COCONUT LEAF ROT DISEASE COMPLEX A REVIEW

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ABSTRACT

Occurrence of leaf rot disease (LRDC) of coconut is related to increased incidence of root wilt disease (RWD). The palms with RWD irrespective of age are susceptible, young ones are more susceptible to LRDC. Tender leaves especially the spindle play a critical role in LRDC incidence and the disease attributed to fungal complex. Among the 14 species of LRDC Angi, several were proved to be pathogenic; Colletotrichum gloeosporioides (Penzig) Penzig and Sacc and Exserohilum rostratum (Drechsler) Leonard and Suggs are discerned as the main pathogens. C. gloesporoides was aggressive during monsoons and positively correlated with rainfall and relative humidity (11% RH, whereas Erostratum less strongly correlated Fusarium spp. predominated in dry seasons. Importance of microclimate, survival and quiescence of the pathogens are to be determined. Diagnosis of RWD by techniques such as PCR and understanding the molecular basis of vulnerability of palms to LRDC would help to initiate early control measures. Planting of RWD cum LRDC resistantl tolerant varieties after eradicating the RWD infected palms is desirable. Protection ofyoung leaves by chemical or biocontrol agents or a combination of both with phytosanitation is important. 4 system approach with integrated measures needs to be utilizedfor sound management of LRDC.

INTRODUCTION

Coconut *(cocos nucifera* L.) is an important plantation crop in India. It is now grown in the country on nearly 1.8 million hectares with the production of 14 billion nuts per year. Diseases are a serious constraint to the production and productivity of the crop. Among the diseases affecting the coconut crown, leaf rot disease (LRDC) is very important and is widely prevalent in the southern districts of Kerala state, India where root wilt disease (RVTD) is endernic. LRDC probably existed in the former Indian princely states of Travancore and Cochin since the 1880s (Butler, 1908; Varghese, 1934; Menon and Nair, 1948, 1951, 1952). Boundaries of the disease zone in the north were between Thodupuzha and Oachenthuruthu and in the south between Punalur and Quilon (Menon and Nair, 1948). The disease incidence was variable irrespective of hill tops, the plans and littoral sandy tracts between the Arabian sea and the backwaters. Menon and Nair (1948) and Menon and Pandalai (1959) also reported the incidence of the disease on palms of all ages and it flourished in palms below the age of 25 years. Currently LRDC is observed along with RWD also in a region (Cumbun Valley) of Tamil Nadu state.

Root wilt disease affected palms come to the farmers attention generally after the onset of LRDC. The extensive destruction of the photosynthetic area of the diseased palm (due to LRDQ is conspicuous. Studies were initiated in the early 20th century, almost in parallel with the investigations on RWD, and intensively in the 1950's. Root wilt disease has been appraised and reviewed (Jayasankar & Ahamed Bavappa, 1986; Nair *et al,*. 1991). Though a brief review of LRDC appeared (Joseph & Rawther, 1991) in a RWD monograph that has since been revised (Srinivasan *et al.,* 1998), a lot of information on different aspects of the disease has accrued. It now seems timely to make a complete reassessment of LRDC. Hence the results available so far on LRDC are critically reviewed with references updated in this article.

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INTERRELATION WITH RWD

Narayanaswamy lyer and Bourdillon (Varghese, 1934), and Butler (l908) seemed to have considered LRDC as a part of R%D and infectious. Varying intensities of LRDC ranging from 14 to 65% were reported by different workers (CCRS, 1970, 1971, Radha & Lal. 1968; Srinivasan, 199 1). Radha & Lal (l968) reported LRDC on palms in both categories - with and without root wilt symptorns. The palms which showed LRD but were devoid of symptoms of RWD earlier, expressed the RWD symptoms subsequently. They inferred that these palms, which were symptomless carriers of the RWD pathogens, contracted secondary infection by LRDC. Evidence for latent infection of a RWD pathogen such as Phytoplasma (Solomon *et al.*, 1983) in LRDC infected palms is not available; that needs to be studied in detail. Molecular techniques such as RFLP, PCR etc might be useful in such direction for confirmation of the pathogen (Solomon *et al.*, 1998) Mathai (1980) correlated incidence of LRDC with RWD indicating the influence of RVIID on LRDC.

Srinivasan (1991) reported that the disease incidence was common in RWD affected palms and on an average 65% of these palms were superinfected (infection of one over another) with LRDC. Palms in early middle and advanced stages of RWD were infected with LRDC in 40%, 79% and 98% of the cases, respectively. A strong relationship of LRDC with RWD incidence generally in relation to the severity of the latter are thus evident (George & Radha, 1973). Among different soil types incidence of RWD alone and with LRDC ranged from 67% to 78% and LRDC superimposition varied from 54% to 76% of RWD affected palms. The study also pointed out the susceptibility of young palms with RWD symptoms to attack by LRDC irrespective of soil types (Table 1).

Leaf rot disease on young palms in Kasaragod, a location away from RWD endemic region, was once reported; inoculations with *Bipolaris halodes* on five year old palms showed mild infection at Kayangulam, a RWD endernic area, while the Kasaragod results were negative (Radha & Lal, 1968). Incidence of LRDC in places other than the RWD endernic region was subsequently neither reported nor confirmed. Inoculation experiment on two year old RWD affected seedlings showed severe infections under field conclitions (Srinivasan & Gunasekaran, 1966a) besides a natural outbreak of the LRDC in the RWD infected seedlings of the same age group (CPCRI, 1966, Srinivasan & Gunasekaran, 1998a). Recently heavy incidence of RWD in palms of different age groups in coconut plantations of Cumburn Valley (Theni district) of Tamil Nadu, bordering Kerala has been observed and common occurrences of LRDC in RAID affected palms in such a hitherto unreported region is also confirmed (Srinivasan et al., unpublished report)

Increased vulnerability of viral infected plants to attack by fungal pathogens is widely reported; physio-chemical changes occur in virus infected plants with consequent reduction in vigour that render the plant susceptible to fungal invasion (Russell, 1966; Larney & Everett, 1967, Raju *et al.*, 1969; Beniwal & Gudauskas, 1974). The greening disease pathogen of citrus is considered to be a phloem-limited non-cultivable pathogen currently named as *Liberobacter* (Jogoueix *et al*, 1994). Greening-fungus complex was involved in the citrus die back in India; in the diseased plants, the die-back symptoms became severe with the infection of fungal pathogens such as *Coletotrichum gloesporioides, Curvularia tuberculata, Diplodia natalensis* and *Fusarium* spp. (Raychaudhuri *et* al., 1969). With artificial inoculations it was also found that greening affected seedlings were more susceptible to attack by these fungi (resulting in severe die back) than were the healthy seedlings (Singh et al., 1971). It may be noted that the phytoplasma diseases of coconut in certain countries such as lethal yellowing (some Caribbean Islands, USA, Mexico, Belize), blast/dry bud rot (Ivory Coast), Cape St. Paul wilt (Ghana), Kaincope (Togo), Kribi (Cameroon), Awka wilt/Bronze leaf wilt (Nigeria), lethal diseases (Tanzania, Kenya, Mozambique) and Stem necrosis (Inclonesia) are all fatal diseases and the affected palms die within a span of time after infection. In India, the phytoplasma associated diseases of coconut (RWD and Tatipaka) are not- fatal but only debilitating (Solomon 1997). The RWD affected palms decline slowly.

The palms weakened by phytoplasma with accompanied physio-chemical changes in the host, resulting in the possible break-down of defense mechanism, might become susceptible to LRDC leading to rotting of tender leaf tissues. This could be corroborated by instances of only restricted lesions/spots in healthy palms in contrast to severe phase of rotting in RWD affected palms. With incidence of LRDC in RWD affected palm, the crown is severely disfigured and the palm declines rapidly. The occurrence of LRDC and RWD thus seems to be a distinct phytoplasma-fungal disease complex and a detailed examination of LRDC becomes more relevant.

ECONOMIC IMPORTANCE

Menon & Nair (l948) put the annual loss clue to RNhD at Rs. 5.6 million, ie on an average 20% of the yield. Radha *et* al. (l962) reported that the LRDC infected palms might yield an average of 70% less nuts as compared to a wide range of loss (43 to 82%) clue to RWD alone. In addition to the loss in nut yield the loss by way of damage to the quality of leaves is also to be reckoned. A survey report (CPCRI, 1985a) pointed out the loss clue to RWD as 968 million nuts annually with an overall disease incidence of 26.44% out of 9.15 crore palms in the disease endemic region. The latest survey (Department of Agriculture, Govemment of Kerala 1997) showed the disease incidence as 24.05% out of 102 million palms. The slight reduction perceived in the disease incidence was attributed to cut and removal of diseased palms, fresh planting, better management practices and crop conversion. The precise estimation of yield loss due to LRDC may not be easy as the disease occurs along with RWD.

