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LEAF ROT DISEASE OF COCONUT

CPCRI

CENTRAL PLANTATION CROPS RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
KASARAGOD - 671 124, KERALA, INDIA

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Front cover : **Coconut palm showing leaf rot disease symptoms**

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LEAF ROT DISEASE OF COCONUT

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1. OCCURRENCE AND DISTRIBUTION

Leaf rot disease (LRD) is widely prevalent in Kerala state, where root (wilt) disease (RWD) is endemic. Root (wilt) affected palms become easily distinguishable with the onset of LRD. The destruction of photosynthetic area of the affected palm being obvious, LRD incidence can be noticed on palms of all ages especially in palms below 25 years of age. Surveys conducted in Kerala revealed the occurrence of varying intensities of LRD, ranging from 14% to 65%. The disease is distributed in the eight southern districts of Kerala *viz.*, Thiruvananthapuram, Kollam, Alappuzha, Pathanamthitta, Kottayam, Ernakulam, Idukki and Thrissur, besides Theni - Dindigul districts (Cumbum Valley) of Tamil Nadu - east of Idukki district.

2. INTERRELATION OF LEAF ROT WITH ROOT (WILT)

LRD appears on palms with RWD only. Root (wilt) affected palms succumb to infection by LRD sometimes even before the root (wilt) symptoms manifest. About 65% RWD affected palms were found to be superinfected with LRD. Further, the occurrence of LRD with RWD indicates the influence of RWD on LRD. Among different soil types, incidence of RWD alone and with LRD ranged from 67% to 78% and LRD superimposition varied from 54% to 76% of RWD affected palms. Young palms with RWD are readily attacked by LRD (Table 1). Even two -year old palms showed the disease symptoms. Occurrence of LRD on RWD affected palms of different age groups was also noticed in Cumbum Valley of Tamil Nadu.

Phytoplasma is implicated as the cause of RWD. Unlike other phytoplasmal diseases of coconut (such as lethal yellowing, blast/dry bud rot, Cape St. Paul Wilt, Kaincope, Kribi, Awka wilt, African lethal diseases etc. observed in other countries that are all fatal diseases), the RWD affected palms do not die immediately (ie., non- fatal) and their growth declines only slowly. The palms weakened by phytoplasma become susceptible to LRD. With the incidence of LRD (in RWD affected palms), the crown is disfigured and the palm vigour / yield declines rapidly. The occurrence of LRD with RWD is thus a distinct phytoplasma-fungal complex.

Although yield loss due to RWD has been estimated, the precise computation of loss in yield due to LRD is not easy since it is difficult to separate the damages caused by RWD and LRD. However, LRD does contribute to the loss in nut yield considerably and also by way of damage to the quality and quantity of leaves.

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Table 1: Incidence of LRD in relation to RWD

Soil type	Non-bearing (young) palms			Bearing (adult)palms		
	No. of palms sampled	No. of palms diseased*	RWD with LRD(%)**	No. of palms sampled	No.of palms diseased*	RWD with LRD (%)**
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	809	589	74.36
Total	959	462	86.80	4526	3580	61.34

*Sum of RWD alone and RWD superinfected with LRD.

**% calculated based on the number of palms diseased.

3. SYMPTOMATOLOGY

In the RWD affected palms, the spindle (the youngest unopened) leaves play a critical role in the LRD incidence. The spindles remain white and soft for a relatively longer period in this case when compared to the spindles of healthy palms. This tender spindle leaf has thinner epidermal layer and higher moisture content and serve as an ideal infection court. LRD appears first in such weakened spindles as minute, water-soaked lesions in different shades of brown colour (brown, reddish brown etc.) and shapes. The symptoms also appear occasionally on different parts of the leaflets of young tender leaves. These lesions enlarge and coalesce freely on the soft and tender tissues of the spindle resulting in extensive rotting especially under high rainfall and relative humidity, and low mean maximum temperature (Figs.1-4). In the affected spindles, mould growth (fungal mycelium and spore masses) also is commonly seen on the surface of the affected tissues. The rotting does extend to the interior of the spindle. If infection happens to be in the early period of spindle leaf emergence, expansion of the lesions would be rapid. The infected spindle gradually decays attracting many insects like ants, earwigs, flies etc. and a fowl smell emanates from the decaying tissues.

Often, the tips of the rotten leaflets of the spindle stick together even while the base of the leaflets are open. This is one of the striking features of the disease. Later, the rotten

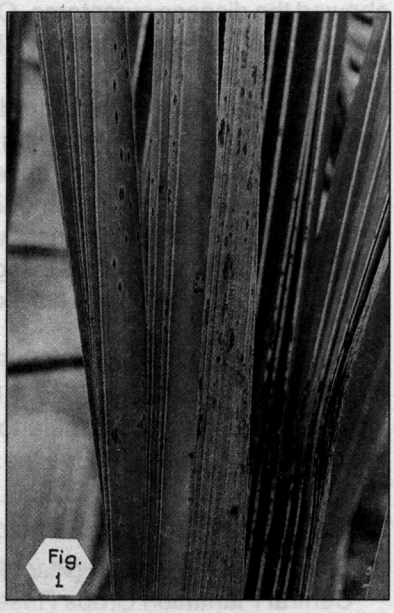


Fig.1. Early lesions of LRD.

