KFRI Research Report No: 403 **ISSN 0970-8103**

Pollination ecology of teak in Kerala
Phase 2: Control of premature fall of teak flower and fruit

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August 2011

CONTENTS

PROJECT PROPOSAL

Project No.	KFRI 292/98 - Phase 2
Title	Pollination ecology of teak in Kerala Phase 2: Control of premature fall of teak flower and fruit
Principal Investigator	Maria Florence E.J
Associate	Mohanadas K
Project fellow	Baburaj T.S
Objectives	(i) Survey of fungi associated with premature flower and fruit fall of teak. (ii) Control of flower and fruit fall using fungicides in different teak seed orchards in Kerala. (iii) Study the role of insects in spreading the fungal infection.
Date of commencement	July 2001
Duration	Three and a half years
Funding agency	Kerala Forest Department

ACKNOWLEDGEMENTS

We are grateful to Dr. K.S.S. Nair and Dr. J.K Sharma, former Directors of Kerala Forest Research Institute, Peechi for their keen interest and support during the study and the present Director, Dr. R Gnanaharan for his valuable suggestions. We are thankful to the Kerala Forest Department for providing necessary funds without which this work would not have been possible. We acknowledge the help extended by Dr. T.C Narendran, Professor, Department of Zoology, Calicut University for identifying the insects and advice throughout the study. The overall guidance given by Dr. R.V Varma, the former Programme Coordinator, Forest Protection Division is also acknowledged. We are very much grateful to Dr. George Mathew, Programme Coordinator, Forest Protection Division for identifying the Lepidopteran group of insects. We extend our sincere gratitude to all our colleagues in Forest Protection Division for helping in various stages of work. Our work will not have been completed by the services extended by Mr. Subash Kuriakose, Artist Photographer for taking the photographs. Useful comments and suggestions by Dr. K.C Chacko, Programme Coordinator, Extension and Training Division, Dr. K.V Sankaran, Scientist, Forest Protection Division, and Dr. George Mathew, Scientist in Charge (Facility), Forest Protection Division for improving the report are gratefully acknowledged.

ABSTRACT

Teak (*Tectona grandis* Linn.) is a valuable and widely planted hardwood tree species in the tropics. Low fruit production and poor germination are the major problems associated with its propagation. One of the main reasons for the poor fruit production is premature flower and fruit fall. A preliminary survey in Thrissur district of Kerala State, India indicated that one of the reasons for premature flower and fruit fall was fungal infection on floral parts. The survey revealed that the premature flower/fruit fall is widespread throughout the state and is due to fungal infection by *Phomopsis tectonae* on floral parts and fruits. Spraying of 0.5% of Carbendazim (Bavistin) or Chlorothalonil (Kavach) on the teak inflorescence at the bud formation stage is effective in preventing the infection and enhancing the seed setting.

Introduction

Teak (*Tectona grandis* Linn.) is one of the most valuable and widely planted tree species in South Asia. About 94 per cent of global teak plantation is in tropical Asia, with the major chunk (44 per cent) in India (Pandey and Brown, 2000). Being highly adapted to a wide range of climatic and edaphic conditions, teak is preferred for large-scale plantation programmes all over the country. In Kerala, about 76,000 ha have been planted with teak (Kerala Forest & Wildlife Department, 1999).

Low fruit production and poor germination have been reported to be the major problems in teak propagation (Anmol Kumar and Kumar, 1992; Bedell and Vijayachandran, 1994). Teak shows extremely low flower to fruit ratio. Under natural pollination fruit setting is as low as 0.2 to 2% (Chawhaan *et al*., 2003). Ovule to seed ratio is also extremely low. About 10-35% fruits are reported to be seedless (Indira and Mohanadas, 2002). Premature flower and fruit fall is another important factor leading to low seed production in teak. Due to the above reasons, the quantity of seeds produced and the germination percentage were found to be too low to meet the current demands.

Fungal pathogens have been reported to regulate the reproductive output in many tropical plants. Premature abscission of the reproductive parts due to fungal infection and persistence of fungus in the developing fruits during their maturation period is reported as problems in teak fruit development (Mohanadas *et al*., 2003).

Insufficient numbers of pollinators, attack by insect pests, rain damage, premature fruit abortion due to unknown physiological reasons and fungal infection have been reported to be some of the reasons for low fruit setting in teak (Hedegart, 1973). The insect pollinators play an important role in teak seed setting. Mathew *et al*. (1987) studied the insect pollinators of teak in Kerala. Seventeen species of insect pollinators were recorded, of which 13 were hymenopterans and two each of dipterans and lepidopterans. A preliminary study conducted under the project entitled “Pollination ecology of teak in Kerala” (KFRI 292/98) revealed that one reason for the premature flower and fruit fall was associated with the infection by a fungus viz., *Phomopsis* sp. The present investigation was undertaken to study the fungi causing premature flower and fruit fall of teak and its control and the role of insect pollinators in spreading the fungal infection.

2. Materials and Methods

2.1 Preliminary survey

A preliminary survey conducted in different teak plantations and isolated trees in Thrissur district to study the abnormal flower/fruit fall of teak revealed that one of the reason for the premature fall is due to fungal infection. In order to establish the results obtained from the preliminary survey, an exhaustive study was carried out for understanding the cause of flower and fruit fall in teak plantations throughout Kerala.

2.2 Survey in the state and seed orchards

The survey started from the end of May to August. As far as possible teak trees from different plantations of each Forest Circle were selected for the survey. In a plantation three trees are selected randomly for the survey. Seed orchards at Arippa, Palappilly, Nilambur and Kalluvettamkuzhy were also surveyed for identifying the cause of premature flower/fruit fall.