SYMPTOMATOLOGY

Earliest mention of the symptoms of LRDC was by Butler (l908). Further references on this are by McRae (l916), Sundararaman (l925), Varghese (l934) and Menon & Nair (l948, 1951). These and subsequent studies (Radha & Lal, 1968; Lily 1981; Srinivasan & Gunasekaran, 1992) have described the disease symptoms in detail.

In the RWD affected palms, deterioration (first crown symptom) is observed in the spindle (unopened youngest leaf), indicated by whitening and softening of leaflets (Dwivedi *et al.,).* These leaflets are weak as compared to the spindle in healthy palms. LRDC appears initially as minute, water soaked lesions on such a weakened spindle with different shades (brown, reddish brown, etc.) and shapes. The disease occurs occasionally on young tender leaves in different parts of the leaflets. These lesions enlarge, coalesce freely especially on the sensitive, soft and tender leaflets of the spindle leading to extensive rotting under high rainfall and relative humidity and low maximum temperature. In severely affected spindle tissues, mould growth (Srinivasan *et al.,* 1995) is also commonly seen on the surface of the affected leaflets. Rapid expansion of lesions relate to infection in the early period of spindle leaf emergence. The rotting may extend into the interior of the spindle. Lily (1981) considered the tender unopened spindle leaf having thinner epidermal layer and with maximurn moisture content serving as the infection court. The infected spindle gradually decays attracting ants, ear wigs, maggots, etc. (Varghese, 1934; Menon & Nair, 1951).

Another striking feature is the sticking together of the tips of rotten leaflets of the spindle while the leaflets are open (Menon & Nair 1951); the rotten portion drys up, tum black and fall off. Tips of leaflets and midribs often become shivelled and blackish. The progress of rotting is slow in mature leaflets. Hence basal portions of leaflets in certain palms remain without the symptoms, giving a fan-like appearance of the leaves in the crown. The fan-like appearance of all leaves in the crown indicates that all the leaves had contracted the LRDC in succession and rotting progressed to varying degrees (Menon & Nair 1951); Srinivasan, 1991; Srinivasan & Gunasekaran 1992) resulting in linear disease progression (Figures l & 2). When the disease severity was high there was a steady decline in the yield of the affected palms. The lesions of the disease on petiole, midrib-midveins of leaflets (Figures 3 & 4) have been reproduced by artificial inoculations similar to such symptoms in naturally affected palms (CPCRI, 1996; Srinivasan & Gunasekaran, 1998a). Typical symptoms of LRDC has been observed in infected palms also in Cumbum Valley of Tamil Nadu (Srinivasan *et al.,* unpublished report).

Srinivasan & Gunasekaran (1992) studied the quantitative pattern of the LRDC symptorns in different whorls (of RWD affected palms). They found that the inner whorls of leaves are more vulnerable to infection. Out of 2597 diseased palms sampled representing different soil types, 24 to 43% expressed the disease symptorns in the entire crown accounting approximately to a third of LRDC affected palms. These palms might have contracted successive infection of freshly emerged leaves (Table 2).

In certain RWD endernic areas, leaves of middle whorl of palms suddenly become yellow even while the outer whorl and central shoot are normal. (Department of Agriculture and Fisheries, Travancore, 1939). In such leaves, lesions/spots appear and these spots coalesce resulting in severe blighting of the lamina (CPCRI, 1985b).

It is evident that younger leaves especially the spindle play a critical role in LRDC incidence. Although the disease is not fatal, chromic infection makes the palm clecline steadily and sometimes the palm might even succumb. Hence early diagnosis is useful in disease management strategies.

DISEASE INDEXING

Radha *et al.*, (1961) aclopted a qualitative four grade scale viz., O-nil, mild-a few small lesions, moderate-numerous small lesions and severe-numerous big lesions which coalesced to form patches of rotten tissues. Mathai (1980 used six infection grades viz., 0-no infection, 1-up to 5% leaf area affected, 2-26 to 50%, 3-51 to 75% and 4- above 75% for each leaf in the crown. From the total numerical ratings the disease index is arrived at by the following formula:

$$\text{Disease Index (DI)} = \frac{\text{Total Numerical Rating}}{\text{No. of leaves x Maximum No. Of grades}} \times 100$$

The above disease indexing method gave satisfactory comparison of disease intensity. Perhaps LRDC indexing should be refined by using more grades with narrow intervals of disease ratings to increase precision. While indexing for LRDCC, intensity of RWDper se, and the very nature of the crop, etc are limiting factors in data acquisition. The possibility of a combined disease indexing system, integrating LRDC with RWD could also be considered.

ETIOLOGY

The earliest record of isolation of a fungus (Penicillium-like) from leaves of LRDCC affected palms was by McRae (1916) followed by Sundararaman (1925). Varghese (1934) finnly believed that LRDC was primarily caused by fungus. Sundararaman (1929) implicated Fusarium sp. with shoot rot of coconut while McRae (1929) observed Gloeosporium sp; the disease appeared in weakened palms (Patel, 1938). Subsequent investigations revealed the association of *Helminthosporium (Bipolaris),* Gloeosporium, Gliocladium, Pestallozia (Pestalotio,psis), Fusarium, *Thielaviopsis p*aradoxa, Rhizoctonia s*olani,* etc with LRDC (Department of Agriculture and Fisheries, Travancore, 1938, 1940; Menon and Nair (l951). Pathogenecity tests were conducted *in vitro* and *in vivo* on young tender leaflets and central shoots respectively. Rotting of leaf tissue was observed with *Helminihosporiwn s*p. Gloeosporium sp. Gliocladium sp and Pestallozia sp. Severity of infection was greatest with *Helminisphorium a*nd the fungus was considered as the most virulent pathogen. Pathogenecity was also established using single and mixed inocula of different fungi. *Helminthosporium* alone caused 84% infection, while it is 93% with mixed cultures of *Helmanthosporium,* Gloeosporium and Gliocludium (Menon & Nair, 1951).

Spores of *Helminthosporium a*re air bome. The fungal spores, enveloped in drops of dew/rain water, on landing on susceptible tender leaflets, germinate within 12 hours producing tiny brown spots which enlarge and coalesce (Menon and Pandalai, 1959). Menon & Nair (l 951) studied the infection histology of H. *halodes. T*he spore on germination produces a hyaline gerin tube through either or both of its apical cells. The germ tube produces an appressorium from which an infection peg develops and the fungus enters the parenchymatous cells by cuticular penetration. The fungus ramifies freely inside the leaf, causing disintegration of cells and rotting of tissues. They described in brief the conidial and other morphological characters of *Helminthosporium,* Gliocladium and Gloesporium and identified these fungi as H. *halodes. G*. roseum and *Colletotrichum paucisetum* respectively. The species of *Pestallozia* was identified as P. *palmarum.* According to Menon and Nair (1951) Sundararaman and Krishnaswami recorded a *Gloeosporium* sp. causing shoot rot of coconuts in Pilicode.

Lily (l 963, 1981) corroborated infection histology of H. *halodes.* While maximum spots appeared on most tender inoculated leaf, no spots developed on older leaves, even though conidia germinated. She inferred that *Bipolaris halodes (H. halodes)* preferred tender most leaf for infection. Radha & Lal (l968) once isolated *(H. halodes)* from coconut leaves in Kasaragod, confirmed the pathogenecity and found that it can even infect the healthy palms free from RWD by artificial inoculation but the lesions did not expand further. Differences in virulence among the four isolates of the pathogen, isolated at Kayangulam were not observed (CPCRI, 1979). Isolates from different areas should be used to ascertain variability. Culture fil-trates of the fungus did not have any toxic effect on the tender leaflets (CPCRI, 1981). Other fungi isolated from diseased leaves included *Curvularia sp., Diplodia sp.,* besides a number of saprophytic fungi (CPCRI, 1985b) and nematode, *Panagrolaimus* Fuchs (Nakadal, 1965), *Aphelenchoides ligarhiensis, Rhabditis sp.* and *Panagrolaimus rigidus* (CPCRI 1997). Nematodes seem to have no role in the LRDC incidence.

Infiltration of arginine (0.05%) into leaflets was considered to have enhanced the infection by *B. halodes* and phenol content increased in necrotic lesions (CCRS, 1965, 1971; CPCRI, 1975). Silica content was higher in the diseased leaves (CPCRI, 1976). Contents of certain biochemical components in the tender leaves of heal-thy and LRDC affected palms were examined (CPCRI, 1981, 1982) and their ranges ate given below:

Component	Healthy	Diseased
Ascorbic acid (mg)	172-280	143-281
Total phenol (mg)	66-105	124-216
Total sugars (%) - dry wt basis	0.31-0.63	0.41-0.83

Lily & Ramadasan (1979) found a steady increase in the total phenot of spindle leaves inoculated with *B.halodes* during host-pathogen interaction. Thus among the biochemical constituents, total phenol seems to play a definite role in LRDC expression. Higher concentrations of total nitrogen, non-protein and protein nitrogen were found in youngest leaf over mature leaves, and severity of infection was minimal in the seedlings which received NPK with Ca and Mg (Lily, 1981).

