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Special Review Article

Coconut root (wilt) disease
Past studies, present status and future strategy

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INTRODUCTION

A world-wide survey organized in 1963 by the Food and Agriculture Organization of the United Nations on the occurrence, geographical distribution, pattern of spread and symptomatology of diseases of uncertain etiology of coconut (*Cocos nucifera* Linn.) revealed that complex and often lethal diseases are prevalent in India, Cameroon, Cuba, Dahomey, Dominican Republic, Florida, Ghana, Guam, Haiti, Jamaica, Nigeria, the Philippines, Sri Lanka, Togo and a few other regions. Since 1963, more such maladies have been reported from Brazil, Ecuador, Indonesia, Malaysia, Mexico, Surinam, Tanzania and Trinidad. During the past 2 decades, extensive research made it possible to detect the presumed pathogens in sections of diseased palm tissues examined through the electron microscope. The efforts have resulted in the implication of phloem-restricted trypanosomatid flagellate *Phytomonas* sp. in the Cedros wilt of Trinidad and hart rot of Surinam, Ecuador, Brazil and Trinidad (Parthasarathy *et al.*, 1976), Mycoplasmalike organisms in the lethal yellowing type of diseases in Jamaica, Florida, Cuba, Dominican Republic, Haiti and West Africa (Plavsic-Banjac *et al.*, 1972; Nienhaus and Steiner, 1976; Dabek *et al.*, 1976; Dollet *et al.*, 1977; Thomas, 1979) and in the stem necrosis in North Sumatra and peninsular Malaysia (Turner *et al.*, 1978). In India, besides the Tanjore wilt of Tamil Nadu, Thatipakka disease of Andhra Pradesh and the ubiquitous stem-bleeding disease, the coconut root (wilt) disease, prevalent mostly in Kerala and parts of Tamil Nadu, has been baffling researchers. The root (wilt) disease forms the subject matter of this review.

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PAST STUDIES

Research assignments

The root (wilt) disease is reported to have made its appearance around 1882 in 3 different foci each about 50 km apart in central Kerala and has been dealt with in detail by Varghese (1934) and Menon (1961), and reviewed subsequently by Lal (1966, 1969), Shanta and Radha (1975), Jayasankar (1981) and Nayar and Jayasankar (1981). Research on this disease on a modest scale was initiated in the late forties at the Central Coconut Research Station, Kayangulam, under the aegis of the erstwhile Indian Central Coconut Committee. The Indian Council of Agricultural Research took over the Research Station at Kayangulam in 1966 and strengthened the research on root (wilt) disease. The programmes received better direction and new dimensions after the Central Plantation Crops Research Institute was formed in 1970 by merging the 2 Central Coconut Research Stations at Kasaragod and Kayangulam and the Central Arecanut Research Station at Vittal. The prolonged period of uncertainty that prevailed on coconut root (wilt) disease investigations may be attributed to the time-lag involved in starting organized research subsequent to the reporting of the disease.

Symptoms

As a result of extensive studies on symptomatology, epidemiology, etiology, nutrition and control, voluminous data have accrued. The sequence of development of symptoms is still not understood fully, but the most distinguishing feature includes yellowing and conspicuous bending of the middle and outer whorls of leaves of the crown and the characteristic ribbing of the leaflets (Fig. 1), termed flaccidity (Radha and Lal, 1972). Foliar yellowing and marginal necrosis, absent in the young diseased palms, are associated invariably with the adult palms (Fig. 2). Recently, the softening and whitening of leaflets of the spear leaf with necrotic spots followed by rotting (Fig. 3) have been described (Dwivedi *et al.*, 1979). Other symptoms such as shedding of buttons and immature nuts, reduction in the number and area of leaves and the overall size of the crown in advanced stages (Menon, 1961) are not so consistent. An indexing method has been worked out for quantitatively scoring the intensity of the disease based on grade points assigned separately for flaccidity, yellowing and necrosis (George and Radha, 1973).

Extensive root damage has been reported in diseased palms (Menon and Nair, 1951; Lily, 1964; Michael, 1964) which lends support to the observation of Butler (1908), who attributed root rot alone to be the cause of the disease. However, Nagaraj and Menon (1955) did not observe any significant difference in root decay between healthy palms and palms in the early stage of the disease and concluded that root decay need not precede the foliar symptoms. Lal (1969) felt that root rot is only secondary. Likewise, observations on the root-system of 7 palms each of 4 categories, viz. healthy, necrosis alone, flaccidity alone, and necrosis + flaccidity, did not reveal any significant difference in the total number of roots, number of tender roots and percentage of root decay (CCRS, Kayangulam, 1966). Joseph and Jayasankar (1982) corroborated this finding. These variations are due to differences in sampling and the techniques adopted in the excavation of the root-system, location, area, depth of the root zone studied, and the age of the palms. For a better understanding of the problem, it is necessary to examine the root-system of sufficiently large number of palms under uniform conditions. Similarly, the earlier observations on the internal browning in the stelar tissues with vascular discoloration in the roots of diseased coconut palms (Indira and Ramadasan, 1968) needed reconsideration, and Dwivedi *et al.* (1978) showed that vascular discoloration is not observed in the presence of an antioxidant.