Fig.2. LRD symptoms in spindle, extending from tip downwards.

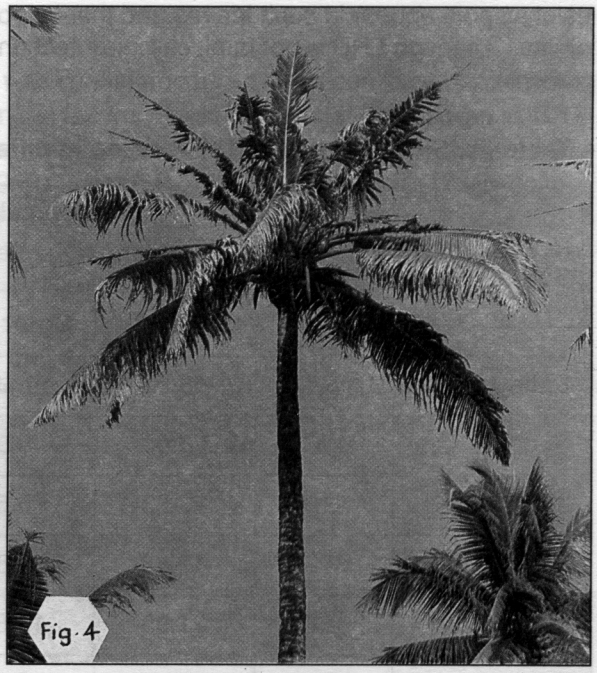


Fig.4. LRD infected adult palm.

Fig.3. LRD infected seedling.

portions dry up, turn black and fall-off. Tips of leaflets and midribs often become shrivelled and blackish. Another characteristic feature is that the progress of rotting is very slow in mature leaflets. Therefore, in certain palms the basal portion of the leaflets remain healthy, i.e. without the LRD symptoms(a fan-like appearance of the leaves in the crown). Such an appearance in most or all leaves in the crown is indicative of the disease infection being contracted by the successively emerging leaves leading to rotting of lamina to varying extents. Disease lesions on petiole, midrib, mid-veins of leaflets were also observed in infected palms(Fig.5).

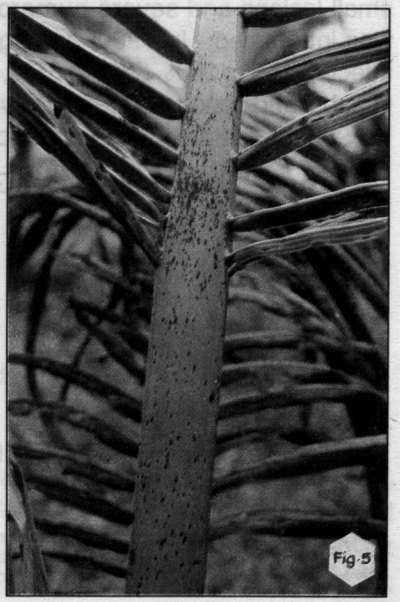


Fig.5. LRD lesions in leaf petiole / mid-rib.

Further, the occurrence of LRD symptoms in different whorls clearly indicate the vulnerability of the inner whorls of leaves to infection and the successive infection of freshly emerging leaves that occur in at least one-third of the infected palms (Table 2). When the disease severity is high, there is a decline in the yield of the affected palms. In the palms with mid-whorl yellow symptoms,

lesions/spots appear in such leaves and these spots coalesce resulting in severe blighting of the lamina. Although LRD is not fatal, chronic infection makes the palm decline steadily in health and productivity.

Table 2: Symptoms of LRD observed in different whorls

Soil type	No. of palms	Palms exhibited LRD in different whorls/whorl combination (%)*				
		Inner (I)	Outer (O)	I+M	I+O	I+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	-	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.

4. DISEASE INDEXING METHOD

A disease indexing method is required to quantify and to assess the severity of the disease. Earlier (1961), a qualitative four grade scale (0-Nil, mild- a few small lesions, moderate-numerous small lesions and severe-numerous big lesions which developed into patches of rotten tissues) was introduced. In 1980, a six grade scale was evolved (0-No infection, 1- up to 5% leaf area infected, 2-6 to 20%, 3-21 to 35%, 4-36 to 50% and 5-above 50%) . Here the ranges were wide and variable and hence the indexing system was reviewed, and a five-point grading system was adopted in 1996 for satisfactory comparison of disease intensity. The details are as under :

Grade	Leaf area affected
0	No infection
1	up to 25%
2	25 to 50%
3	50 to 75%
4	Above 75%

(for each leaf in the crown)

The disease index (DI) is arrived by:

$$DI = \frac{\text{Total Numerical Ratings}}{\text{No. of leaves X Maximum No. of grades}} \times 100$$

The scope for evolving a combined disease indexing system, integrating LRD with RWD, is under experimentation.

5. ETIOLOGY

In the beginning of the 20th century LRD was considered as an infectious (disease). Earliest record of isolation of an organism (fungus) from the leaves of leaf rot affected palms was in 1916. Then itself it was strongly believed that LRD was primarily caused by a fungus. During the course of the investigations during the period 1930s -1950s a number of fungi were found to be associated with the disease. These were *Helminthosporium halodes, Colletotrichum paucisetum (Gloeosporium* sp.*), Gliocladium roseum* and *Pestalotia palmarum.* Wind dispersal, conidial germination, histopathology, patho-physiology etc. of especially *Helminthosporium (Bipolaris) halodes* in relation to leaf rot was investigated.

