Root (wilt) disease of coconut

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It is a proud privilege for me to deliver the Mundkur Memorial Lecture and I am grateful to the Indian Phytopathological Society for having given me this oportunity. My respects for the person Dr. Balachandra Bhavanishankar Mundkur became more intense when I had to study in detail his contributions to Mycology and Plant Pathology, a Seminar topic that was assigned to me during my M.Sc. in the then Division of Mycology and Plant Pathology at the Indian Agricultural Research Institute.

I have selected the topic the " Root(wilt) disease of coconut" because of my association with the coconut diseases for the last 27 years. The root(wilt) disease of coconut is of national importance as the disease causes an annual loss of 968 million coconuts in Kerala. Though figures are not available for the loss in Tamil Nadu, the disease is very serious and causes considerable crop losses in Cumbam valley, Shenkottai, Kulasekharam and Pollachi. Systematic investigations on this disease was initiated by Butler in 1908. Since then more than 350 publications by 154 scientists have appeared on this disease in the last 90 years. Apart from scientists, large number of perosons in other categories such as technical, administrative and supporting have contributed to the investigations over a period of almost a centuary. Many scientists from abroad have also visited the CPCRI Regional Station and collaborated in research as well as participated in formulating research programmes. The disease was discussed in the past in several national and international symposia, seminars, group meetings, expert panels and in political and social gatherings because of its national importance particularly to Kerala's economy. With the limited time available, I may not be able to do full justice to all the work that have been carried out but shall try to summarise the most important aspects.

Coconut is the most useful tropical palm grown in India as a traditional plantation crop for the last 3000 years specially along the coasts of India. It is intimately related to the economic, social and cultural life of a vast multitude of small and marginal coconut growers. Every part of the coconut tree is used for some purpose or the other. On account of this, it is called 'Kalpavriksha' the "tree of heaven" - the tree that provides all the necessities of life. India ranks first both in terms of production and productivity and third in area among the coconut producing countries of the world. The palm is affected by a number of diseases and pests some of which are fatal while others reduce its vigour resulting in economic loss. Eight hundred and thirty insects and mites, 173 fungi and 78 species of nematodes have been found to be associated with coconut (Anon, 1979). Only a few of them cause serious damage to the crop. In India, the Root(wilt), Tatipaka, Thanjavur wilt, Stem bleeding and Bud rot are the important diseases on coconut. The low productivity of coconut in Kerala is due to the prevalence of root(wilt) disease.

Origin, distribution and production loss

The occurrence of root(wilt) disease of coconut was first noticed in 1882 in Erattupetta area of Meenachil Taluk in Kottayam District (Butler 1908, Pillai 1911, Menon and Pandalai, 1958). Around 1907 the disease was reported from Kaviyoor and Kalloopara areas of Tiruvalla Taluk and later from Kayangulam of Karthikappally Taluk. The disease which appeared simultaneously in the above foci began to spread to adjoining areas (Varghese, 1934). In later years a number of attempts were made to determine the extent of spread and intensity of the disease (Menon & Nair, 1951, Verghese, 1959; Pillai *et al.*, 1973; George *et al.*, 1979; Pillai *et al.*, 1980).

A comprehensive survey was undertaken by the Central Plantation Crops Research Institute in collaboration with the Department of Agriculture, Kerala and

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other agencies in 1984/85 to estimate the area of spread, intensity of the disease and production loss due to the disease(Anon, 1985). The survey showed that the disease was prevalent in more or less contiguously in 4,10,000 ha in eight southern districts of Kerala. The intensity of the disease in both bearing and non-bearing palms was highest in Kottayam district (75.6%) followed by Alappuzha (70.7%). In the northern district of Thrissur the incidence was 2.6% and in the southern district of Thiruvananthapuram it was 1.5%. The survey also revealed sparse and sporadic occurrence of the disease in the districts of Palakkad, Malappuram, Kozhikode and Kannur. Recently it was reported from Kasaragod district (Solomon, J.J, 1999, Personal Communication). The incidence of the disease was also reported from the adjoining areas of Tamil Nadu such as Shenkotta, Coimbatore, Cumbam, Pollachi and Kulasekharam.

The survey revealed that the annual loss due to the disease was 968 million nuts in Kerala. Loss of husk per nut was 25.8% and loss of copra and oil per nut was 9.08 and 11.3% respectively. Sixty per cent of the leaves was found damaged due to the malady. Mathew *et al.* (1993) reported decline in yield to the tune of 45% in West Coast Tall variety and 60% in DxT hybrids and delayed on set of bearing in seedlings that took up the infection.

Nature of the Disease

Butler referred to it as "root disease", probably due to the rotting of roots noticed by him in the affected palms. McRae (1916) called it the leaf rot disease, Menon (1935) as the coconut leaf disease and Menon and Nair (1948) as the leaf rot disease of coconut. Nagaraj and Menon(1955) felt that the name wilt would be more appropriate taking into account the nature of foliar symptoms. Subsequently the disease came to be known as root(wilt) disease(Shanta *et al.*,1960; Mathen *et al.*,1983). The non lethal, slow spreading and debilitating nature of the disease, gradual decline in yield, amelioration of symptoms and economic returns with management practices, and total absence of wilt symptoms in the leaves or roots clearly indicate that the name root (wilt) is a misnomer that gives wrong impression about the symptoms of the disease in the minds of the readers. Keeping these points in view, the name COCONUT DECLINE was suggested by Dr.M.S. Swaminathan in 1976 in his inaugural address of the International Symposium on Coconut Research and Development at CPCRI Kasaragod, Kerala.

Symptoms

Flaccidity, ribbing, yellowing, paling, and necrosis of margins of leaflets of the leaves of central and outer whorls were considered to be the typical foliar symptoms (Varghese,1934; Menon and Nair,1951; Menon & Pandalai,1958). Radha & Lal(1972) recorded flaccidity, the characteristic bending or ribbing of leaflets as the earliest consistent visual symptom. Holmes(1965) pointed out that such affected leaflets were curved along the entire length and formed a structure resembling the ribs of mammals. Rajagopal *et al.*(1979) attributed this to the impaired stomatal regulation resulting in excessive water loss. Softening and whitening of the leaflets of the spindle were considered to be the initial symptoms by Dwivedi *et al.*(1979). Symptom expressions vary with the age, nutritional status/management practices, variety, and the time lag after disease incidence. In general, 67 to 97 % palms show flaccidity, 38 to 67% develop yellowing and 28 to 48% show marginal necrosis. Palms below the age of 10 years exhibit 96.8% flaccidity while yellowing and marginal necrosis are virtually absent in them.

Based on the relative contribution of flaccidity, yellowing and necrosis, George and Radha (1973) developed a scoring system taking into account the symptom expression in all the leaves for quantifying the disease severity. The method was further simplified by rating the leaves in any of the five spirals (Nambiar and Pillai, 1985).