2.3 Collection of samples

For examining the fungal infection as well as the damage caused by insects, 10-15 inflorescences were selected at random from each tree. For evaluating the infection, the total number of healthy and infected buds, flowers and fruits were counted from each selected inflorescence and infection percentage calculated. The buds or flowers or fruits damaged by the insects were also counted. During the survey, some inflorescences on teak trees were also found drying. To understand the cause of drying, the dried inflorescences were collected to isolate the pathogen. Infected bud, flower and fruit samples from each inflorescence were also collected for isolation of the causal organism.

2.4 Isolation of Pathogen

Isolations were made from dried inflorescence, discoloured buds, flowers and fruits separately in the laboratory. The dried fruit stalk and inflated and persistent calyx were also used for isolating the pathogen. The infected seeds were cut open to examine the fungal infection inside the fruit. The affected internal tissues were also cultured for examining the spread of infection inside the seed. To understand the role of insects in spreading the fungal infection (by carrying the fungal spores on their body), insects visiting the inflorescence were also cultured. Potato Dextrose Agar medium (PDA) was used for isolating the pathogen from the infected samples.

2.5 Fungicidal evaluation

Various fungicides were evaluated for testing their efficacy against the fungi causing infection on teak flower and fruits using poison-bait technique in the laboratory and the effective ones were sprayed on teak trees in the field (Table 1).

Table 1. Fungicides evaluated during the study

Period and locality	Fungicides evaluated *
Year 2002 KFRI Campus	Mancozeb (Indofil)
	Saaf (Carbendazim + Mancozeb)
	Thride (Thiram) Bavistin (Carbendazim)
Year 2003 Thrissur, Viyoor, Irinjalakuda	Chlorothalonil (Kavach)
	Propineb (Antracol)
	Copper oxychloride (Blitox)
	Copper oxychloride (Fujione)
	Tridemorph (Calixin)
Year 2004 Seed orchard at Kalluvettamkuzhy	Chlorothalonil (Kavach)
	Propineb (Antracol)
	Carbendazim (Bavistin)

* 0.1, 0.25 and 0.5% were the concentrations tested for all the fungicides

2.5.1 Poison- bait technique

The commonly available fungicides were selected for screening against fungi isolated. The appropriate quantity of the selected concentrations of the fungicide was mixed thoroughly with the sterilized PDA medium. A mycelial disc of 5 mm dia. taken from the margin of the actively growing colony of the pathogen was inoculated in the centre of the fungicide-mixed medium in Petri dishes. The inoculated Petri dishes were incubated at 25 ± 2 ^{o}C for 7 days. Control plates containing the medium without added fungicides were also maintained. For each concentration, three replicate plates were inoculated. At the end of incubation, five observations of radial or diameter growth of the fungal colony were recorded and the inhibition of the fungal growth in each Petri dish calculated.

2.5.2 Field evaluation

The fungicides found effective in the laboratory screening were tested on teak inflorescences in the field. The fungicidal applications began when the buds started appearing on the inflorescences. Three concentrations of the fungicides (Table1) were selected for spraying. Three teak trees were selected for each fungicide and for each concentration; five inflorescences were selected on a tree. Initially, the total number of buds, flowers and fruits (if any) were counted on each inflorescence. Spraying of the fungicide was done using a hand sprayer and spraying was continued at fortnight interval till the fruit setting was complete. Controls without fungicidal spray were maintained on each tree. Every fortnight, before each spray, the total number of infected and healthy buds, flowers and fruits were counted. After the completion of the treatment and when the fruits become mature, they were collected and subjected to cutting test to know the development of seeds inside the four locules of the fruit.

2.6 Fungicidal evaluation (Year 2002)

Four fungicides such as Bavistin (Carbendazim), Indofil (Mancozeb), Saaf (Carbendazim + Mancozeb) and Thiram (Thride) were selected for the test. Three concentrations such as 0.1, 0.25 and 0.5% of each fungicide were selected for carrying out the poison-baittechnique in the laboratory. Three teak trees growing in the KFRI campus were selected for spraying the fungicides and three trees for control. Those fungicides that had shown good inhibition in the laboratory were further tested on teak trees as described in 2.4.2. After the treatment when the fruits became mature, they were cut open to understand the development of seeds both in treated and untreated bunches.

2.7 Field evaluation (Year 2003)

In the year 2003, five new fungicides such as Kavach (Chlorothaloinil), Antracol (Propioneb), Blitox (Copper oxychloride), Fujione (Copper oxychloride) and Calixin (Tridemorph) were selected. Initial screening of the fungicides against the pathogen was done using poison- bait technique in the laboratory. All fungicides screened in poison-bait technique were tested in the field even though the percentage of inhibition was varying. Teak trees growing at three different localities in Thrissur District (Thrissur, Viyoor and Irinjalakuda) were selected for spraying the fungicides. Three concentrations of each fungicide (0.1, 0.25 and 0.5%) were selected for spraying. The selection of inflorescences and the spraying procedure is described in 2.4.2.

