KFRI Research Report 122

MANAGEMENT OF THE BARK CATERPILLAR INDARBELA QUADRINOTATA IN FOREST PLANTATIONS OF PARASERIANTHES FALCATARIA

George Mathew

KERALA FOREST RESEARCH INSTITUTE
PEECHI, THRISSUR

July 1997 Pages: 24

CONTENTS

ABSTRACT

The bark caterpillar ***Indarbela quadrinotatais*** apolyphagous wood boring insect, attacking a variety of tree species in India Although generally considered as a pest of minor importance in forestry, this insect is a serious pest in horticultural plantations of guava apple, pomegranate, jujube, etc., in several parts of India

I. quadrinotata is widely distributed in Kerala attacking a variety of tree species like ***Peltophorum pterocarpum, Delonix regia, Terminalia catappa, Casuarina equisetifolia, Swietenia macrophylla, Macaranga peltata, Anacardium occidentale*** and ***Ceiba pentandra***

Recently, large-scale build up of this insect was noticed in some plantations of ***Paraserianthes falcataria*** in the southern Forest Circle, mainly at Punalur. Studies were made on the factors leading to the build up of this insect in plantations and its possible control.

Among the factors favouring establishment of this insect, availability of appropriate alternative host plants which will enable survival of a residual pest population was found to be important. Age of the plants was also found to have direct relation with borer attack as saplings were found to be more susceptible. At Punalur, the avenue trees of ***P. pterocarpum, S. macrophylla*** and ***D. regia*** were found to be the major host plants of this insect.

In plantations, infestation generally starts with the onset of premonsoon rains in late May. The signs of infestation become apparent from July on wards when the sleeve-like structure made of frass and excreta extending from the borer holes are seen on the trunk of affected trees. The rate of feeding was found to be faster during the summer months. Larval stage lastsfor about 8 months. Pupation occurs within the tunnel, with the cephalic end of the pupa slightly protruding from the tunnel mouth. In the field, pupation was noticed to commence from late February onuxuds. Pupal period lastsfor about 9 days.

Control trials have indicated that plantations of ***P. falcataria*** can be protected from this insect by spot application of insecticides. Of the various insecticides screened against this insect, monocrotophos (0.1%), quinalphos (0.1%) andfenvalerate (0.08%) gave best results.

Key words: ***Paraserianthes falcataria, Indarbela quadrinotata*** bark caterpillar, Kerala, India.

INTRODUCTION

Paraserianthesfalcataria (Linn.) Nielson (= *Albiziafalcataria* (Linn.) Fosb. (Mimosaceae)is one of the fast growing tree species native to the eastern islands of the Indonesian archipelago, notably the Molucas and New Guinea (NAS, 1979). Its wood is light and is put to a variety of commercial uses - for making matches, tea chests, veneers, fisherman's floats, etc.

P. falcataria has been introduced to several countries from its original habitat from 1870 onwards. In India, small-scale trial plantations have been raised since 1960, mostly in Assam, Tamil Nadu, Kerala and Andamans (Ghosh, 1977). In Kerala, an area of about 1350 ha have been planted with *P.falcataria* in Trichur, Quilon and Trivandrum Forest Divisions by the Kerala Forest Department (KFD) and the Kerala Forest Development Corporation (KFDC). The establishment and performance of this tree in forest plantations have been satisfactory, although incidence of various pests and diseases was noticed in some areas which caused serious set backs in plantation programmes.

The insect pests associated with this tree have been listed by Bhasin and Roonwal(1954) and Browne (1968). Of about 14 species of insects recorded by them, only seven were from India. This included three species of Lepidoptera *(Indarbela quadrinotata* Walker, Metarbelidae; *Ericea inangulata* Guenee, Noctuidae; and *Eurema blanda silhetana* Wallace, Pieridae); two species of Hemiptera *(Coccus elongatus* Signourt and *Perissianus virgatus* Cockerell,both Coccidae)and two Coleoptera *(Xyleborusasperatus* Blandford and *X. discolor* Blandford, both Scolytidae). None of these insects was assigned serious pest status. Outside India, the pierid *Eurema hecabe contuberndis* Moore and the geometrid *Semiothisa emersaria* causing defoliation in plantations and nurseries in Malaysia (Menon, 1958) and the cerambycid, *Xystrocera festiva* Pascoe which bore into the wood of live trees in natural pure stands and plantations in Indonesia were considered as economically important pests (Alrasjid, 1973; Sidabutar and Natwiria, 1973).

In a recent study on the pest problems of this tree species in Kerala. Nair and Mathew (1988) have reported 25 species of insects as pests, out of which the most important was the bagworm. *Pteroma plgiophleps* Hampson (Lepidoptera: Psychidae) which caused heavy defoliation leading to die-back of trees in some plantations.

Recently, incidence of the bark feeding caterpillar *Indarbela quadrinotata* Wlk. was noticed in some plantations in the Punalur Forest Division. This

insect which causes considerable bark injury has resulted in the failure of several plantations in Punalur. Therefore. attempts were made to develop appropriate management strategies against this pest and the findings are presented in this Report.

2. REVIEW OF LITERATURE

Indarbela quadrinotata is a primitive lepidopteran belonging to the family Metarbelidae. Members of this family are wood boring in habit and the larvae feed on the bark surrounding the tunnel mouth under a sleeve, made of frass and excreta webbed together, which extend from the tunnel opening. Only about 14 species of these moths under 3 genera have been reported from India. Among these, the genus *Indarbela* is the largest containing 12 species of which, at least 5 species viz., *I. campbelli* Hampson, *I. minima* Hampson, *I. watsoni* Hampson. *I. tetraonis* Moore and *I. quadrinotata* Walker, occur in southern India. Of these, *I. quadrinotata* is the most common and widely distributed species.