Sudden appearance of bright yellowing of 3-4 leaves in the middle whorl, followed by appearance of large number of brown spots of various shapes with a halo around on all leaflets of yellowed leaves is the first symptom of root(wilt) in certain cases. In the beginning, the yellowing is sometimes restricted from the leaf tips to the middle of the leaf. Shedding of buttons/immature nuts and inflorescence necrosis are the other prominent symptoms in these palms. These yellowed leaves dry up faster and shed when leaves of lower whorls remain green. Yellowing is very bright and conspicuous in the variety Chowghat Orange Dwarfs, their segregants and even in their hybrids. More incidences of mid whorl yellowing is noticed in this variety. These palms invariably develop rotting of spear leaf subsequently. Incidence of leaf rot can be prevented by treating the palms against leaf rot immediately after the appearance of yellowing. However, inflorescence necrosis and total button shedding continue to occur for 6-12 months even after treatment. Application of 50 g Borax alongwith the fungicide was found helpful in faster recovery of affected palms (Koshy, personal observation).

Inflorescence necrosis, lack of ability to produce female flowers and pollen sterility render the palm unproductive (Varghese, 1934, Varkey and Davis 1960). The extent of decline in yield is 43% in disease early and 74% in disease advanced as compared to disease free palms (Anon, 1985c). Shedding of immature nuts even before the appearance of other visual symptoms or after is another important character.

Rotting of spear leaf (spindle) is the first symptom to appear in seedlings below the age of 5 years and this symptom is expressed in some cases within 10 months after planting of one year old seedlings in the field.

Rotting of roots was considered to be one of the important symptoms by many (Butler, 1908; Menon and Nair, 1949; Michael, 1964; Radha *et al.*, 1971). Butler (1908) observed that half of the main roots were rotten in some disease advanced palms and the smaller roots exhibited rotting in high proportion. Percentage of root decay varied from 12-94.4% depending upon the intensity of the disease (Michael, 1964; Radha *et al.*, 1971) Michael (1964) reported reduction in the number of roots produced by diseased palms compared to healthy. Joseph and Jayasankar (1981) did not consider root rot as a characteristic symptom of the disease as they could not observe more than 10.6% root decay in diseased palms. Anatomy of the roots of diseased palms revealed degenerated phloem, disorganised tracheal elements and tyloses in metaxylem (Indira and Ramadasan, 1968; Govindankutty and Vellaichamy, 1983).

ETIOLOGY

Fungi

Butler (1908) observed the common occurrence of *Botryodiplodia theobromae* Pat in the roots of diseased palms. He suggested that the rotting due to this fungus could be the cause of the disease. Radha and Menon (1954) indicated that *Rhizoctonia solani* is more specific to diseased roots than *R. bataticola.* They also recorded the presence of *Gleosporium* sp., *Neocosmospora vasinfecta, Gliocladium* sp., *Pestalotia* sp., *Curvularia* sp., *Chaetomium* sp. and *Trichoderma* sp. Incoulation experiments with *R. solani* and *R. bataticola* in large size cement tubs as well as in field brought about rotting of roots but failed to produce the foliar symptoms characteristic of root(wilt) disease (Menon and Nair 1951).

Apparently healthy roots from disease affected palms harboured *Fusarium equisetti* and *Cylindrocarpon effusum.* On inoculations, these fungi caused rotting specially of the surface feeder roots. Trials with *C. lucidum* also showed extensive rotting of tips of main and lateral roots. On an average 50 per cent of roots were decayed in inoculated seedlings as against 5 per cent in the control seedlings (Lily, 1981 a&b). Pathogenicity trials conducted on coconut seedlings in microplots of size 1.8 x 1.8 x 1.2 m using the fungi *F. equisetti* and *C.. effusam* failed to reproduce symptoms of root(wilt) disease when inoculated singly and in combination with the burrowing nematode, *Radopholus similis* and the bacterium *Enterobacter cloacae.* The investigations carried out have not indicated any role of the fungi in inciting the disease (Anon, 1985).

Bacteria

Srivastava *et al.* (1969) was the earliest to observe vascular streaming movement of *Pseudomonas* sp. Several attempts made since then failed to establish consistent asociation of any major group of bacteria with the root(wilt) affected palms. George *et al.* (1976) isolated *Enterobacter cloacae* from the roots of the diseased palms. Injection of a formulation containing 3 g active ingredient of oxytetracycline in one litre distilled water under pressure four times in a year reduced the intensity of root(wilt) disease in 10 treated palms compared to equal number of control palms (George, 1983). The bacterium failed to produce the symptoms when inoculated singly and in combination with burrowing nematode and fungi (Jayasankar and George, 1998).

Nematodes

Increasing evidences on root rotting, soil transmissible nature of the disease and the suspected involvement of virus in the sixties indicated the possible involvement of plant parasitic nematodes as probable vectors or incitants. (Butler, 1908; Menon and Nair, 1949; Shanta *et al.*, 1972). Weischer, 1967 examined a total of 60 soil samples and concluded that presence of *Xiphinema* and *Longidorus* could be of importance if viruses were involved in the disease. Very high populations of *Radopholus similis* from roots of healthy and diseased palms in the root (wilt) prevalent tracts were recorded (Koshy *et al.*, 1975; Koshy *et al.*, 1978). In an extensive survey carried out comprising 965 samples each of soil and root from Kerala (836), Karnataka (13) and Tamil Nadu (116) during 1973 to 1982, the widespread occcurrence of the burrowing nematode on coconut was reported from both healthy and root(wilt) prevalent areas. *R. similis* infestation produces small, elongate, orange coloured lesions on tender, creamy white roots. On multiplication of nematodes, these lesions enlarge, coalesce and cause extensive rotting. Lesions are not conspicuous on the secondary and tertiary roots as they are narrow and rot quickly on infestation. Maximum number of nematodes and cavities are seen in the outer cortex. Multiple cavities and their coalescence destroy the cortex to a great extent. The pathogenicity experiment first of its kind on a perennial crop conducted at CPCRI RS Kayangulam in 1.8X1.8X1.2 m soil tanks have clearly established the pathogenic potential of the nematode on growth, flowering and yield of coconut under field conditions over a period of eleven years from planting. The absence of production of typical root(wilt) disease symptoms even after eleven years on palms inoculated with one million nematodes clearly shows that *R. similis* is not involved in the etiology of root(wilt) disease. The root(wilt) affected palms may decline at a faster rate on infestation by *R. similis* which is wide spread on coconut, arecanut and intercrops such as banana, black pepper, etc. (Koshy and Sosamma, 1996). Thirty per cent increase in yield and 5-10 per cent decrease in disease indices of palms affected with root(wilt) disease have been obtained by the application of *Hydnocarpus* oil cake @ 4 kg per palm or phorate @ 10 g ai/palm in June-July and October-November (Koshy, 1986).

