KFRI Research Report No. 386

ISSN 0970 - 8103

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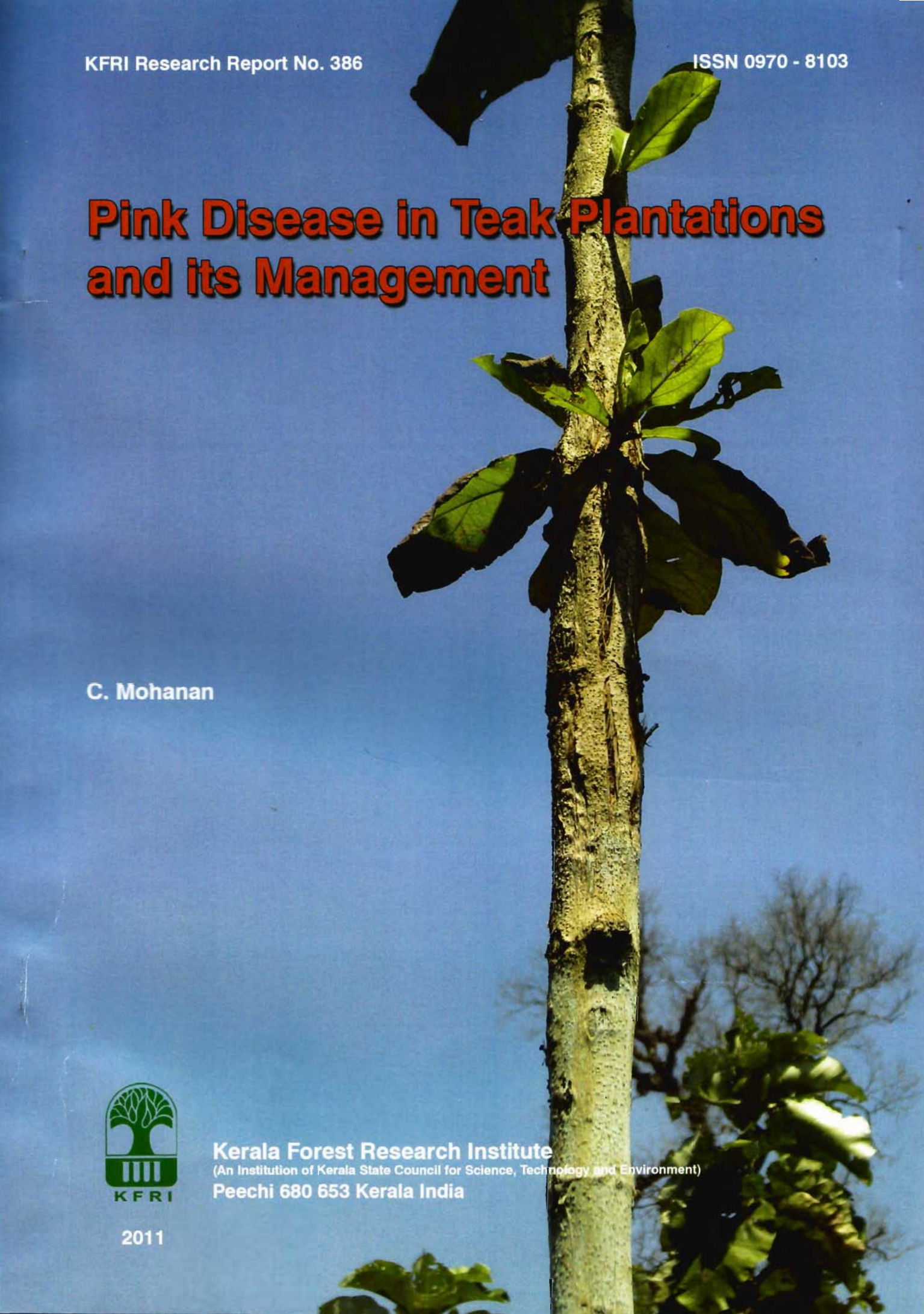

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(An Institution of Kerala State Council for Science, Technology and Environment)
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2011

PINK DISEASE IN TEAK PLANTATIONS AND ITS MANAGEMENT

(Final Report of Project No. KFRI 579/09)

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Abstract of the Project Proposal

1. Project No. KFRI 579/09
2. Project title: Pink disease in young teak plantations in Kerala and its management
3. Objective:
    i. To carry out a disease survey in young teak plantations
    ii. To work out disease management measures

4. Duration of project: One year
5. Date of commencement of the project: July 2009
6. Date of completion: June 2010
7. Project team:
   Principal Investigator: Dr. C. Mohanan
   Technical Assistant: Mr. Shiran, K.
8. Funded by: KFRI Plan Grants

Contents

ACKNOWLEDGEMENTS

The author is grateful to Dr. K.V. Sankaran, Director, KFRI for encouragement and support. The excellent technical assistance by Mr. K. Shiran in the field and laboratory, and help rendered by the field staff of Kerala Forest Department for selection of experimental plots in different teak growing areas of the State are gratefully acknowledged.

