaves, etc., were recorded. Yellowing and necrosis of veins were observed on Canavalia plants while on Vinca plants vein clearing, vein yellowing and production of smaller leaves were observed (Menon, 1963).

Both in arecanut and test plants, there was necrosis along the conducting channels showing thereby that the sites of multiplication of the pathogen and of maximum damage are in the phloem region. As transmission of the yellows agent from areca to coconut was also possible under specific conditions, the causal agents of yellows in arecanut and coconut may be either identical or at best related. The symptom expression of the disease is maximum soon after the rains. Paradoxically with rise in temperature, the symptom expression is reduced. This suggested that heat sensitivity of the pathogen associated (Nayar, 1976). However, the electron microscopic investigations failed to show the presence of virus like particles in disease affected leaf tissues. But further investigations could not confirm the virus/viroid etiology of the disease.

Soil transmission by adding diseased leaf sap to sterilised autoclaved soil in which arecanut seedlings were grown resulted in their death after 6-7 months (Menon, 1963). The spindle bug *Carvalhoia arecae* was suspected to be associated with the disease since it feed on leaf sap. But transmission trials with mealy bugs, mites and spindle bug failed to yield any positive results.

Nayar (1971) cultured mycoplasma like organisms from leaf tissues of disease affected palms. Numerous umboid colonies similar to other MLOs were produced in solid plates. Inoculation trials with a few arecanut seedlings grown under glass house produced some yellowing symptoms. But foolproof transmission of the disease was not achieved. The areca antigen reacted with sandal spike specific rabbit antiserum.

Disease affected tissues yielded mycoplasma like organisms under electron microscopy (Nayar and Seliskar, 1978). The organisms resembled those MLOs found in coconut palms affected by lethal yellowing in Florida. The young rachillae had more MLOs than partly expanded leaves while they were absent in mature and old leaves as well as in the healthy tissues.

Association of MLOs with the disease was confirmed by succeeding studies. Electron microscopic observations on root tissues of disease affected palms invariably showed the presence of MLOs while these were totally absent in the healthy roots (Anon., 1985). The association of MLOs with the disease was supported by the intensive staining of diseased tissues by Dienes' stain and fluorochrome DAPI. Constant association of MLOs with diseased tissues were confirmed by subsequent studies.

Attempts to transmit the disease through dodder *Cassytha filiformis* was initiated during 1986. Laurels were established on disease affected palms and were bridged to healthy areca seedlings and test plants kept in insect proof conditions. Though MLO's could be detected on the laurels, none of the recipient plants showed typical MLO symptoms. The test plants included periwinkle, *Stachytarpheta, Sesamum, Cassava, Cajanus cajan, Dodonaea, Mirabills* and *Zyzyphus*.

Insecticidal control trial and keeping the plants under insect-proof conditions helped to keep them healthy for longer period suggesting the involvement of an aerial vector in the transmission of the disease. The spindle bug of arecanut *Carvalhoia arecae* was suspected to be a possible vector of the disease from very early since it feeds on leaf sap of areca palms. But no MLOs could be detected in the insect tissues with varying degrees of incubation and acquisition periods. Hence, its role as a vector of the disease has now been ruled out (Anon., 1988). Investigations on possible putative vectors of the disease have revealed the occurrence of the plant hopper *Proutista moesta*, *Anigris* sp. and *Oliarus* sp. with areca palms. Electron microscopic observations on the salivary glands of *P. Moesta* revealed the presence of MLOs having 30-41 days acquisition and incubation periods (Anon., 1988). Transmission trials by using this insect as vector could successfully transmit typical YLD symptoms on recipient areca seedlings after a period of 3 years. But none of the test plants showed any MLO symptoms (Anon., 1990). Transmission trials with *Anigris* sp. and *Oliarus* sp. are yet to produce any positive result on the test plants. Treatments with chlortetracycline hydrochloride (Aureomycin) and tetracycline hydrochloride (Achromycin) through root feeding and stem injection at monthly and weekly intervals for a period of two years had no ameleorative effect on the disease (Rawther, 1976). In another trial with OTC, tetracycline hydrochloride and penicillin, the disease index of all the experimental palms reduced irrespective of the treatments (Anon., 1988).

5.4 Nematological Observations

Nair (1964) was the first to report the presence of nematodes associated with the disease. He observed *Meloidogyne javanica, Helicotylenchus* sp. and *Tylenchorynchus* sp. from root zone of disease affected palms. Neither the presence of nematodes nor their population density could be correlated with the disease. Weischer (1967) recorded 7 genera of plant parasitic nematodes from the root zone of healthy and disease affected palms. Kumar (1971) recorded the presence of *Hemicriconemoides gaddi, Hemicriconemoides* sp., *Pratylenchus coffeae, Radopolus similis* And *Tylenchorhynchus* sp. from soil samples collected from areca gardens. Koshy *et al.* (1976) in an intensive survey conducted in Kerala and Karnataka states recorded 22 genera of plant parasitic nematodes from root zone of arecanut. The burrowing nematode *R. similis* on inoculation produced lesions, rotting and blackening of the root tips. Possibility of *R. similis* as an aggravator in the disease complex was broughtout. Pathogenicity of *R. similis* in combination with the fungus *Cylindrocarpon obtusisporum* on arecanut seedlings was established in pot culture experiment. Though inoculated palms showed reduced growth, poor root system and root lesions no typical YLD symptoms were produced (Anon., 1988).