2.8 Fungicidal evaluation in the seed orchard at Kalluvettamkuzhi

The effective fungicides selected after screening in different localities of Thrissur district during the previous years were tested in the seed orchard at Kalluvettamkuzhy. The fungicidal application could not be carried out in other orchards because the flowering was poor and the trees were taller to carry out effective spraying. Three fungicides such as Bavistin (Carbendazim), Kavach (Chlorothaloinil) and Antracol (Propioneb), which were proved to be effective during the previous years, were selected for spraying. Three concentrations of the fungicides such as 0.1, 0.25 and 0.5% were selected for spraying. Since the flowered trees in the orchard were fewer in number, only three trees were selected for spraying each fungicide. For each concentration of the fungicide, 5 inflorescences were selected on a tree. The spraying began at the bud stage and continued at fortnight intervals till the fruit setting was complete. Before spraying, the total number of buds and flowers on each inflorescence was counted. Five inflorescences without spraying the fungicides were also maintained on each tree as control. Before spraying, the disease incidence on each inflorescence was observed by counting the total number healthy and infected buds, flowers and fruits. At the end of the treatment, when the fruits mature, they were collected and subjected to cutting test to know the seed filling inside the fruit.

2.9 Pollinator fauna and their activity

To study the pollinator fauna and their activity and the role of insects in spreading the fungal infection, regular observations were made on insects visiting the inflorescences of selected teak trees. Five trees in the KFRI Campus at Peechi were selected for observations. In addition to this, occasional observations were also made on four other trees selected at Vellanikkara, Olarikkara, Trichur and Karuvannur. In order to reach the inflorescence, two scaffold towers have been erected at Peechi. At other places, ladders were used. On each tree, the foraging activities of various insect pollinators were closely observed from the scaffold towers. Initially the observations were made continuously from morning to evening and subsequently, the observations were limited to specified hours (i.e., 7.30 am - 2.00 pm) when the insects were found to be most active. The foraging time, frequency of insect visit and the number of individuals of each species visiting the inflorescences were noted. Samples of insects were collected using a sweep net and observed under a microscope for presence of pollen on their body parts in order to assess the pollen carrying capacity of the insects. The insects collected were later preserved for confirming their identity. Those insects found feeding on the flower buds and premature fruits were collected. In order to ascertain the spread of the fungal infection by insects, the body parts of the insects were cultured on PDA medium to examine any fungal growth.

3. Results

3.1 Preliminary survey

The flowering of teak generally coincides with southwest monsoon in Kerala. Sporadic flowering may occur towards the end of April to May in some localities. The results of the preliminary survey conducted for identifying the cause of abnormal flower/fruit fall indicated that the infection started during the pre monsoon period and increased during monsoon. The infection percentage was calculated by counting the total number of infected and healthy flower/fruits in an inflorescence. The survey results indicated that the percentage of infection during the month of May was 42% and later in heavy monsoon period, the infection increased to 96% (Table 2).

Table 2. Percentage of fungal infection in different localities of Thrissur during April – June

Month of collection	Fungi isolated	Percentage of infection
April	*Alternaria* sp.	42
May	*Alternaria* sp. and *Phomopsis tectonae*	22
June (early days)	*P. tectonae* and *Colletotrichum gloeosporioides*	11
June - August	*P. tectonae*	96

3.2 Isolation of the pathogen

Isolation from the infected floral parts collected from various localities of Thrissur District indicated that the cause of abnormal fall of flower and fruits is may be due to the infection by fungi on floral parts. Three different fungi such as *Alternaria* sp., *Phomopsis tectonae* and *Colletotrichum gloeosporioides* either alone or in combination may be responsible for premature flower/fruit fall in teak. The infection percentage during different months and the fungi responsible for infection during that period is given in Table 2. During the month of April, 42% of the infection was caused by *Alternaria* sp. alone and later in May, two different fungi *viz.* *Alternaria* sp. and *Phomopsis tectonae* were responsible for 22% of the infection. During the early days of June, the infection (11%) was caused by *P. tectonae* and *Colletotrichum gloeosporioides.* When the monsoon progressed in June 96% of infection was caused by *P. tectonae* alone.

3.2.1 Inflorescence

On an average, each tree bears 70-300 inflorescences (Fig. 1). During rains, on some trees, few 'whole' inflorescences were found drying. The infection started from the stalk of the inflorescence and proceeded upwards which resulted in total wilting of the inflorescence. Isolations from the stalk of the inflorescence also repeatedly yielded the fungus, *Phomopsis tectonae.* This also indicated that the drying of the bunch might be due to the infection by *P. tectonae.*

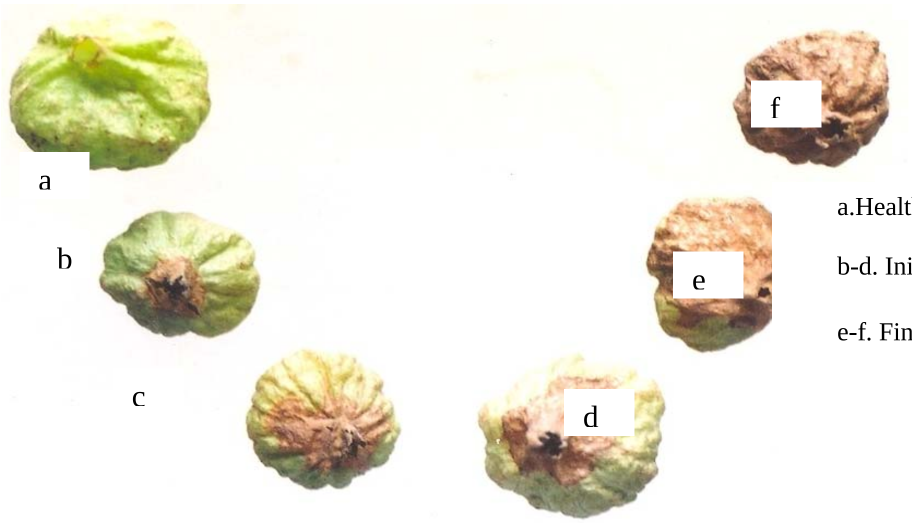
Fig. 1. Teak with flowers and fruits

3.2.2 Buds and flowers

Phomopsis tectonae was repeatedly isolated form all infected buds and flowers collected from various localities during the month of June to August.