2.1. HOST RANGE

I. quadrinotata is highly polyphagous and the recorded hosts include *Acacia catechu, A. lenticularis, A. tortilis, Albizia chinensis, A. lebbeck, A. odoratissima, A. sini, A. procera, A. siris, Anogeissus sp., Artocarpus integra. Bassia, Bauhinia, Berrya, Bombax, Boswellia. Callicarpa, Cassia fistula, Casuarina equisetifolia, Citrus aurantifolia, Grnelina arborea, Lagerstroemia speciosa, Mangifera indica, Morus alba, Mytrogyna sp., Phyllanthus emblica, Psidium guajava, Populus nigra, P. deltoides, Prunus armeniaca, P. salicinae, Punica granatum, Samanea saman, Shorea robusta, Stephegyne sp., Strychnos sp., Syzygium curnini, Tectona grandis, Terrninalia arjuna, T. myriocarpa, T. superba, Xylia xylocarpa* and *Zizyphus mauritiana* (Beeson, 1941 ; Gope and Roy, 1986; Kumawat and Swaminathan, 1990; Patil *et al*, 1990; Pratap Singh and Bhandari 1987; Remadevi, 1989; Mote and Tambe. 1990; Sandhu *et al*, 1987; Sharma and Kumar 1986; Sharma and Verma, 1987).

The related species, I. campbelli has been reported on *Ochna squamosa; I.* dea on *Erythroxy* (COCO) and *I. theivora* on *Mangifera indica* and *Camellia thea* (tea) (Beeson, 1941).

2.2. LIFE CYCLE

The life cycle of this insect has been worked out on various hosts by different workers. Life cycle is annual with one generation per year. Adults start emerging during May to July. Females oviposit under loose bark in clusters in early June. Eggs hatch in 15-25 days.

Larvae that hatch out initially feed on the bark and subsequently bore into the trunk. The tunnel entry remains closed with a frass covering which is drawn out into a sleeve through which the larva moves (Fig. 1a). The tunnel is used as shelter by the larva and is kept clean of the faecal pellets and frass which are added on to the distal end of the sleeve. The larval period lasts for 9-10 months.

Pupation occurs within the larval tunnel, with the cephalic end of the pupa slightly protruding out side. The pupal period lasts for about 15-25 days (Sharma and Kumar, 1986).

2.3. NATURAL ENEMIES

Two species of entomogenous fungi viz., *Aspergillus candidus* Link. and Beauveria bassiana (Bals.) Vuvill, have been reported to cause mortality of this insect in the field. Of these, *A. candidus* was reported on Indarbela developing on pomegranate in Hissar, (Haryana), where about 5-11% infection was recorded (Ramsingh, *et al*, 1982). Laboratory trials using this pathogen have indicated 100% larval mortality indicating its potential as a biocontrol agent against this pest. Similarly, 41.6% and 65% infestation by *B. bassiana* was noticed on *I. quadrinotata* attacking guava in Lucknow during the months March and July respectively. Laboratory tests confirmed high pathogenicity (100%) of this fungus (Fasih and Srivastava, 1988). In another study, Arshad and Hafiz (1983) recorded 33.8-45% larval mortality in the field and 21.4-33.6% mortality in lab trials. An insect parasite *Podagrionella indarbelae* (Chalcidoidea: Torymidae) was reared from the eggs of a related species viz., *I. tetraonis* collected on cashew from Kerala (Narendran and Sureshan. 1988).

2.4. CONTROL STUDIES

Several attempts have been made to control this insect mostly in orchards and horticultural farms. Overcrowding of trees and prevalence of unsanitary conditions (like excessive weed growth) were considered as factors promoting infestation by this insect (Beeson, 1941; Sharma and Kumar, 1986). Attempts to select cultivars resistant to this pest, have been made in some crops. For instance, in the case of jujube *(Zizyphus mauritiana)*, of the 21 cultivars, most were susceptible (Singh, 1984; Kumawat and Swaminathan. 1990).

Control strategies reported against this pest were either mechanical or chemical. The mechanical method involved killing the larvae within the tunnels by inserting a sharp metallic probe and sealing the tunnel entrance using tar or wax.

In the chemical method, application of a toxic substance either by injection or by inserting a cotton swab soaked in the chemical was the most widely used method. Spot application either by brushing or spraying was also tried in certain cases.

Sidhu and Poon (1983) achieved good control of the bark caterpillar, *I. disciplaga* Swinhoe, attacking cocoa in Malaysia by injecting chlorphyriphos into the borer tunnels and plugging the holes with soil soaked with insecticides. Verma (1985) also tried the same technique in field trials carried out on plum at Solan. Of the five insecticides used, Phorate (10% at 1 g/hole) and DDT (0.05% at 5 ml/hole) gave 100% mortality in 7 days.

Das *et a1* (1985) tried application of 5-10 ml of a diluted solution of quinalphos 25 EC at 1:200, endosulphan 35 EC at 1:200 or deltamethrin 2.8 EC at 1:2000 into the borer holes and observed good control of this insect on shade trees in north-east India. Application of Phorate 10 G at the rate of 2 g per hole or to the soil around the collar of the trees at 25, 50 or 100 g/plant gave good control for upto 6 weeks after application.

Singh and Dhamdhere (1989) tested 6 insecticides as soaked cotton plugs to control the bark caterpillar on guava trees. Of these, (0.05%) demeton methyl, dichlorvos and quinalphos gave 57.5, 62.03 and 50.67% control, respectively. In addition to these insecticides, he also tried petrol and kerosene which gave 95.5 and 73.5% control, respectively. Another trial using aluminium phosphide (1 tablet per hole) gave 60.6% control of this insect.

In another field experiment in a guava orchard, Patil et *al.* (1990) tested the effect of dichlorvos and petrol by inserting cotton swabs soaked with 10 ml of either of the above into the tunnel. Observations after a week indicated 100% mortality in the case of treatment with dichlorvos and 96.7% in the case of petrol.

The efficacy of 10 insecticides by injecting into the borer holes was tried on pomegranate in Maharashtra. Results indicated fenvalerate (0.01%) and quinalphos (0.05%) as the most effective pesticides (Mote and Tambe. 1980).

Sandhu *et al* (1987) tested different methods of application like spot spraying, brushing etc., 'on the bark of affected trees. Surface application of chemicals was effective in trees like orange having coarse bark where 90-95% control was recorded and less effective in trees like guava, loquet, jujube, etc., in which the bark is smooth. Direct application using a wash bottle was successful on all trees except *Albzia siris.* Application with cotton swabs was effective in some cases while application with a veterinary syringe was effective in others.