Although fungal etiology of LRD had been accepted, earlier emphasis was only on *H(B). halodes.* However, a review of LRD etiology was felt necessary for evolving effective management measures for the disease.

Isolations of fungi

Isolations of fungi from hundreds of leaf rot affected spindles established substantatively the complex fungal etiology of LRD.

Identification and documentation

All fungi isolated from LRD affected palms were authentically identified at CAB-International Mycological Institute, United Kingdom and documented. The fungi assoicated with LRD are listed below in the order of frequency:

Colletotrichum gloeosporioides (Penzig) Penzig and Sacc.,
Exserohilum rostratum (Drechsler) Leonard and Suggs,
Gliocladium vermoeseni (Biourge) Thom.,
Fusarium solani Martius (Sacc.),
Fusarium moniliforme Sheldon var. *intermedium* Neish and Legget,
Cylindrocladium scoparium Morgan,
Thielaviopsis paradoxa (Dade) C. Moreau,
Rhizoctonia solani Kuhn,
Mortierella elongata Linnem,
Curvularia sp.,
Acremonium sp.,
Thielavia microspora Mouch,
Thielavia terricola (J. Gilman & E.V. Abbott) Emmons, and
Chaetomium brasiliense Batista & Pont.

The fungi more frequently associated are: *C.gloeosporioides,E. rostratum, G. vermoeseni, Fusarium* spp. and *T. paradoxa* (Tables 3 and 4; Fig.6). *Pestalotiopsis palmarum* is usually isolated from older leaves only. Species composition of leaf rot (associated fungi) is generally similar irrespective of soils or regions. From blighted leaves of mid-whorl yellowed palms, *C.gloeosporioides, Fusarium* spp. etc. were isolated.

Pathogenicity

All the fungi isolated from LRD, except *Acremonium* sp., *T. microspora*, *T. terricola* and *C. brasiliense* were found to be pathogenic. The pathogenicity/symptom induction was effected both in the laboratory and field conditions (Figs. 7 and 8). While other fungi induced wet-rotting of the tissues, the fusarial fungi induced a distinct dry rotting symptoms. Re-isolations also corroborated pathogenic nature of the fungi. In healthy palms (free form RWD), the fungi induced only restricted spots; on RWD affected palms these fungi produced extensive lesions which coalesced subsequently resulting in extensive rotting of the leaf tissues. Further, *C. gloeosporioides* and *E. rostratum* were found to be comparatively more aggressive and had higher frequency of occurrence and were therefore considered as the main pathogens of LRD. Leaf rot symptoms were reproduced in RWD affected field palms by artificially inoculating with *C. gloeosporioides* and *E.rostratum*, individually and in combination. Disease lesions developed also on petioles, mid veins/midribs and the LRD symptoms occurred in leaves that emerged successively.

Table 3 : Occurrence of fungi in spindles of leaf rot affected coconut palms (data represents year aggregate)

Fungus	% palms showing association in	
	Expt.1*	Expt.II**
(A) Co-occurrence of fungi (Total) (observed in different combinations; the most common co-occurrences are as in foot note***)	71.2	77.5
(B) Individual occurrence of fungi		
Colletotrichum gloeosporioides	3.8	10.8
Exserohilum rostratum	0.4	0.8
Gliocladium vermoeseni	3.3	4.2
Fusarium spp.	17.5	3.3
Thielaviopsis paradoxa	0.8	2.5
Cylindrocladium scoparium	0.4	—
Rhizoctonia solani	2.1	0.8
Mortierella elongata	0.4	—
Total of B	**28.8**	**22.5**
Grand Total	**100.0**	**100.0**

*Out of 240 palms (20 palms/month; 25 leaf pieces/palm).
**Out of 120 palms (10 palms/month; 15 leaf pieces/palm).
***Most common co-occurrences :

C. gloeosporioides +*E. rostratum*,
C. gloeosporioides +*Fusarium* spp.,
C.gloeosporioides +*E. rostratum*+*Fusarium* spp.,
G. vermoeseni +*Fusarium* spp.

Table 4: Association of fungi in leaf rot affected spindles as isolated from different stages of the disease lesions (data represents year aggregate)

Fungus	% leaf pieces yielding fungi from*	
	Early lesions	Advanced lesions
(A) Individual isolations		
Colletotrichum gloeosporioides	49.4	29.0
Exserohilum rostratum	16.2	16.8
Gliocladium vermoeseni	7.9	12.6
Fusarium spp.	16.7	17.0
Thielaviopsis paradoxa	4.2	4.1
Rhizoctonia solani	0.8	11.2
Mortierella elongata	0.1	3.2
Other fungi	1.1	0.6
Total	**96.4**	**94.5**
(B) Mixed isolations	3.6	5.5
Grand total	**100.0**	**100.0**

*From a total of 120 palms.