3.2.3 Fruits

The infection on fruits appeared as a minute pale brown spots, 2-3 mm across on the tip on the inflated and persistent calyx. Soon these spots enlarged to 5-10 mm in diameter and later enlarged into a large necrotic lesion and extended downwards, finally the whole seed becomes dark brown in colour (Figs. 2a-f & 3a-d). When the infection reached the stalk of the fruit it fell down. *P. tectonae* was repeatedly isolated from all infected seeds from all localities of the state.



a.Healthy fruit

b-d. Initial stages of infection

e-f. Final stages of infection

Fig. 2a-f. Healthy and infected fruits with different stages of infection

a. Healthy fruits

b. Minute pale brown spots on the fruits

c. Spots enlarged into necrotic lesions

d. Fully infected fruit

Fig. 3a-d. Healthy and infected fruits

During heavy rains, due to infection, most of the seeds on an inflorescence became brown in colour (Fig. 4). Those fruits which escaped infection became healthy and green in colour and in such an inflorescence very few healthy fruits were observed (Fig. 5).

Fig. 4. Teak inflorescence
With infected fruits

Fig. 5. Teak inflorescence with few
healthy fruits after premature fall

The internal tissues of the infected fruit appeared brown in colour (Fig. 6). Isolation from the infected internal tissue of the fruit also yielded *P. tectonae.* It is clear that the fungus had grown inside the seed and the infection caused the brown colouration.

Fig. 6. Teak fruit showing internal infection

3.2.4 Insects

During the study one species of Hemipteran insect was found to carry the spores of *P. tectonae* on its body. But this insect was not present at other places where flower and fruit infection by the fungi was noticed. Isolations from the body parts of several other insects collected from the inflorescence did not yield any fungi, which indicated that insects had no role in spreading the infection. Though in some trees, the teak defoliator, *Hyblea puera* was noticed it was not at all associated with the premature fruit fall.

3.3 Survey in the state and seed orchards

The results of the survey indicated that the abnormal fall of flower and fruits caused by fungal infection were rather widespread in almost-all teak plantations as well as seed orchards of the state. The number of localities surveyed, total number of trees observed and the percentage of fungal infection are given in Table 3. Trees from 38 localities were surveyed in Central circle, 36 from southern, 30 from Northern and 15 and 16 from Olavakkode and High Range circles respectively. Maximum fungal infection (47%) was observed in Central circle followed by High Range circle (29%) (Table 3 & Fig.7).

Table 3. Infection percentage observed in different Forest circles and seed orchards

Forest Circle (FC)/ Seed orchards (SO)	No. of localities surveyed	Total number of trees observed	Fungal infection Percentage
Northern (FC)	30	90	13
Southern (FC)	36	108	20
Arippa (SO)	1	3	20
Olavakkode(FC)	16	48	21
Kalluvettamkuzhy (SO)	1	3	26
High Range FC)	15	45	29
Central (FC)	38	114	47

Lowest infection percentage (13%) was observed in Northern circle. In the seed orchards at Kalluvettamkuzhy and Arippa, the infection by fungi was recorded as 26 and 20% respectively. The trees in the seed orchard at Nilambur were too tall to take observations. No observations were recorded from seed orchard at Palappilly due to poor flowering.

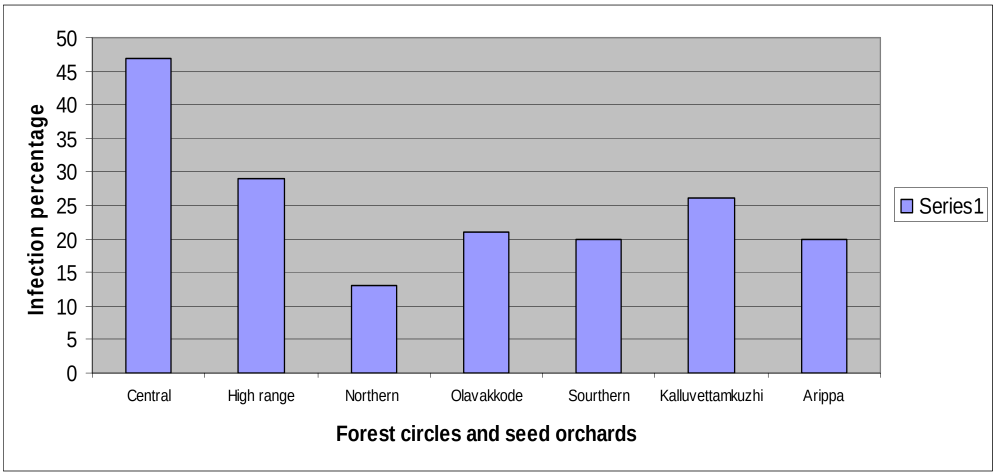


Fig. 7. Infection percentage observed on teak trees in different Forest Circles

3.4 Fungicidal evaluation (Year 2002)

3.4.1 Poison-bait technique

The results of the poison-bait technique are given in Table 4. Except Thiram (Thride) all other fungicides were found effective in controlling the growth of fungi in laboratory condition. Bavistin (Carbendazim) was showing 100% inhibition of the fungal growth followed by Indofil (Mancozeb 97%).