Recently, Shevale (1991) tested the efficacy of eight insecticides on the bark caterpillar on pomegranate. Dichlorvos at 0.08% was the most effective followed by monocrotophos (0.08%), fenvalerate (0.04%) and carbaryl (1%).

Although a number of studies as detailed above have been carried out for managing this pest on various trees, no general control recommendation suited to various tree species has been made. Since specific dosages and methods of application are required depending upon the tree crop and pest intensity , a detailed study was undertaken on the factors leading to the infestation by *I. quadrinotata* and its management using appropriate chemicals.

3. MATERIALS AND METHODS

3.1. BIOLOGY AND ECOLOGY

The biology of this insect was studied by making regular larval samplings in the field by cutting the affected branches and examining the larvae inside. In addition to this, attempts were also made to rear field collected larvae in the laboratory on potato tubers.

In order to study its ecology, observations were made at monthly intervals, in an experimental plot of 100 trees (in 20 rows of 5 trees each) in a 1991 planted *P. falcataria* plantation at Kumaramkudy in Punalur Forest Division. This plantation which was about 20 ha in extent, was spread over two hills as well as in the intervening valley, through which meandered a stream. The trees were planted at 2.5 x 2.5 m espacement.

All the 100 trees in the experimental plot were marked and observations were made on the number of live borers in each tree, every month, from May 1994 to April 1996. The state of the larva inside the tunnel was established from the appearance of the sleeve extending from the borer hole. The sleeve is maintained only if the larva inside the tunnel is alive.

For estimating the overall infestation of the plantation, each tree along every 10th row was examined and the level of infestation recorded in either of the following score classes:

Score 0 = Healthy tree with no borer attack
Score 1 = Tree infested by only one borer (low infestation)
Score 2 = Tree affected by 2 to 4 borers (medium infestation)
Score 3 = Tree with more than 4 borers (heavy infestation)

3.2. INFESTATION PROGRESSION

The infestation progression rate was calculated from the data gathered on the number of insects present in trees in the experimental plot, during the period of this study.

3.3. CONTROL STUDIES

Based on information already available in the literature, seven insecticides representing organophosphorous. organochlorine, carbamate, pyrethroid and biocide groups were selected for initial trials. Spot application using a

rocker sprayer was tried. For each insecticide, two dosages *viz.*, the lowest recommended as well as the next higher dose, were tested. The chemicals tested in this study are the following:

Organophosphorous

1. Quinalphos (Ekalux)
2. Monocrotophos (Dimecron)

Organochlorine

3. Endosulphan (Thiodan)

Carbamate

4. Carbaryl (Sevin)

Pyrethroid

5. Fenvalerate (Sumicidin)

Biocides

6. BTK *(Bacillus thuringiensis* var. *kurstaki)*
7. Dipel *(B. thuringiensis)*

Infested trees belonging to score 2 and above were selected within a heavily infested plantation and numbered. The number of active borers per tree was recorded based on observation of the condition of the sleeve . The spray was given in such a way that the bark surrounding the borer hole and the sleeve were thoroughly drenched in the insecticide solution. Caterpillars of *I. quadrinotata* which characteristically feed under cover of the sleeve were expected to get contaminated while feeding on the green bark surrounding the distal end of the sleeve. The effect of treatment was recorded after 24 h, 7 days and 14 days, and the percentage mortality at various levels recorded. Other types of pesticide application as detailed under 'Review of Literature' were not tested in this study, as these methods were not practicable on a plantation scale.

Observations on larval mortality were recorded on the basis of larval activity. Larvae when affected by the insecticide, became inactive and were unable to maintain the protective 'sleeve' which started to tear off at various points. The sleeves when removed were not repaired confirming larval mortality. The data on percent mortality were transformed to angular values and subjected to analysis of variance followed by Duncan's multiple range test for mean comparison.

4. RESULTS AND DISCUSSION

4.1. BIOLOGY

Eggs are laid in clusters on the bark of trees. The newly hatched larvae are light brownish, bare and initially occur in groups browsing on the bark. Subsequently they migrate and get lodged in the axils of side shoots or lateral buds to initiate an infestation.

As the larva grows, it slowly tunnels into the wood (Fig. lb). This tunnel is used only as a shelter and is kept free of frass. The dimensions of the tunnel in the wood are continuously maintained by the larva inside so as to accommodate its growth. The frass and excreta that are removed from the tunnel are used for constructing the sleeve-like structure extending from the tunnel mouth.

The larva invariably feeds upon bark under concealment in the sleeve. Large patches of bark that are eaten away, expose the tree to various pathogenic organisms. Larval feeding is brisk during the summer months compared to that in post monsoon months. Earlier, Mishra (1991) has shown that larval feeding is related to temperature and relative humidity. He also observed that food consumption increased with a rise in temperature, the maximum being 166 mg/day at 35°C and minimum 16 mg/day at 12.5°C. Similarly, the food consumption was maximum at 96% RH while it decreased with lowering of RH, the minimum being 3 mg/day at 56% RH.

The full grown larva is smooth, with sparse hairs and measures 3.5 to 4 cm in length. Light brown sclerotized patches are present dorsolaterally. The thoracic legs are simple with the last segment ending in a curved claw. Abdominal legs are present on segments 6-9.

Pupation occurs in the tunnel itself with the cephalic end of the pupa slightly protruding from the borer hole. Following pupation, the sleeve extending from the tunnel mouth falls off. Larval sampling in the field has indicated that, part of the larval population pupates by late February.

The pupa is light. brownish in colour measuring 1.5 cm in length and with 2 short pointed cephalic processes (Fig. 2a). Abdominal segments bear transverse rows of spine-like processes, of which there are two rows each on segments 5 to 8. Segments 3, 4 and 8 have only one row and only two spines on segment 10. The caudal end (cremaster) bears several small spine - like

processes (Fig. 2b). These spines and teeth - like processes help the pupa to orient itself towards the tunnel mouth prior to eclosion. Pupal period lasts for 3 weeks.