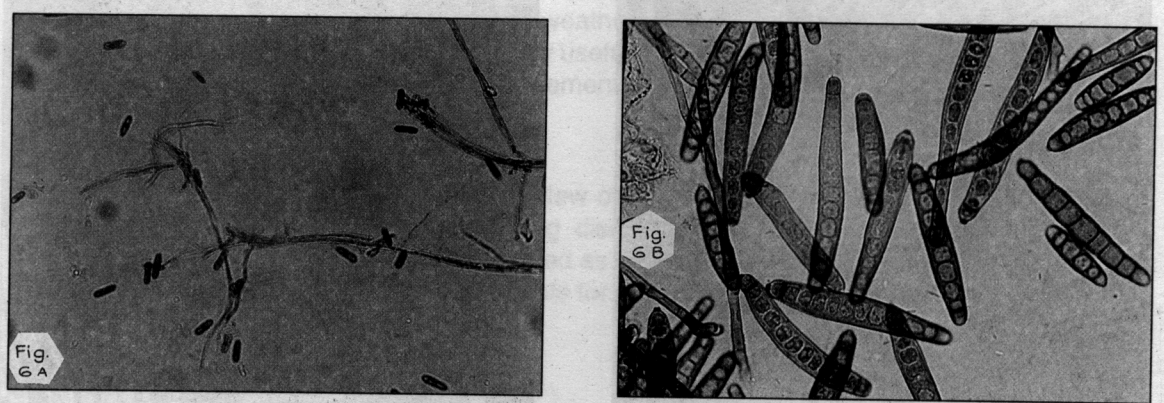
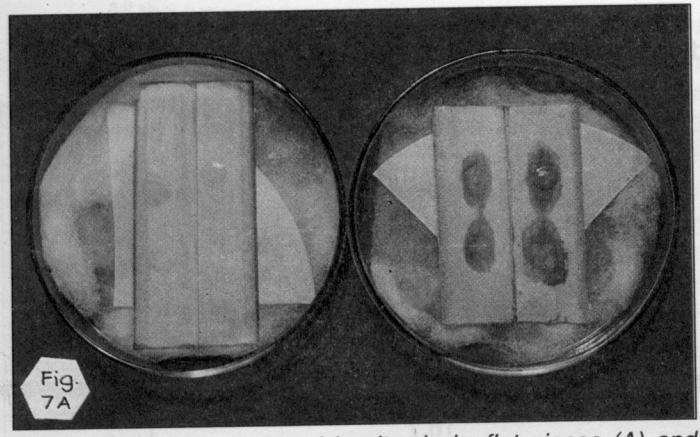


Fig.6. Main pathogens of LRD - conidia of C.gloeosporioides (A) and E. rostratum (B).

In summary, the analysis of evidences of fungal frequency, pathogenic behaviour, seasonal relationship, *in vitro* interaction (predominant fungi associative than antagonistic) etc. have clearly established that LRD is a disease of fungal complex and that *C. gloeosporioides* and *E. rostratum* are the main pathogens. Coconut palms weakened by phytoplasma (RWD) are susceptible to LRD.

6. EPIDEMIOLOGY

Weather factors have no significant influence on the incidence of RWD. Although RWD is the critical pre-disposing factor in LRD incidence, the severity and incitants of LRD are influenced



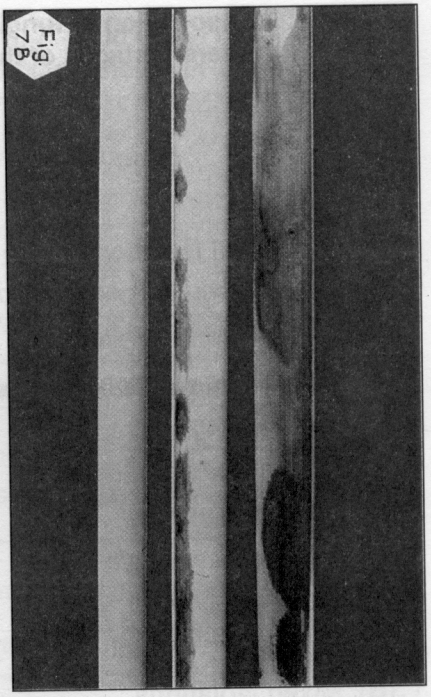


Fig.7. LRD lesions induced in vitro in leaflet pieces (A) and leaflets (B).

by weather factors. Most severe incidence of LRD is observed during monsoons when high atmospheric humidity and low temperatures prevail.. Fungal spore population in the atmosphere is high during monsoons. Free moisture or wetness (rain water) and dew (during dry months), and compactness of spindle foliage (which helps in delaying the drying of leaf surface) are also found to influence the incidence of LRD.

Fig.8. LRD induced in field palms (A, B, C).

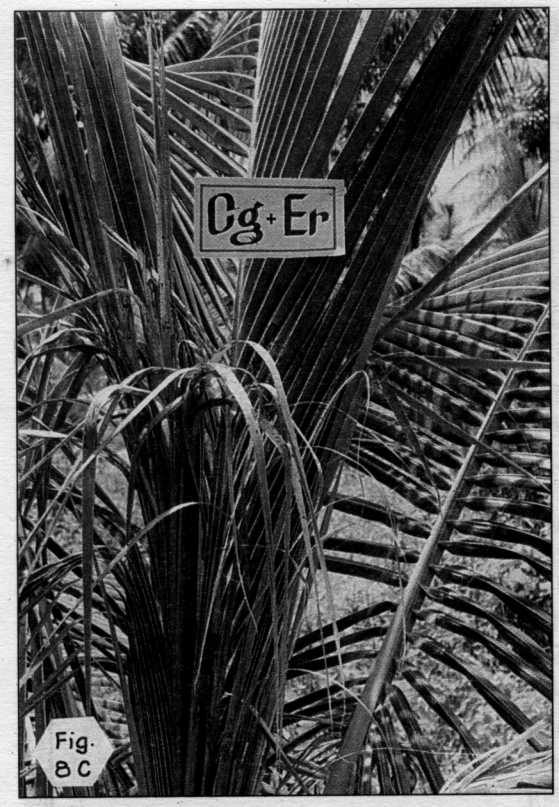


Fig.8 contd...