Table 4. Percentage of inhibition using poison-bait technique

Sl. No	Fungicides	Inhibition percentage of *Phomopsis tectonae*
1	Bavistin (Carbendazim)	100
2	Indofil (Mancozeb)	97
3	Saaf (Carbendazim + Mancozeb)	45
4	Thiram (Thride)	23

3.4.2 Field evaluation

The results of inhibition of fungal infection on teak inflorescences sprayed with different fungicides in the field are given in Table 5. Irrespective of the type of fungicide, the lowest concentration of 0.1% was not effective in the field. On the inflorescence sprayed with 0.5% of Bavistin (Carbendazim) the infection was only 19%, whereas in controls (untreated) the infection was 90%. Indofil (Mancozeb) at a concentration of 0.5% reduced the infection up to 42%. The fungicide Saaf (Carbendazim + Mancozeb) was not effective in controlling the infection at both the concentrations.

The seed filling percentage of treated and control fruits are given in Table 5. It is clear from the results that the seed setting percentage was enhanced by fungicidal application. In the seeds collected from the inflorescences sprayed with Bavistin at 0.5%, the seed filling was 50%, where as in control, it was only 16%. The seed setting was increased to 35 and 38% due to spraying of Indofil at 0.25 and 0.5%, respectively. No increase in the seed filling was noticed in the case of Saaf since it was not effective in controlling the infection.

Table 5. Inhibition of fungal infection using different fungicides on various teak trees during the year 2002

Fungicides	Percentage of infection		Seed filling per cent	
	Treated	Untreated	Treated	Untreated
Carbendazim 0.25%	23	69	45	20
Carbendazim 0.50%	19	90	50	16
Indofil (Mancozeb) 0.25%	37	85	35	24
Indofil (Mancozeb) 0.50%	42	85	38	26
Saaf (Carbendazim + Mancozeb) 0.25%	90	90	15	20
Saaf (Carbendazim + Mancozeb) 0.50%	70	85	18	21

3.5 Fungicidal evaluation (Year 2003)

3.5.1 Poison bait- technique

In the laboratory, all the fungicides showed varying percentages of inhibition in the culture media. The inhibition of fungal growth by fungicides such as Calixin, Antracol, Kavach is shown in Fig. 8. There was 100% inhibition in plates containing 0.5% of Calixin and Fujione whereas in control plates the fungus had covered the whole plate. In cultures containing Antracol and Kavach, restricted growth of the fungus was observed.

Control

PDA mixed with 0.5% of Antracol

Control

PDA mixed with 0.5% of Calixin

Control

PDA mixed with 0.5% of Fujione

Control

PDA mixed with 0.5% of Kavach

Fig. 8. Fungicidal evaluation of *Phomopsis tectonae* using poison- bait technique

3.5.2 Field evaluation

The results of the fungicidal application in the field during the year 2003 are shown in the Table 6.

Table 6. Fungal infection percentage using different fungicides

Concentration	Fungal infection percentage				
	Chlorothalonil (Kavach)	Tridemorph (Calixin)	Isoprothilane (Fujione)	Propineb (Antracol)	Copper oxychloride
0.1%	28	24	22	25	100
0.25%	23	20	17	19	
0.5%	18	19	13	14	
Control	76	79	75	69	

Except Copper oxychloride, all fungicides tested were effective against the fungal infection. The percentage of inhibition varied with concentration of the fungicide. Among the three concentrations tested, 0.5% gave maximum control of infection. In the case of Fujione and Antracol, the infection was only 13 and 14% respectively where as in control it was 75 and 69%.

3.6 Fungicidal evaluation in the seed orchard at Kalluvettamkuzhi

The percentages of infected and healthy seeds on inflorescences sprayed with different fungicides at different concentrations are given (Figs. 9 and 10). Of the three fungicides, Kavach and Bavisitin were giving good inhibition of fungal infection. Inflorescences treated with 0.5% of Bavistin and Kavach, had 83 and 84% healthy seeds respectively whereas on control it was 37%. Of the three fungicides, Bavistin consistently gave good control of fungal infection.