Symptoms on the foliage are the guiding factors for the coconut, and flaccidity as the earliest consistent visual symptom cannot be overlooked. The change in texture noticed in the leaflets of the spindle suggests that foliar symptoms are developed before the leaf is fully opened.

Diagnosis

Several attempts have been made to develop diagnostic tests for the detection of the disease before the onset of visual symptoms. A colour test based on dehydrogenase activity (Joseph and Shanta, 1963) has not been pursued. Infrared aerial photography as a diagnostic tool (Dakshinamurthy *et al.*, 1971a, b; Dakshinamurthy and Summanwar, 1972) could not be made use of for want of adequate data on ground level (Nair *et al.*, 1984).

A serodiagnostic test (Solomon *et al.*, 1983) and a rapid biochemical test (Dwivedi *et al.*, 1979) have been developed, of which the former offers scope for improvement and is under refinement. Recently, a physiological test based on stomatal regulation has been observed to compare favourably with the serodiagnostic test in disease detection (Rajagopal *et al.*, 1984).

Fig. 1. Young coconut palm affected by root (wilt) disease, showing bending of leaves, and ribbing of leaflets, termed flaccidity.

Fig. 2. Advanced stage of coconut root (wilt) disease of an adult palm, showing foliar yellowing and marginal necrosis, absent in young diseased palms.

Fig. 3. Softening and whitening of the leaflets of the spear leaf, with necrotic spots followed by rotting, is sometimes superimposed on palms affected by coconut root (wilt) disease.

Epidemiology

The epidemiology of the root (wilt) disease of coconut has not been consistent with nutritional disorders. According to the available information 250,000 ha, approximating to 22% of the overall coconut area of the country, is affected by the disease (Gopinathan Pillai *et al.*, 1972). Different attempts at survey (Varghese, 1934; Menon and Nair, 1951; Menon and Pandalai, 1960; Gopinathan Pillai *et al.*, 1972) indicated that the disease has occurred in sporadic isolated pockets spreading in all directions in all soil types — the diseased tract being contiguous with a zonal core, getting scattered in the outlying areas with faster spread in sandy and sandy-loam soils than in the lateritic belts. The accuracy of these observations has been diluted to an extent as severely diseased palms have been located, since then in areas hitherto considered to be disease-free. Palms of all ages are susceptible, and disease-free gardens occur in the midst of diseased areas and apparently healthy palms in heavily infected gardens. There is a need for detailed studies on host-pathogen interaction that is conducive to the establishment of a pathogen and the events leading to disease development.

Search for the cause

The spreading nature of the disease suggests the involvement of a pathogen. This hypothesis is supported by the observations of symptoms in the field and controlled conditions by transmission studies (Mathen, 1978; Menon and Shanta, 1962; Nagaraj and Menon, 1956; Shanta *et al.*, 1964; Joseph *et al.*, 1972). Several efforts have been made to elucidate the etiology of the disease from various angles.

Fungi : Eversince a 'fungoid' concept was attributed in 1906 by Bourdillon (Varghese, 1934), species of *Botryodiplodia* were isolated by Butler (1908), perhaps from rotten roots — a factor responsible for its lack of presence in subsequent investigations. But Menon and Nair (1951) have indicated a possible association of not only *Botryodiplodia theobromae* Pat. but also *Rhizoctonia solani* Künn and *R. bataticola* (Taub.) Butler with the rotted root-system. However, subsequent studies have brought out the inability of these isolates to produce the foliar symptoms in young experimental palms in spite of their ability to infect root tips (Menon *et al.*, 1952), contrary to the suggestion of Butler (1908) that the root rot alone can pave the way for the disease. Similarly, survival of *R. solani* in soil with adequate moisture has also been reported as poor in young experimental palms (Radha and Menon, 1957). Continued attempts have resulted in the isolation of *Fusarium equiseti* (Corda) Sacc. and *Cylindrocarpon effusum* Bugn. (Joseph, 1978) from apparently healthy roots of the diseased palms. Likewise, *Cylindrocarpon lucidum* Booth. has been isolated from nematode-induced root lesions (Sosamma and Koshy, 1978). Though a number of fungi have been implicated, none could induce the disease.

Bacteria : The observation of Menon and Nair (1951) on the presence of 2 species of bacteria did not receive attention until Srivastava *et al* (1969) recorded not only a characteristic vascular streaming movement of bacteria in the roots of disease-affected palms, but also identified them as species of *Pseudomonas*. But persistent efforts have revealed only the association of *Enterobacter cloacae* (Jordon) Hormaeche & Edwards (Mathew George *et al.*, 1976) in the affected tracts, a situation not readily acceptable to conventional pathologists. Detailed studies have brought out the ability of the isolates of *Enterobacter cloacae* to produce wilt-inducing toxic principles in growing culture filtrates. The toxin has been purified and characterized and the isolates are antigenic (Mathew George, 1983). But its actual role in the causation of the disease awaits elucidation.