Virus

Virological investigations on root(wilt) disease of coconut were initiated following the unsuccessful attempts of Menon and Nair (1951) to reproduce the characteristic symptoms through inoculation of fungal isolates including *Botryodiplodia theobromae* proposed by Butler (1908) as the causal agent. The virus theory gained significance with positive transmission of the disease through sap inoculation and the insect vector *Stephanitis typica* Distant under field conditions (Nagaraj and Menon, 1956) and insect proof conditions. Flaccidity, paling and slight stunting of younger leaves were observed in five of the six seedlings mechanically inoculated with sap of diseased palms and in one out of six seedlings inoculated with *S. typica* (Shanta *et al.*, 1960; and 1964).

Shanta and Menon (1960) reoported crinkling and malformation in the first trifoliate leaf of 71.8 per cent cowpea (*Vigna unguiculata*) plants inoculated with crude leaf sap of diseased palms on the first pair of the simple leaves. Cowpea plants also became infected when inoculated through viruliferous lace bug *S. typica.* Even a single insect could transmit the disease and 16 per cent of the field population was found infective (Joseph *et al.*, 1972) and Pillai *et al.* (1970) observed that pollen, nuts, husk, kernel and embryo of diseased palms had the virus in them since inoculated cowpea developed typical symptoms. All further studies such as infectivity of roots of diseased palms, soil in the basin of diseased palms, physical properties of the virus such as thermal death point, dilution end point, favourable pH for maximum activity, longevity under varying temperatures and biololgical activity such as acquisition-feeding period, incubation, transmission feeding period, etc. were studied in detail and reported using cowpea as indicator host. Sasikala and Pillai (1978) after a detailed study on cowpea indicated that it cannot be used as a reliable test plant.

Summanwar *et al.* (1969) isolated a virus from *Chenopodium amaranticolor* after infecting with purified fraction of diseased coconut leaf sap. The purified fraction caused chlorotic lesions on *Nicotiana tabacum* cv white Burley. Based on its positive reaction to antisera of three tobacco mosaic virus strains, the virus was classified as TMV. (Summanwar *et al.*, 1971). Through detailed studies on pathogenicity, EM and serology it was confirmed that TMV is not associated with root wilt disease. (Shanta *et al.*, 1975; Solomon and Sasikala, 1980). Maramorosch and Kondo (1977) reported the presence of icosahedral particles of 56 nm diameter in the epidermis and ground parenchyma cells of diseased palms. But Parthasarathy (1978) identified these particles as plasmodesmata sectioned in tangential plane.

Phytoplasma

The presence of phytoplasma was identified in sieve tubes of roots, tender stem, petiole and developing leaf bases of root(wilt) diseased palms (Solomon *et al.*, 1983). Constant association of phytoplasma with the disease has since been established with the detection of the organism in tissues of all the 75 diseased palms as against their total absence in an equal number of healthy palms from disease free area. Abnormal bluish colouration in sieve tubes of diseased palms following Dien's staining and increased fluorescing sites in sieve area consequent to DAPI staining are indicative of accumulation of DNA in extra nuclear sites and thus the presence of phytoplasma.

Phytoplasma was observed in brain and salivary glands of lace bug given an acquisition plus incubation period ranging from 18-23 days whereas phytoplasma was not observed in lace bugs collected from healthy areas as well as in bugs offered an acquisition and incubation period less than 18 days. (Mathen *et al.*, 1987). Phytoplasma has also been observed in the salivary glands of the plant hopper *Proutista moesta* given an acquisition feeding period of more than 30 days(Anon, 1991). Mathen *et al.* (1990) transmitted the disease under insect proof cages using *S. typica.* Two out of five seedlings exhibited flaccidity in the 17th month and presence of phytoplasma in 4/5 inoculated seedling was confirmed by EM examination. *Proutista moesta* was also able to transmit the disease under insect proof conditions. Five out of eight seedlings exhibited the diagnostic symptom flaccidity (Anon,1977). The incidence of the disease could not be checked by the application of insecticide at fortnightly interval with ten times increased concentration than the normal recommended dose (Anon, 1993, 1997). Transmission of phytoplasma to periwinkle, *Catharanthus roseus* was achieved through *Cassytha filiformis* by growing periwinkle in sterile soil under insect proof condition and bridging with dodder established on diseased coconut seedlings. The periwinkle developed chlorotic spots in the intervenal areas of fully opened leaf within 3-4 weeks of establishment of haustorium. The presence of phytoplasma was confirmed in leaf tissues of periwinkle through EM and staining techniques (Sasikala *et al.*, 1980). Phytoplasma from coconut could not be cultured though various methods were tried (Anon, 1989).

A field trial was initiated in 1984 with four concentrations (1, 2, 3 and 6 g a.i.) of oxytetracycline hydrochloride with Neomycin, Penicillin and distilled water control. Fifteen palms each in the early stage of disease were given the different treatments at quarterly intervals. Fifty three palms treated with 3 and 6 g of OTC showed remission of symptoms. Contrastingly palms in distilled water and penicillin treatments deteriorated significantly (Pillai *et al.*, 1991).

Soils and nutrition

The coconut root(wilt) disease has been found to occur on all soil types of Kerala under varying ecological conditions ranging from the high ranges of the Western Ghats to the coastal plains. Menon and Nair (1949) and Menon *et al.* (1950) suggested that the disease might also be associated with nutritional deficiencies. They reported that the soils of disease affected areas were generally deficient in major nutrients particularly K and had a lower content of exchangeable cations. An intensive study of the major soil groups of erstwhile Travancore Cochin state representing healthy and diseased pockets was conducted by Sankarasubramoney *et al.*, 1954, 1955, 1956 and Pandalai *et al.*, 1958a, 1958b, 1959a 1959b. These studies showed that in general the soils in disease affected areas were low in available K, total Ca and Fe exchangeable Ca and Mg, total exchangeable cations, CEC, pH and percentage base saturation. Water logging was found to favour disease incidence and severity. Verghese (1966) indicated the association of faulty nutrient status in soils particularly K/Mg,K/Ca and N/K with disease incidence. Pillai *et al.*,(1975) carried out a nutritional survey of all the districts of Kerala and studied the major and micro-nutrient status of soils from healthy and diseased areas. Cecil (1981) recommended the application of magnesium for the management of diseased palms. The prebearing age was reduced by 9 months by the addition of Mg and the response of Mg was more pronounced on the diseased palms compared to healthy ones. Cecil *et al.* (1982) based on field fertility trials concluded that the disease was not caused by deficiency of any major nutrient. A comparative study on the performance of WCT (Cecil, 1981) and CODxWCT (Amma *et al.*, 1982) under rainfed conditions and regular fertilisation with NPK Ca and Mg since field planting showed that the hybrid was superior to WCT with respect to disease incidence and nut yield.

Zinc and Mo both as soil application and foliar spray had no effect on incidence or intensity of the disease (Mathew *et al.*, 1986).

A systematic micronutrient manurial experiment consisting of all combinations of two levels of each of Fe, Mn, Cu, Zn, B and Mo since field planting had shown that the disease was not related to micronutrient nutrition of the palm (Anon, 1986a). Khan *et al.* (1985) did not observe any relationship between the micronutrient composition of diseased palms and the disease index compared to healthy palms.