ABSTRACT

Young teak plantations in the State are affected by pink disease caused by *Erythricium salmonicolor* and often outbreak of disease occurs resulting in heavy damage to the stands. A short-term study was undertaken to assess the disease situation in young teak plantations in different Forest Circles of the State and to work out possible disease management measures. A total of 26 teak plantations of the age group 2- to 7-years-old were selected in the Central, Southern and Northern Forest Circles of the State. Observations on disease incidence and severity, measurements of tree height, girth, etc. were recorded from the selected plots. Causal organism, *Erythricium salmonicolor* was isolated from disease specimens collected from the plots and growth studies were carried out. Fungicides, Calixin (Tridemorph), Contaf (Hexaconazole) and Fytran (Copper oxychloride) at different concentrations were screened against selected isolates of *E. salmonicolor* employing poisoned food technique.

The disease survey revealed that pink disease occurs in all the 26 teak plantations selected for the study, however, incidence rate and severity vary depending upon the rainfall and microclimatic conditions, especially relative humidity in the site and age of the plantations. The highest incidence of disease and disease severity index were recorded in 2-year-old plantation at Kakkinada, Vazhani, Thrissur Forest Division. Mean disease incidence in this plantation was 65 per cent and mean disease severity index (dsi) was 0.78. In this plantation, multiple stem cankers were common and die-back and death of plants were also recorded. Among the plantations surveyed, the lowest disease incidence was recorded from 2-year-old plantation at Pulimunda, Nilambur South Forest Division. Mean disease incidence and mean dsi were 5.00 per cent and 0.05 respectively.

High rainfall together with persistence of very high atmospheric humidity for a long period in the teak stands, possible high genetic variability and coexistence of genetically different strains of pathogen in the same locality are possible factors for high incidence, development, and fast spread of the disease. Presence of large stretches of plantations of *Hevea brasiliensis, Acacia mangium, A. auriculiformis* or *Eucalyptus tereticornis* on the peripheral areas of teak stands possibly influences the microclimate, especially the relative humidity of the area. As these plantation species are potential hosts of *Erythricium salmonicolor*, there is also possibility of existence of genetically different strains of pathogen and also build up of inoculum potential of the pathogen. Presence of heavy weeds and undergrowths in the teak stands further contributes in maintaining the conducive environment for the growth and development of the pink disease pathogen.

Results of laboratory screening of fungicides showed that both the systemic fungicides, Calixin 80 EC (Tridemorph) @ 0.01 % a.i. and Contaf 5 EC (Hexaconazole) @ 0.001 % a.i. are highly effective in arresting the colony growth of *E. salmonicolor*. The contact fungicide Fytran (Copper oxychloride) was also effective @ 0.3% a.i. For managing the pink disease in plantation, application of Calixin @ 0.1% a.i. or Contaf @ 0.001 % a.i. as spray on main stem will be effective. However, to avoid or reduce the incidence of pink disease in young teak plantations, the scheduled silvicultural operations including weeding have to be carried out timely and promptly. Moreover, for achieving best result on disease management in teak plantation, more information on the genetic variability of pink disease pathogen and disease etiology is warranted.

INTRODUCTION

Teak (*Tectona grandis* L. f.), the prime forestry species in India, is one of the most favoured timbers all over the world. Teak is known for its strength, durability and attractive appearance and is the most sought after hardwood in the international markets. The ever-increasing demand for the teak timber has resulted in large-scale plantations both within and outside its range of natural distribution. It occurs in natural forests between 9° to 26° N latitude and 73° to 104° E longitude, which includes southern and central India, Myanmar, Laos People's Democratic Republic and northern Thailand (White, 1991). Teak has been introduced in South-East Asia, Indonesia, Sri Lanka, Vietnam, Malaysia and Solomon Island as well as in Africa and Latin America. In India, teak has a wide, but discontinuous distribution. It grows in dry and moist-deciduous forests below 24° N latitude in the States of Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Chattisgarh, Madhya Pradesh, Rajasthan, Uttar Pradesh, Manipur and Orissa.

There are about 8.9 million ha teak bearing forests in India within the precipitation range of 800 to 2500 mm per annum (Tewari, 1992). It grows well from sea level to an elevation of 1200 m a.s.l. Five sub-types of teak forests have been recognized, very dry, dry, semi-moist, moist and very moist (Seth and Khan, 1958). Teak shows poor growth in dry localities and thrives best in moist, warm and tropical climate. The first teak plantation in India was established in 1846 at Nilambur. At present about 1.5 million ha of teak plantations exist in India and about 5000 ha of teak plantations are raised annually (Subramanian *et al.*, 2000). Silvicultural practices like site matching, spacing, thinning methods, rotation age, and harvesting have been refined, yet the productivity of plantations is low and is declining steadily in successive rotations. The rotation period of teak plantations in India differs according to site conditions, environmental factors, management and varies from 40 to 80 years; dry teak plantations in Madhya Pradesh have 80 years and moist teak plantations in Kerala have 50 to 60 years rotation. Stump (prepared from 1-year-old bare root seedlings) are generally used for planting. However, recently, root trainer-grown seedlings (90-day-old) are used for raising large-scale plantations in Kerala and elsewhere.

Teak is one of the most researched tropical hardwoods. Almost the entire century that followed the first planting of teak was spent on perfecting the technique of growing teak plantations. Nursery techniques, choice of site, planting, weeding and maintenance of plantations, thinning, and fixing rotation age dominated the research priorities during the early years. More recently, emphasis has been given to standardize the nursery practices and production of quality planting stock (Chacko *et al.*, 2002; Mohanan, 2000, 2005, 2009) and also to improve the productivity of stand by fertilizer application and irrigation (Balagopalan *et al.*, 1998). Very recently, improvement of planting stock through vesicular arbuscular mycorrhizal application and there by improving the productivity of teak stands has been successfully field demonstrated (Mohanan, 2005, 2009).