Nematodes : Investigations on the involvement of nematodes (Weischer, 1967; Mathen, 1969; Mathen *et al.*, 1970;

Khan *et al.*, 1971) have resulted in the isolation of 35 genera of nematodes from the root zone of coconut. They included species of *Xiphinema*, *Longidorus* and *Trichodorus*, all known virus vectors, as well as the burrowing *Radopholus similis* (Cobb, 1893) Thorne, 1949 (Fig. 4). Weischer (1967) concluded that the low population density of nematodes, the widespread occurrence and the general

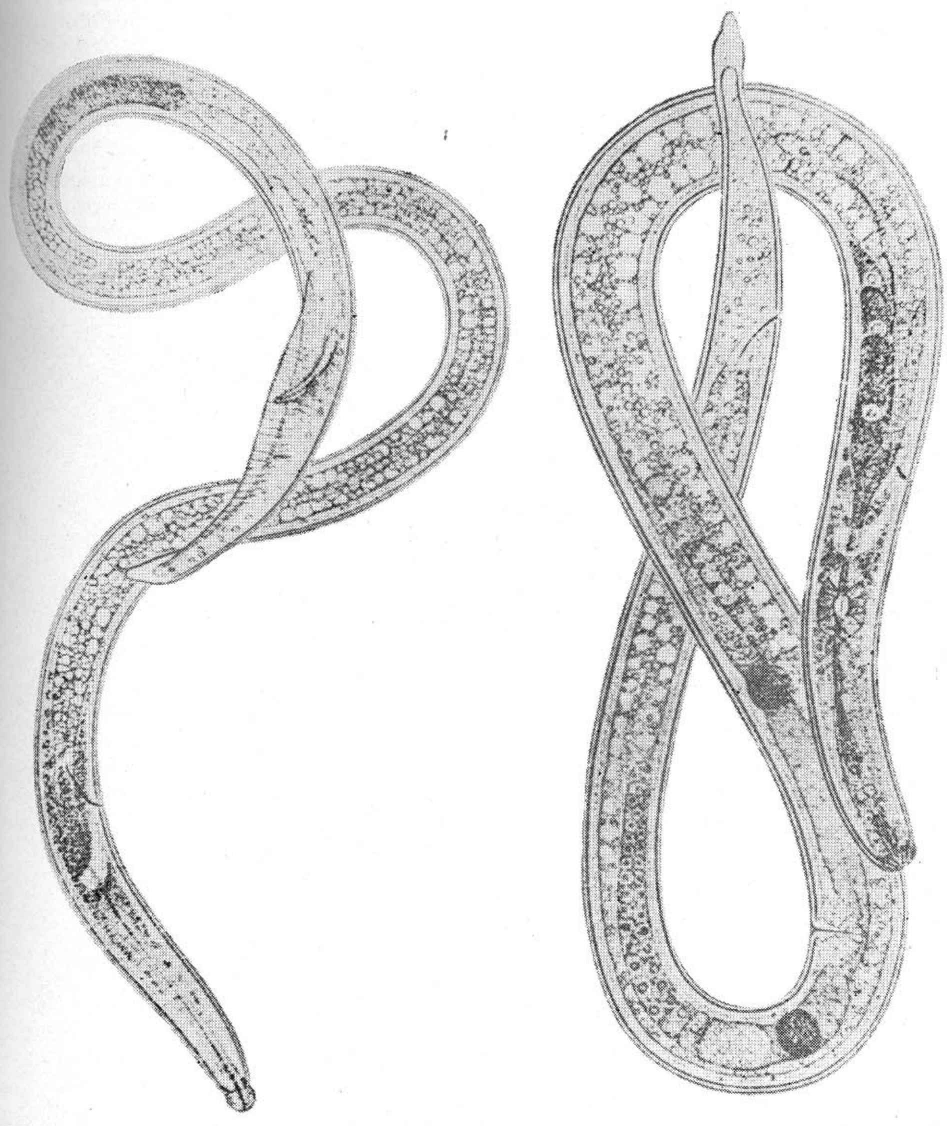

Fig. 4. *Radopholus similis* (Cobb, 1893) Thorne, 1949, a burrowing nematode was found to be associated with coconut root (wilt) disease, but its exact role in the disease is still not fully understood.

distribution pattern could exclude the nematodes as primary cause of the disease. Detailed studies since then have indicated the association of *R. similis* (Koshy and Sosamma, 1975, 1977; Koshy *et al.*, 1979; Koshy, 1981), but its exact role in the disease is still not fully understood.

Viruses : Studies on the association of virus or virus-like pathogen were in progress since 1952 with the successful transmission of the disease in the field by mechanical abrasion and by banana lace-wing bug *Stephanitis typica* (Distant) (Nagaraj and Menon, 1956). But flaccidity of leaflets was the only symptom produced in potted young palms grown inside insect-proof glass-houses. Likewise flaccidity and paling of leaflets with slight stunting were reported in young palms inoculated with leaf extracts of diseased palms in insect-proof glass-houses (Shanta *et al.*, 1964). The presence of a sap-transmissible agent in the diseased tissue has been demonstrated by production of transmissible symptoms on cowpea (Shanta and Menon, 1960). In view of the peculiar nature of the symptoms on cowpea, Holmes (1965) and Holmes *et al.* (1965) suggested that the sap-transmissible agent might be a virus-like spirochete or protozoa. This possible involvement of a 'virus-like' pathogen is of interest in view of the discovery of mycoplasma and