The moth is light brown in color and measures 15-18 mm across the wings. Fore wing has a subapical brown spot and with several transverse rows of brown scales. Hindwing is light black in colour. Head is depressed and antennae strongly pectinate, with the pectination uniform throughout.

4.2. ECOLOGY

4.2.1. Infestation trends

Although moths were available in the field from March onwards, there was no evidence for the beginning of a fresh generation. However, with the onset of rains in late May, new generation started to appear. During this period, eggs as well as the newly hatched larvae could be seen on the bark of trees. Usually, it takes 2 to 3 months for the larva to make the tunnel in the wood and to construct the sleeve . The sleeve extending from the borer hole is a clear indication of the existence of the larva inside. Fresh attack continued until October, after which the population remained more or less steady (Table 1). As there is only one generation in a year, this insect is univoltine.

4.2.2. Infestation progression

When this study was initiated in 1994, the overall infestation in the plantation was only 15% with low intensity of attack. While completing this study in Dec. 1995, 49.66% of the total trees in the plantation were found to be affected with different levels of damage intensity - 31.8% belonging to score 1; 11.97% to score 2 and 6.09% to score 3. Up to 8 borers were present in the heavily affected trees belonging to score 3.

Data gathered from the experimental plot have also indicated a similar rate of pest build up. Of the 100 trees in the plot only 29 were affected in 1994-95. The proportion of trees belonging to low and heavy infestation intensity was more or less the same. But during 1995-96 there was an increase in the infestation with 58 trees showing infestation. There was also a clear cut increase in the proportion of trees showing heavy infestation (Fig. 3). This heavy pest buildup might be due to the high fecundity of moths. It is also possible that *I. quadrinotata* being feeble fliers, may not migrate to any great distance and may remain within the same locality and continue to attack trees leading to an increase in infestation.

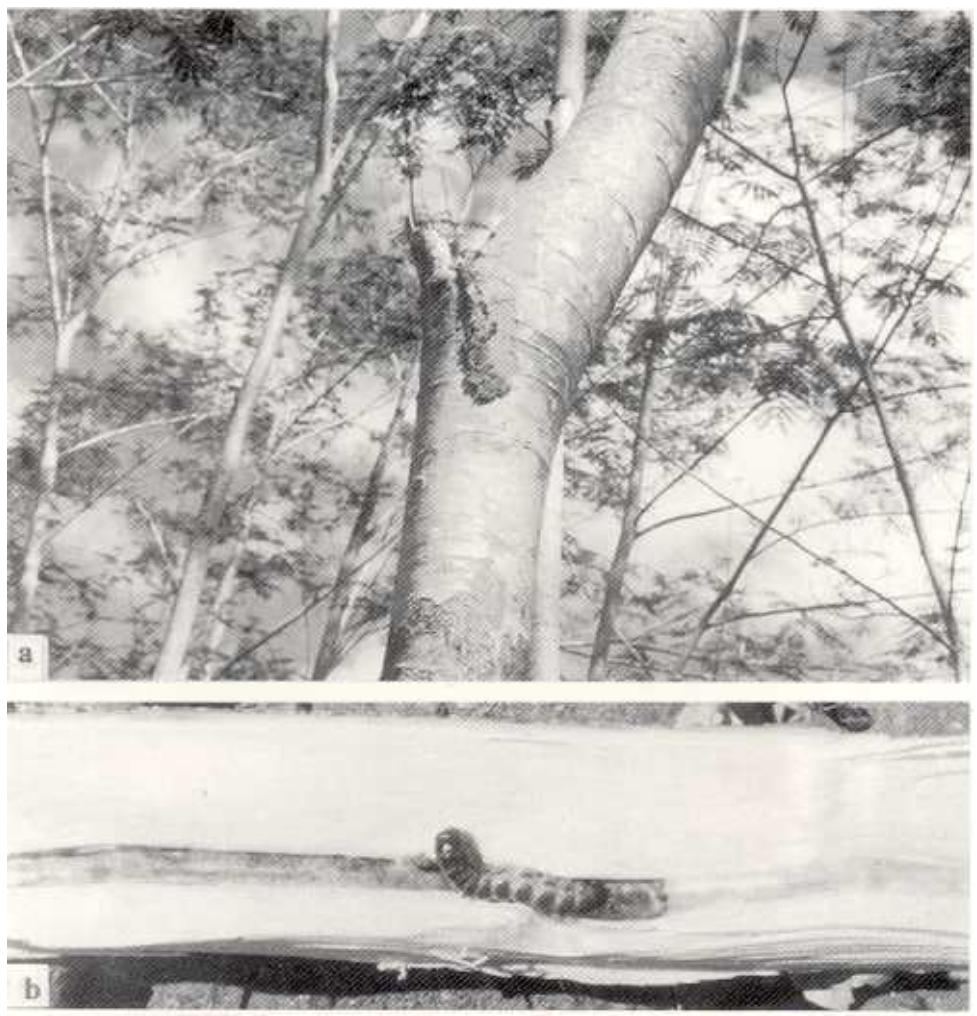

Fig. 1. (a) *Paraserianthes falcataria* tree affected by *Indarbela quadrinotata*; (b) A twig affected by *I.quadrinotata* split open to show the caterpillar inside.