Although a fungal etiology for the disease was evident and a number of fungi were found associated with the disease, earlier studies gave emphasis on *B.halodes* only. Hence the need for detailed study of LRDCC felt in recent years. Srinivasan & Gunasekaran (l993, 1996c,d) made isolations from spindles showing symptoms of LRDC and attributed LRDC to a fungal complex. The fungi isolated were identified at CAB-Intemational Mycological Institute, United Kingdom as *Exserohilum rostratum* (Drechsler) Leonard and Suggs, *Colletostrichum gloeosporiodes* (Penzig) Penzig and Sacc., and *Gliocladium vermoeseni* (Biourge) Thom., and their cultural and morphological features were described (Srinivasan & Gunasekaran, 1994a). Reassessment of pathogenic role of each fungus in the disease was initiated using the method adopted by Menon & Nair (1951), *E.rostratum, C.gloeosporiodes,* and *G. vermoeseni* induced symptoms leading to rotting. *Erostratum* inoculated leaves took up infection faster. *G.vermoeseni* induced 100% infection with injury. Mixed inoculum of the spores of these three fungi gave higher incidence (100%) of LRDC.

The pathogenic nature of *Cylindrocladium scopurium* Morgan, *Fusarium solani* Martius (Sacc.), *F. moniliforme* Sheldon *vanintermedium N*eish and Legget, *Thielaviopsis paradoxa* (Dade) C.Moreau and *Rhizoctonia solani* Kum in relation to LRDC was also established (Srinivasan & Gunasekaran, 1994b, 1995a, 1996a, 1998b).

rofuse mycelial growth and spore masses are common over the LRDC lesions specially between infected leaflets of spindles (Srinivasan *et al.*, 1995). They recorded the mycoflora of spindles and older leaves of 120 palms by observing the scrapings of leaves as well as by isolations from diseased leaf tissues. Among nine species of fungi observed from infected spindles, *G.gloeosporiodies, E.rostratum, G.vermoeseni, Fsolani, F.moniliforme* var. *intermedium* and *Tparadoxa* were more frequently detected in scrapings or isolations. *Pestalotiopsis palmarum* was isolated from the older leaves only and never from the young tender leaves or spindles. Other fungi occurred in very low frequency only. The fungi were recorded either independently or in association with other species.

In further studies, six species of fungi viz. Mortierella elongata Linnem, Curvularia sp., Acremonium sp., Thielavia microspora Mouch, Tterricola (J. Gilman & EN. Abbott) Emmons and Chaetomium brasiliense Batista & Pont were isolated from the infected spindles (Srinivasan & Gunasekaran, 1994b). A. Chactomium sp.been recorded earlier (Johnston, 1965) also. These fungi were grouped into three categories (Group A, B and Q based on the frequency pattern and relative association with the disease (CPCRI, 1994). C. Gloeosporioides, E. rostratum etc. were isolated from LRDCC infected palms also from the newer diseased region of Cumbum Valley of Tamil Nadu state (Srinivasan et al., unpublished report).

Though LRDC initially appears as a spot in spindle irrespective of the pathogen, results in rotting of tissues. A number of diseases of coconut palm recorded worldwide cause leaf blight/leafrot (Ohler, 1984; Chase & Broschat, 1993; Nambiar, 1994). Hence a comparison of such diseases with LRDC might be worthwhile.

Colletotrichum spp. in general are considered potential pathogens (Jeffries et al., 1990). C. gloesporioides is common on a number of crop plants, affecting tender/soft tissues leading to die-back and anthracnose (Mathai et al., 1989; Chase, 1993; Chakraborty & Billard, 1995). E rostratum is associated with graminicolous hosts in India and other countries (Sivanesan, 1987), ornamental palms (Aragaki et al., 1993) and other hosts (Mohanan & Sharma, 1986). In Fiji a Helminthosporium sp. was associated with leaf rot of coconut beside other fungi (McPaul, 1962). B. incurvata has been cited as causing leaf spot/leaf blight of coconut in French Polynesia, Inclonesia, Malaysia, New Caledonia, Philippines, Sri Lanka, Thailand, Virgin Island, Papua New Guinea, etc. The fungus is also reported on omamental palms (Aragaki et al., 1993). Gliocladium diseases of palm in Florida (U.S.A.) (Reynolds, 1964) and of G. vermoeseni on several palm species had been reported (Hodel, 1985; Ohr, 1993).

Cylindrocladium scoparium was isolated from root and bole of coconut in Malaysia (Coleman, 1959). In Brazil, *C. pteridis* caused leaf spot (Silva & Souza), 1981). Different species of Cylindrocladizim caused leaf spots/blights on ornamental palms (Aragaki & Uchicla. 1993). In Brazil (Batista & Coelho, 1947) and Burma (Department of Agriculture, 1943),. *Fusarium* sp. had been discovered with coconut top rots and tip break in Papua New Guinea (Dwyer, 1937), and spear rot in Malaysia (Tey & Chan, 1980). *T.paradoxa*, the causal agent of stem bleeding of coconut is also reported to cause foliar diseases-bitten leaf in Jamaica (Bain, 1940) and Mauritius (Shepherd, 1930) and leaf spot in the Philippines (Protacio, 1965). The pathogen is associated with several other species of palm (Simone, 1993).

Rhizoctonia solani, conventionally a root pathogen, has been isolated from LRDC. *Curvularia maculans* causes leaf die-back/leaf spot of coconut in Malaysia (Chan, 1974). In Brunei, Fiji, Indonesia, Malaysia, Vietnam, etc. *Botryodiplodia (Lasiodiplodia) theobromae* has been implicated with the coconut leaf rot (Nambiar, 1994).

Srinivasan & Gunasekaran (1955b) studied the in vitro interaction among select nine species of fungi by dual culturing. The interaction of fungi varied in respect of colony merger, over-growing capacity and inhibition zone. The behaviour of the predominant fungi of LRDC was seen to be associative rather than antagonistic, having etiological significance for a disease complex. *Fusarium* spp. had competitive interaction over certain less frequent fungi. Behaviour of the predominant fungi was evaluated in potted seedlings and field palms to elucidate potential species among them and their role in disease expression (Srinisavan & Gunasekaran, 1996a). Based on the frequency of occurrence, seasonal relationship, pathogenicity, etc. *Cgloeosporioides* and *E.rostratum* were considered as main pathogens of the disease. LRDC symptoms were reproduced in field planted coconut seedlings having mild symptoms of RWD by artificial inoculation with *Cgloeosporioides* and *Erostratum* individually and in combination (CPCRI, 1996, Srinivasan & Gunasekaran, 1998a). However, in healthy seedlings (free from RWD) in pots and field planted the LRDC fungi induced only restricted spots (Srinivasan & Gunasekaran, 1996a).

C. gloeosporioides is one of the predominant pathogens of LRDC (Srinivasan & Gunasekaran, 1996c,d). It is likely that the fungus gains access (90%) to yellowed leaves of RWD affected palms (Srinivasan & Gunasekaran, Unpublished) and hastens the destruction of the lamina) Department of Agriculture & Fisheries, Travancore, 1939; CPCRI, 1985b).

Menon and Nair (1951) studied certain growth requirements of the fungi associated with the disease. *H.halodes (=Erostratum)* grew best in oat meal agar and *Gloesporium (Collectotrichum)* in Brown's agar. Optimum growth of the fungi took place around neutral pH while high acidity or alkalinity had a depressing effect. Therman death point of *Hhalodes* was 60^0C whereas it was 55^0C for *Gloesporium sp., P.palmarum* and *G.roseum.*

EPIDEMIOLOGY

No correlation was found between weather factors and the incidence of RWD (CCRS, 1970). Though RWD is the critical predisposing factor, the incidence, severity, species composition, etc. of LRDCare influenced by weather factors. Menon & Nair (1951) observed the most severe incidence of the LRDCC (on RWD affected palms) during the monsoon when the atmospheric humidity was high. Artificial inoculations during different seasons of the year also showed that severe infection was seen during the monsoons. They also reported the largest number of fungal spores in the atmosphere during the South-West monsoon (JuneAugust) Radha *et al,* (l961) and Radha & Lal (l 968) from their studies employing artificial inoculation with different fungi, related severity of infection to high humidity (above 90%) and low temperatures ($27^{0)}$ that prevailed during the monsoon period (CCRS, 1962, 1965). Free water or wetness such as rain water or dew during dry months favoured infections. Conditions which delay drying of the leaf surface like humidity and compactness of foliage (spindle) also influenced the infection. Dwivedi *et al* (l979) observed the frequency of LRDC rotting/necrosis in spindles of RWD affected palms at the same level during rainy and summer seasons, but the severity was visually greater in the rainy season. Mathai (1980) also indicated that maximum expression of disease symptoms was during the North-East monsoon (September-October) and lowest during April-June.