In Kerala, productivity of teak plantations is alarmingly declining. A meager 2.85 m^3 ha^{-1} on an average for rotation of 53 years, where all thinning schedules were followed in Nilambur, Kerala has been reported (Chundamannil, 1998). Even though, many factors such as silvicultural measures, genetic make up of the plant and edaphic factors are partly responsible for the drastic reduction in stand productivity, pests, diseases and disorders play the most critical role, especially in warm humid tracts (Nair, 2005; Mohanan, 2009). Even though, teak is a hardy species, it suffers from a large number of diseases, which cause minor to considerable damage to the crop in young plantations in the establishing phase, as well as in old plantations and natural stands (Bakshi, 1976; Sharma *et al.,* 1985; Mohanan *et al.,* 1997; Jamaluddin, 2005; Mohanan, 2009). Fungi, bacteria and phanerogamic parasites are the agents associated with various diseases and disorders in teak.

Foliage diseases (leaf spot, leaf blight, powdery mildews, leaf rust) caused by various fungi widely occur in teak plantations through out the country (Sharma *et al.*, 1985; Jamaluddin, 2005; Mohanan *et al.*, 2007). Leaf spot (target spot) and leaf blight caused by *Phomopsis tectonae* and *P. variosporum* occur in both plantations and natural stands. In young plantations, especially, where the canopy' is almost closed before the first thinning, Phomopsis leaf spot emerges as a major foliage disease. Colletotrichum state of *Glomerella cingulata* causes foliage disease and occurs in teak stands throughout the country. The disease is widespread in teak stands in both dry and wet tracts (Bakshi *et al.*, 1972; Sharma *et al.*, 1985; Mohanan, 2005). In 1- to 2-

year-old plantations, *Phoma eupyrena* and *P. glomeratum* cause severe damage to the crop (Mohanan, 2005). Teak rust fungus *Olivea tectonae* occurs throughout the range of distribution of teak in India and causes severe foliage rust and thereby premature defoliation of the affected plants (Mohanan, 2010).

Die-back of teak caused by a fungus, *Phialophora richardsiae* associated with an insect borer, *Alcterogystia cadambae* (=*Cossus cadambae*) occurs in certain localities in the Kerala State (Sharma *et al.*, 1985). Severe infection occurs in plantations close to the human settlements. The insect borer (vector) plays a major role in spreading the fungus and the disease; the insect causes extensive damage to the wood by making numerous bore holes and galleries (Mohanan, 2005).

The disease caused by a bacterium, *Pseudomonas tectonae* affects 1- to 2-year-old teak plantations. Even though, the bacterial diseases in teak were recorded during 1980s in Kerala State (Sharma *et al.*, 1985) with little consequences, over the years, the disease incidence and severity have increased in plantations, especially those raised in high rainfall areas (> 2500 mm per annum) (Mohanan, 2009). The disease also occurs in other teak growing States (Jamaluddin, 2005). Occurrence of canker and die-back disease in young (1.5- to 2-year-old) teak plantations has been reported from different parts of the country (Jamaluddin, 2005; Mohanan, 2007). Severe incidence of disease occurs in plantations situated in high rainfall areas (>2000 mm per annum) and those under high input management system, where high dose of fertilizer application was carried out. The disease manifests in the form of longitudinal cankers on main shoot and branches; longitudinal splitting of the bark and partial to complete girdling of the cankered areas occurs resulting in die-back of the affected branches/main shoots. The causal fungus is *Phomopsis tectonae*.

Very recently, an epidemic outbreak of pink disease in young teak plantations in Vazhachal Forest Division has been reported by the author (Mohanan, 2008,2009). The disease severity was too high and disease affected more than 70 per cent of the plants in certain localities. Timely intervention and appropriate disease management measures saved the plantation and arrested the further spread of the disease.

Systematic disease survey was carried out in forest plantations including teak in the State by the author during 1979-1985. During 1980s, only branch canker caused by *Erythricium salmonicolor* was recorded from teak stands in different parts of the State (Sharma *et al.*, 1985). Disease incidence and severity was too low and main stem canker seldom observed.

As the threat from pink disease in young 1- to 3- year-old plantations has been reported from different Forest Divisions of the State, a one-year study was undertaken to conduct a quick survey on pink disease in young teak plantations through out the State and to work out disease management measures.

MATERIALS AND METHODS

Selection of plantations for disease survey and recording observations

Teak plantations of the age group 2- to 7-years-old were selected in the Central, Southern and Northern Forest Circles of the State (Table 1). Three plots each of 50 x 50 m were selected in representative plantations in each Forest Division. From each plot, a total of 40 plants from alternate rows were selected and observed for the incidence of disease. The disease incidence and severity in each selected plant was recorded on a numerical scale (1-3) of disease rating index as given in Table 2. The average severity index of pink disease (dsi) in a plantation was calculated from the sum of total number of trees of each severity rating (dsr) in all the plots multiplied separately by the disease index (1-3) and dividing it by the total number of trees assessed (N) as given in the following formula:

$$\text{Disease severity index (dsi)} = \frac{nL \times 1 + nM \times 2 + nS \times 3}{N}$$

Where nL, nM, nS represent total number of plants with low (L), medium (M) and severe (S) disease severity; 1,2,3 disease severity index (dsi) for low, medium and severity respectively and N the total number of trees assessed in all the observation plots. The per cent incidence of disease in plantation was calculated from the total number of plants affected (nd) and total number of plants observed in all the plots (N):

$$\text{Per cent incidence} = \frac{nd}{N} \times 100$$

Height and gbh of the selected plants from the observation plots were also recorded.