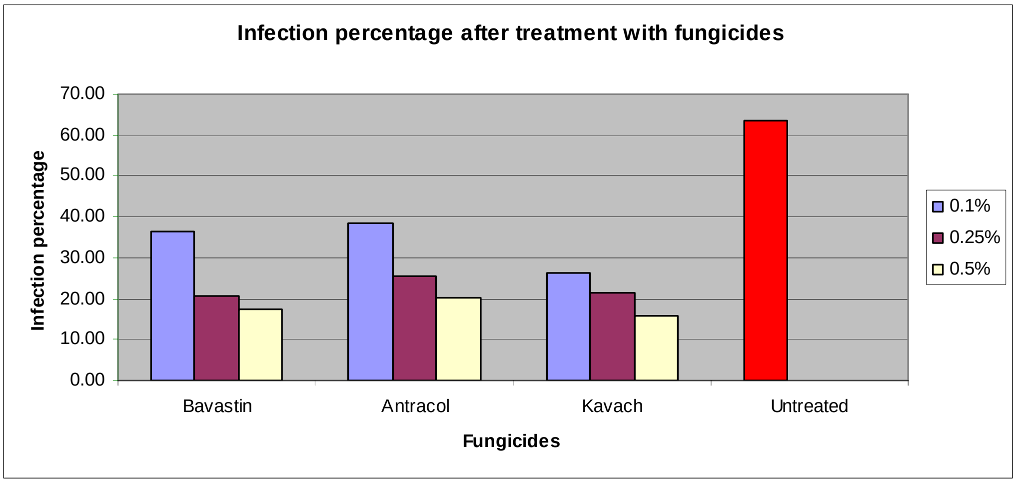


Fig. 9. Percentage of infected seeds on inflorescence treated with fungicides

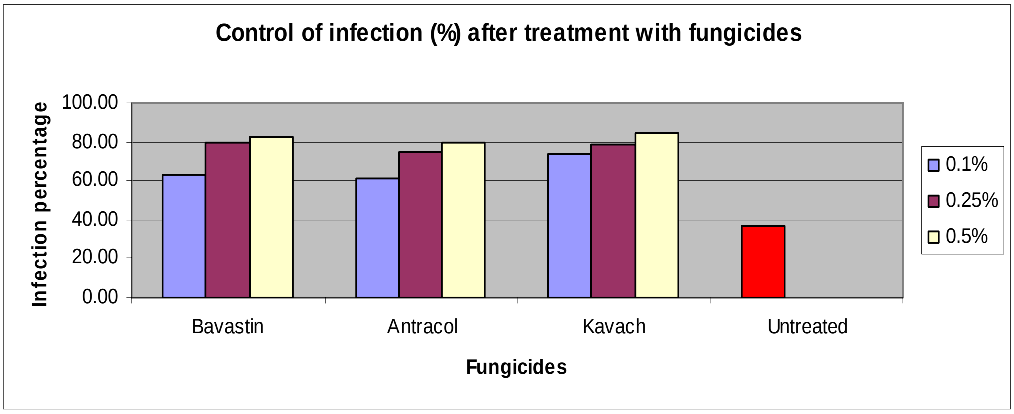


Fig. 10. Percentage of healthy seeds on inflorescence treated with fungicides

It is observed that the size of the fruits was increased after the application of Bavistin (Carbandazim) and Antracol (Propineb) when compared to control (Fig. 11). All the three concentrations of the above two fungicides were effective in increasing the size of fruits. No remarkable increase in fruit size was observed when sprayed with Kavach (Chlorothalonil).

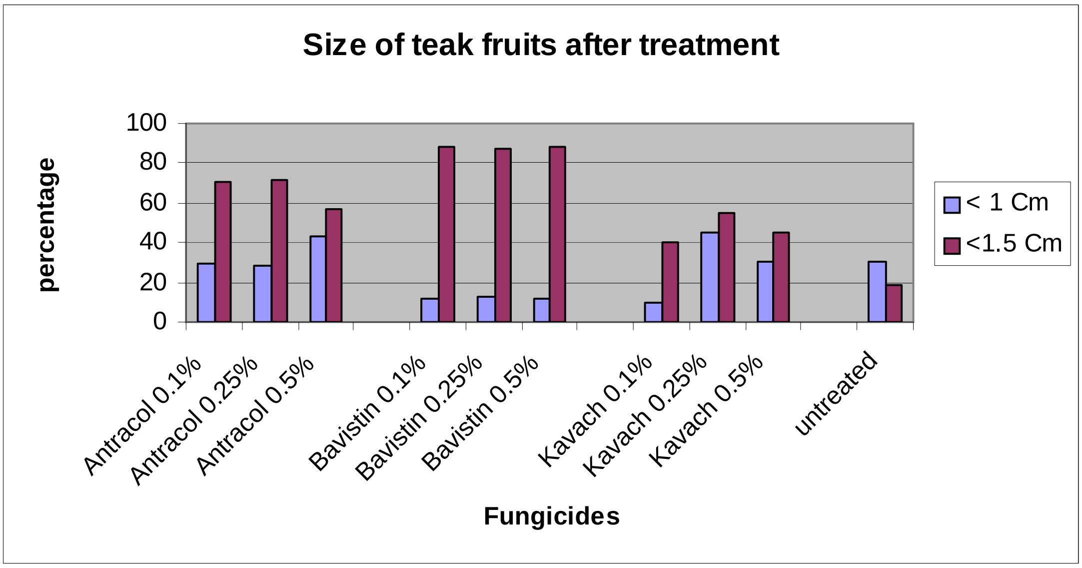


Fig. 11. Percentage of fruit size after fungicidal application

The seed filling status in the four locules of the treated fruits was assessed after subjecting the seeds to cutting test (Fig. 12). The results showed that the percentage of fruits with seeds and the seed setting inside the locules was enhanced by fungicidal application. When compared to untreated, the percentage of total fruits with seeds was more in all inflorescences treated with different concentrations of fungicides such as Antracol, Bavistin and Kavach. The maximum fruits with seeds were obtained by treatment with 0.5% of Kavach. The percentage of seed setting was also increased by the increase in the percentage of the concentration of the fungicides. Fruits with one seed were more than those with 2 and 3 seeds. In untreated fruits, 2- seeded stage was only 8.4% whereas in fruits, which received 0.5% of Antracol, Bavistin and Kavach, it was 26.6, 20 and 25% respectively. The percentage of 3-seed setting was also increased in fruits with the application of fungicides whereas in untreated fruits it was 0%. Comparatively the percentage of 3-seeded fruits was more in the inflorescence sprayed with Kavach (0.5%).