Population dynamics of fungi associated with LRD in relation to weather factors has been assessed. Maximum population of *C.gloeosporioides* occurred during monsoon months (peak being June-July) coinciding with high rainfall and high RH and negatively correlated with the maximum temperature and hours of sunshine. The pathogen was isolated from young lesions more frequently and than from advanced lesions. Hence *C.gloeosporioides* has been implicated as the principal pathogen of LRD during monsoons. Incidence of *E.rostratum* was less strongly correlated with weather. In winter, population of *C. gloeosporioides* was low while population of *E.rostratum* was high. *Fusarium* spp. were found common during the dry season (January through May) (Fig. 9). *R. solani* was also seen at higher frequencies during dry months. The incidence of other fungi were not influenced by specific weather factors and may have lesser significant role in LRD, but may play some role in disease expression under certain circumstances. In young infected palms also similar trend was observed. Relatively low incidence of *C.gloeosporioides* during the dry season suggests a quiescent phase. It sports an aggressive re-emergence when favourable weather conditions appear during the South-West monsoon. Hence such informations are highly useful for LRD prediction, early diagnosis, disease forecasting and in formulating disease management technology.

7. MANAGEMENT

Control of LRD is very important in view of its destructive potential. A large number of experiments have been conducted for evolving disease management practices. Since leaf rot is interrelated to root (wilt), LRD should be viewed as a part of root (wilt) complex. Even though the phytoplasma induced root (wilt) is not amenable for conventional crop protection measures, there is scope for management of LRD.

(a) Phytosanitation

Rehabilitation of chronically infected gardens is an accepted disease management practice. Eradication of RWD affected palms would bring down the foci of primary infection. Since RWD-LRD complex is debilitating, prompt eradication of the disease advanced palms is very important. As leaf rot usually strikes the emerging spindle leaves, greater attention should be given to protect this most vulnerable part of the palm, at the eartly stage of the disease itself. Cutting down the infected portions of the spindle and one or more of the diseased leaves next to it had been proposed as a phytosanitory measure for LRD control as early as the 1930s. Hence the infected spindle and a few leaves close to it should be judiciously pruned at the initial stage of the disease. The pruned leaves should be collected and disposed off by burning. Such a simple measure rendered at the initial stage itself would reduce the inoculum potential and aid the palm to recover. It would also prevent colonization of a few scavenging insects and insect pests which otherwise compound the problem further.