5.5 Soil Conditions and Nutritional Aspects

Lack of balanced nutrition and improper cultivation practices made the palms susceptible to the disease (Menon, 1961). Water logging was considered as one of the predisposing factors in the incidence of the disease (Anon., 1960). Application of fertilizers improved the condition of the diseased palms (Anon., 1967). Intensity of yellowing reduced when sprayed with the salts of magnesium and manganese (Radha Menon and Kalyanikutty, 1961).

The studies during the early fifties in the diseased areas of Kerala state revealed that their soils are acidic with pH as low as 3.8 and deficient in all the 3 major nutrients (Anon.., 1960). Heavy manuring with N, P, K was suggested. Water table was invariably high within the root zone of diseased palms. YLD incidence at water table 80 cm was high as 60.4 percent as against 7.3 percent at 155 cm height (Anon., 1970).

Deficiency of phosphorus in diseased garden soils were observed through deficiency symptoms expressed on test plants as well as low P content in the leaves (Anon., 1976). Application of additional 1 kg superphosphate delayed symptom expression on areca seedlings (Anon., 1982). Addition of 120 g P_2O_5 over normal package of practices gave maximum yield in the management trial (Anon., 1990). Soil application of NPK fertilizers plus lime reduced foliar yellowing in Karnataka (Dastagir, 1963).

Plants which received NPK + dolomite + neem cake showed reduction in disease intensity (Anon., 1990). Mohapatra *et al.* (1976) after an elaborative analysis of soil components in both healthy and diseased soils suggested that the disease manifestation can be due to the direct or indirect effect of the anaerobic conditions prevailing around the palms. Their data is presented in Table 7. No definite conclusion can be derived from this data.

The high water table in the root zone of diseased palms gives rise to reduction condition particularly during rainy periods (Anon., 1971). Velappan (1969) observed that the diseased soils are low in pH, organic matter, available P and Mg. Though application of Mg yielded only negative results (Anon., 1974, 1981) the present management trials showed the beneficial effect of Mg in containing the disease (Anon., 1990).

Table 7 : Mechanical and fertility constituents of soils from yellow leaf affected and healthy areas of Kerala and Karnataka (Mohapatra *et al.*, 1976)

Constituents	Kerala				Karnataka			
	Apparently healthy palms		Diseased palms		Healthy palms		Diseased palms	
	Low lying	High elevation	Low lying	High elevation	Low lying	High elevation	Low lying	High elevation
Sand (%)	72.48	62.60	69.92	65.91	59.68	55.84	56.77	58.45
Silt (%)	8.42	8.92	8.87	8.39	15.52	6.85	16.22	17.86
Clay (%)	19.08	26.34	21.20	25.68	24.79	27.29	27.26	23.68
pH (H_2O)	5.66	5.60	5.58	5.58	6.34	6.36	6.54	6.14
pH (KCl)	4.39	4.27	4.31	4.26	5.13	5.16	5.30	5.06
Organic carbon (%)	0.82	0.91	0.84	0.96	1.27	1.32	1.38	1.10
Available P_2O_5 (ppm)	12.17	6.06	9.23	6.01	21.46	14.84	18.95	9.05
Available K_2O (ppm)	66.52	84.00	75.81	84.90	144.10	163.18	153.18	130.80
Exchangeable Ca (ppm)	179.50	215.00	186.20	185.40	692.90	720.30	834.00	497.50
Exchangeable Mg (ppm)	47.90	68.80	45.20	59.00	173.10	190.90	220.10	152.40
Exchangeable Al (ppm)	54.35	64.53	59.95	68.84	1.59	0.10	0.45	Trace
Extractable Al (ppm)	66.97	97.48	83.30	105.60	41.21	42.10	48.23	37.84
Fe^2 + Fe^3 + (ppm)	19.53	14.77	23.98	16.16	14.84	12.80	12.90	12.36
Exchangeable Mn (ppm)	8.03	8.83	7.65	8.82	12.50	17.47	15.68	16.30
Dithizone extractable zn (ppm)	1.03	1.08	1.15	0.98	2.32	2.36	2.49	2.22
Exchangeable Cu (ppm)	2.04	1.92	1.99	1.97	3.94	4.02	3.57	3.32