Table 1. Teak plantations surveyed for pink disease

No.	Location	Forest Division	Age of plantation
1	Chettikulam	Chalakudi	7 year
2	Kanhirakadav	Nilambur South	5 year
3	Ayyanppuzha	Vazhachal	4 year
4	Mundumuzhi	Konni	4 year
5	Ayyanppuzha	Vazhachal	3 year
6	Meenakshipathu	Thrissur	3 year
7	Kombankallu, Edavana	Nilambur North	3 year
8	Kanhirakadav	Nilambur South	3 year
9	Kummanur	Konni	3 year
10	Avanipara	Konni	3 year
11	Naduvathumzhy	Konni	3 year
12	Kanhirakadav	Nilambur South	< 3 year
13	Pattanikadu	Thrissur	2 year
14	Kakkinikad, Vazhani	Thrissur	2 year
15	Akamala, Panamkutti	Thrissur	2 year
16	Pulimunda 1955 FFA	Nilambur South	2 year
17	Chembamkandum	KFDC, Thrissur	2 year
18	Avanipara	Konni	2 year
19	Elanad	Thrissur	< 2 year
20	Edakod	Nilambur North	< 2 year
21	Pulimunda 1956 FFA	Nilambur South	< 2 year
22	Udampanur	Konni	< 2 year
23	Peruvaley	Konni	< 2 year
24	Kummanur	Konni	< 2 year
25	Valayam	Konni	< 2 year
26	Naduvathumzhy	Konni	< 2 year

Table 2: Disease index to assess the severity of pink disease in plantation

Disease severity	Main stem canker	Branch canker	Disease severity index (1-3)
Nil	Nil	Nil	0
Low (L)	1 canker, no apparent damage to tree	Up to 25% of the shoots of plant affected	1 (0.1-1)
Medium (M)	1-2 cankers; epicormic shoots present	> 25-50% of shoots of plant affected	2 (1.1-2)
Severe (S)	Multiple cankers; girdling, epicormic shoots, partial die-back	>50-75% of the shoots of plants affected	3 (2.1-3)

Collection of disease materials and isolation of causal organisms

Disease specimens were collected from the field; a small portion of bark from the diseased 'cankered' area was removed and aseptically kept in the polythene bags and brought to the laboratory. Isolation of the causal organism was made on potato dextrose agar medium.

Meteorological data collection

Meteorological data, viz., rainfall, max-minimum temperature, relative humidity, wind speed, etc. were collected from plantations or from the nearby weather stations.

Growth studies on *Erythricium salmonicolor*

Erythricium salmonicolor isolated from cankered areas of teak from different teak growing areas in the State were subjected to growth studies. A total of 10 isolates of *E. salmonicolor* were grown on potato dextrose agar medium and colony diameter growth and morphological characteristics were recorded from 3rd day to 8th day.

Screening of fungicides against *Erythricium salmonicolor*

Isolates of *E. salmonicolor* were selected on the basis of their colony morphological and growth characteristics. Among 10 isolates of *E. salmonicolor,* five isolates from Ayyampuzha (Vazhachal Forest Division), Udumpannur (Konni Forest Division), Kombankallu (Nilambur North Division), Chettikulam (Chalakkudy Forest Division)

and Kakkinikkad (Thrissur Forest Division) were selected for fungicidal screening. Fungicides were screened against *E. salmonicolor* employing poisoned food technique. To obtain a desired concentration, an appropriate quantity of the test fungicide was mixed thoroughly with the sterilized potato dextrose agar medium (PDA) before it solidified. Each concentration of fungicide was replicated in five Petri dishes which were inoculated in the centre with a mycelial disc of 3 mm diam., cut from the margin of an actively growing colony of selected isolate of *E. salmonicolor*. Three fungicides viz., Calixin 80 EC (Tridemorph), Contaf 5 EC (Hexaconazole) and Fytran 50% (Copperoxychloride) were selected for the study and various concentrations ranging from 0.1 to 0.0001 % a.i were screened against five selected isolates of *E. salmonicolor*. The inoculated Petri dishes were incubated at 25 +-2^{0}C and three to four observation of diameter growth of the colony recorded.

RESULTS AND DISCUSSION

Pink Disease: Causal organism

Erythricium salmonicolor (Berk. & Broome) Burds. (= *Corticium salmonicolor* Berk & Broome) is the causal agent of the disease. *E. salmonicolor* has a very wide host range and includes both indigenous and exotic, agricultural, horticultural and forestry species. Very high genetic variability in pathogen has recently been reported (Fernuda Luiza de Souza *et al.*, 2007).