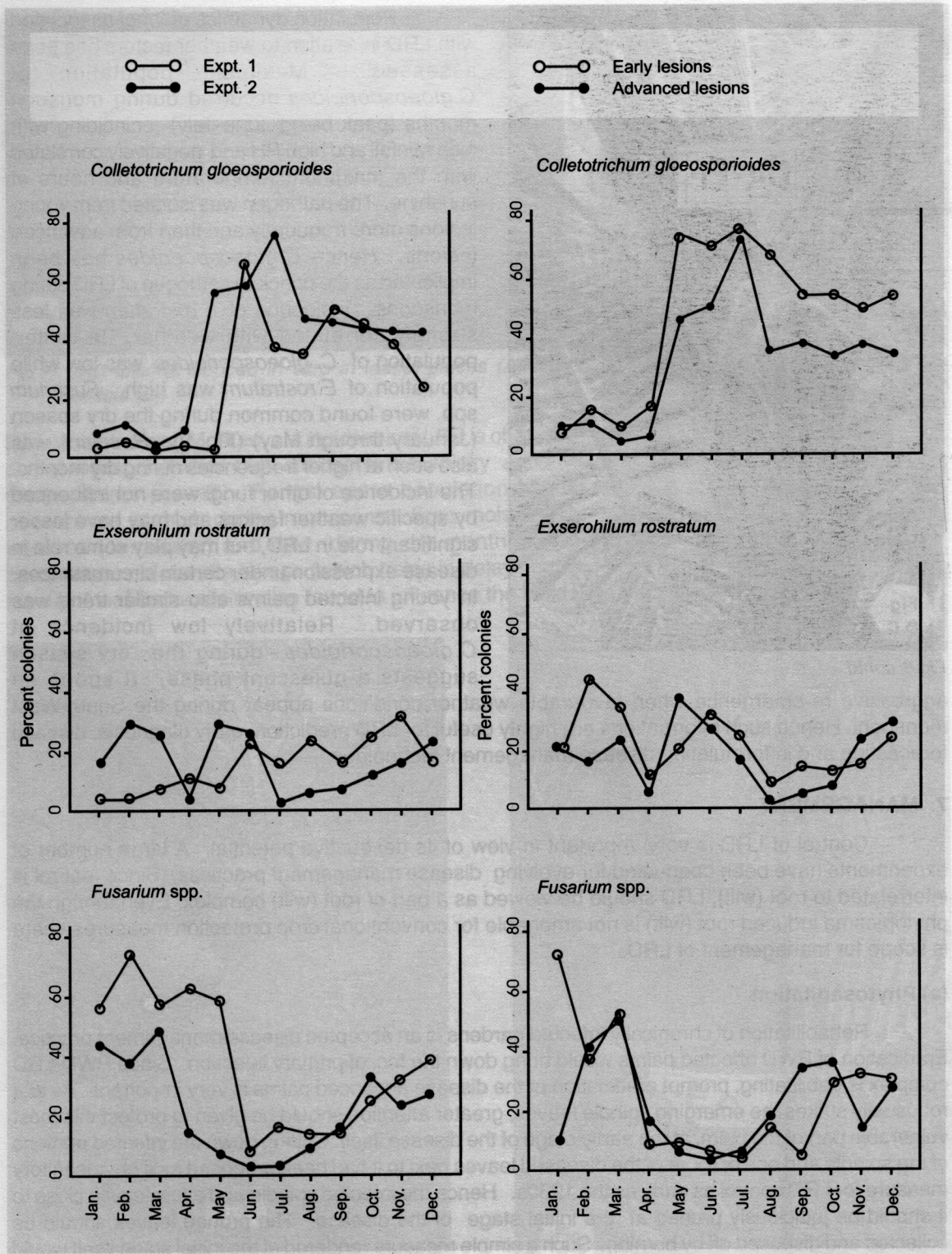


Fig. 9. Frequency of isolation of fungi in different months (based on colonies enumerated from leaf pieces).

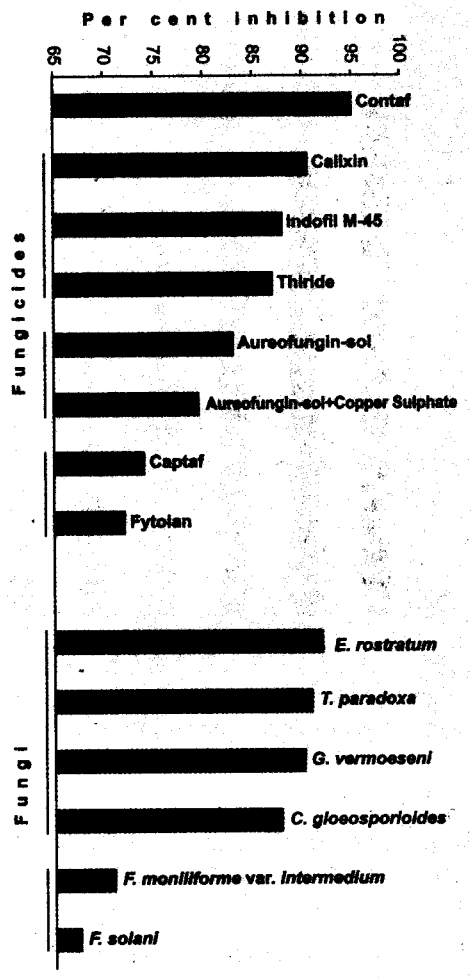


Fig.10. Comparative efficacy of fungicides and average growth inhibition of LRD fungi.

(b) Fungicides and chemicals

In vitro assay conducted at CPCRI (1950s-1960s) showed toxicity of various fungicides (Bordeaux mixture, Fungimar etc.) and chemicals (copper sulphate, mercuric chloride etc.) on *H.halodes*. Recent studies on the effect of various contact and systemic fungicides on the pathogens of LRD helped to identify an effective systemic fungicide-Hexaconazole (Contaf) - which has broad spectrum activity (Fig. 10).

The results of the field trials conducted since 1950s using contact fungicides are variable eventhough there were some reducton in the disease intensity. It was reported that spraying with Bordeaux mixture 1%, followed by Dithane M-45 0.3% and Fytolan 0.5% on diseased palms sequentially at quarterly intervals reduced the disease. However, no significant reduction in the disease was found in a trial involving Benlate, Agrimycin-100, Dasanit and plant nutrients (N, P, K, Ca, Mg and Zn).

Spraying fungicides/chemicals on coconut is cumbersome and labour intensive, and hence an alternate easy measure is preferable. Hence a simple method of pouring fungicide into the top leaf axil (well of the spindle) has been recently standardized. Application of fungicide by such a method reduces the leaf rot in newly emerging spindles (Fig.11). Combining the phytosanitation measure with pouring of Hexaconazole (Contaf) prevents incidence and also helps to suppress incipient infections from further development (Figs. 12 and 13).

(c) Biological control

During the 1950s it was found that the bacterium *Bacillus subtilis* and its culture filtrate were inhibitory to *H. halodes* and its infectivity on leaves. Recent studies showed that growing cultures of *Pseudomonas fluorescens* and its cell-free culture filtrate were found to be inhibitory to the various pathogens involved in leaf rot. The bacterial antagonist reduced lesion development under laboratory conditions. Antagonistic bacteria have been isolated from coconut rhizosphere and phylloplane that are inhibitory to leaf rot pathogens (Fig.14) and the scope for integrating biocontrol measure in LRD management is being evaluated.

(d) Cultural and agronomic practices

RWD infected palm is weakened and hence is predisposed to fungal attack. Consequent to LRD infection, the condition of the palm further deteriorates. Hence, measures like balanced application of organic manures and fertilizers, irrigation and all other routine cultural and sound agronomic measures should be adopted to keep the palms in good health and vigour which would largely reduce the LRD incidence and intensity.