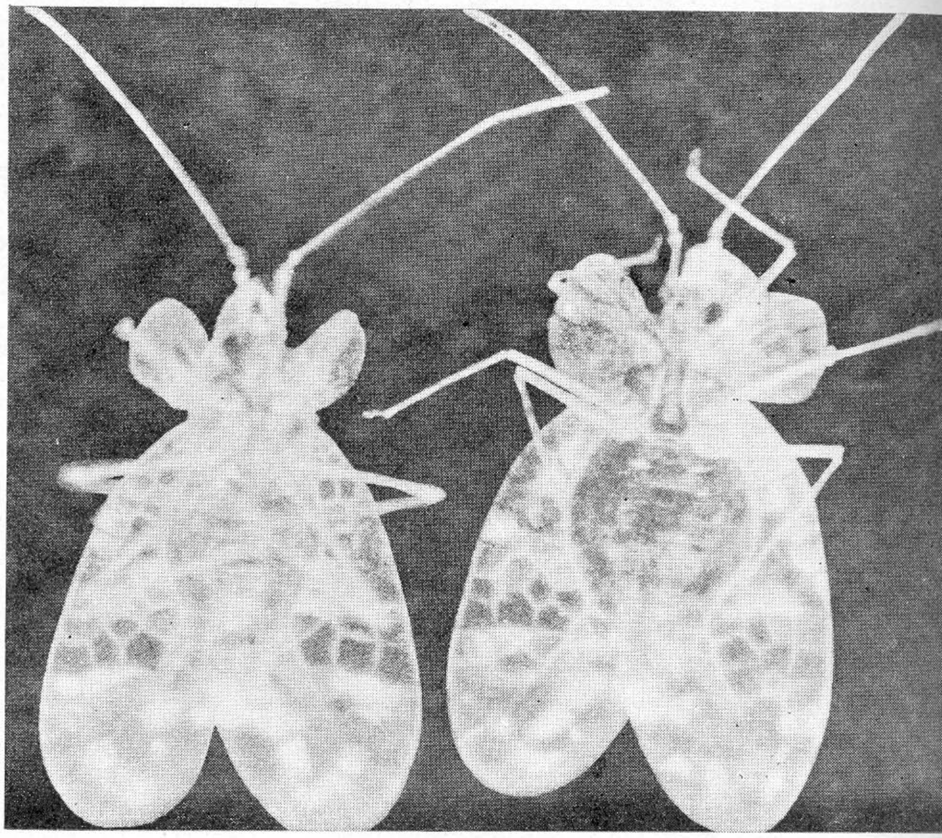

Fig. 5. The coconut root (wilt) was successfully transmitted in the field through banana lace-wing bug, *Stephanitis typica* (Distant).

other organisms (Doi *et al.*, 1969; Davis *et al.*, 19 2; Davis and Worley, 1973; Goheen *et al.*, 1973; Diener, 1974), once considered to be viruses.

Insect vectors : Reproduction of typical disease symptoms reported by Nagaraj and Menon (1956) in coconut seedlings inoculated mechanically in the field with leaf extracts of diseased palms and with *Stephanitis typica* (Distant), an insect pest of coconut. These observations were confirmed by Shanta *et al.* (1964) in field trials where inoculated palms produced higher percentage of infection than the uninoculated control group. In tests using cowpea, 16% of the field population of the insect was reported infective when used for inoculation tests with groups of 10 bugs up to a period of 24 hr after acquisition (Joseph *et al.*, 1972). In insect-proof house coconut seedlings inoculated with infective *S. typica* got diseased and had pale stunted leaves (Shanta *et al.*, 1964). However, due to reasons unknown the symptom production on cowpea was erratic in subsequent studies (Shanta *et al.*, 1971). Reports substantiating a viral etiology of coconut root (wilt) disease have also emerged from other laboratories. Summanwar *et al.* (1969, 1971) attributed a strain of tobacco mosaic virus (TMV) while Maramorosch and Kodo (1977) reported the presence of 2 types of submicroscopic particles identified as Phytoferritin and a icosahedral virus in diseased palm tissues. The association of the TMV strain has not been confirmed in separate investigations using serology and electron microscopy (Hariharasubramonian and Shanta, 1971; Shanta *et al.*, 1975; Solomon and Sasikala, 1980) and the icosahedral particles reported earlier (Maramorosch and Kondo, 1977) have since been confirmed as plasmodesmata only (Parthasarathy, 1978). Polyacrylamide gel electrophoresis of isolated nucleic acid from limited number of diseased palms also failed to reveal any viroid type pathogen (unpublished data of Randles, J. W.).

Physiological disorders

Investigations on the physiological aspects of the disease have shown an increase in respiration (Michael, 1978), a deranged translocation and distribution of sugars (Chacko Mathew, 1977), an altered nitrogen metabolism (Varkey *et al.*, 1969) with an accumulation of aminoacids, particularly Arginine, in the diseased palms (Pillai and Shanta, 1965) and an accelerated phenol metabolism with a fall in phenol content and an increase in phenol-oxidizing and synthesizing enzymes (Joseph and Jayasankar, 1973, 1979; Joseph *et al.*, 1976; Joseph, 1983). The permeability of root tissues of diseased palms was observed to have been altered and an imbalance in the water mechanism subsequent to disease development indicated (Ramadasan, 1966, 1967). These observations by and large lend support to a pathological condition.