Population dynamics of LRDC pathogen in relation to weather variablesan essential insight into the disease epidemiology has to be understood in view of the complex nature of the disease. The influence of climatic factors on population dynamics of foliar pathogens is a widely known phenomenon. The incidence of various fungi in relation to weather factors (rainfall, % RH, maximum and minimum temperature) was recorded by sequential monthly isolations from diseased palms, in multiple samplings of two experiments, each lasting one year in a disease endemic locality (Srinivasan & Gunasekaran, 1996d). *C.gloesporioides* occurred conspicuously in higher frequency and population during monsoons with a peak detection in June/July. Its incidence was most strongly correlated with rainfall and RH and negatively, with maximum temperature and hours of sunshine. It was isolated from early lesions more frequently than advanced lesions. *C.gloesporioides* was thus implicated as the principal pathogen of LRDC during monsoons. *E.rostratum* occurred less frequently and its incidence and population was less strongly/consistent correlated with weather. In winter (with low RH and low temperatures) *C.gloesporioides* incidence was subdued while that of *Erostratum* moderate. *Fusarium* spp. were isolated most commonly during the dry season (January through May) (Figures 5 & 6). Their presence throughout the year and their predominance in the dry period sugorest they arc potential pathogens of LRDC, co-occurring with other fungi and perpetuating the disease in the dry period. They may predispose the palms to subsequent infection by other pathogens when conditions become favourable. Dry conditions generaily favoured *Rsolani* also. The incidence of other fungi were not influenced by specific weather conditions and may have less significance in LRDC, but may play some role in disease expression in certain circumstances. Relatively low incidence of *Cgloesporioides* in dry season suggests a quiescent phase. Its aggressive re-emergence in favourable weather conditions (with the onset of South West monsoon) is also evident. Such information could be useful for the early detection of pathogen(s), to devise disease prediction models and to streamline disease management strategy.

Population fluctuations of relevant fungi of LRDC in relation to weather variables were similar to that of *Cgloesporioides* (Chakraborty & Billard, 1995 Dodd et al., 1991) and *Fusurium* spp. (Parry, 1990; Bateman, 1993) affecting a number of crop plants.

DISEASE CONTROL

Control of LRDC is very important in view of its destructive potential. Application of fungicides was initiated around 1950s. Screenin g of fungicides *in vitro* against various pathogenic fungi, control studies-chemical and biological, and breeding for disease resistnce/tolerance arc discussed here.

1. *In vitro* studies

Menon & Nair (l951) determined toxic concentrations of chernicals like copper sulphate, mercuric chloride and phenol against leaf rot fungi. Mercuric chloride and phenol were found to be lethal at various concentrations tried.

Prasannakumari *et al.* (l 960) studied *in* vitro inhibitory effect of different copper fungicides on mycelial growth and spore germination of *H.halodes* and found that complete inhibition of mycelial growth by Bordeaux mixture and Fungimar at 0.3% and at 0.5% of Kirti copper. Control of infectivity of *B.halodes* in leaflets *in vitro* with various fungicides was attempted (CCRS, 1965).

In vitro assay of few contact (Indofil M-45, Fytolan, Captan and Thiram) and systernic (Hexaconazole (contaf), Calixin and Aureofungin-sol) fungicides was done by poisoned food technique on solid medium against *Cgloesporoiodes, Exostratum* etc. using discs of 7 mm diameter inoculum prepared from concerned fungus cultured in petridishes (Srinivasan & Gunasekaran, 1998). Varying degrees of inhibition of fungi by fungicides was observed. Hexaconazole completely inhibited the main incitants of LRDC. Hence systemic fungicides like Hexaconazole with promising broad spectrum potential need to be evaluated under field conditions.

2. Field investigations

Varghese (1934) gave an account of LRDC control measures practiced. "Cutting down the innennost infected spear and one or more of the leaves next outside of it, which might be infected. The cut wound must be protected with Bordeaux paste, tar or tar preparations and the infected bits collected and burnt. Such treatments rendered at the initial stage of infection aided the tree to recover easily. The infected trees when treated in the dry season after monsoon rains recovered better than those in rainy months". Subsequently, there is little published evidence to show that the above practice formed a part of the LRDC control measures.

Menon & Nair (l 951) tested copper fungicides; 'Bar-cop' and 'Oxi-cop' at a concentration of 0.2% were found to be as effective as 1% Bordeaux mixture. Apparent beneficial effect of spraying Bordeaux mixture in the LRDC control was not statistically significant with three applications (Menon & Nair, 1952). Patel (l938) reported that Bordeaux mixture used for shoot rot control helped to reduce the infection. However, it did not check the disease completely. In another study (CCRS, 1965) foliar spraying of copper fungicides was reportedly reduced LRDC intensity upto 74.5%. Diseased palms reportedly responded well to application of boric acid and hence boron deficiency was considered as the probable cause of the disease (George & Samraj, 1966), whereas in inoculation trials (with *B.halodes)* no relation of LRDC with boron could be established (CCRS, 1970). Radha (l965) observed that foliar applications of manganese, zinc, copper, iron and molybdenum at different concentrations four times a year, reduced LRDC infection. Aerial spraying of oil-based copper fungicide did not protect the spindle leaf adequately (Samraj *et al*, 1966). Two trials of aerial spraying in 1968 using oil-based copper fungicides, Olecop and Fycol 8, with Orchex 964 as oil suspension was conducted in 400 acres of garden at Vypeen islands. Visual observation showed a decrease in LRDCC incidence in the January spraying as compared to August (CCRS, 1970).

Combined effect of manuring and fungicidal spraying was also evaluated (CCRS, 1965; Nair & Radha, 1959). Spraying of Bordeaux mixture l %, Dithane M-45 0.2% and Cuman 0.4% with or without manuring in alluvial, laterite and sandy loam soils gave no significant difference among fungicides in disease reduction and a slight increase in average nut yield by manure alone (CPCRI, 1972). Spraying three times a year for three continuous years with Bavistin 0.l %, Bordeaux mixture l %, Difolatan 0.3% and 0.5%, FM spray 0.3% and FM spray-55 0.3%, Fytolan (acidic) 0.3%, Fytolan (neutral) 0.3% and Kitazin 0.3% did not provide complete control (CPCRI, 1982).

Prevention of the disease incidence was not successful by basal application of Actidione, Bavistin, Benlate and MBC (ail systernic fungicides) at the rat eof 4 g per palm twice a year (CPCRI, 1983). Sprayings of Bordeaux mixture l %, Dithane M-45 0.3% and Fytolan 0.5% on diseased palms individually and sequentially thrice a year for three years, reportedly reduced the disease intensity by 73% in sequential spraying (CPCRI, 1985b). However, disease recurrences became common and LRDC amelioration in farmers' fields was not attained. Mathai *et al* (l 984) did not find significant reduction in number of leaves infected by LRDCC in a trial involving fungicide

(Benlate), bactericide (Agrimycin-l00), nernaticide (Dasanit) and different plant nutrients (N,P,K, Ca, Mg and Zn).

A field trial on 20 year old naturally infected palms was conducted (Srinivasan & Gunasekaran, 1996b) with contact (Indofil M-15 0.3%; Fytolan 0.5% and systemic (Calixin 1%) fungicides three times a year for three years by different methods of application namely, pouring into axil around the spindle, spraying onto the crown and root feeding. Spraying of Indofil M-45 and pouring of Calixin were beneficial as the disease intensity reduced in newly emerged leaves. Although fungicides gave disease suppression to some extent (l 1.326.7%), the final disease indices among treatments were not statistically significant further underlining the need to fully understand the RWD-LRDC complex.

The inconsistent results obtained on the LRDC control may also be due to inoculum pressure prevailing during the experimental period, differences in the evaluation methodology, etc. Phytosanitation must form a part of LRDC management techniques and a broad spectrum systemic fungicide should be used to protect the tender leaves with encouraging results noticed recently (CPCRI, 1997, 1998).