(e) Disease resistance/tolerance

The need for a resistant / tolerant variety hardly deserves emphasis. The search for resistant / tolerant variety to combat the coconut disease(s) was stressed by Butler as early as 1908. The intensity of LRD has been found low in varieties where the incidence of RWD is low. The varieties such as Andaman Ordinary and New Guinea were found to be resistant to LRD. Similarly, the cultivars San Ramon, Guam, St. Vincent and Kenya recorded lower disease incidence. During the 1960s it was reported that in the variety Chowghat Green Dwarf (CGD) the LRD incidence was low.

Growing RWD cum LRD resistant/tolerant variety would form the best means of controlling the disease complex. The hybrid developed by crossing disease free CGD and West Coast Tall (selected in RWD hot spots) has been reported as tolerant to RWD. The response of such hybrids to LRD is being studied.

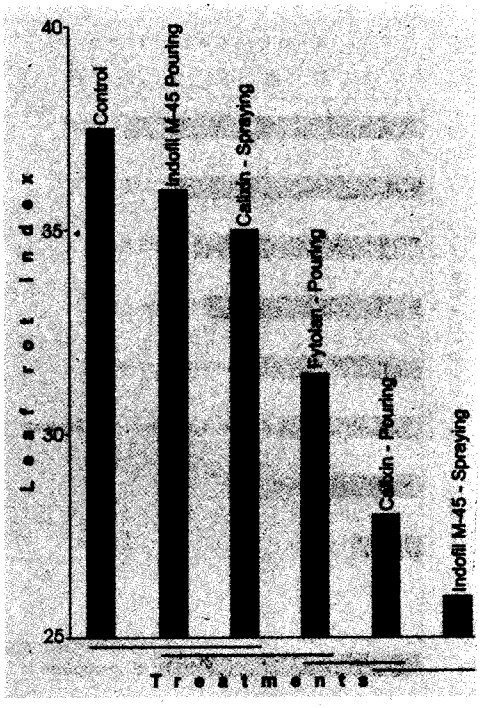
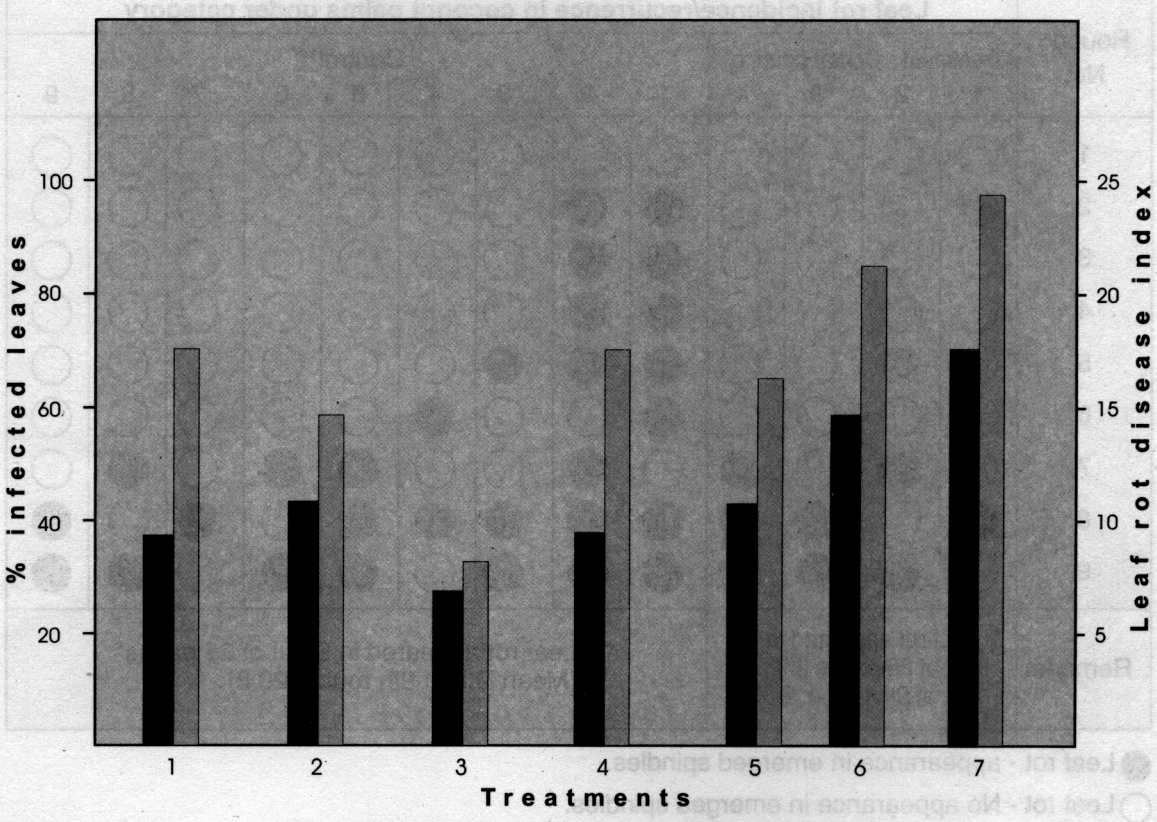


Fig. 11. Mean LRD indices in emerged leaves of coconut under different treatments in experiment 1.