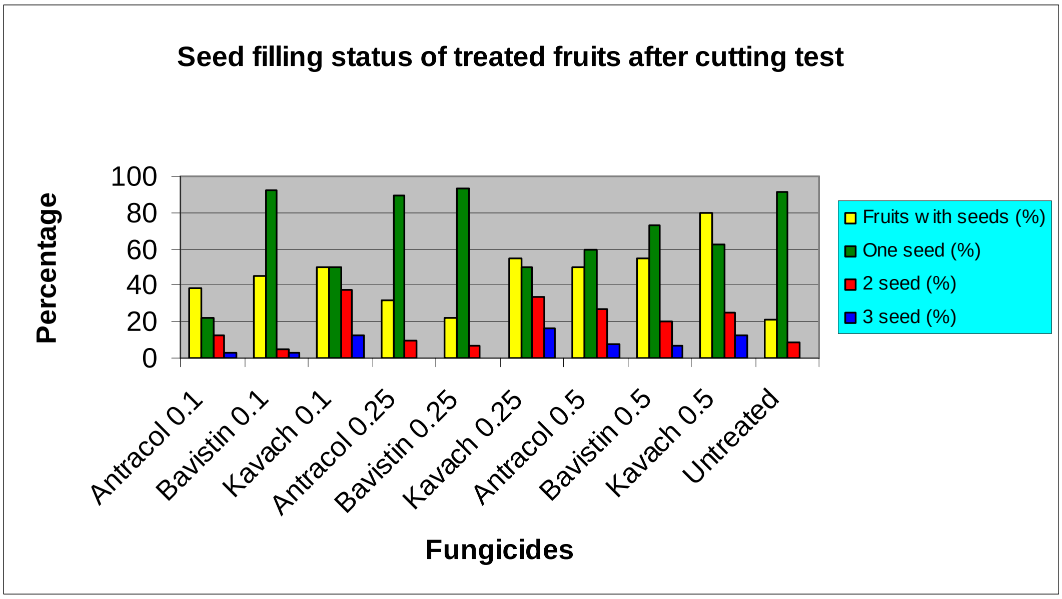


Fig. 12. Seed filling status of fruits after cutting test

3.7 Pollinator fauna and their activity

The open flower structure as well as the richness in pollen and nectar attracted diverse groups of insects to teak inflorescence. Observations on insect activity on teak flowers had shown an increasing trend from morning to noon (9 AM - 12 Noon) coinciding with the increase in temperature. Insect activity showed a gradual decrease towards the evening. Altogether 81species of insects were collected representing various insects Orders. Among these insect groups, Hymenopterans and Lepidopterans were the most frequent visitors of teak inflorescence. The Hymenopterans were the most effective pollinators due to their structural adaptations.

Among the 81 species of insects were collected from the teak inflorescence 41 species got identified. (Appendix I-VI). They belonged to the Order Coleoptera (6 species unidentified) Diptera (9 species, unidentified), Hemiptera 1 species identified (6 species unidentified), Lepidoptera 21 species identified (2 species unidentified) and Hymenoptera 19 species identified (1 species unidentified). A separate list of insects on teak inflorescence (photographs not available) is given in the Table 8. The collected insects were classified into three groups such as visitors, pollinators and harmful ones.

3.7.1 Pollinators

Insects of this functional group are mainly belonging to the Order Hymenoptera (Appendix VI), some belonged to Order Diptera (Appendix II) and a few belonged to Order Coleoptera (Appendix I). They are having special feeding behavior and body structure which contributed to the pollination of teak flowers. Among these, those insects with smaller body size are slow flyers. Because of the availability of large number of inflorescences on the same tree they spend most of their time feeding on the same tree. Hymenopteran insects with larger but stout body size are quick flyers and they move among the flowering trees in the same locality in quick succession and thus they help in cross pollination.

3.7.2 Visitors

These insects belong mainly to the Order Lepidoptera, butterflies and moths (Appendix IV). A few species belonging to Order Coleoptera and Diptera were also observed. Though these insects feed on the nectar, they do not act as pollinators because of their peculiar feeding nature and body structure.

3.7.3 Harmful insects

The caterpillars of some butterflies feed on the flower buds, flowers and premature fruits thus causing premature fall of flower and fruits. (Appendix V). Some other insects feed the sap of the premature fruits and prevent seed setting (Appendix III). Among these insects one species (unidentified) was found to carry the fugal pathogen in its body. But this insect was not present at all places where ever the buds, flowers and premature fruits were found to have fungal infection. Other than this one single incidence there was no evidence to prove that insect are involved in spreading the infection from one inflorescence to another. Some insects belonging to the group of praying mantis and spiders were also found predating on the slow moving pollinators.

It was observed that in the presence of active pollinators, the number of fruits formed on the inflorescence varied from 60-238 (Table 7). But when insects were prevented from pollination, the fruit setting varied from 0-3 in cloth bags and 3-45 in net bags whereas in the open inflorescence it was 60-238. This clearly showed the role of insects in fruit setting.

Table 7. Comparative fruit setting in covered and open inflorescence of Teak

Tree location and No. of inflorescence observed	Fruit setting in cloth bag	Fruit setting in net bag	Fruit setting in open inflorescence
KFRI campus R1*	0	9	145
R2	0	5	95
R3	0	9	60
Olarikkara R4	2	45	238
R5	3	3	180
R6	1	4	120

*R= Replication

Table 8. List of insects recorded on the teak inflorescence, but photographs not available.

Sl. No.	Name	Order
1	*Cleora* sp.	Lepidoptera
2	*Aphomia* sp.	Lepidoptera
3	*Antepepona* sp.	Hymenoptera
4	*Antodynerus ornatus* Smith	Hymenoptera
5	*Eumenes flavopicta* Blanch.	Hymenoptera
6	*E. punctata* Saussure	Hymenoptera
7	*Hylaeus* sp.	Hymenoptera
8	*Lasioglossum* sp. I	Hymenoptera
9	Lasioglossum sp. II	Hymenoptera
10	*Nomada* sp.	Hymenoptera
11	*Nomia chalybeata* Smith	Hymenoptera
12	*Nomia ellioti* Smith	Hymenoptera
13	*Paraleptomenes* sp.	Hymenoptera
14	*Ropalidia spatulata* Van der Vecht	Hymenoptera
15	*Trigonisca* sp.	Hymenoptera

4. Discussion

The premature flower/fruit fall in teak is widespread throughout Kerala. Variation in percentage infection was observed among the different forest circles. The infection was more in the Central Circle and less in Northern Circle.