Major nutrients : Menon and Nair (1949, 1951) and Menon *et al.* (1952) reported that the symptoms of the disease were more pronounced in areas with poor soil aeration, and in soils with poor moisture-retentive capacity, high water-table, shallow depth and poor drainage. Earlier studies on the major soil groups (Sankarasubramoney *et al.*, 1954, 1955, 1956; Pandalai *et al.*, 1958a; 1959a, b) showed that soils in diseased area had low available potash, exchangeable calcium and magnesium, iron and total exchangeable bases, and it was also suggested that waterlogging could be the main feature pre-disposing the palms to disease. ?

Varghese *et al.* (1962a, b) observed an accumulation of major nutrients and silica in the leaves of diseased palms, while Cecil (1975) noticed a deficiency of calcium and magnesium. However, detailed studies on soil and leaf samples from healthy and disease-affected tracts all over the major coconut-growing soils of Kerala have ruled out the possibility of the direct involvement of major nutrients on the incidence of the disease (Pillai *et al.*, 1975; Pillai, 1975). An imbalance of cationic : anionic ratios like

K : Mg, P : S and N : S was noticed in disease-affected palms and the addition of magnesium sulphate was found to have a favourable influence on inducing early flowering of palm and higher yields (Pillai *et al.*, 1975; Cecil, 1975). According to Pillai (1975) micro-nutrients especially zinc and molybdenum, followed by manganese and iron, were in lower concentrations. The overall conclusion on the mineral nutrition of the palms in relation to the disease reveals the non-involvement of major nutrients.

Secondary nutrients : Secondary nutrients at different levels and through different sources did not completely control the disease or prevent fresh incidence. At the same time, general improvement and increase in yield have been reported due to judicious manuring (Menon and Nair, 1951; Nair and Radha, 1962; Sahasranaman *et al.*, 1964; Lal, 1966). In a micro-nutrient fertilizer trial (Davis and Pillai, 1966), fresh incidence of disease was not prevented but sustained economic yield was obtained.

Attempts on control

The root (wilt) disease is a slow debilitating one which responds favourably to appropriate management practices. A number of beneficial effects have emerged in the attempts made in this direction, particularly during the last decade, and have promoted the concept of 'live with the disease', sustaining productivity.

Organic recycling : The canopy of coconut permits approximately 50% percolation of sunlight and its land utilization is limited to about 25% which is ideal for raising suitable crops in the interspaces. A research project on mixed farming involving the raising of fodder crops and maintaining milch cows with a recycling of the organic wastes in a coconut garden affected by root (wilt) over a period of 5 years has increased the yield of nuts by nearly 26.1% irrespective of the disease condition of the palms (Sahasranaman *et al.*, 1983). This has also resulted in a significant increase in the soil organic carbon, exchangeable calcium, magnesium and potassium and soil microbial activity in the root region of the coconut palm (Potty *et al.*, 1977; Potty, 1977).

Mixed cropping : The observation on the profitability of crop mixing cacao in the interspaces of coconut in enhancing the number of nitrogen-fixing, phosphate-solubilizing, and auxin-producing micro-organisms led to the initiation of such a cropping system in affected tracts, with irrigation and recommended dose of fertilizers (for both the crops). The yield of coconut has increased substantially (Nambiar, 1984).

Intercropping: Experiments conducted by raising tuber crops particularly with yam and elephant-foot yam, in the interspaces of coconut have resulted in an increase in the mean yield of palms, irrespective of disease conditions, and a decline in the severity of the disease (Menon and Nair, 1978), unlike in plots with tapioca raised as an intercrop and in the control plots, in which the intensity of the disease was on the increase. But detailed studies conducted later in a cultivator's garden indicated that intercropping with tapioca too, like intercropping with elephant-foot yam, colocasia, greater yam, ginger and turmeric, had no adverse effect (Antony, 1983).

Soil amendments : Continuous application of NPK fertilizers showed progressive improvement in the yield of diseased palms (Sahasranaman *et al.*, 1964). More recent systematic fertilizer trials carried out at Kayangulam (Cecil, 1981) have shown that regular addition of magnesium at the rate of 3.0 kg magnesium sulphate (500 g MgO) per palm per year along with the normal dose of NPK fertilizers right from the time of planting has not only increased the vegetative growth of the young palms to a significant level but also reduced the pre-bearing age by about 9 months. The addition of magnesium sulphate also prevented the development of foliar yellowing and increased the yield of nuts by about 40% in the early-bearing periods. Such an effect was evident more on the root (wilt)-affected palms than in the healthy ones.

Performance of 'Dwarf' × 'Tall' : On heavily infected, sandy rainfed soils with good fertilizer management, 'Chowghat Dwarf Orange' × 'West Coast Tall' hybrids have been found to be more productive with a lower incidence of disease compared with 'West Coast Tall' palms (Kamalakshy Amma *et al.*, 1982).

Varietal reaction to the disease : A programme of assessing the yield potential and resistance or tolerance to root (wilt) disease has been in progress since 1972 at research farms and in cultivator's gardens with 45 varieties and 62 hybrid combinations. The performance of the material is under evaluation.

Plant protection : Though root (wilt) disease is not totally amenable to normal plant-protection measures, periodic spraying with fungicides could significantly reduce the incidence of the leaf-rot disease superimposed on root (wilt) (Jayasankar and Radha 1982). Application of oxytetracycline (Terramycin tree-injection formula) prevented the deterioration due to disease, while the untreated control palms showed deteriorating effects (Jayasankar, 1983; Mathew George, 1983).