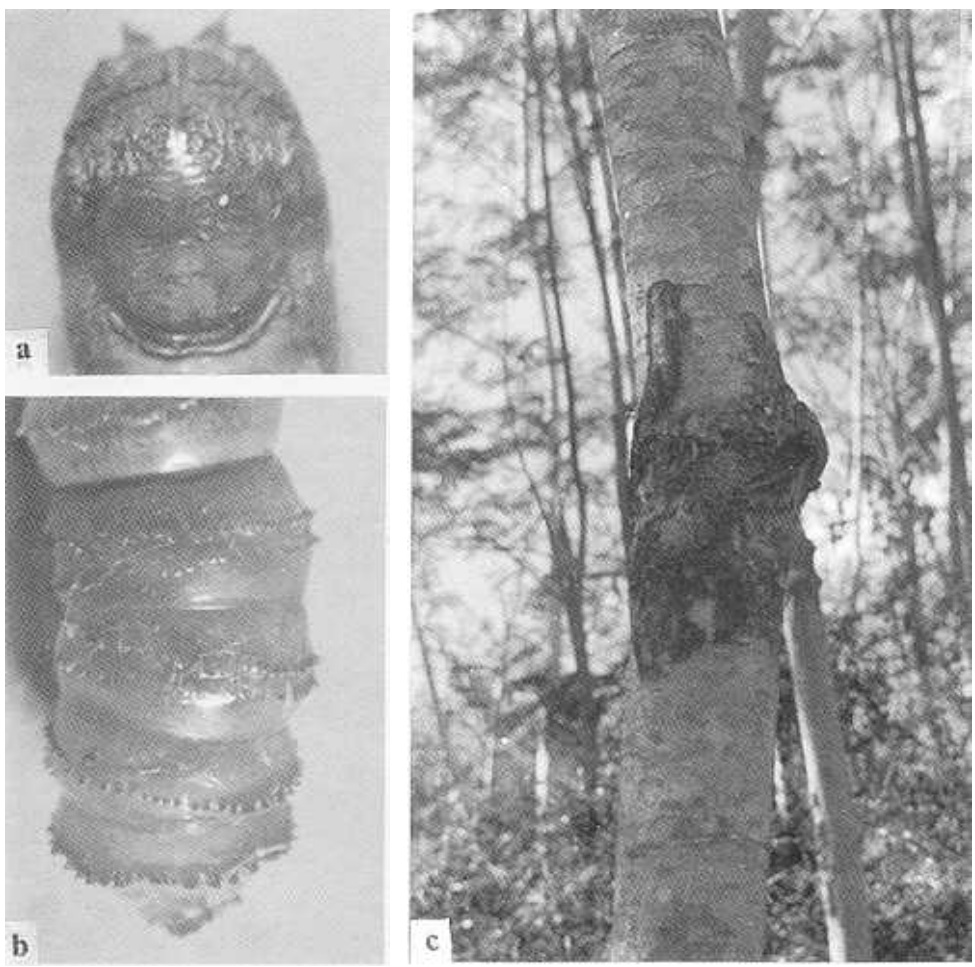

Fig. 2. (a) Enlarged photograph of the anterior end of the pupa of *1. quadrinotata* to show the cephalic processes;
(b) Enlarged photograph of the posterior end of the pupa to show the circlets of abdominal spines;
(c) View of borer affected tree after chemical treatment. Note the crumbled appearance of the 'sleeve' due to mortality of larva inside.

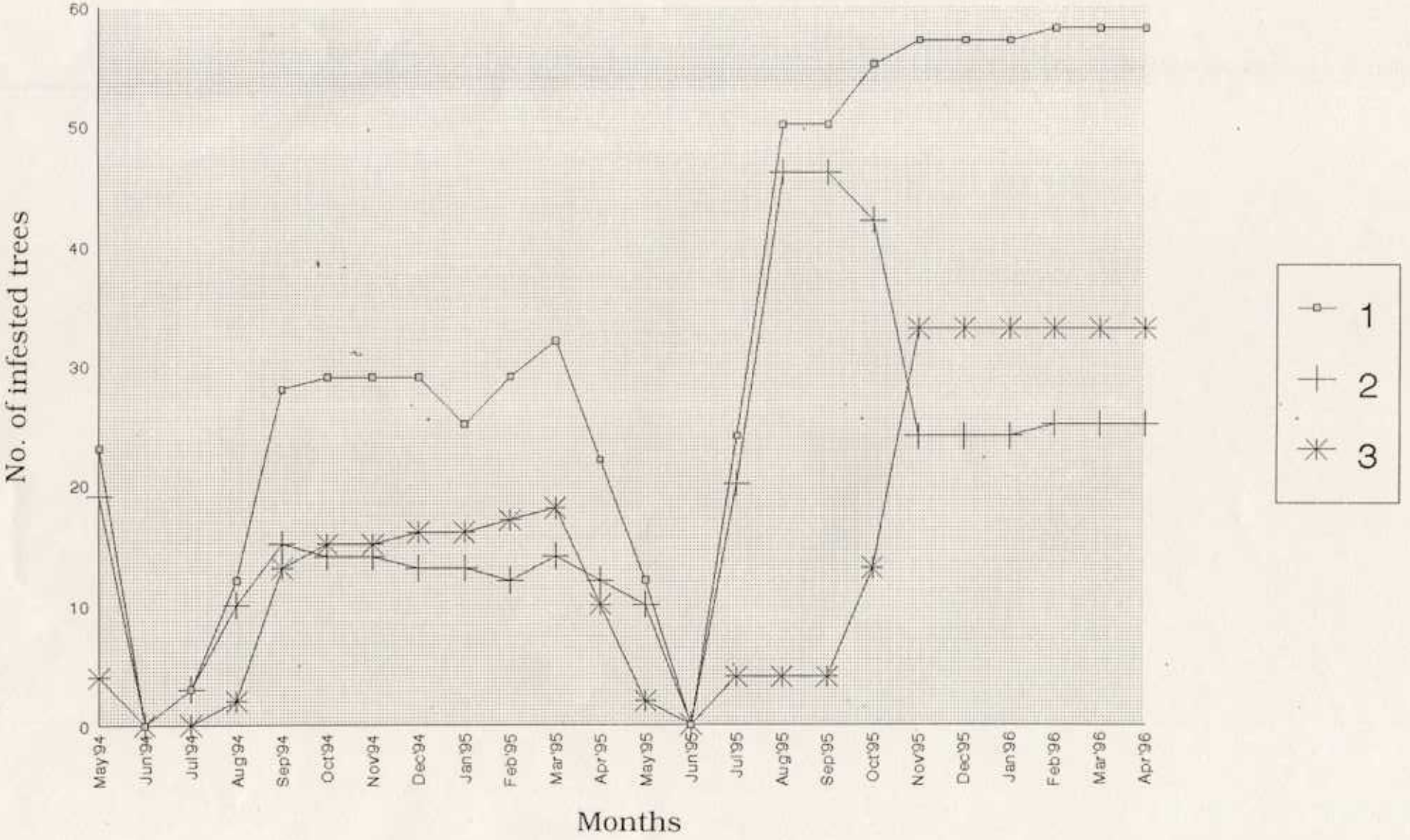

Fig. 3. Infestation pattern of *Indarbela quadrinotata* in plantations of *Paraserianthes falcataria*.
1. Trees showing infestation.
2. Affected trees of low infestation intensity.
3. Affected trees of high infestation intensity.