The survey revealed that the initial infection which occurs during April- May was due to *Alternaria* sp. and later by *Alternaria* sp. + *Phomopsis tectonae* and during the early monsoon; the infection was caused by *Phomopsis tectonae* + *Colletotrichum gloeosporioides*. But when the monsoon progressed, the infection was due to *Phomopsis tectonae* only. In teak, *Phomopsis variosporum, P. tectonae* and *Colletotrichum gloeosporioides* cause severe leaf damages. (Tiwari *et al*., 1981; Sharma *et al*., 1985). *Alternaria* is a common facultative leaf pathogen found to cause foliage disease of many plants. The present survey also revealed that *Alternaria* sp. infects the buds, flower and fruits only during hot periods. Later, during the monsoon period, the infection is dominated by *P. tectonae*.

Colletotrichum gloeosporioides is world-wide in distribution causing diseases on large number of cultivated and wild plants. *C. gloeosporioides* also causes citrus post bloom and fruit drop (McMillan, Jr and Timmer, 1989). The flower/fruit fall in teak caused by *C. gloeosporioides* is not very significant since it is seen only during the early days of monsoon.

Phomopsis leaf spot is another disease to appear during the late monsoon on teak and fresh infection persists till the leaf is shed in December/January. During the leaf-shedding period, the infected leaves remain in the soil. It is assumed that during the monsoon, the fungus grows and infects the teak inflorescences and cause premature fall. It is evident from the survey that *P. tectonae* can infect all floral parts during flowering such as inflorescence stalk, buds, flowers and fruits. The infection mainly occurs during the severe monsoon period and causing maximum flower fall and thus causing low fruit setting.

Premature fruit drop is frequently noticed in teak seed orchards at Madhya Pradesh due to the deficiency of certain hormones and chemicals during fruiting (Ram Prasad *et al.*, 1990). But in our state, the premature flower/fruit fall in the monsoon can mainly be attributed to fungal infection.

Even though many insects as pollinators are collected from teak inflorescence from different localities none of them had a clear role in spreading the fungal infection. In this study only one species of Hemipteran insect was found to carry pathogen on its body parts. But this insect was not present at other places where flower of fruit infection by the fungi were noticed. The pathogen spread could be mainly through rainwater since infection percentage increases with the heaviness of the monsoon. Ram Prasad *et al*. (1990) reported that in teak seed orchards insects/borer and sapsucker found to cause extensive damage. During our survey it is observed that the damage caused to the fruits by the insects is negligible.

Few commonly available fungicides are found to be effective in controlling the infection. The application of fungicides in plantations is not feasible and uneconomical. But the spraying strategies can be adopted for seed orchards from where quality seeds are collected. The initial infection of the fungus can be prevented by the application of fungicides. It is very evident from the cutting test that the seed filling had increased by fungicidal application. But the fungicidal application has to be started from the stage of bud formation.

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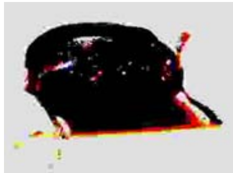
Appendix I

Coleopteran insects on teak inflorescence (unidentified)

1	2	3
		
4	5	6
		

Appendix II

Dipterans flies feeding on the nectar and pollen (unidentified)

1	2	3
		
4	5	6
		

7	8	9
		

Appendix III

Homopteran insects feeding the premature fruits (unidentified)

1	2	3
 vector of pathogen		

4	5
 *Tessaratoma* sp. (F: Pentatomidae)	
6	7
	

Appendix IV

Lepidopteran insects   feeding on the nectar

 *Unidentified* sp.	 *Tirumala limniace iopardus(Butler)*	 *Tirumala septentrionis (Butler)*
 *Euploea core Cramer*	 *Potanthus* sp.	 *Potanthus* sp.
 *Tagiades litigiosa Moschle*	 *Telicota ancilla*	 *Hyblaea puera Cramer* .
 *Junonia iphita* Cram	 *Neptis hylas* Moore	 *Ischyja manila* Stal.

 *Catopsilia pyranthe* Lin	 *Catopsilia pomona Fb.*	 *Delias eucharis Drury*
 *Graphium agamemnon* Lin	 *Graphium doson* Felder	 *Papilio polytes* Lin.
 *apilio polytes*	 *Ythima huebneri* Kirby	 Unidentified sp.
 Unidentified sp.		

Appendix V

Lepidopteron insects larvae feeding on buds, flowers and premature fruits

 *Euproctis scintillans* Walker	 *Dasychira mendosa* Hb

Appendix VI

Hymenopteran insects on teak inflorescences

 *Apis cerana* indica	 *Apis dorsata*	 *Lisotrigona mohandasi* Jobiraj and Narendran sp. nov.
 *Melipona iridipennis* Dall	 *Heriades* sp.	 *Halictustectonae* Narendran & Joberaj

 *Nomia basalis* Smith.	 *Nomia curvipes* Fb	 *Megachila* sp.
 *Megachile carbonaria* Smith.	 *Sphex sericeus* Fb	 *Sphex* sp.
 *Delta arcuata* (Fabricius)	 *Delta conoidus(Gemlin*	 *Delta petiolata*

 *Rhynchium brunnuem* (Smith)	 *Chalybion bengalense* Dalbhom.	 *Xenorhynchium abdominae(* Illiger)
 Unidentified sp.	 *Sphecodex* sp.	