(f) Integrated management

Based on the knowledge available, a systems approach with integrated measures is suggested for the management of the disease:

1. Removal of all disease advanced and uneconomic palms (both RWD alone and RWD with LRD). If replanting becomes necessary (based on crop density) use healthy seedlings from elite palms and varieties or hybrids tolerant to RWD/LRD.
2. Observe general recommendation practices as applicable to root (wilt) affected regions such as application of balanced dose of fertilizers and farm yard manure and growing green manure crops (for incorporation in the coconut basins); provision of proper drainage and irrigating the palms during summer. Judicious adoption of such practices right from planting onwards would enable them to grow in good health and vigour which by itself would help reduce the LRD incidence and intensity.
3. Regular monitoring of individual palms, especially the emerging spindle and other young leaves close to it. Pruning portions of spindles and young leaves showing symptoms. This should be followed by the pouring of an effective fungicide (e.g., Contaf 5E) at the recommended concentration around the base of the spindle leaf.
4. The treatment of palms at the initial stage itself would aid the palms to recover soon. If the disease has already progressed to a moderate extent, treatments may have to be prolonged. All treated palms should be kept under regular observations as the disease may recur.
5. General cleaning of crown (before the onset of monsoon) is advised so as to reduce the LRD inoculum. Activity of LRD (pathogen) is intense during rainy season and hence the palms should be properly monitored.
6. Leaf rot management measures could also be appropriately integrated with the control of other pests such as rhinocerose beetle, red palm weevil etc. However, caution should be exercised to



Sl. No	Treatment	C.D. (P = 0.01)
1.	Phytosanitation	: 21.9 7 6 5 2 1 4 3
2.	Contaf-pouring	
3.	Phytosanitation + Contaf - pouring	
4.	Contaf - spraying	: 9.5 7 6 4 1 5 2 3
5.	Phytosanitation + Contaf - spraying	
6.	Sequential spraying (Bordeaux mixture; Dithane M - 45; Fytolan) - one/round	
7.	Control	

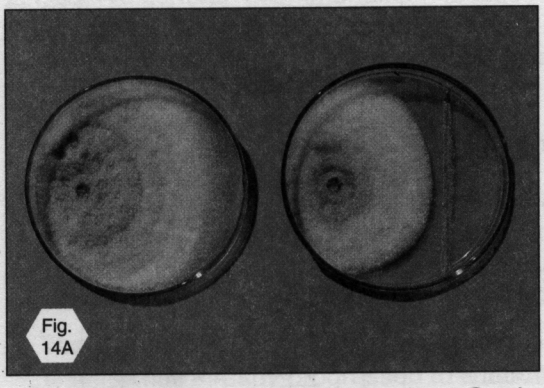
Fig. 12. Mean % of leaf rot infected leaves (■) and disease index (■) for emerged leaves of coconut under different treatments in experiment 2 .

Round No.	Leaf rot incidence/recurrence in coconut palms under category												
	Treatment : Contaf pouring*				Control**								
	1	2	3	4	1	2	3	4	5	6	7	8	9
1	○	○	○	○	○	○	○	○	○	○	○	○	○
2	●	○	○	○	●	●	○	○	○	○	○	○	○
3	○	○	○	○	●	●	○	○	○	○	○	○	○
4	○	○	○	○	●	●	○	○	○	○	○	○	○
5	○	●	○	○	●	●	●	○	○	○	○	○	○
6	○	○	○	○	●	○	○	●	○	○	○	○	○
7	○	●	○	●	○	●	○	○	●	●	○	●	○
8	●	○	●	●	●	●	●	●	●	○	●	○	●
9	○	●	●	○	●	●	●	○	●	●	○	●	●
Remarks	* Leaf rot appeared in 4 out of 25 palms (Mean D.I. at 9th round: 2.3)				** Leaf rot appeared in 9 out of 25 palms (Mean D.I. at 9th round: 20.8)								

● Leaf rot - appearance in emerged spindles.

○ Leaf rot - No appearance in emerged spindles.

Fig. 13. Leaf rot incidence - recurrence pattern in coconut palms under prophylactic control experiment.



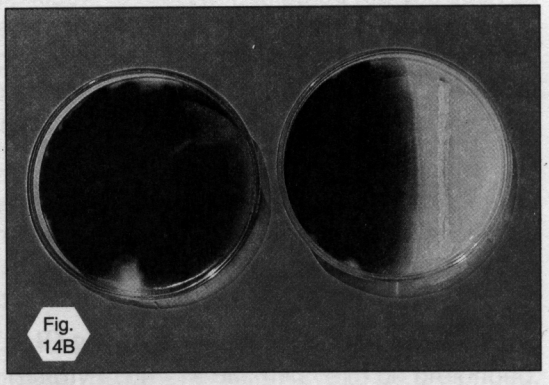


Fig. 14. Biocontrol of LRD pathogens, C. gloeosporioides (A) and E. rostratum (B),by fluorescent Pseudomonas (Left : Control).

avoid indiscriminate use of plant protection chemicals (while fixing their dosage, frequency etc.). The spindle is very soft, tender and sensitive. Therefore, the dosage and frequency of chemical application are very important as they may result in phytotoxicity and in environmental pollution.