The field experiment to study the effect of different organic manures on the growth and productivity of palms in the root (wilt) prevalent areas revealed that by application of organic manures alone or in combination with inorganic fertilizers, the incidence of root(wilt) disease could not be controlled/arrested. By the end of fifth year 21.8% of the palms had contracted the root(wilt) disease irrespective of the treatment (Anon, 1996a).

Biddappa and Khan (1985) studied the heavy metal status of coconut growing soils of Kerala and found that the contents of ethylene triamine-pentaacetic acid (DTPA) extractable Ba, Cr, Cd, Pb, Sr and V were significantly higher in diseased soils compared to healthy. Biddappa and Cecil (1984) and Biddappa (1985) studied the deposition of heavy metals using scanning electron x-ray microprobe analyser in diseased palms. High deposition of Al, Mn, Cu, and Co in the roots and Cr, Ti, Pb, B1 and Ga in the cabbage tissues of diseased palms was found compared to identical tissues of healthy palms.

Valiathan *et al.* (1992) reported lower level of magnesium and higher concentrations of cerium in the leaves of root(wilt) diseased coconut palms. Wahid *et al.*, (1998) studied the rare earth elements in diseased and healthy palms. Among these, foliar levels of Gadolinium (Gd) was significantly less in palms of disease affected tract than in those of healthy tract.

Physiology

A number of physiological derangements were noticed in the root functioning, water relations, mineral nutrition, respiration, photosynthesis and phenol metabolism.

Michael (1964) studied the extent of root damage caused in two to ten year old diseased palms and reported that the number of functioning roots and the diameter of the bole were drastically reduced. The percentage of dead roots was higher and the regenerating capacity of roots was also reduced. Amma and Patel (1982) attempted regeneration of roots in root(wilt) affected palms. The palms which received IBA 500 ppm + phenols 400 ppm produced maximum roots and showed reduction in disease indices. Davis (1964) studied the nature and composition of root sap. The root sap of apparently healthy palms was acidic in nature, odourless, clear, rich in K20 and Mg0 contents. Ramadasan (1964) noted that root sap of diseased palms contained 65.7% more solid contents than that of healthy palms. A single root of diseased palm absorbed 150 ml water per day compared to 250-500 ml by a root of a healthy palm (Davis, 1964). The uptake and transpsort of water through the trunk in diseased palms was reported to be 35% less than that of healthy palms. (Ramadasan, 1964).

Root (wilt) diseased palms were seen to have higher stomatal frequency than that of healthy palms (Mathew, 1981). Rajagopal *et al.* (1986a) found abnormal, stomatal opening in the infected palms with impaired regulation leading to excessive water loss, irrespective of the time of the day, season, or growing condition. Root(wilt) affected palms had consistently lower leaf water potential than the healthy palms at any given time (Rajagopal *et al.*, 1987). Michael (1978) reported significantly higher rate of respiration in root(wilt) diseased palms compared to healthy ones. Percentage increase of the chlorophyll content in the first fully opened and middle leaves of healthy palms was 16 and 70 respectively over that in diseased palms (Dwivedi *et al.*, 1978). In spite of higher total reducing and non-reducing sugars in the leaves of diseased palms a depletion of these sugars occurred in roots of diseased palms indicating a derangement in translocation (Mathew, 1977). Padmaja *et al.* (1981) reported low protein values in the leaves of diseased palms compared to healthy. Reduced C/N ratio was noticed in the roots and leaves of diseased palms (Varkey *et al.*, 1969). Pillai and Shanta (1965) reported accumulation of free amino acids with considerable quantity of arginine in leaves of diseased palms. Pectin lyase activity was found to be nearly six times higher in the roots of diseased palms compared to the healthy (Amma and Patel, 1985). Reduced utilisation of absorbed phosphorus in the synthesis of P constituted organic substances was reported in diseased palms (Dwivedi *et al.*, 1979). Joseph and Jayasankar (1973) reported highest concentration of polyphenols in roots of healthy palms compared to roots of diseased palms. Joseph (1983) reported distinct differences in isozyme pattern of polyphenol oxidase between healthy, apparently healthy and diseased palms. Rajagopal *et al.* (1989) reported decreased rate of flow of phloem sap from diseased palms compared to apparently healthy. The sap collected from inflorescences of diseased palms registered higher values of arginine and aspartic acid among amino acids and malonic and lactic acids among organic acids and glucose and galactose among sugars (Chempakam *et al.*, 1991).

Diagnosis

The earliest visual symptoms of the disease reported was in 18 month old seedlings (Anon, 1981). A number of tests were developed to forecast/detect infection sufficiently early before the visual manifestation of symptoms (Joseph and Shanta, 1963; Pillai and Shanta,1965; Lal, 1968; Davis *et al., 1964*; Rajagopal *et al.*, 1988). Remote sensing technique using false impaired aerial photography was undertaken by ISRO and IARI in collaboration with NASA of USA. But this could not be used for want of adequate data on ground level (Dakshinamoorthy *et al., 1971*; Dakshinamoorthy and Summanwar, 1972). Dwivedi *et al.* (1977) developed an EDTA test which did not give consistent results (Rajagopal *et al.*, 1988). Agar Gel Double Diffusion Test (Solomon *et al.*, 1983) could be used to detect the disease in palms irrespective of their age group. The time lag between the detection of latent infection and manifestation of visual symptoms varied from 6 to 24 months (Anon, 1985 a). Enzyme linked Immunosorbent Assay (ELISA) has been standardised for the quick detection of root (wilt) disease (Anon, 1996a).

Low stomatal resistance and high transpiration rate was recorded in diseased palms compared to healthy palms. The leaf water poential was lower in clearly diseased palms than in apparently healthy palms. These parameters were recorded in the last fully opened leaf to the spear leaf during mid day in the dry season using a Li-cor 1600 steady state porometer(Rajagopal & Amma, 1989).

Varietal resistance

Butler (1908) suggested search for resistance in the local cultivars but it was Verghese (1934) who initiated the work. He surveyed about 10 sq. km in and around Kayangulam an endemic area but could not locate genotypes resistant to root(wilt) disease. Davis (1953) reported occurrence of high yielding palms among the heavily diseased palms. Open pollinated progenies of such palms were collected and planted in Block II and III of CPCRI farm (1951-1968). A few of them still remain as apparently healthy and yield well. It is unfortunate that the breeding for resistance studies which could have offered the most profitable and lasting solution for a disease of this magnitude in a perennial crop like coconut was not pursued until 1989. However, a humble beginning was made by using a few absolutely healthy and high yielding palms available in the disease endemic areas in 1989 which has proved to be a very promising line of investigation.

Radha (1961) reported high degree of resistance to leaf rot in Andaman Ordinary and New Guinea varieties under field conditions. Mathai (1985) also reported high degree of resistance to root (wilt) and leaf rot disease in Andaman Ordinary. Even after 40 years, no action has been taken to make use of this information. Being an indigenous cultivar seednuts of this could have been introduced in large scale to Kerala for planting in root (wilt) prevalent areas. Even now the situation can be corrected by giving high priority for this because the cultivar Andaman Ordinary is at par or even slightly better than WCT in terms of yield of nuts, copra and oil contents.