3. Biocontrol

Lily et al. (l952, 1955) noted an 'antifungal factor' from *Bacillus subtilis* inhibiting *Hhalodes.* The culture filtrate of *B.subtilis* inhibited the infection of the fungus on leaves when applied either at the time of inoculation or prior to inoculation. The bacterium inhibited spore germination and the fungal growth on solid medium. Prevalence of competitive interaction by *Fusarium* spp. on certain less frequent fungi of LRDC like *T.paradoxa, R..solani, C.scoparium* and *Melongata* has been noticed (Srinivasan & Gunasekaran, 1995b). Manipulation of the competitive mechanism may be of importance in the disease management. In a study *Pseudomonasflourescens* and its culture filtrate were inhibitory to the growth of LRDC pathogens. Application of the bacterium along with the main pathogen(s) reduced the disease severity with inhibition of lesion development in the leaves.Flourescent *Pseudomonas* isolates from coconut rhizosphere and other bacterial isolates form phylloplane were also antagonistic to the main pathogens. Effective isolates from among such native bacterial were detected (CPCRI, 1997, 1998).

4. Disease resistance/tolerance

Selection/breeding for resistance/tolerance against diseases of crop plants is widely practiced. Butler (l908) stressed the need for evolving a resistant variety for the 'coconut palm disease of Travancore' in his classical report.

Patel & Nair (1936) observed that out of 26 varieties from different parts of the world, none was resistant to shoot rot disease. Andaman ordinary and New Guinea were later observed to be more resistant than others to LRDC (Radha, 1961; CCRS, 1962). Natural incidence of LRDC was low in the indigenous dwarf (Chowghat green) as compared to tall varieties (CCRS, 1965, 1971). Mathai (l980) reported the lowest incidence of the disease in West Coast Tall (WCT) x Laccadive dwarf and WCT x Nyior Gading among nine hybrids/varieties tested. The intensity of disease was low in varieties where the incidence of RWD was low. Screening trials (Mathai *et al*., 1985) indicated significantly lower levels of incidence of RWD and LRDC in the variety Andaman ordinary followed by SSG and Cochin China. Reactions of l0 exotic and geographically distinct cultivars to RWD/LRDC (Mathai *et al.,* 1988) revealed susceptibility of all the exotic cultivars. The cultivar of San Ramon recorded lower disease incidence followed by Guam, St. Vincent and Kenya.

RWD infected palm is weakened and with the onset of LRDC the condition of the palm deteriorates. Since LRDC generally occurs superimposed on RWD infected palms, identification of resistant/tolerant palms to RWD will be of paramount importance. Such palms are likely to be resistant/tolerant palms to LRDC also. Use of RWD curn LRDC resistant/tolerant variety might be the cheapest and best means of controlling the disease. Chowghat Green Dwarf (CGD) x WCT hybrids, developed by crossing disease free high yielding CGD and WCT palms (selected from RWD endemic area), were reported to be tolerant to RWD (Nair *et al.,* 1996). Therefore, response of varieties/cultivars, resistant/tolerant to RWD and also to major LRDC pathogens is very important.

CONCLUSIONS

The prevalence of LRDC restricted to the RWD endemic region points out towards the relationship of the disease with the RWD. Generally RWD infected palms succumb to LRDC. There exists a correlation between RWD and LRDC; the incidence of LRDC increases with the increase in incidence of RWD. Such a systemically (RWD) infected host allows even weak pathogens to attack and cause feaf rotting. The latent presence of phytoplasma is to be confirmed in LRDC contacted seedlings/palms without visible symptorns of RWD. Understanding of molecular basis of vulnerability of RWD affected palms to the LRDC is suggested. Application of advanced techniques like PCR would enable early detection of RWD and help hasten the control of LRDC.

In this disease complex several species of fungi are pathogenic and two fungi namely, *C.gloeosporioides* and *Erostratum* have been shown as the main pathogens. Cultural and biological diversity of the pathogens, toxin production, toxin induced changes would add to the knowledge of the pathogenesis. Information on molecular basis of host pathogen(s) interaction would help understand the disease mechanism. The influence of weather factors on the epidomiology is important. More knowledge on the significance of predisposing factors like RWD, survival of the pathogens, etc.are also necessary.

Control of LRDC had been a perplexing problem. Although reduction in the disease intensity under field condition has been demonstrated by fungicidal application, further refinement is needed with regards to methods, dose and frequency of application.The control of LRDC is significant because of the vulnerability of RWD infected palms to fungal infection. Systernic fungicides having broad spectrum activity may have to be tested. Most of the chemicals so far tested could only protect the leaf area on which they are applied from subsequent infection and could not afford any cure from the disease as they were not systernic. In view of the high incidence of the disease in spindles, protection of young leaves by systemic chemicals or biological agents coupled with strict phytosanitation is of paramount importance. The use of chernicals such as salicylic acid, capable of inducing systemic resistance in plants against diseases, should be studied. Application of mineral oil in the crown for protecting the spindle leaf may also be tested.

Preventive measures like growing resistant/tolerant varieties, application of balanced manures, fertilizers and fungicides to keep the palms in good health and vigour can help reduce the LRDC incidence and intensity. As a disease occurring wtih RWD the palms resistant/tolerant to RWD might be resistant to LRDC also. Hence, while screening varieties against RWD, reactions to LRDC should be assessed to evaluate their degree of resistance/toterance. Since the RWD is a debilitating disease and the infected palms respond to management practices, caution should be exercised to distinguish the true genetic potential of palms from that of response to management. Development of molecular techniques and use of genetic engineering to produce plants, if that express antibody, against RWD phytoplasma would greatly reduce vulnerability of palms (Gamier, 1997) and are the perspectives for disease control.

Rehabilitation of phytoplasma infected coconut (plantations) has been recognized as an important interim measure of management of relevant diseases in various countries *(e.g.,* Dery *et al.*, Kullaya *et al*., 1997; Harries, 1998). Hence phased rejuvination of coconut gardens by eradication of RWD affected palms in the region by regulatory measures would bring down the foci of infection. Phytosanitation - judicious pruning of infected spindle and a few leaves close to it from initial stage itself (LRDC) to reduce the inoculum potential-should forrn an integral part of LRDC control. Incorporation of chemical and biological components for disease control, balanced nutrition of palms, etc. also should form components in the integrated disease management package for LRDC. As the yield of coconut in the disease endemic area depends on the use of resistant/tolerant varieties with better management practices, controlling LRDC would help to reduce the damages done to the leaf lamina and thereby increasing the average yield.

REFERENCES

ARAGAKI, M; CHASE, A.R. UCHIDA, J. (1993) *Bipolaris, Exserohilum and Phaeotrichoconis leaf spots.* In: Diseases and Disorders of Omamental Palms (Ed. By Chase, A.R. Broschat, T.K.), pp. 5-6 APS Press. *The American Phytopathological Society*, St. Paul Minnesota.

ARAGAKI, M; UCHIDA, J. (1993) *Calonectria* leaf spot *(Cylindrocladium* leaf spot) In: Diseases and Disorders of Omamental Palms (Ed. By Chase, A.R. Broschat, T.K.), pp. 5-6 APS Press. *The American Phytopathological Society*, St. Paul Minnesota

BAIN, F.M. (1940) Report on the coconut growing areas of Jamaica. Bulletin of the Department of Science and Agriculture, Jamaica, 12 pp

BATEMAN, G.L. (1993) Development of disease symptoms and fungal pathogens on shoot bases in continuous winter wheat and effects of fungicides. *Plant Pathology* 42, 595-608

BATISTA, A.C. COELHO, M (l 947) Investigations on the control of damping-off of dwarf coconut seedlings. *Bol. Agriculture*. Pemambuco 14, 297-3) 16

BENIWAL, S.P.S.; GUDAUSKAS, R.T. (1974) Maize dwarf mosaic virus increases susceptibility to sorghum and com to *Helminthosporium maydis* race *T Phytopathology* 64, 1197-120 1.

BUTLER, E.J. (1908). Report on Coconut palm disease in Travancore, Bulletin No. 9. Agricultural Research Institute, Pusa India, 23 pp

CCRS, Kayangulam. (l962) Annual report for the period July 1960-June 1960, Central Coconut Research Station, Kayangulam, India, 166 pp

CCRS, Kayangulam. (1965) Annual report for the period July 1963-June 1964,

Central Coconut Research Station, Kayangulam, India, 218 pp

CCRS, Kayangulam. (1970) Annual report for 1968, Central Coconut Research Station, Kayangulam, India, 87 pp

CCRS, Kayangulam. (l971) Annual report for 1966, Central Coconut Research Station, Kayangulam, India, 64 pp

CHAKRABORTY, S.; BILLARD, L. (1995) Quantitative relationships between *Colletotrichum gloesporioides* infection of *Stylosanthes scabra* and weather under field conditions. *Plant Pathology* 44, 63-72

CHAN, C.L. (1974) Chernical control of *Curvularia* leaf spot of coconut seedlings *MARDI* Research Bulletin 2, 19-24

CHASE, A.R. (1993) Anthracnose *(Colletotrichum* leaf spot) In: Diseases and Disorders of Omamental Palms (Ed. By Chase, A.R. Broschat, T.K.), pp 2-3. APS Press. *The American Phytopathological Society*, St. Paul, Minnesota.