Pink disease: Disease symptoms and stages of infection

The disease appears as small 3-5 mm long vertical crack on bark around the main stem. The infected areas become slightly depressed. The number of the vertical cracks increases quickly often covering the entire girth of the main shoot. The length of the vertical slits also increases reaching 5-15 cm. Tissues of inner bark including cambium in the affected area become necrotic and killed. At this stage of infection, the vertical splitting of the bark becomes very prominent, exposing the inner wood of stem. The cankered area reaches about 5-20 cm in length and 40-90 per cent of the girth of the shoot causing partial girdling of the stem. Numerous epicormic shoots

develop from below the cankered area. Complete girdling of stem at cankered area occurs which lead to die-back of the main shoot above the cankered area. In young teak plants (2 to 3-year-old), under conducive microclimatic conditions, multiple cankers are produced along the main shoot. Development of 3 to 7 multiple cankers of 10-20 cm in length along the main shoot are observed in severely affected areas. These cankers often coalesce together which lead to death of the plants (Figs.2-4).

The pathogen usually exhibits four stages of infection viz., cobweb, pustule, basidial or pink encrustation and necator. Depending on the microclimatic conditions prevailing in the site, one or two infection stage (s) may be missing or overlapping. The cobweb stage occurs first and fungal mycelium spreads over the surface of the main shoot. This is followed by the pustule stage; small pin-head sized mycelial bodies of the fungus develop over the cobweb (Plate 1). The perfect stage, characterized by pink encrustation, develops over the diseased area. Numerous club-shaped basidia with basidiospores develop on the pink encrusted area ((Plate 1). Development and progression of these three infection stages require high humidity. Necator stage usually occurs during dry period (Plate 1).

Disease incidence and severity in plantations

Pink disease was observed in all the 26 teak plantations selected for the study, however, incidence rate and severity vary depending upon the rainfall and microclimatic conditions, especially relative humidity in the site and age of the plantations. The highest incidence of disease and disease severity index were recorded in 2-year-old plantation at Kakkinada, Vazhani, Thrissur Forest Division. Mean disease incidence was 65.00 per cent and Mean Disease Severity Index (dsi) was 0.78 (Table 3). In the plantation, multiple stem cankers were common and die-back and death of plants were also recorded. The lowest disease incidence was recorded from 2-year-old plantation at Pulimunda, Nilambur South Forest Division. Mean disease incidence and mean dsi were 5.00 per cent and 0.05 respectively. Of the eight plantations of 3-year-old group surveyed, disease incidence ranged from 12.5-47.5 per cent and dsi ranged from 0.13-0.56. The girth at breast height (gbh) of main shoot ranged from 14.3- 21.1 cm. In this group, highest disease incidence of 47.4 per cent was observed in a plantation at Ayyampuzha, Vazhachal Forest Division. Mean dsi

recorded was 0.56. Earlier, in the same location an outbreak of pink disease was recorded affecting more than 78 per cent of the plants (Mohanan, 2008).

Table 3:Disease incidence and severity in teak plantations surveyed

No.	Location	Forest Division	Age of platation (year)	Mean gbh (cm)	Mean DSI	Mean Incidence (%)
1	Chettikulam	Chalakudi	7	19.7	0.42	36.50
2	Kanhirakadav	Nilambur South	5	20.9	0.28	25.00
3	Ayyanppuzha	Vazhachal	4	23.3	0.73	54.17
4	Mundumuzha	Konni	4	24.3	0.25	21.67
5	Ayyanppuzha	Vazhachal	3	20.8	0.56	47.50
6	Meenakshipathu	Thrissur	3	21.1	0.48	37.50
7	Kombankallu, Edavana	Nilambur North	3	15.2	0.13	12.50
8	Kanhirakadav	Nilambur South	3	21.1	0.34	29.38
9	Kumanur Station	Konni	3	19.5	0.23	22.50
10	Avanipara	Konni	3	20.2	0.30	26.70
11	Naduvathumzhy	Konni	3	15.5	0.20	17.50
12	Kanhirakadav	Nilambur South	< 3	14.3	0.32	28.22
13	Pattanikadu	Thrissur	2	11.7	0.58	50.00
14	Kakkinikad, Vazhani	Thrissur	2	14	0.78	65.00
15	Akamala Panamkutti	Thrissur	2	11.5	0.14	14.17
16	Pulimunda 1955 FFA	Nilambur South	2	5.1	0.05	5.00
17	Chembamkandum	KFDC	2	14	0.43	41.67
18	Avanipara	Konni	2	16.5	0.25	23.75
19	Elanad	Thrissur	> 1	6.5	0.13	12.50
20	Edakod	Nilambur North	> 1	6.2	0.07	5.83
21	Pulimunda 1956 FFA	Nilambur South	> 1	5.0	0.10	9.50
22	Udampanur	Konni	> 1	6.1	0.33	26.67
23	Peruvaley	Konni	> 1	6.1	0.21	16.25
24	Kumanur Station	Konni	> 1	8.2	0.16	13.99
25	Valayam	Konni	> 1	11.3	0.17	16.67
26	Naduvathumzhy	Konni	> 1	12.2	0.13	12.50

*DSI: Disease severity index; gbh: girth at breast height

Among the six plantations belonging to 2-year-old category, disease incidence ranged from 5-65 per cent. The girth of main shoot of this group ranged from 11.5-16.5 cm. The highest per cent disease incidence was recorded in Kakkinad, Vazhani, Thrissur Forest Division followed by Pattanikkadu, Thrissur Forest Divisions with 50 per cent disease incidence and dsi 0.58. Of the eight plantations belonging to the category of less than 2-year-old, the per cent disease incidence ranged from 5.83-26.67 and dsi

ranged from 0.07-0.33. The gbh of main shoot ranged from 5.00-12.20 cm. In 4 to 5-year-old plantations disease incidence ranged from 21.67-54.17 per cent. The highest disease incidence was recorded in plantation at Ayyampuzha, Vazhachal Forest Division with comparatively very high dsi (0.73). Pink disease incidence (36.5%) was also recorded in a 7-year-old plantation (trial plot) at Chettikulam, Chalakkudy Forest Division.