Containing the disease : Efforts made to contain the root (wilt) disease by repeated removal of affected palms in the border areas north of Karuvannur river in Trichur district have yielded additional information. This programme was started by the Central Plantation Crops Research Institute in 1979 with the establishment of the Field Station from where continuous monitoring was done to locate, identify and eradicate the affected palms in the north of the border areas. A comprehensive survey was conducted for the purpose and disease-affected palms were located. These palms were uprooted and their boles and roots were burnt in the same pit. Periodic observations of these gardens have revealed that majority of the gardens has remained free of the disease. Isolated pockets of the disease have also been located in some of the northern districts of Kerala and information collected in this context from the cultivators on the source of planting materials indicated that atleast in some cases, the seedlings have been brought from the areas affected by the root (wilt).

PRESENT STATUS

A summation of retrospects clearly indicates that the coconut root (wilt) disease is pathogenic in nature as extensive investigations have excluded nutritional deficiency, hormonal imbalance and water stress as factors directly involved in the expression of symptoms. Palms of all ages are susceptible to the disease which by itself is not lethal, but debilitating and occurs in all soil types in a sporadic manner; further spread is either sporadic or contiguous. Fungi, bacteria and nematodes have been implicated with the malady but pathogenicity experiments conducted to decide the role of these biotic agents have only yielded negative results. Reports substantiating a viral etiology of coconut root (wilt) disease have emerged strongly from different laboratories; however, repeated attempts on purification, screening of a wide range of test plants belonging to Leguminosae and Malvaceae and electron microscopy have ruled out the association of any virus. At the same time, the disease has been successfully transmitted in the field by mechanical inoculation and by the banana lace-wing bug *Stephanitis typica* (Distant). These results have been confirmed later in potted plants grown in insect-proof houses; but flaccidity of leaflets has been the only symptom produced which remains as the most consistent symptom of the disease.

In this context, the observation of Solomon *et al.* (1983) that Mycoplasma-like organisms under electron microscope in ultrathin sections of developing leaves, unopened inflorescences, root tips and terminal bud tissue (in the sieve tubes of phloem) in coconut palms affected by root (wilt) and its conspicuous absence in samples from healthy palms is highly significant as no virus-like particles or micro-organisms other than Mycoplasma-like organisms were made out in the ultrathin preparations. These observations have gained additional support through successful transmission trials (CPCRI, Kasaragod, 1984). The parasitic angiosperm *Cassytha filiformis* Linn. established on a 4-year-old diseased palm when bridged with periwinkle [*Catharanthus roseus* (Linn.) G. Don], maintained under insect-proof conditions, the test plants developed characteristic interveinal yellowing which is suggestive of infection by Mycoplasma-like organisms. Electron microscopic studies have brought out the presence of Mycoplasma-like organisms in the vegetative vector and test plants. It has been subsequently bridged from a set of primary infected periwinkle to a secondary set of healthy plants. Serial transmission from periwinkle has been successful.

In the lethal yellowing type of disease of coconut in the Carribean area with Mycoplasma-like organisms as presumed pathogens, the pattern of spread is characterized by leaps or jumps suggestive of the involvement of aerial vectors. The situation is almost comparable with that observed in root (wilt) disease in which case transmission trials in the past have proved successful with the lace-wing bug *Stephanitis typica* (Distant). The insect is not a conventional phloem feeder but feeds through the stomata and its stylet is capable of reaching the inner tissues of palm leaves. It is present in the contiguously root (wilt) disease prevalent areas. Electron microscopic examination of the lace-wing bug which has a sufficient acquisition or incubation periods on diseased coconut palms revealed the presence of structures resembling Mycoplasma-like organisms in the salivary glands and brain tissues, which are yet to be observed in bugs collected from the disease- free areas (CPCRI, Kasaragod, 1984).

Relevant also in the context is the correlation observed between the presence of the free aminoacid Arginine and susceptibility to lethal yellowing (McCoy *et al.*, 1983). Nearly 2 decades ago, under less refined conditions, nitrogen metabolism was reported to have been impaired and arginine accumulated in the leaf tissue of root (wilt)-affected palms (Pillai and Shanta, 1965). The role of Mycoplasma-like organisms in the etiology of coconut root (wilt) disease gains additional impetus from the results of a preliminary experiment that has been already dealt with, using oxytetracycline hydrochloride.

It is also realized that hard-and-fast similarities are not available on symptom, spread, resistance, etc., in the diseases induced by Mycoplasma-like organisms. The lethal yellowing type of disease of coconut in Carribean areas and the West African coast have similarity in symptoms and are suspected to be induced by Mycoplasma-like organisms, but the pattern of spread differs. Unlike in the Carribean area referred to earlier, the spread of the Kaincope disease of coconut is continuous from a single focus of infection like an oil stain resembling a soil-borne disease. 'Malayan Dwarf', which is considered to be resistant or tolerant to lethal yellowing, is known to succumb to a disease caused by Mycoplasma-like organism in Africa. So also the 'Mawa' hyrbid to stem necrosis in Malaysia and Sumatra. The symptom picture also varies as the lethal yellowing type of coconut diseases are characterized by foliar discoloration, progressing from lemon-yellow to orange-yellow, followed by drying and browning, premature nut fall in all stages of development and necrosis of inflorescence and spear leaf. The coconut stem necrosis, on the other hand, has a discolored spear leaf which turns brown and dies, showing light-brown necrotic flaccidity. The older fruits succesively dry up with a shift in colour from green to brown, and extensive necrosis occurs within the stem both above and below the apical bud. In a like manner Mycoplasma induced diseases in general are non-lethal but affect the productivity of the crop by way of induced sterility, metamorphosis of floral parts, yellowing and stunting. Exception to this pattern is observed in lethal yellowing and stem necrosis where rapid death of palms is imminent. Perhaps variations in the Mycoplasma-like organisms a host-pathogen interaction and the environment could be the reasons contributing towards this differential behaviour.