CHASE, A.R; BROSCHAT, T.K. (Eds.) Diseases and Disorders of Ornamental Palms. APS Press, *The American Phytophatological Society*, St. Paul, Minnesota, 56pp.

COLEMAN, P.G. (1959) Annual Report 1958. Department of Agriculture, Federation of Malaya, 98 pp

CPCRI, Kasaragod, (l972) Annual Report 1971. Central Plantation Crops Research Institute, Kasaragod, India, 212 pp

CPCRI, Kasaragod, (1975) Annual Report 1974. Central Plantation Crops Research Institute, Kasaragod, India, 177 pp

CPCRI, Kasaragod, (l976) Annual Report 1975. Central Plantation Crops Research Institute, Kasaragod, India, 215 pp

CPCRI, Kasaragod, (l979) Annual Report 1977. Central Plantation Crops Research Institute, Kasaragod, India, 204 pp

CPCRI, Kasaragod, (l981) Annual Report 1978. Central Plantation Crops Research Institute, Kasaragod, India, 242 pp

CPCRI, Kasaragod, (1982) Annual Report 1979. Central Plantation Crops Research Institute, Kasaragod, India, 276 pp

CPCRI, Kasaragod, (l983) Annual Report 1981. Central Plantation Crops Research Institute, Kasaragod, India, 279 pp

CPCRI, Kasaragod, (l985a) Coconut Root (wilt) Disease- Intensity, Production Loss and Future Strategy, A Survey Report. Central Plantation Crops Research Institute, Kasaragod, India, 45 pp

CPCRI, Kasaragod, (1985b) Annual Report 1984. Central Plantation Crops Research Institute, Kasaragod, India, 211 pp

CPCRI, Kasaragod, (1994) Annual Report 1993-94. Central Plantation Crops Research Institute, Kasaragod, India, 193 pp

CPCRI, Kasaragod, (1996) Annual Report 1995- 96 Central Plantation Crops Research Institute, Kasaragod, India, 220 pp

CPCRI, Kasaragod, (1997) Annual Report 1996-97. Central Plantation Crops Research Institute, Kasaragod, India, 208 pp

CPCRI, Kasaragod, (1998) Annual Report 1997. Central Plantation Crops Research Institute, Kasaragod, India, 158 pp

DEPARTMENT OF AGRICULTURE, BURMA. (1943) *Mycology*. Report of Department of Agriculture. Burma 1941-42 and 1942-43, pp 4-9

DEPARTMENT OF AGRICULTURE, GOVERNMENT OF KERALA Thiruvananthapuram, (1997). Coconut root (wilt) survey 1996. Department of Agriculture, Government of Kerala, Thiruvananthapuram, India. 55 pp

DEPARTMENT OF AGRICULTURE AND FISHERIES, Travancore, Trivandrum (1938). Annual Report of the Scheme of Investigations on the Diseases of coconuts in South India for 1937. Department of Agriculture and Fisheries, Travancore, Trivandrum, India 9 pp

DEPARTMENT OF AGRICULTURE AND FISHERIES, Travancore, Trivandrum (1939). Annual Report of the Scheme of Investigations on the Diseases of coconuts in South India for 1937. Department of Agriculture and Fisheries, Travancore, Trivandrum, India 16 pp

DEPARTMENT OF AGRICULTURE AND FISHERIES, Travancore, Trivandrum (1940). Annual Report of the Scheme of Investigations on the Diseases of coconuts in South India for 1939. Department of Agriculture and Fisheries, Travancore, Trivandrum, India 16 pp

DERY, S.K.; N'CHO, Y.P. SANGARE, A.; ARKHURST, E.D. (1997). Cape St. Paul wilt disease: Resistance screening and prospects for rehabilitating the coconut industry in Ghana. In: Proceedings of an International Workshop on Lethal Yellowing-Like Diseases of Coconut, Elmina, Ghana, November 1995 (Ed. By Eden-Green, S.J.; Ofori, F.). pp. 147-151. Natural Resources Institute, Chatham, UK .

DODD, J.C. ESTRADA, A.B. MATCHAM, J.; JEFFRIES, P.; JEGERS, MJ. (1991) The effect of climatic factors on *Colletotrichum gloeosporioides,* causal agent of mango anthracnose, in the Philippines. *Plant Pathology* 40, 568-575.

DWIVEDI, R.S. MATHEW, C.; RAY, P.K., AMMA, B.S.K.; NINAN, S. (1979). Certain closely associated morphological symptoms of root (wilt) disease of coconut (Cocos *nucifera).* Plant Disease Reporter 63, 461- 463.

DWYER, R.E.P. (1937). The diseases of the coconuts (Cocos *nucifera)* in New Guinea. *New Guinea Agricultural Gazette* 3, 28-93.

EDEN-GREEN S.J.; OFORI, F. (Eds). Proceedings of an intemational Workshop on Lethal Yellowing-like Diseases of Coconut, Elmina, Ghana, November 1995. Natural Resources Institute, Chatham, United Kingdom, 308 pp.

GARNIER, M. (1997) Non-cultivable phytopathogenic mycoplasms: Characterization, detection and perspectives for control. Weiner Kinische Wochenschrijt 109, 613-617

GEORGE, M.V. RA DHA, K. (l973). Computation of disease index of root (wilt) disease of coconut. *Indian Journal of Agricultrural Sciences* 43, 366-370

GEORGE M.K.; SAMRAJ, J. (1966). Deficiency of boron, a possible cause of the leaf rot in coconut palms. *Agricultural Research Journal* of Kerala 4,71-73

HARRIES, H.C. (l.998) On the common origin in South east Asia of Phytoplasma associated diseases of coconut. CORD 24 1-25

HODEL, D.R. (l 985) *Gliocladium and Fusarium* diseases of palms Principes 2985-88

JAGOUEIX, S.; BOVE, J.M. GARMIER, M. (1994). The phloem-limited bacterium of greening disease of citrus is a member of subdivision of the Proteobacteria. *International Journal of Agricultural Sciences* 56,309-328

JAYASANKAR, N.P. AHAMED BAVAPPA, K.V. (1986) Coconut root (wilt) disease-Past studies, present status arid future strategy. *Indian Journal of Agricultural*. Sciences 56. 309-328

JEFFRfES, P.; DODD, J.C.; JEGER, M.J.; PLUMBLEY, R.A. (1990). The biology and control of *Colletotrichum* species on tropical fruit crops. *Plant Pathology* 39. 343-366

JOHNSTON, A. (1965). Host list of fungi, etc. arid insects record in the south East Asia arid Pacific Region. Cocos *nucifera* L. Coconut. Technical Report No. 16 FAO Regional Office, Bangkok, Thailand, 18 pp.

JOSEPH, T.; RAWTHEF, T.S.S. (1991). Leaf rot disease In: Coconut root (wilt) disease Monograph Series No. 3. (Ed. by Nair, M.K.; Nambiar, K.K.N.; Koshy, P.K.; Jayasankar, N.P.), pp 81-89. Central Plantation Crops Research Institute, Kasaragod, India.

KULLAYA, A.; MPLTNA MI, A.; HARRIES, H.C.; SCHUILING, M.; KAIZA, D (1997). Lethal Disease resistance screening in Tanzania arid prospects for rehabilitation. In: Proceedings of an International Workshop on Lethal Yellowing-Like Diseases of Coconut, Elmina, Ghana, November, 1995 (Ed. by Eden-Green, S.J.; Ofori, F.), pp. 163-172. Natural Resources Institute, Chatham, United Kingdom.

LAMEY, H.A.; EVERETT, T.R. (1967) Increased susceptibility of hojablanca virus-infected rice leaves to *Cochiliobolus myabeanus.* Phytopathology 57,227

LILY, V.G. (1963). Host parasite relations of *Helminthosporium halodes* on coconut palm. *Indian Coconut Journal* 16, 149-153

LILY, V.G. (l 98 1). Host parasite relations of *Bipolaris halodes* (Drechs) Shoemaker on the coconut palm. *Indian Coconut Jourrial* 11 (l 1), 1-4

LILY, V.G. NAIR, U.K. PANDALAI, K.M. MENON, K.P.V. (1952). Observations on the inhibitory activity of a species of bacterium on some fungi parasitic on the coconut palm. *Indian Coconut Journal* 5 (4) 162-170.