Among the Forest Divisions, very high pink disease incidence was recorded in Thrissur and Vazhachal Forest Divisions. Disease incidence in plantations in Thrissur Forest Division ranged from 14-65 per cent and dsi ranged from 0.14-0.78. Among the 10 teak plantations of 2 to 4-year-old surveyed in Konni Forest Division, the disease incidence ranged from 12.5-26.00 per cent and dsi ranged from 0.13-0. 33. Comparatively low incidence of disease was recorded in both Nilambur South and North Forest Divisions. In plantations in Nilambur South Division, the disease incidence ranged from 5-29 per cent. In Nilambur North Forest Division disease incidence ranged from 5-12 per cent.

Table 4. Pink disease severity and severity index in teak plantation during 1980-1982

Locality	1980			1981			1982		
	Incidence (%)	DSI	DSR[b]	Incidence(%)	DSI	DSR[b]	Incidence (%)	DSI	DSR[b]
Rampur	4.07	0.07	L	5.42	0.17	L	6.27	0.25	L
Kudhirakkode	8.08	0.13	L	12.42	0.13	L	13.88	0.16	l
Mundukadavu	0	0	-	0	0	-	-	-	-
Ezhuthukallu	7.82	0.08	L	1.05	0.03	L	-	-	-
Thundathi	7.27	0.08	L	11.43	0.12	L	12.82	0.16	L
Naduvathumoozhi	0	0	-	0	0	-	0	0	-
Mampazhataraa	13.12	0.13	L	19.9	0.18	L	-	-	-
Choodal	3.35	0.05	L	17.56	0.09	L	31.61	0.17	L

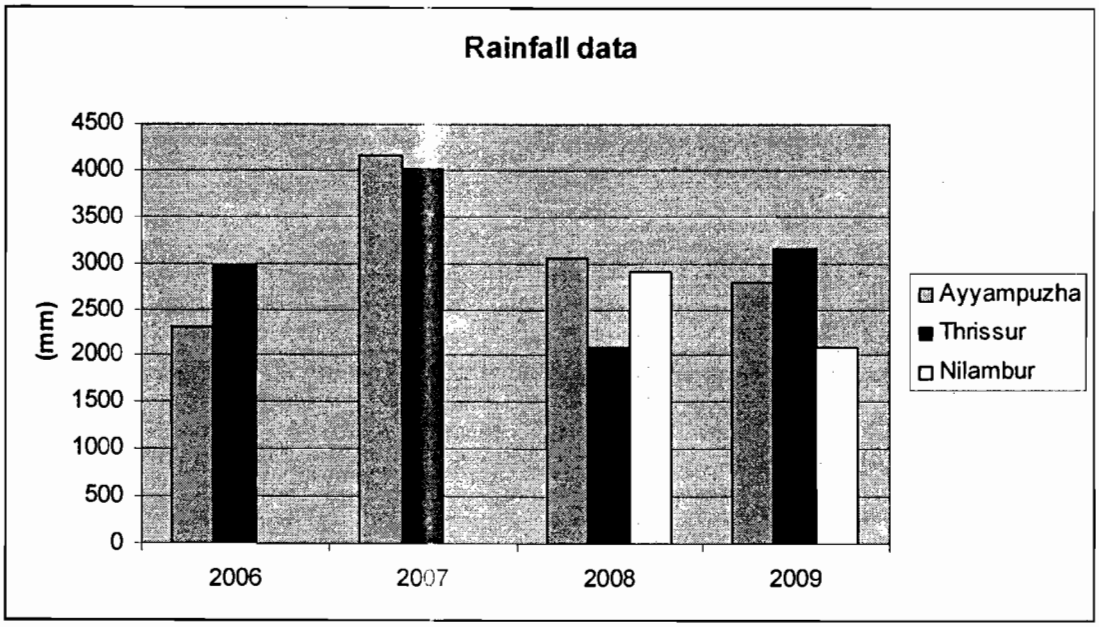
*DSI: Disease severity index; DSR: Disease severity rating; L : low.

Factors affecting the disease outbreaks

High rainfall together with very high atmospheric humidity in the plantation serves as the conducive environmental factors for the development and spread of the disease. Plantation areas in Thrissur Forest Division received an average rainfall of 3150 mm during 2009 (Fig. 1). The corresponding figure for Ayyampuzha and Nilambur are 2800 and 2090 respectively. Maximum disease incidence was recorded in teak

plantations in Thrissur Forest Division followed by Vazhachal and Nilambur Forest Divisions. Thus, there is a direct correlation between high rainfall and high disease incidence. Further, an outbreak of pink disease in 2-year-old plantation at Ayyampuzha, Vazhachal Forest Division occurred during the year 2007; the rainfall for the corresponding year was very high, 4150 mm. During the following years 2008 and 2009, the rainfall was 3050 and 2800 mm respectively and the disease incidence was also reduced considerably during these years.