Attempts to screen the available germplasm at CPCRI, Kasaragod were made as early as 1961 at CPCRI, Kayangulam. All cultivars developed typical symptoms of root (wilt) disease (Menon *et al.*, 1981). Rawther and Pillai (1972) reported higher tolerance to the disease by natural cross Chawghat Orange Dwarfs. These hybrids also gave higher yields even after contracting the disease. Screening of open pollinated progenies of cultivars and hybrids were taken up at CPCRI, Kayangulam and in cultivators' gardens involving different soil types in 63 villages of Alappuzha, Kollam and Kottayam districts during 1972. All the 36 cultivars and 43 hybrids planted in gardens contracted the disease with 40-70% disease incidence irrespective of soil types.

In another trial conducted at CPCRI, Kayangulam involving 21 cultivars and 15 hybrid combinations with WCT as check during 1972 revealed that all of them are susceptible. The percentage incidence varied from 33.3 to 100. The average annual yield (52.5 nuts) was maximum in WCT x COD hybrid with 91.6% disease incidence followed by Java Giant x KGD with 43 nuts and 83% incidence in the 16th year of planting (Jacob *et al.*, 1998)

Hybrid combination, COD x WCT yielded 80% nuts/palm/year with 50% disease incidence followed by WCT x COD with 70.3 nuts and 94% incidence and WCT x GB with 52.5 nuts and 87.5% disease incidence comparaed to 70 nuts and 37.5% incidence in WCT in a screening trial in sandy loam soil planted in 1972.(Jacob *et al.*, 1998).

In 1982 a new trial was laid out in cultivators' gardens in and around Kayangulam with 27 cultivars, 10 hybrid combinations, F2(OP) of D x T and T x D, progenies of elite palms, high yielding WCT and prepotent WCT. Among these, 27 cultivars were planted in 5 locations and the remaining in 8 locations. Data collected from the above trials have shown that among the 27 cultivars all except Kenthali have taken up the disease with disease indices ranging from 7.1 to 55.6% in the fourth year of planting (Jacob *et al.*, 1998). The reported resistance in the local cultivar Kenthali which is also known to have high degree of resistance to the burrowing nematode (Sosamma *et al.*, 1980), a serious problem in root (wilt) prevalent area, needs to be explored.

Iyer *et al.* (1979) identified 9 elite palms in root(wilt) disease prevalent areas. All the open pollinated progenies of these elite palms planted in CPCRI farm in 1980 contracted the disease, intensity ranging from 40-100%.

An intensive survey covering heavily diseased tracts of Kottayam, Pathanamthitta, Alappuzha & Kollam districts was initiated in 1985 and is being continued to locate disease resistant high yielding WCT and CGD palms. The criteria for selection in case of WCT are (1) The palms should be free from all diseases and pests. (2) The palms should yield regularly, i. e. 80 or more nuts per palm per year and the bunches should rest on the petioles. (3) Eighty per cent or more surrounding palms should be diseased, preferably in the advanced stages of disease. (4) The palms should react negatively to the root(wilt) disease in the sero-diagnostic test. (5) The age of the palms should be 35 years or above. (6) The palms should have all typical characters of WCT confirmed by the progeny test to make sure that no hybrid palm is selected as mother palm. The Chowghat Green Dwarf (CGD) palms are selected using the same criteria except that the age of palms should be 20 years or above. The cross combinations are WCT x WCT (Inter-se). WCT selfed, WCT x CGD, CGD x WCT, CGD selfed, CGD x CGD Inter-se (Nair *et al.*, 1996). The first set of 31 CGD x WCT progenies planted during 1991 revealed that they have an yield potential of 100 nuts per palm per year in the fifth year of planting. They came to flowering in 30-40 months after planting. The copra content was 215g/nut. Disease was noticed in 5/31 palms(16%)(Jacob *et al.*,1998). The inter-se crossed and selfed progenies of high yielding tolerant WCT from endemic area are also being evaluated. Thirty per cent seedlings planted in gardens with 80% disease incidence showed disease symptoms while in open pollinated seedlings from the same mother palms showed 50% disease incidence.

A number of healthy, high yielding Chowghat Orange Dwarf (COD) palms have been located in the disease endemic areas. Adopting the criteria for the selection of CGD, they also have been included in the breeding programme in progress.

Seed gardens one each at CPCRI, Kayangulam, Coconut Development Board Farm at Neriamangalam and CPCRI Research Centre, Kannara are being established with WCT x WCT, CGD x CGD and WCT, COD and CGD selfed progenies to cater to the need of planting material for the disease endemic districts. The present indications are that we may be able to release high yielding disease tolerant CGD, COD, WCT, WCT x CGD,CGD x WCT, CODxWCT and WCTxCOD in the near future.

LEAF ROT DISEASE

Leaf rot disease of coconut presumably was in existence in the erstwhile states of Travancore and Cochin since 1880 (Menon, 1935; Menon and Nair, 1948; 1952). Though Butler (1908) briefly described the symptoms on unopened spindle, he did not report any pathogen from the affected leaflets. Root (wilt) disease minus leaf rot is not a disease of much economic importance. Radha and Lal (1968) reported close relationship between leaf rot and root (wilt) disease in the field as well as in inoculation trials. Leaf rot was found to develop on palms without root (wilt) also, probably because these plants had latent infection. They observed that nearly 16-40% of the palms in the root(wilt) affected area developed leaf rot. Verghese (1934) reported that both leaf disease and root disease occurred together on the same palm. Srinivasan (1991) reported that leaf rot disease gets superimposed on 65% root (wilt) affected palms. Menon and Nair (1948) and Menon and Pandalai (1959) observed leaf rot disease on palms of all ages. It does not attack seedlings in the nursery. Every root (wilt) affected palm gets leaf rot disease. In certain cases it may occur quickly but in certain palms it may take even 5 or 7 years depending upon the genetic make up, age of the palm, nutritional status of soil, irrigation etc.

Leaf rot is seen to occur within 10 months of field planting of one year old seedling. The rotting of the spear leaf is always the first symptom to appear in seedlings but this has not been reported as such in the past. Flaccidity, yellowing and necrosis occurs later on these seedlings. Normally, farmers identify a palm to be root (wilt) affected only when leaf rot sets in. Flaccidity and marginal necrosis of leaflets are not easily recognised by the farmers specially in the early stages.

Information on the loss due to leaf rot disease alone is not available or not possible to estimate since it is always associated with root(wilt). The loss due to leaf rot was computed and estimated to be 461 million nuts annually (Joseph and Rawther, 1991).

The coconut palm disease of Travancore is locally known as Kattuveezcha (transmitted through wind) spreads along the direction of the wind (Menon and Nair, 1951). Spread of the leaf rot disease is aerial. Menon and Nair (1952) collected the spores of the fungus *Helminthosporium halodes (Bipolaris halodes)* at a height of 12 M at Kayangulam in aerospore studies.