The possibility of promoting the concept of 'live with the coconut root (wilt) disease' under care and management becomes evident particularly since the disease has several positive attributes to reckon with, barring its elusive complexity, unlike the other major maladies of the palm. The malady does not kill the coconut palm outright but only brings about decline in yield during the course of several years. The diseased gardens are observed to sustain yield in response to different management practices, Crop mixing and intercropping assume particular interest in view of the ideal canopy of the coconut permitting about 50% of light percolation, restricted land utilization by the crop limiting to 25% or so and its perennial nature. It should not be the endeavour to partition the response to the various individual treatments like mixed or intercropping, fertilizer application, plant protection and irrigation. The requirement is to rehabilitate the affected plantations by adopting a set of package of practices consisting of balanced fertilization, weed control, recycling of organic matter, multiple cropping, mixed farming and irrigation for improving the health and yield of disease-affected palms and increase in income from unit area.

To obtain a better insight into the current extent of severity of the disease, a massive survey has been undertaken recently by the Central Plantation Crops Research Institute in collaboration with the State Directorate of Agriculture, Special Agricultural Development Unit, Bureau of Economics and Statistics, the Coconut Development Board, Centre for Development Studies, the Kerala Agricultural University and the Central Plant Protection Station (CPCRI, Kasaragod, 1985). The disease is found to occur in a contiguous manner in the tracts stretching from Trivandrum district in the south to Trichur district in the north of Kerala affecting an estimated population of 59.2 million bearing and 32.4 million non-bearing palms (Fig. 6). The loss consequent on the development of the disease is in the order of 960 million nuts in the year 1984–85. The disease also has an impact on copra/oil, husk and leaves. In addition to the contiguously disease-affected tracts, stray occurrence of root (wilt) disease is noticed recently in Palghat, Malappuram, Calicut and Cannanore districts of Kerala (further north of Trichur district) as also in the adjoining Kanyakumari district (in the south) and Coimbatore district (in the south-east) in Tamil Nadu. It is observed that the incidence of coconut root (wilt) in Trivandrum and Trichur districts is only 1.52 and 2.60%, respectively, while its occurrence is sparse in the districts of Palghat, Malappuram, Calicut and Cannanore. The extent of intensity of the disease in the rest of the contiguously disease-affected tracts varies from 28.6% in Quilon district to 70.7% and 75.6% respectively in Alleppey and Kottayam districts.

The efforts to contain the disease within the present geographical region have yielded useful information (CPCRI, Kasaragod, 1985). A comprehensive survey conducted with the objective of containing the disease in the areas north of Karuvannur river in Trichur district has brought out incidence of coconut root (wilt) disease in 75 villages in Trichur, Palghat, Malappuram, Calicut and Cannanore districts. The disease-affected palms were eradicated, their roots and boles were burnt *in situ* with a vigil on occurrence of the disease. Observations have indicated that out of the 156 root (wilt)-affected gardens, 151 have remained free of the disease. Similar observations on the effect of eradication of disease-affected palms in areas farther away from the belt region in Trichur district with sparse incidence were likewise encouraging. The observa-