Manganese deficiency in diseased garden soil was reported (Anon., 1960). One percent $MnSO_4$ foliar spray reduced the chlorosis of diseased palms. Beneficial effect of Mn on symptom remission was recorded by many workers (Anon., 1962, 1965, 1969). Diseased soil contained higher amounts of Fe and alumina (Yadava *et al.*, 1969; Anon., 1970, 1973; Mohapatra *et al.*, 1976). But root feeding with Fe failed to produce typical YLD symptoms (Anon., 1962, 1965) and had no effect on diseased palms (Anon., 1967). Toxic effects of Fe and alumina induced yellowing on treated areca seedlings (Vajranabhaiah, 1986). Samraj and Paily (1965) reproduced symptoms akin to YLD by soil application of boron. But subsequent studies could not confirm the above observation. They attributed that induced boron toxicity symptoms were different from typical YLD (Anon., 1967). Though deficiency of other micronutrients like Cu, Mo, Zn, etc., were recorded, their role in the symptom production could not be confirmed (Anon., 1962; Velappan, 1969).

5.6 Physiological Observations

Disease affected leaf tissues showed low moisture content (59.1%) as against 70.8 percent in healthy tissues. The disease has considerably reduced the photosynthetic efficiency of the palms. Higher accumulation of carbohydrates and sugars in the diseased tissues suggested altered metabolism. Diseased leaf tissues exhibited elevated diffusive resistance, lower transpiration rates and higher water and turgor potentials (Anon., 1989). Affected leaf tissues showed high leaf sap capacity, total phenols, solids, tannin and dehydrogenase activity (Anon., 1962).

The disease affected leaf tissues contained higher amounts of N, P and K. Typical YLD symptoms could not be reproduced in pot culture experiments with deficiency of N and K (Anon., 1972). Though foliar sprays with N, P and Mn increased their contents in leaf tissues, no effect on symptoms could be recorded (Anon., 1979). Mohapatra *et al.* (1976) recorded that except P all other elements are sufficient in diseased leaf tissues. The high CaO/MgO ratio was attributed to low content of Mg in diseased tissues (Anon., 1967). Foliar sprays and root feeding with growth regulators, viz., NAA, catechol, ascorbic acid and caffeic acid yielded only negative results (Anon., 1982).

5.7 Biochemical Aspects

Earlier studies gave strong indications for the presence of nucleoproteins in diseased arecanut leaves and its absence in healthy (Menon., 1961). The observations envisaged detailed studies to characterise the associated proteins. The difference observed in the electrophoretic patterns and paper chromatograms between healthy and diseased leaf extracts offer good scope for developing diagnostic tests before the onset of visible symptoms. Nair (1969) studied the amino acid make up in different parts of healthy and diseased palms. The amino acid content of diseased leaf (cystine, aspartic acid and threonine) showed a fall in the early and middle stage of the disease and an accumulation in the advanced stages. On the other hand, lysine and arginine contents of leaves progressively increased with advancement of disease. The amino acids, serine and glutamic acids were absent in leaves but present in large quantities in the inflorescence tissues. Glutamic acid was present only in diseased tissues. Serine, arginine and threonine in stem tissues declined with intensity of disease. Proline, Cystine and histidine totally disappeared from roots on infection. These results suggested an impaired amino acid metabolism as a characteristic feature of the disease. Antiserum prepared against partially purified spear leaf antigen gave only faint reaction. Concentration of globulin has not improved the titer of the antiserum (Anon., 1989).

6. VARIETAL REACTION

The use of varietal reaction in containing the disease was initiated from early 60s. All the 25 indigenous and exotic varieties planted in 1961 got diseased by 1968 (Anon., 1970). Similarly, all the 21 diallel cross combination of arecanut planted in 1976 showed typical YLD symptoms by 1982 (Anon., 1984). Though dwarf mutants and Mangala hybrids showed some degree of tolerance in separate experiments, the results were not consistent. Radiation of areca seeds with X-ray and UV irradiation did not yielded any positive results (Anon., 1969). In the present studies, the hybrid Saigon x Mangala continues to yield maximum nuts with minimum disease intensity (Anon., 1990). The superiority of true Mangala seedlings over its segregants and South Kanara variety on diseases tolerance is also consistent in the present observation. The progenies of escape palms identified from a statewide hot spot survey have yet to yield any positive results.

7. MANAGEMENT OF THE DISEASE

Since the disease is not amenable to control by any conventional plant protection measures, it became imperative to look into other means of containing it to obtain maximum economic returns from affected gardens. A mixed farming trial with grass and dairy involving regular organic recycling started with this objective yielded promising results. A general increase in yield in all treatments was observed though no significant difference on disease intensity could be recorded. (Anon., 1983). Application of higher dose of P reduced the disease incidence. Combining all the available leads in containing the disease a management experiment started in 1982 involving 2 varieties, higher dose of P_2O_5 and organic matter. In the trial, application of additional P_2O_5 over normal package gave highest yield while true Mangala palms were superior in their disease tolerance. In another management trial, palms which received higher dose of K ad Mg recorded minimum disease intensity (Anon., 1990).

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