Symptoms

Fungal spores enveloped in dew-drops or rain water adhere to the cuticle of the tender whitish leaflets and germinate within 24 hrs producing tiny spots of various colours and shapes. These water soaked lesions enlarge, coalesce freely leading to extensive rotting. The rotting may advance into the interior of the spindle. When the spindle grows the rotten portions dry up, turn black, break and get blown off in the wind. The development of the symptoms and rotting is severe at the distal end of the leaf specially 1 to 1.50 M in length. On leaflets also the distal ends are more susceptible. Occurrence of intermittent rotting of leaflets and mid ribs on the same leaf is also seen. In many cases, the rotten distal portions of leaflet adhere to each other from top to bottom on both sides thereby giving a fish bone appearance. On drying these drop off.

Dwivedi *et al.* (1979) reported whitening and softening of leaflets of the spindle as an important symptom of root(wilt) disease. The leaflets of the spindle of healthy palms are green at the margin and the remaining portion of leaflets is creamy to yellowish or yellowish green whereas in diseased palms the leaflets of spindle are white, devoid of chlorophyll and the margins are pale green. When the leaflets open they are weak and do not have the strength to stand straight. Such white leaflets show large number of orange to brown spots and marginal rotting.

Hardening of the tissues and development of chlorophyll in the maturing leaflets generally slows down the progess of rotting towards the base of the leaflets so that the basal portions of the affected leaflets remain green and normal giving a fan like appearance. Normally the symptoms would appear on each successive spindle there by showing symptoms on all leaves but the disease is never fatal. In the early stages of the disease some spindles escape rotting during summer months.

In some palms the distal ends of leaves at the 4th or 5th position from the spindle, curl (1 - 1.5 M behind the leaf tip) break, hang down, become yellow, dry and drop off. Such palms show many such leaves in a crown without leaf tip and leaf rot is not very severe on such palms. About 15-20 per cent of leaf area probably the most susceptible area for leaf rot is broken and dropped off.

Severity of leaf rot symptom is more during monsoons and trees of all ages are susceptible and during summer months the leaflets show more of dry rot. The disease causes drastic reduction in photosynthetic area thereby reduction in yield.

Etiology

McRae (1916) and Sunderaraman (1925) isolated a *Penicillium* like fungus from diseased leaves in Kochi. *Helminthosporium halodes (Bipolaris halodes) Gleosporium sp., Curvularia sp. Gliocladium roseum, Pestalotia* sp. and *Fusarium* sp. were isolated from the diseased leaves (Menon and Nair, 1948; Anon, 1985). Srinivasan and Gunasekharan (1993) reported isolation and identification by IMI of CAB, UK of the following species viz. *Colletotrichum gleosporioides, Exserohilum rostratum, Gliocladium vermoeseni, Cylindrocladium scoparaium , Fusarium solani, F. moniliformae* var. *intermedium, Thielaviopsis paradoxa, Rhizoctonia solani, Mortierella elongata, Curvularia* sp., *Acremonium* sp., *Thielavia microspora, T. terricola,* and *Chaetomium brasiliense.*

Studies on the pathogenicity of the fungi were initiated by Menon and Nair (1948, 1951). Inoculating bits of tender leaves and leaflets of mature leaves with spore suspensions of *H. halodes, Gleosporium sp, G. roseum* and *Pestalotia* sp. *in vitro,* they found that *H. halodes* induces infection within 12 hr and the rest in 48 hr. They considered *H. halodes* as the most virulent and the rest only as secondary parasites, aggravating the rotting initiated by *H. halodes*. They confirmed these findings through *in vitro* tests and established the pathogenicity of *H. halodes* using single and mixed inocula. Later Radha and Lal(1968) also confirmed the infectivity of *H. halodes* on coconut. Culture filtrate of *H. halodes* when applied on tender leaves of coconut failed to demonstrate any toxic effect (Anon,1981). The pathogenicity of *C. gleosporioides, E. rostratum, G.vermoeseni F. solani, F. moniliformae* var *intermedium T. paradoxa, R. solani, Mortierella elongata* and *Curvularia* sp was established by Srinivasan and Gunasekharan (1996d)

The leaf rot affected spindle leaf is also colonised by mealy bugs, mites, nematodes etc. (Nadakkal, 1965) Individual or collective role played by them as aggravators or synergists or as disseminating agents of the disease to the next spindle is to be studied. The leaf rot affected palms are more prone to red palm weevil infestation. Nematodes such as *Aphelenchoides aligarhiensis, Panagrolaimus rigidus* and *Rhabditis* sp. in large numbers are found associated with rotting spindles (Koshy, unpublished). Application of a systemic insecticide that has nematicidal property (Phorate 10 G) alongwith fungicide was found to give better protection against leaf rot and other insect pests.(Koshy, Unpublished).

Epidemiology

Leaf rot infection was found to be more severe during the seasons when atmospheric humidity was at its maximum (Menon and Nair, 1951). Severity of leaf infection with *H. halodes, Gleosporium* sp. and *G. roseum* was found correlated with high humidity and low temperatures prevalent during the monsoon period (Radha *et al.*, 1961). Monthly records of observations for 3 years revealed that period of high atmospheric humidity and low temperatures are favourable for natural development of leaf rot disease(Radha and Lal 1968). The incidence of *C. gleosporioides* in LRD infected young palms was consistent and significantly higher than *E. rostratum* (Anon, 1996).

Disease Management

The leaf rot disease is the most important factor in the management of root (wilt) disease, because it is leaf rot which is responsible for the reduction in photosynthetic area, disfiguration of the palm, and reduction in yield. Ideally, an inflorescence is to be produced from every leaf axil in coconut. The number of female flowers, setting per cent, number and size of nuts, quantity of copra, oil content, etc. is directly dependent on the health of the leaf that produced the inflorescence. Hence, the role of the leaf that produced the inflorescence is equivalent to or more than that of the boot leaf of wheat or rice. From the studies conducted earlier it is very clear that a number of fungi are associated with leaf rot but most of them belong to the group, Fungi Imperfecti. Most of the new generation as well as old generation contact and systemic fungicides are effective against all these fungi reported in association with leaf rot. Earlier field trials using the contact fungicides had given excellent results. Menon and Nair (1952) conducted spraying in the field using 1.0% and 0.5% Bordeaux mixture against leaf rot. Half strength was almost as good as the full strength Bordeaux mixture. In a fungicidal trial using copper fungicides it was found that Bordeaux mixture reduced the intensity by 74.5% followed by Kirti Copper 65.6% and Fytolan 59.6% (Anon, 1963). Gregory (1960) felt that aerial spraying in Vadayar and Malankara estates was useful in controlling leaf rot, but Samraj *et al.*, (1966) observed that there was no adequate coverage of the spray fluid on the spindle leaf. George and Samraj (1966) reported that coconut palms affected by leaf rot responded favourably to foliar application of boron suggesting boron deficiency as the factor responsible for development of disease. Prophylactic basal application of systemic fungicides (Actidione, Bavistin, Benlate and MBC) at the rate of 4g per healthy palm twice a year failed to prevent incidence of leaf rot (Anon, 1983). Four sequential spraying of Bordeaux mixture 1%, Dithane M 45 0.3% and Fytolan 0.5% on leaf rot affected palms in farmers' gadens resulted in the control of the disease (Anon, 1985). Srinivasan and Gunasekharan (1998a) reported moderate impact of pouring of calixin and spraying of Indofil M-45 in the control of leaf rot when applied thrice a year.