Figure 1. Raifall data from teak stands at Ayyampuzha, Thrissur and Nilambur



Also, disease incidence was very high in young plantations with very intense weed growth. The poorly managed young stands with very heavy undergrowths increase the atmospheric humidity, and thus make conducive environment for the growth and development of the pink disease pathogen. Most of the young teak plantations, where very high disease incidence was recorded, are surrounded by large stretches of rubber, acacia or eucalypt plantations. These large stretches of these plantations serve to maintain the high humidity in the site for a long period. Moreover, rubber (*Hevea brasiliensis*), acacia (*Acacia mangium, A, auriculiformis*), eucalypt (*Eucalyptus tereticornis*) are potential hosts of the pink disease pathogen. Pink disease occurring in acacia stands is usually not managed. However, in rubber plantations (private plantations), the disease is managed by chemicals. Hence, the presence of these

potential hosts possibly increases the build up of inoculum potential of the pathogen in the site.

Growth studies on *E. salmonicolor*

All the ten isolates of *E. salmonicolor* exhibited almost similar colony growth characteristics (Plate 2). Isolate Nos. ES4 and ES5 showed comparatively fast growth between 3rd and 5th day of incubation and reached colony diam. of 8.2 and 8.6 cm respectively and attained 90 mm on 6th day. However, all the isolates except isolate No. ES2 and ES3 attained 90 mm diam. growth on 7th day of incubation. All the 10 isolates reached 90 mm diam. growth on 8th day of incubation.

Table 4. Growth characteristics of *E. salmonicolor*

Isolate No.	Growth (mm)				
	3rd day	5th day	6th day	7th day	8th day
ES 1	2.1	5.2	7.3	9.0	>9
ES 2	2.0	4.5	6.0	8.0	9.0
ES 3	2.0	4.5	6.2	8.1	9.0
ES 4	2.6	8.2	9.0	>9.0	>9.0
ES 5	2.5	8.0	9.0	9.0	>9.0
ES 6	1.8	6.6	8.8	9.0	>9.0
ES 7	2.5	6.7	8.8	9.0	>9.0
ES 8	2.3	6.5	8.7	9.0	>9.0
ES 9	2.2	6.9	8.7	9.0	>9.0
ES 10	2.2	6.8	8.7	9.0	>9.0

Efficacy of fungicides against *E. salmonicolor*

Of the five different concentration of Calixin (Tridemorph) viz., 0.05%, 0.01%, 0.005%, 0.002%, 0.001% tested, complete inhibition of growth of the test fungus was obtained at 0.01% a.i. At the concentration of 0.005 % a.i, very slight growth of *E. salmonicolor* was noticed on 6th day of incubation (Table 5). Among the six concentration of contaf (Hexaconazole) viz., 0.05%, 0.01%, 0.005%, 0.002%, 0.001%, 0.0005% a.i tested complete inhibition of growth of *E. salmonicolor* , except at 0.0005% a.i. was observed. At 0.0005% a.i, very slight growth of the test fungus was observed on 5th day of incubation. Of the eight concentrations of Fytran

(Copperoxychloride) viz., 1%, 0.55, 0.3%,0.2%, 0.15, 0.05%, 0.01%, 0.005%, complete inhibition of growth of the test fungus was obtained in 0.3% a.i, 0.5% a.i and 1% a.i. Comparatively, inhibition of growth of the test fungus occurred at very high concentration.

Table 5. Results of fungicidal evaluation against *E. salmonicolor*

Treatment	Growth of *E. salmonicolor* (mm)			
	2nd day	4th day	6th day	8th day
Control	0.5	2	5	9
Calixin(80E.C)				
0.05	0	0	0	0
0.01	0	0	0	0
0.005	0	0	0.2	0.5
0.002	0	0.5	0.9	2
0.001	0.5	1	1.5	2.5
Contaf(5EC)				
0.05	0	0	0	0
0.01	0	0	0	0
0.005	0	0	0	0
0.002	0	0	0	0
0.001	0	0	0	0
Fytran (50WP)				
1.0	0	0	0	0
0.5	0	0	0	0
0.3	0	0	0	0
0.2	0	0	0.4	0.5
0.1	0	0.2	0.6	1
0.05	0	0.5	1	1.5
0.01	.5	1.5	4	6
0.005	.5	2	6	9

Disease management in plantation

Outbreak of pink disease in young teak plantations of the State is a major concern, since it affects the stand establishment and productivity. Teak is comparatively less susceptible to major fungal pathogen, including *Erythricium salmonicolor*. Earlier,