Table 1. Infestation trends of *Indarbela quadrinotata* in a plantation of *P. falcataria* (1991)

Months	No. of trees under infestation score			
	0	1	2	3
1994				
May	77	19	4	-
June	100	-	-	-
July	97	3	-	-
August	88	10	1	1
September	72	15	10	3
October	71	14	12	3
November	71	14	12	3
December	71	13	11	5
1995				
January	71	13	11	5
February	71	12	11	6
March	78	14	12	6
April	78	12	6	4
May	88	10	1	1
June	100	-	-	-
July	76	20	1	3
August	50	46	1	3
September	50	46	1	3
October	45	42	10	3
November	45	24	16	17
December	43	24	16	17
1996				
January	43	24	16	17
February	42	25	16	17
March	42	25	16	17
April	42	25	16	17

4.2.3. Alternative hosts

Earlier, *I. quadrinotata* was recorded as a minor pest of *P. falcataria* . by Mathew and Nair (1985).Observations made in this study on trees along the roads and in homesteads in various parts of Kerala have indicated incidence of this insect on various other tree species as well (Table 2). Only a few insects were present on each of these species and the extent of bark loss was not much. It may be noted here that there was no instance of die-back of these trees due to secondary infestation by pathogenic organisms or decay fungi.

Table 2. Incidence of *Indarbela quadrinotata* on various trees in Kerala

Locality	Plant host	Remarks
Peechi	*Xylia xylocarpa*	Minor pest
Pothundy		
Pattikad	*Casuarina equisetifolia* *Peltophorum pterocarpum**	On road side trees: minor pest
Wadakkancheny	*P. pterocarpum*	
Nemmara	*P. pterocarpum*	
Amballoor	*Delonix regia*	
Harippad	*Terminalia catappa*	
Karunagappally	*Swietenia macrophylla**	
Mannar	*Ceiba pentandra**	Trees in homesteads; minor pest
Mavelikara	*Macaranga indica**	
Ranni	*Mesua ferrea**	Trees in natural forest: minor pest
Calicut	*Anacardium occidentale*	Trees in homesteads: minor pest

4.3. ECONOMIC IMPORTANCE

Extensive bark injury as well as tunneling into the wood by *I. quadrinotata* often affect the vigour of the trees. The affected trees may also get exposed to infestation by various pathogenic organisms which result in the die-back of trees. Infestation by pathogenic organisms may also lead to rot of timber. Since the wood of *P. falcataria* is mainly used as 'catamarans' (floats) by fishermen and also for match and pulp industries, such defect to the wood

Table 3. Revenue obtained from *Paraserianthes falcataria* plantations in the Punalur Forest Division

Year of planting	Date of felling	Area (ha)	Yield (m^3)		Yield/ha	Revenue (Rs.)	Income/ha (Rs.)
			Round wood	Branch wood			
1984-85	Dec. 1993	6	21.88	82.848	17.454	47,500	75.59
1984-85	Dec. 1993	5	26.395	221.580	49.595	52,900	42.67
1984-85	Dec. 1994	6	70.485	343.820	69.050	1,81,000	72.55
1984-85	Jan. 1995	5.5	30.279	137.637	30.530	74,400	80.55
1986-87	Dec. 1995	8.4	196.136	66.44	31.259	4,75,000	215.35

Source: Punalur Forest Division, Kerala Forest Department.

will affect its commercial value. Revenue obtained from certain recently felled *P. falcataria* plantations at Karavaloor in Punalur is presented in Table 3.

Data presented in Table 3 show that the yield per ha was very low (Rs. 17.454) in the 1st plantation as compared to that from others. Yield obtained from the 3rd plantation was found to be the highest. With regard to revenue, income obtained from the 5th plantation was the highest (Rs.215.35/ha). The plantations with reduced income were reported to be affected by this pest. Although it was not possible to evaluate the extent of economic loss caused by borer infestation, it must be certainly one of the reasons for the reduction in yield/revenue.

4.4. CONTROL TRIALS

A preliminary field trial using insecticides from biocide, pyrethroid, organochlorine, organophosphorous and carbamate groups was carried out in a 1991 planted *P. falcataria* plantation at Kumaramkudy in Punalur. There were 15 treatments including control. Three trees were used for each treatment. Spot application using a rocker sprayer was tried as other methods were found to be impracticable on a plantation scale.

Analysis of variance on the efficacy of different treatments indicate that all insecticidal treatments were significantly different during all the periods like 24 h ($F = 2.8402$, $P = 0.05$), 48 h ($F = 2.81488$, $P = 0.05$) and 7 days ($F = 3.3218$, $P = 0.05$) and 14 days ($F = 2.3717$, $P = 0.05$) after treatment.

The trend of efficacy amongst the treatments varied from period to period. In the observation made after 14 days, fenvalerate (concentration 0.04%. mortality 100%), monocrotophos (concentration 0.1%, mortality 100%), endosulphan (concentration 0.1%, mortality 100%) and Dipel (concentration 0.05%, mortality 94.44%) gave best results (Table 4).

Based on the results obtained, further trials were carried out using the insecticides that gave good results. The concentration remained the same but the replications are doubled i.e., 6 trees were used for each treatment. Analysis of variance on the percentage of mortality revealed that there exists significant difference between the treatments during all periods such as after 24 h ($F = 8.0829$. $P = 0.01$). 48 h ($F = 8.0372$, $P = 0.01$). after 7 days ($F = 9.6192$, $P = 0.01$) and after 14 days ($F = 9.5132$, $P = 0.01$) of treatment. The mean values obtained in various treatments are given in Table 5.