In the management of leaf rot the role of the photosynthetic area available in every leaf and its contribution to yield is the most important factor to be considered. The second is the labour requirement for the operation. Difficulty in getting the services of climbers in time of need and the prohibitive cost are the other limiting factors. The fact that the white, soft, achlorophyllus leaflets of spindle alone is susceptible to fungal attack, suggests that the spindle alone is to be protected. The rhinoceros beetle also attacks only the spear leaf. Though the earlier recommendation of sequential spraying of Bordeaux mixture 1%, Dithane M-45 0.3% and Fytolan 0.5% on leaf rot affected palms using rocker sprayer (6 labour) and separate application of BHC 10% or Sevidol 8g for the control of rhinoceros beetle three times a year (3 labour) is effective, farmers had not adopted because of the very high requirement of 9 skilled labours (6+3)and the cumbersome spraying involved.. Therefore, the need for a simpler, environment-friendly and less labour intensive method combining the application of fungicide and insecticide, without the aid of a sprayer was keenly felt. A series of field trials conducted using various fungicides, bactericides and insecticides having contact and systemic properties led to the development of the following methods in three years: (1) Contaf 5 EC (Hexaconazole) 2ml per palm Rs. 1.20 or Dithane M-45 OR Indofil M-45-3g per palm Rs. 0.70; (2) Phorate 10G 20 gm/palm Rs. 1.10; and (3) Climbing charges for treatment alongwith harvest Rs. 5.00, Rs. 7.30 or 6.80; Frequency : Twice a year in April-May and October-November.

Mode of application

1. Cut and remove rotten portions of **only** the spindle and the adjacent two innermost fully opened leaves.
2. Dissolve either of the fungicides in 300 ml water and pour into the cavity around the base of the spindle leaf.
3. Apply Phorate 10 G - 20 g mixed in 200 gm sand around the base of the spindle leaf.
4. Treat all palms in the garden (healthy and diseased).
5. Treatment should not be carried out during rainy days.
6. Palms in early stages of disease will recover with two or three applications. Palms in advanced stages (with an index of more than 50%) would take 3 years to recover fully. After three years, the treatment is to be given only once in a year in May.
7. Residue analysis done for the chemicals, Contaf, Dithane M45, Furadan and Phorate 10 G in mature and tender nuts show that the nut water, kernel, coconut oil and coconut cake are free from residues after 45 days of application at the rates suggested (Koshy, unpublished).

The advantages of the method are:

1. Pouring of fungicides is more effective and target specific since it is applied directly on to the susceptible, white, non-chlorophyllous tender leaves resulting in better protection.
2. The cumbersome spraying and the need of a sprayer is avoided.
3. The quantity of spray fluid is reduced from 3000 ml to 300ml.
4. The leaf rot affected spindle leaf is also colonised by mealy bugs, mites, nematodes, etc. the individual or collective role played by them as aggravators or synergists or as disseminating agents of the disease to the next spindle is to be confirmed. The leaf rot disease affected palms are more prone to red palm weevil infestation. Application of a systemic insecticide that has nematicidal property (Phorate 10 G) alongwith fungicide was found to give better protection against leaf rot, rhinoceros beetle, red palm weevil, coreid bug, ash weevil, mealy bugs and nematodes.
5. Instead of separate quarterly spraying of fungicides (6 labour) and insecticides (3 labour) both can be applied together, two times in a year (April-May) and (October-November) saving 88 per cent labour cost.
6. The cost of two applications will work out to be Rs.14.60 or 13.60 compared to separate quarterly applications of fungicides and insecticides (Rs.50 + Rs.29) costing Rs.79 per palm per year.
7. The combined application of insecticide and fungicide did not affect the effectiveness of each other.
8. Other operations such as harvesting, cleaning of crown and tying of bunches can be combined with this in May and October to reduce the labour cost.
9. The same treatment may be given to all unaffected healthy palms also twice a year as a prophylactic measure.
10. The mid whorl yellowing (quick yellow decline) affected palm succumbs to leaf rot and inflorescence necrosis within two months of the appearance of initial symptoms of yellowing, immature nut fall and abnormal button shedding. Combined application of fungicides, Contaf 5 EC - 4 ml OR Dithane/Indofil M45 - 3g in 300 ml water and systemic insecticide Phorate 10G - 20g mixed in 200 g sand per palm immediately after the appearance of the initial yellowing symptoms can protect the palm from the incidence of leaf rot. The treatment needs to be repeated twice a year. Though the inflorescence necrosis disappears with one or two treatment the female flowers produced on subsequent inflorescences are small and shed quickly for another 6-12 months.(Koshy, unpublished).

Initial studies have shown that the systemic fungicide, Contaf – 5 EC (Hexaconazole) gets absorbed on feeding through cut ends of functional main roots of palms of all ages. No adverse effect was noticed in 5 palms each treated with 2ml, 4ml, 6ml and 10ml per palm. All palms absorbed the fungicide in 24 – 48 hrs (Koshy, Unpublished)

Antagonistic activity of *Pseudomonas fluorescence* against *C. gleosporioides* and *E. rostratum* is being tested *in vitro* (Srinivasan *et al.*, 1998). The bacteria *P. fluorescence* and *Bacillus subtilis* was multiplied on neem and marotti oil cake and applied around the base of the leaf rot affected spindle leaf twice a year did not give encouraging results (Koshy, Unpublished).

Radha (1961) reported high degree of resistance to leaf rot in Andaman Ordinary and New guinea varieties under field conditions. The resistance observed in Kenthali against root (wilt) and burrowing nemataode which is a very serious problem in root (wilt) prevalent areas should be taken into consideration in future breeding programmes for resistance. The tolerance to root (wilt) in Chowghat Green Dwarf and its crosses with WCT is also very encouraging. Though a certain percentage of them (maximum of 30%) are susceptible to leaf rot they respond quickly to management practices and recover faster from leaf rot and continue to give good yield. The tolerance/resistance observed in Andaman ordinary, New guinea, Kenthali, CGD and its crosses should be made use of at the earliest.