mild branch infection has been reported on teak from Kerala (Sharma *et al.*, 1985) and main shoot canker seldom occurs. It seems that increase in virulence of pathogen may the possible major factor for the sudden outbreak of the disease. Recently, very high genetic variability in *Erythricium salmonicolor*, has been reported (Fernuda Luiza de Souza *et al.*, 2007). Possibility of coexistence of genetically different strains of *E. salmonicolor* in the same region, presence of large stretches of potential hosts like rubber (*Hevea brasiliensis*), acacia (*Acacia mangium, A. auriculiformis*), *Eucalyptus tereticornis* in the peripheral area which contributes to the build up of the inoculum potential of the pathogen, together with conducive environmental factors for the growth, development and spread of the pathogen prevailing in the plantation, may predict greater difficulty of management of this disease. Screening of fungicides against *E. salmonicolor* showed that both the systemic fungicides, Contaf 5E (Hexaconazole) and Calixin 80 EC (Tridemorph 80 EC) in very low concentration were effective. Fytran (Copper oxychloride) in high concentration was also effective against *E. salmonicolor*. On the basis of laboratory studies, for managing the pink disease in plantations, application of Calixin 80 EC @ 0.01% a.i or Contaf 5EC @ 0.001% a.i. is recommended. Earlier, field application of Calixin @ 0.01% a.i. was carried out in a severely diseased plantation at Ayyampuzha during 2007 and encouraging results obtained (Mohanan, 2008). Further, for reducing the incidence and spread of the disease, proper stand management measures including timely weeding in young plantations is required.

CONCLUSION

Young teak plantations in high humid tracts in different Forest Divisions of the State exhibit very good growth performances. However, most of these young teak stands are affected by pink disease and often outbreak of disease occurs resulting in heavy damage to the stands. High rainfall and persistence of very high atmospheric humidity in the teak stands are possible factors for incidence, development, and spread of the disease. Presence of large stretches of plantations of *Hevea brasiliensis, Acacia mangium, A. auriculiformis* or *Eucalyptus tereticornis* on the peripheral areas of teak stands possibly increases the relative humidity of the area. As these plantation species are potential hosts of *Erythricium salmonicolor*, there is also possibility of build up of inoculum potential of the pathogen in this area. Presence of heavy weeds

in the teak stands further contributes in maintaining the conducive environment for the growth and development of the pink disease pathogen. Both the systemic fungicides, Calixin 80 EC (Tridemorph) and Contaf 5 EC (Hexaconazole) were highly effective in arresting the growth of *E. salmonicolor* under laboratory conditions. Calixin @ 0.1 % a.i and Contaf @ 0.001 % a.i were highly effective against *E. salmonicolor*. The contact fungicide Fytran (Copper oxychloride) was effective at 0.3% a.i. Application of Calixin @ 0.1% a.i. or Contaf @ 0.001 % a.i. will be effective for managing the pink disease in young teak plantations. However, to avoid or reduce the incidence of pink disease in young teak plantations, the scheduled silvicultural operations including weeding have to be carried out timely and promptly.

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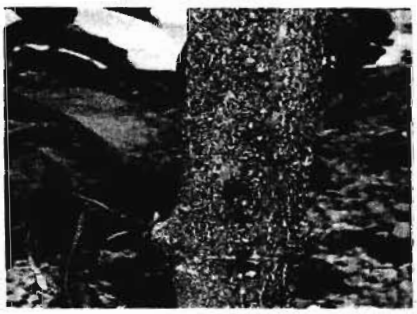
2-year old teak plantation

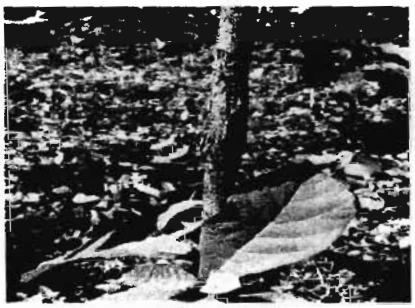
Erythricium salmonicolor: pustule stage

Basidial stage



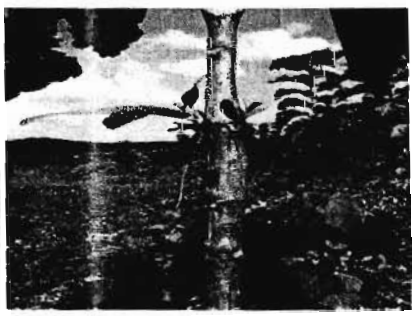
Necator stage of *E. salmonicolor*

Stem canker and necator stage



Pink disease: stem canker: various stages of infection

Production of epicormic shoots



Pink disease: multiple cankers on main shoot

Pink disease: multiple stem cankers on main shoot: different stages

Yellowing of foliage and stem girdling

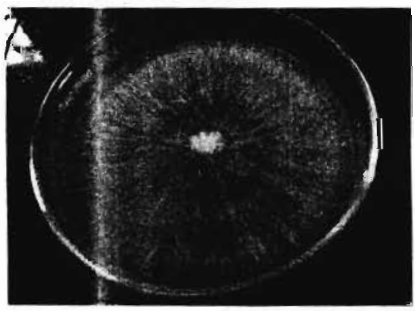
Stem canker: longitudinal spliting of bark and exposing the wood

Longitudinal spliting of bark

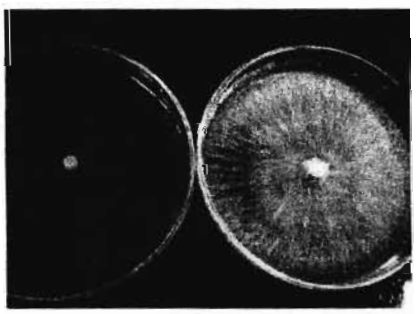
Partial girdling of stem

Girdling and die-back of main shoot

Die-back of main shoot



Erythricium salmonicolor colony



E. salmonicolor