Of the various treatments, quinalphos (concentration - 0.1%: mortality - 100%), monocrotophos (concentration - 0.1%: mortality - 95.83%) and fenvalerate (concentration - 0.08%; mortality - 95.83%) gave excellent results. These three chemicals at the above dosages were further field tested with

Table 4. Evaluation of insecticides against *Indarbela quadrinotata*

Sl. No.	Treatment	Concent-ration	Percent mortality after			
			24 h	48 h	7 days	14 days
1.	Dipel	0.05%	38.89^{abc*}	83.33^{cd}	94.44^{b}	94.44^{d}
2.	Dipel	0.1%	33.33^{abc}	33.33^{ab}	66.67^{ab}	83.33^{b}
3.	BTK*	0.05%	16.67^{abc}	83.33^{bcd}	83.33^{ab}	83.33^{b}
4.	BTK*	0.01%	0.00^{a}	53.33^{abcd}	76.67^{ab}	76.67^{b}
5.	Fenvalerate	0.04%	100.00^{d}	100.00^{d}	100.00^{b}	100.00^{c}
6.	Fenvalerate	0.08%	81.11^{abc}	81.11^{abc}	1.11^{a}	91.11^{ab}
7.	Carbaryl	0.50%	66.67^{bcd}	66.67^{abcd}	83.33^{ab}	83.33^{bc}
8.	Carbaryl	1.00%	8.33^{ab}	37.22^{ab}	63.89^{ab}	63.89^{bc}
9.	Endosulphan	0.05%	43.33^{abcd}	76.67^{bcd}	76.67^{ab}	76.67^{b}
10.	Endosulphan	0.1%	83.33^{cd}	83.33^{bcd}	83.33^{ab}	100.00^{c}
11.	Monocrotophos	0.05%	8.33^{ab}	27.78^{ab}	69.44^{ab}	69.44^{b}
12.	Monocrotophos	0.1%	16.67^{abc}	16.67^{ab}	100.00^{b}	100.00
13.	Quinalphos	0.05%	33.33^{abc}	50.00^{abcd}	83.33^{ab}	83.33^{b}
14.	Quinalphos	0.01%	27.78^{abc}	27.78^{ab}	72.22^{ab}	88.89^{b}
15.	Control	-	0.00^{ab}	0.00^{a}	0.00	0.00^{a}

*BTK. *Bacillus thuringiensis* (commercial formulation).

]Figures superscribed by the same letters are non significant.

Table 5. Evaluation of insecticides against *Indarbela quadrinotata*

Sl. No.	Treatments		Mortality after		Percentage	
			24 hours	48 hours	7 days	14 days
1.	Dipel	0.05%	16.67ab	44.45b	83.33bcd	91.67bcd
2.	Dipel	0.10%	47.23bcde	91.67d	97.23de	97.22cd
3.	BIK	0.05%	30.55abc	52.78b	61.12b	75.00bc
4.	BIK	0.1%	36.12bcd	52.78bc	83.33bcde	91.67bcd
5.	Fenvalerate	0.04%	0.00a	0.00a	91.67^{bcde}	91.67bcd
6.	Fenvalerate	0.08%	95.83d	95.83d	95.83de	95.83bcd
7.	Endosulphan	0.05%	71.12def	74.45bcd	85.55cde	85.55bcd
8.	Endosulphan	0.1%	83.33def	91.67cd	91.67bcde	91.67bcd
9.	Monocrotophos	0.05%	50.00cde	50.00b	75.83bc	83.33b
10.	Monocrotophos	0.1%	69.45ef	73.62cd	95.83de	95.83'
11.	Quinalphos	0.05%	58.33cde	75.00bcd	91.67bcde	91.67bcd
12.	Quinalphos	0.1%	91.67f	91.67d	100.00e	100.00d
13.	Control	-	0.00a	0.00^{a}	0.00^{a}	

Figures superscribed by the same letters are non significant.

12 replicates per treatment and observations were recorded after 7 days and 14 days. It was observed that the treatments were statistically significant in both the periods such as after 7 days (F= 5.6846, P = 0.01) and 14 days (F= 13.8844, P = 0.0l).The mean values are given in Table 6.

Table 6. Evaluation of insecticides against *Indarbela quadrinotata*

Sl. No.	Treatments	% mortality after	
		7 days	14 days
1.	Fenvalerate 0.08%	46.67^{ab}	60.83^{b}
2.	Monocrotophos 0.1%	81.02^{b}	100.00^{c}
3.	Quinalphos 0.1%	63.90^{b}	72.22^{bc}
4.	Control	0.00^{a}	0.00^{a}

Figures superscribed by the same letters are non-significant.

Based on the results obtained, the treatment monocrotophos (Dimecron) at 0.1% concentration) which gave 100% mortality was ranked as the best followed by quinalphos (Ekalux) at 0.1% concentration (72% mortality) and fenvalerate (Sumicidin) at 0.08% concentration (60% mortality).

5. CONCLUSIONS

The bark caterpillar, *I. quadrinotata* is a polyphagous pest attacking a variety of tree species in Kerala. This insect which was considered as a pest of minor importance until recently, has suddenly assumed serious pest status in forest plantations of *Paraserianthes falcataria.*

Being a wood borer, specialised conditions are required for its establishment. Among various factors, age of the tree is important, as this insect is capable of building up very fast in young trees compared to older trees. Observations made in the present study has indicated that, infestation in *P. falcataria* plantations has always occurred when the plants were in the sapling stage.

The biological characteristics of this insect are such that, once established within a tree, it has better chances of survival due to its concealed habits. The avenue trees of peltophorum, mahogany, casuarina etc., that are planted on road sides, were frequently found affected by this insect. In such cases there will be always a heavy pest population in the locality, leading to greater chances of pest attack.

In Punalur Forest Division, *P. falcataria* is extensively planted both in forest plantations as well as in private land. The build up of this insect on this tree could be from population that must have built up on avenue trees of *P. pterocarpum, S. macrophylla* and *D. regia.* Having developed on a favourable host like *P. falcataria,* this insect has developed into large populations.