From the review of work done on root(wilt) disease, it is clear that the incidence of root(wilt) disease cannot be prevented by the technology available today. The farmers identify a palm to be diseased only when leaf rot occurs and rotting of spindle is the first symptom to appear in seedlings. Coconut seedlings take up infection early when they are planted in the same pits after uprooting the diseased palms or under planted in gardens affected by leaf rot disease. On treatment of leaf rot affected palms with the new treatment suggested above, yellowing, marginal necrosis of leaflets and inflorescence necrosis disappears. Considerable reduction in flaccidity, increase in per cent set and yield also take place. This gives an impression that flaccidity, yellowing, marginal necrosis of leaflets, inflorescence necrosis and softening and whitening of leaflets of spear leaf are only the early symptoms of leaf rot. The present trend of investigations by separating root (wilt) disease as a predisposing disease for leaf rot may not be correct and over emphasis of research efforts to find out the cause of root (wilt) disease in the past had only led to many controversies, wrong conclusions and public criticism. It is leaf rot that causes economic damage and an effective simple control method for leaf rot is the immediate need of the day. Farmers in root (wilt) prevalent areas of Kerala and Tamil Nadu will stand benefited only by researches on breeding for resistance and by research on field control of leaf rot which has never been given the due attention that it deserved. As such more research efforts in future should be directed towards management of leaf rot disease by taking into consideration the following:- (1) the unopened white, tender, leaflets of spindle alone are susceptible (2) the palms in advanced stages(above 70% index) of leaf rot do not respond to treatments quickly. (3) difficulty in getting the services of climbers in time and the prohibitive cost involved. (4) the cost: benefit ratio. (5) all palms in disease prevalent areas irrespective of their health status need to be treated for curative and prophylactic action continuously (twice a year), (6) palms in early stages of the disease respond quickly to treatment and (7) environment pollution and residual toxicity in nuts, if any, born on palms treated with systemic fungicides and insecticides.

I am sure the treatment suggested for leaf rot will be very effective against Spear Rot of Oil Palm and Arecanut Yellow Leaf Disease that exist in Kerala, since the fungi and other organisms associated with leaf rot and spear rot are the same. Here again, more research efforts should be concentrated immediately on field control of spear rot and yellow leaf diseases. In a new area, the arecanut yellows always appear first and coconut leaf rot appears later, many times after 10-15 years, which was also mentioned by Butler (1908) in his report.

Future Thrust Areas of Research

1. Development of methods by which systemic fungicides can be administered through root feeding/ stem injection avoiding the employment of climbers.
2. Development of easy methods for determining the susceptible/resistant nature in seedlings to leaf rot before planting.
3. Studies on the biochemical nature of healthy and leaf rot affected palms.
4. Use of modern molecular methods in the investigation of leaf rot disease such as identification of resistance linked markers in seedlings and development of diagnostic PCR tests for the various associated fungi.
5. Development of sero dignostic tests for the detection of important fungi such as *Exserohilum rostratum*, *Colletotrichum gleosporioides*, *Fusarium solani* and *Fusarium moniliformae* var. *intermedium*.
6. Use of tolerance available in certain varieties, and their response to management practices in terms of quick recovery and yield and finding out the reasons for early/delayed occurrence of leaf rot in root(wilt) affected palms
7. Development of environment friendly control methods using bioagents/plant products.
8. Studies on the role of mealy bugs, nematodes, bacterium, mites etc. found associated with the rotting spindle.

MANAGEMENT OF ROOT (WILT) DISEASE

Experiments carried out in the past clearly brought out the fact that the farmers of Kerala and the adjoining areas of Tamil Nadu have to live with the disease. The loss can be reduced to the minimum if palms can be attended immediately on appearance of symptoms and prophylactic and curative treatment against leaf rot are given to all palms in the disease prevalent areas twice a year.

Eradication of disease affected palms to contain the disease within contiguously infected geographic limits can be successful if continuous monitoring for occurrence of the disease and uprooting of suspected and diseased palms are taken up simultaneously. But if the programme is not monitored uninterruptedly the desired goal will not be achieved. This is evident from the present status of disease incidence in Vallom village in Shencottai in Tamil Nadu (Anon, 1986) and in the areas in north of Karuvannur river in Trichur district (Rethinam *et al.,* 1982).

Disease advanced palms with a root (wilt) index of 70 and above) never respond to any kind of management practice (Muralidharan *et al.,* 1986) because of lack of sufficient roots and photosynthetic leaf area or in other words the palms do not have the capacity to make use of the increased nutrition and water made available in the root zone and the fungal infection is so deep seated that normal application of fungicides twice a year is not effective. They would only respond, if the fungicide treatment is given after every 3 months coupled with application of fertilizers and irrigation during summer months. Juvenile palms that contract the disease before the onset of flowering seldom yield (Ramdasan *et al.*, 1971) or flowering is delayed (Mathew *et al.*, 1993).

Multiple cropping and mixed farming systems in root (wilt) disease prevalent gardens have indicated the possibility of increasing the income from unit area of land as well as the employment potential of farmers. Menon and Nayar (1978) reported that intercropping with cassava, elephant foot yam and greater yam for five years gave an overall increase of nut yield of root (wilt) affected palms to the extent of 5, 15 and 8 per cent respectively and 5% reduction in disease intensity. Nair *et al.* (1975) reported 27-35 percent increase in yield by mixed cropping. Increase in yield of palms as a result of legume treatment, fertilizer application and adoption of plant protection measures under farmer's condition was reported by Thomas *et al.* (1993). Studies on the regeneration of root system of disease affected palms showed that application of 500 ppm IBA + 400ppm phenols produced 51 fresh roots compared to two roots in the control and reduction of disease index from 35 to 26 within a period of one year (Amma & Patil, 1982). Dwivedi *et al.* (1980) reported that ascorbic acid 400 ppm fed through cut root not only reduced disease symptom but also improved the yield of palms. However, Rajagopal *et al.* (1986b) ruled out the role of ascorbic acid in reducing the disease indices or increasing the yield. Significant decline in disease index and increase in yield was reported by summer irrigation and fertilisation in root (wilt) affected palms compared to deterioation in control by Rajagopal *et al.* (1987). Strategies have been evolved for management of disease affected palms in the mildly affected border districts as well as in severely affected continguous area (Anon, 1982, 1986, 1998).

Management practices

1. Control leaf rot disease and insect attack in April-May and in October-November by the following method.
   a. Cut and remove rotten portions of only the spindle and the adjacent to innermost fully opened leaves.
   b. Mix Contaf 5 EC (Hexaconazole) 2ml or Dithane M-45 3 g in 300ml water and pour into the well around the base of the spindle leaf.
   c. Apply 20g Phorate 10G mixed in 200g sand around the base of the spindle leaf.
   d. Treat all palms in the garden (healthy and diseased) twice a year.
   e. Treatment should not be carried out during rainy days.
2. Apply balanced doses of fertilizers (500g N, 300g P2O2, 1000g K2 and 1Kg magnesium sulphate in two split doses) and 50Kg Farm Yard manure/palm/year.
3. Irrigate palms during summer months @ 250 litre/palm/week and provide proper drainage wherever necessary.
4. Remove disease advanced and uneconomic palms yielding less than 10 nuts/palm/year as well as juvenile palms that contracted the disease and replant with tolerant/resistant seedlings.
5. Grow green manure crops in the basins and interspaces and incorporate into the soil at flowering.
6. Practice mixed farming or raise inter and mixed crops to generate more income from unit area of land.
7. Remove diseased and suspected palms in mildly affected areas to check the spread of the disease.

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