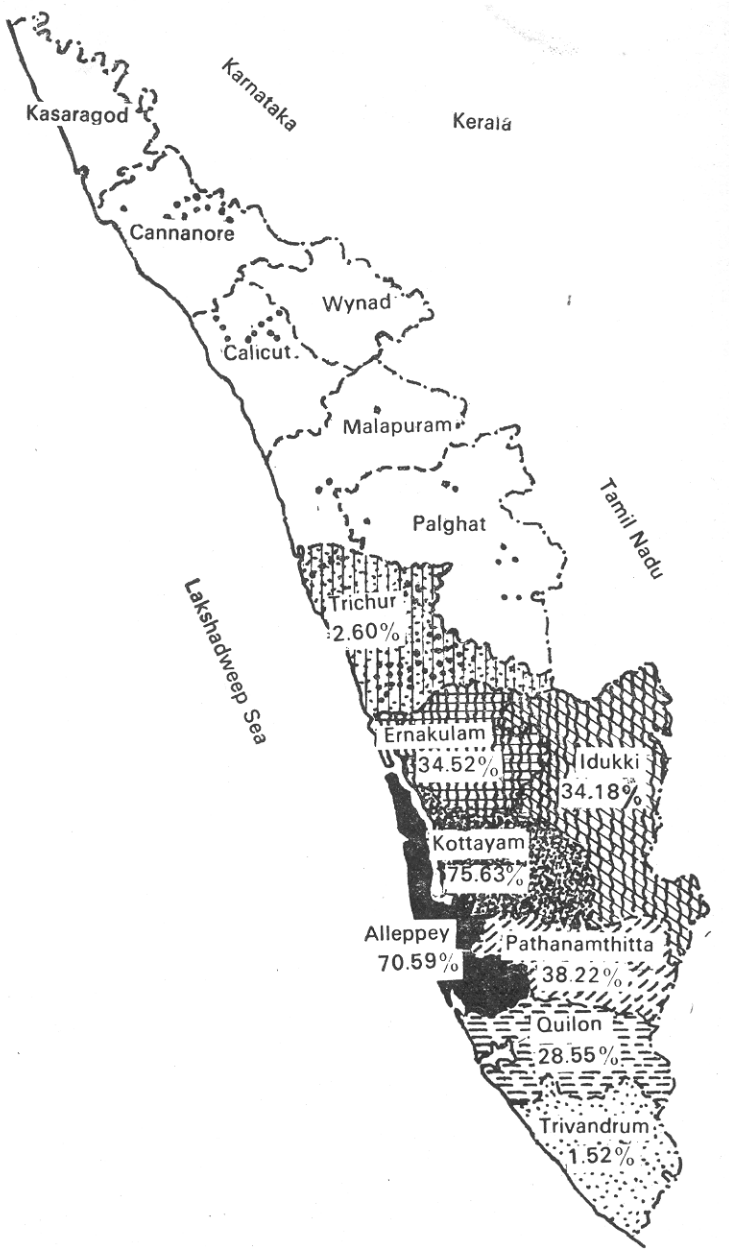

Fig. 6. Distribution of coconut root (wilt) disease in Kerala.

tions were suggestive of the need of eradication of root (wilt)-affected palms in isolated and mildly affected areas (CPCRI, Kasaragod, 1985).

FUTURE STRATEGY

The consistent intercellular presence of Mycoplasma-like organisms in the root (wilt)-affected coconut palms and their total absence in the disease-free palms have gained additional support through successful transmission trials. The preliminary observation on the efficacy of oxytetracycline hydrochloride to prevent deterioration of the disease in treated palms also provides evidence in favour of a mycoplasmal etiology. In a like manner, the implicated vector lace wing bug *Stephanitis typica* (Distant) has acquired additional weightage by virtue of its preponderant abundance in the root (wilt)-affected tracts combined with the observation of Mycoplasma-like organisms in the brain and salivary glands of the insects. An exact understanding of the pathogen need not necessarily provide a permanent cure but can assure an economic control. Renewed attempts will have to be made to suppress the transmitting agents. Admittedly, no plant pathogenic Mycoplasma-like organisms have been cultured so far with the exception of species of *Spiroplasma*. Nevertheless, a possible isolation of the implicated organism can pave way to new scientific directions. Its impact will be particularly reflected on the possibility of screening germplasm material before planting.

The technology that is currently available to develop strategies for containing the disease as well as for the better maintenance of the disease-affected areas has to be translated to the farming community. the observations on the comparatively low percentage of incidence of disease in Trivandrum and Trichur districts within the contiguously disease-affected tracts and the sparse occurrence in areas beyond Trichur as well as the neighbouring Tamil Nadu necessitates a process of eradication of all diseased palms including the non-bearing young ones, combined with phytosanitary measures and active surveillance. In the context, it will be worthwhile to pursue a survey of the disease, in the neighbouring Tamil Nadu and initiate one in Karnataka adjacent to Cannanore district, followed in other coconut-growing tracts in the country. With regard to the heavily infected tracts, a preliminary requirement is the eradication of palms that have contracted the disease before bearing as they might not bear at all. Among the bearing palms, eradication of palms in the advanced stage of the disease shall receive priority. The remaining stock of palms shall receive a strategy by which productivity can be enhanced with an increase in income from unit area. In order to achieve this, it is necessary to formulate several production models comprising of balanced fertilization, plant protection, irrigation, cultural practices and crop combinations to suit the needs of the farmers in the different agroclimatic conditions.

The need of a cultivar resistant to the disease is well realized but is yet to be fulfilled. Systematic efforts are required in this direction and it is necessary to formulate long-term programme for locating disease resistant or tolerant cultivars. The disease-free palms in 'hot-spot areas' shall receive attention along with other germplasm materials. The possibility of raising resistant or high-yielding seedlings from good mother palms by tissue culture techniques shall also be explored. Needless to emphasize the desirability to probe into the factors determining the resistance to the disease observed in certain palms in heavily infected coconut plantations.

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Ridge-regression technique for selection of yield components in late-maturing rice varieties

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ABSTRACT

Ridge-regression technique applied to 3 sets of data relating to 'Anamika', 'Pankaj' and 'Mahsuri' varieties of rice (*Oryza sativa* Linn.) indicated that only ear-bearing tillers, grains/panicle and 100-grain weight should be given more weightage while selecting potential genotypes in late-duration rice varieties.

Morphological characters influencing yield are often highly inter-correlated, leading to multi-collinearity when the inter-correlated variables are regressed against yield in a multiple-regression equation. For such situations estimation of regression coefficients through ridge-regression was developed by Hoerl and Kennard (1970a) to ameliorate problems like inflation in absolute value of the regression coefficients and wrong sign of the regression coefficients resulting from these inter-correlated variables.

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