LILY, V.G.; RADHA, K.; MENON, K.P.V. (l 95 5). Observations on the inhibitory activity of a species of a bacterium. Activity of the antifungal substance produced by the bacterium *Bacillus subtilis. Indian Coconut Journal* 8 (3), 137-149

LILY, V.G.; RAMADASAN, A. (1979). Changes in phenolic content of coconut leaf in relation to the development of leaf rot. *Indian Phytopathology* 32, 112-113

MATHAI, G. (1980). Seasonal and varietal variations on the incidence of leaf rot of coconut in the root (wilt) affected tracts. *Indian Coconut Journal* 11(6),1-3

MATHAI, G.; BALAKRISHMAN, B.; MATHEW, J.; Leaf rot of Oil palm. Current Science 58, 513-514

MATHAI, G.; INDRASENAN, G.; MAHAMED KUNJU (1984). Investioons on the integrated control of root (wilt) disease of coconut. *PLACROSYM VI*, 99-105

MATHAI, G.; MATHEW, J.; BALAKR1SHNAN, B. (1988). Reaction of exotic cultivars of coconut (cocos *nucifera* L) to root (wilt) disease of Kerala National Symposium on Coconut Breeding and Management, held on November 23-26, Kerala Agricultural University, Trichur, India Abstracts of papers, p. 19

MCPAUL, J.W. (1962) Coconut growing in Fiji. Bulletin of Department of Agriculture Fiji 38, 99

MCRAE, W. (l916). Communication to the Dewan of Cochin. In: Menon, K.P.V. & Nair, U.K. (1948). The leaf rot disease of coconuts in Traveancore and Cochin. Indian Coconut Journal 1 (2) 33-39

MCRAE, W. (1929) India: New diseases reported during the year 1928. International Bulletin of Plant Protection 3(2) 21-22

MENON, K.P.V.; NAIR, U.K. (1948) The leaf rot disease of coconuts in Travancore and Cochin. *Indian Coconut Journal* 2(l) 5-10

MENON, K;P.V.; NAIR, U.K. (l 951) Scherne for the investigation of the root and leaf diseases of the coconut palm in South India. Consolidated final report of the work done from 8th March 193 7 to 3 1 st March 1948. *Indian Coconut Journal* 5(l), 5-19

MENON, K;P.V.; NAIR, U.K. (1952) Scherne for the investigation of the root and leaf diseases of the coconut palm in South Idnia. Consolidated final report of the work done from 8th March 1937 to 3 1 st March 1948. *Indian Coconut Journal* 5(2),81-100, 113

MENON, K;P.V.; PANDALAI, K.M. (1959). The Coconut Palm. A Monograph. Indian Central Coconut Committee, Emakulam, 384 pp.

MOHANAN, C.; SHARMA, J.K. (1986) *Bipolaris specifera* and *Exserohilum rostratum* causing leaf spots; of *Eucalyptus tereticornis*- New record from India. Current Science 55, 990-992.

NADAKAL, A.M. (1965) A note on the occurrence of nernatodes on the leaves of diseased coconut palms in Kerala. Science and Culture 31, 157-158

NAIR, M.K.; KOSHY, P.K.; JACOB, P,M. NAIR, R.V. BHASKARA RAO, E.V.V.; NAMPOOTHIRI, K.U.K.; IYER, R.D. (1996) A root (wilt) disease resistant coconut hybrid and strategy for resistance breeding. *Indian Coconut Journal* 27 (1) 2-5

NAIR, U.K.; RADHA, K. (l 959) Manuring curn spraying for the control of coconut palm diseases. Proceedings of lst Conference of Coconut Research workers. Trivandrum, India, 250-254

NAMBIAR, K.K.N. (1994) Diseases and Disorders of Coconut. In: Advances in Horticulture Vol. 10. Plantation and Spice Crops Part 2 (Ed. by Chadha K.L.; Rethinam, P.). pp. 857-882. Malhotra Publishing House, New Delhi, India

NAMPOTHIRI, K.U.K., KOSHY, P.K. (Eds). 1998. Coconut root (wilt) disease. Central Plantation Crops Research Institute, Kasaragod, India 124 pp.

OHLER, J.G. (1984) Coconut, tree of life. FAO Plant production and protection paper 57. Food and Agriculture Organization of the United Nations, Rome, 446 pp

OHR, H.D. (1993) Pink rot *(Gliocladium* blight). In: Diseases and Disorders; of Ornamental Palms. (Ed. by Chase, A.R.; Broschat, T.K.) pp 24-25. APS Press. *The American Phytopathological Society*, St. Paul, Minnesota.

PARRY, D.W. (1990). The incidence of *Fusarium spp.* in stern bases of selected crops of winter wheat in the Midlands, U.K. *Plant Pathology* 39, 619-622

PATEL, J.S. (1938) The Coconut - a mongraph. Government of Madras, Madras, India, 313 pp

PATEL, J.S.; NAIR, A.P.B. (1936) Natural and induced resistance to shoot-rot in the coconut. Proceedings of Indian Academy of Sciences 3, 432-437

PRASANNAKUMIARI, T.O.; RADHA, K., KURIAN, V.C. (1960). Efficacy of copper fungicides with reference to *Helminthosporium halodes - t*he leaf rot fungus of coconut. *Indian Coconut Journal* 13 (2) 70-75

PROTACIO, D.B. (1965) The *Ceratostomella (Thielaviopsis) paradoxa* leaf spot of coconut new in the Philippines. *Philippine Journal of Agficulture* 2567-76

RADHA, K. (1961) Leaf rot disease of coconut. Proceedings of lst Session FAO Technical Working Party, Coconut Production, protection and Processing. Trivandrum, India 30-36

RADHA, K. (1965) Effect of foliar application of micronutrients on leaf rot and yield of coconut. Science and Culture 31, 371.

RADHA, K.; LAL, S.B. (1968) Some observations on the occurrence of leaft rot disease of coconut and associated factors. 3rd Session FAO Technical Working Party, coconut Production, Protection and Processing, Jogjakarta, 1-5

RADHA, K.; SAHASRANAMAN, K.N.; MENON, K.P.V.(1962). A note on the yield of coconut in relation to rainfall and leaf rot and root (wilt) disease. *Indian coconut Journal* 16, 3-11

RADHA, K.;SUKURAMARAN, C.K.; PRASANNAKUMARI, T.O. (1961) Studies on the leaf rot disease of coconut. Fungal infection in relation to envirornmental conditions. *Indian Coconut Joumal* 15 (1) 1-11.

RAJU, D.G.; SILL, W.H.; BROWDER, L.E. (1969) The combined effects of two viral diseases & leaf rust on wheat. *Phytopathology* 59, 1488-1492

RAYCHAUDHURI, S.P.; NARIANI, T.K.; LELE, V.C.; SINGH, G.R. (1969) Citrus die-back problem in India. In: Proceedings of the First Intemational Citrus Symposium. Riverside, U.S.A. 16-26 March, 1968. (Ed.by Chapman, H.D.), pp. 1432-1437. University of Califormia, Riverside, USA.

REYNOLDS, J.E. (1964). Gliocladium disease of palm in Dade County Florida. Plant Disease Reporter 48, 718-720

RUSSEL, G.E. (l 966). Some effects of inoculation with yellowing viruses on the susceptibility of sugar beet to fungal pathogens. LS usceptibility to *Perenosporafarinoso. Transactions of the British Mycological Society* 49,611-619

SAMRAJ, J.; PAILY, P.V. AND CHEERAN, A. (l 966) Observations on the aerial application of oil based fungicide against the leaf rot disease of the cocopalm. Agricultural Research Journal of Kerala 4, 67-70.

SHEPHERD, E.F.S. (1930) Botanical Division, Annual Report 1928. Mauritius Department of Agriculture, pp. 10-13.

SILVA, G.S. DA; SOUZA, E.A.P. (1981) Leaf spote of coconut palm caused by *Cylindrocladium pteridis Wolf* Fitopatologia Brasileira 6, 515-517

SIMONE, G. W. (l 993). *Thielaviposis* bud rot (Stem bleeding, B itten leaf, Black scorch, Dry basal rot, Heart rot) In: Diseases and Disorders of Ornamental Palms (Ed by Chase, A.R.; Broschat, T.K.) pp. 30-32. APS Press. *The American Phytopathological Society*, St. Paul Minnesota.

SINGH, G.R.; RAYCHAUDHURI, S.P.; KAPOOR, I.J. (1971) Interaction of fungi, pathogen in producing Citrus die-back. Citrograph 57, 27-28

SIVANESAN, A. (1987) Setosphaeria generic description. In: Graminicolous species of *Bipolaris, Curvularia, Drechslera, Exserohilum* and their *Teleomorphs* (Mycological paper No. 158), pp 201-237. CAB-IMI, United Kingdom.

SOLOMON, J.J. (1997) Current status of research on root (wilt) disease of coconut India. In: SJ Eden Green & F. Stone (eds). International Workshop on LY like diseases of coconut. Elmina, Ghana.

SOLOMON, J.J.; GOVINDANKUTTY, M P.; NIENHAUS, F. (l983). Association of mycoplasma-like organisms with the coconut root (wilt) disease in India. Journal of Plant Disease and Protection 90, 295-297 Srinivasan, N. (1991) Occurrence of coconut leaf rot in relation to root (wilt) disease. *Indian Coconut Journal* 21 (10), 14-18

SRINIVASAN, N.; GLJNASEKARAN, M. (1992) An appraisal of symptom expression in coconut due to leaf rot disease. *Indian Coconut Joumal* 23 (10),2-7

SRINIVASAN, N.; GUNASEKARAN, M. (1993) Fungi associated with leaf rot disease of coconut. *Indian Coconut Journal* 23 (10), 2-7

SRINIVASAN, N.; GUNASEKARAN, M. (1994a) Identification of *Colletotrichum gloeosporioides. Exserohilum rostratum* and *Gliocladium vermoeseni* associated with leaf rot disease of coconut in India CORD 10, 34-50

SRINIVASAN, N.; GLTNASEKARAN, M. (1994b) Additional fungi associated with leaf rot disease of coconut in India. *The Philippine Journal of Coconut Studies* 19, 26-27

SRINIVASAN, N.; GUNASEKARAN, M. (l 995a) *Cylindrocladium scoparium* in relation. to leaf rot disease of coconut. *Indian Phytopathology* 48, 196198

SRINIVASAN, N.; GUNASEKARAN, M. (1995b) *In vitro* interactions among fungi associated with leaf rot disease of coconut Indian Phy-topathology 48369-370

SRINIVASAN, N.; GUNASEKARAN, M. (1996a) Pathogenecity of preponclent fungi associated with leaf rot disease of coconut. *Indian Coconut Joumal* 27(3)2-4

SRINIVASAN, N.; GLTNASEKARAN, M. (1996b) Field control of leaf rot disease of coconut with fungicides. CORD 12, 34-42

SRINIVASAN, N.; GUNASEKARAN, M. (l 996c) Coconut leaf rot intensity and fungal incidence. *Indian Coconut Journal* 26 (9), 10-13

SRINIVASAN, N.; GUNASEKARAN, M. (1996d) Incidence of fungal species associated with leaf rot disease of coconut palms in relation to weather and the stage of lesion development. Annals of Applied Biology 129, 433-449

SRINIVASAN, N.; GUNASEKARAN, M.; ROHINI IYER; CHANDRAMOHAN, R.; KOCHU BABU, M. (1995) Mycoflora of leaf rot affected coconut palms. *Indian Phytopathology* 48, 93-95

SUNDARARAMAN, S. (l 925) Preliminary note on coconut leaf rot of Cochin. Year Book. Pp 6-8 Madras Agricultural Department, India.

SUNDARARAMAN, S. (1929) Administrative report of the Government Mycologist, Coimbatore, India. Report of the Department of Agriculture, Madras Presidency for the Official Year 1928-29. 27 pp

TEY, C.C.; CHAN, E. (1980) Diseases of coconut palms in Peninsular Malaysia. In: Proceedings of the International Conference on Cocoa and coconuts, Kuala Lumpur, Malaysia, 21-24 June 1978. Pp 692-707. *MARDI*, Kuala Lumpur.

VARGHESE, M.K. (1934) Disease of the coconut palm. Department of Agriculture and Fisheries, Travancore, 105 pp.

Table 1 Incidence of LRDC in relation to RWD

Soil Type	Non-bearing (young) palms			Bearing (adult) palms		
	No. of palms sampled	No. Diseased*	RWD with LRDC (%) **	No. of palms sampled	No. Diseased *	RWD with LRDC (%)**
Sandy loam	354	126	85.71	1496	1316	50.61
Sandy	161	86	90.70	860	597	58.29
Alluvial	153	90	82.22	645	529	63.89
Clay	186	113	85.84	719	549	73.95
Laterite	105	47	93.62	806	589	74.36
Total	959	462	86.80	4526	3580	61.34

* Sum of RWD alone and RWD superinfected with LRDC,
** Out of diseased palms (The rest of palms in soil types RWD alone).

Table 2 Symptoms of LRDC observed in different whorls

Soil Type	No of Palms	Palms exhibited LRDC in different whorls/whorl combination (%)				
		Inner (1)	Outer (O)	1+M	1+O	1+M+O
Sandy loam	774	58.53	4.65	0.26	12.14	24.42
Sandy	426	26.06	18.54		12.44	42.96
Alluvial	412	32.53	16.50		18.69	32.28
Clay	503	19.48	29.62		13.12	37.78
Laterite	482	21.99	12.86	0.08	26.97	38.18
Total	2597	34.73	15.17	0.08	16.17	33.85

* Symptoms only in Middle (M) whorl or M +O whorl combination not observed.

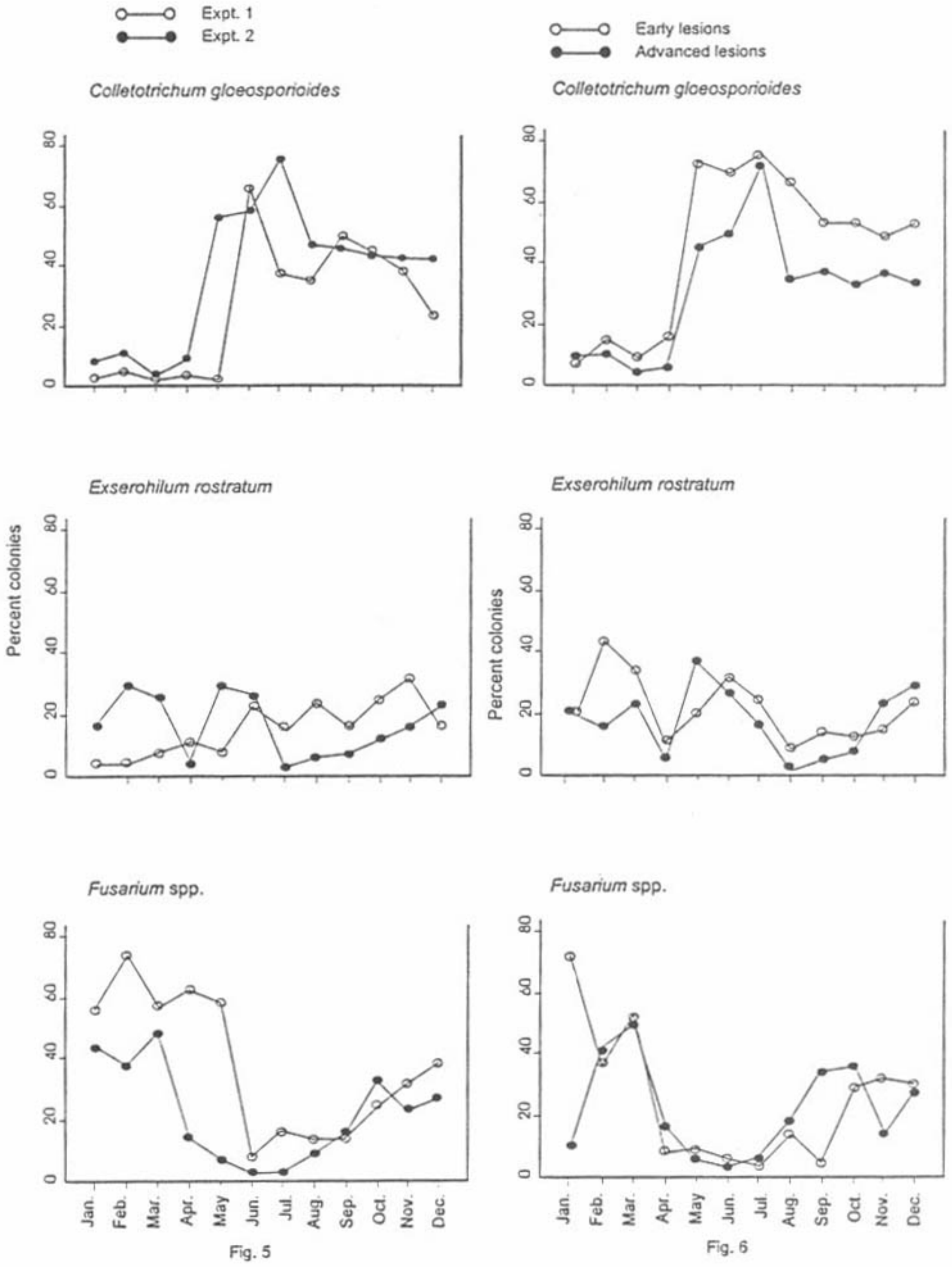

Fig. 5 Fig. 6

Frequency of isolation of fungi in different months