Since *P. falcataria* is a much preferred tree species in this region on account of its faster growth, planting of this species has to be continued. At present, incidence of the bark caterpillar is the only problem for maintaining plantations of *P. falcataria.* The results of the studies made herein indicate that it can be controlled by application of appropriate pesticides when its attack is noticed. Since the establishment of this insect generally occurs when the trees are still young, regular inspection of plantations is essential in order to detect the infestation in the very beginning itself. The chemicals recommended for its control are monocrotophos (Dimecron)(0.l%),quinalphos (Ekalux)(0.1%) or fenvalerate (Sumicidin) ,(0.08%). Spot application of any of the above chemicals, using a rocker sprayer drenching the borer hole, sleeve and the surrounding bark: will be enough to control this pest, since the larva while feeding on the bark surrounding the sleeve will get contaminated and be killed. As the chemical is applied only on the bark, there is not much contamination of the environment. Spot application of the chemical also minimises possible adverse effects on non target organisms. This will also be

economical since the spray is required to be applied only on the affected patches. The effect of application can be easily recorded by observing the condition of the sleeve (Fig. 2c) extending from the borer hole, which will disintegrate and fall down if the larva is dead inside its tunnel.

I. quadrinotata has annual generations beginning from June-July . The larval stage lasts for about eight months and pupation occurs from February onwards. Therefore, chemical application may be carried out immediately after the rains preferably during the months September/October when the infestation is easily detectable. The treatment will be very effective and economical in younger plantations compared to older plantations, where there will be difficulty in pesticide application on account of the height of the trees.

7. REFERENCES

Alrasjid, H. 1973. Beberapa keterangen tentang *Albizia falcataria* (L.) Fosberg, Department Pertanian Direktorat Jenderal kehutanan Lambaga Penelitian Hutan. Laporan No. 157. 6 p.

Arshad, M. and Hafiz, I.A. 1983. Field performance of *Beauveria bassiana* (Bals.) Vuvill., on *Indarbela quadrinotata* Wlk., Pseudarbelidae: Lepidoptera. *Bulletin of zoology,* I: 11-16.

Beeson, C.F.C. 1941. The Ecology and Control of Forest Insects of India and the neighbouring Countries. Govt. of India. 767 p.

Bhasin, G.D. and Roonwal. M.L. 1954. A list of insect pests of forest plants in india and the adjacent countries (arranged alphabetically according to plant genera and species for the use of Forest Officers). Part I. General Introduction by M.L. Roonwal, Part II. List of insect pests of Plant genera 'A.' *Indian For. Bull.*, 171(1): 93.

Browne, F.G. 1968. Pests and Diseases of Forest Plantation Trees. An annotated list of principal species occurring in the British Commonwealth. Clarendon Press, Oxford. 1330 p.

S.C.: Kakoty, N.W. and Goswami, M.G. 1985. Note on the biology and control of the bark eating caterpillar, *Indarbela quadrinotata* Wlk. a pest of shade trees in north-east India. *Two and a Bud.* 32: 1-2, 40-41.

Fasih, M. and Srivastava, R.P. 1988. Natural occurrence of *Beauveria bassiana* an entomogenous fungus on bark eating caterpillar, *Indarbela* spp. *Indian Journal of Plant Pathology,* 6: 1, 11-16.

Ghosh, R.C. 1977. Handbook of Afforestation Techniques. Government of India, 411 p.

Gope, B. and Roy, S.K. 1986. Shade tree pest survey in the Dooars. Two and a Bud 33: 1-2, 26-27.

Kumawat S.R. and Swaminathan, R. 1990. Relative preference of jujube *(Zizyphus mauritiana* Lamk.) cultivars by bark eating caterpillar, *Indarbela quadrinotata* (Walker). *Indian journal of Entomology,* 52(2): 336-338.

Mathew, George and Nair, K.S.S. 1985. Insects associated with forest plantations of *Paraserianthes falcataria* in Kerala. India. *Malaysian Forester,* 48(3):200-205.

Menon, K.D. 1958. Defoliation of an experimental pulpwood plantation. *Malaysian Forester,* 21: 230-235.

Mishra, S.C. 1991. Effect of temperature and relative humidity on consumption and digestion of food (bark) by larvae of *Indarbela quadrinotata* Wlk. (Lepidoptera: Indarbelidae). *Journal of Entomological Research,* 15(4):287-293.

Mote, U.N. and Tambe, A.B. 1990. Chemical control of bark eating caterpillar *Indarbela quadrinotata* (Walker) in pomegranate. *Plant Protection Bulletin*, 42: 4, 7-8.

Nair, K.S.S. and Mathew, G. 1988. Biology and control of insect pests of fast growing hardwood species. *KFRl Research Report No:* 51.45.

Narendran, T.C. and Sureshan, P.M. 1988. A contribution to our knowledge of Torymidae of India (Hymenoptera: Chalcidoidea). *Bollettino-del-Laboratorio-di-Entomologia-Agraria-Filippo- Silvestri,* 45: 37-47.

NAS, 1979. *Albizia falcataria*. In: Tropical legumes: Resources for the future. National Academy of Sciences, Washington: 173-177.

Patil, P.V.; Patil, V.K. and Deshpande, A.D. 1990. Incidence and control of bark eating caterpillar, *Indarbela* sp. on guava trees. *Journal of Maharashtra Agricultural University,* 15(2): 230.

Pratap-Singh and Bhandari. R.S. 1987. Insect, pests of *Acacia tortilis* in India. *Indian Forester,* 113(11): 734-743.

Ramsingh; Jaswant Singh, J.; Singh, R. and Singh, J. 1982. New record of *Aspergillus candidus* Link - a potential entomogenous fungus on *Indarbela* spp. *Science and Culture,* 48(8): 282-283.

Remadevi, O.K. 1989. Bark eating caterpillar *Indarbela quadrinotata* (Walker), attacks mulberry too. *Newsletter - Central Sericulture Research and Training Institute Mysore,* 4: 3-4.

Sandhu, G.S.; Sohi, A.S. and Batra, R.C. 1987. Comparison of different methods for the management of the bark-eating caterpillar *Indarbela quadrinotata* (Metarbelidae: Lepidoptera) infesting fruit and avenue trees in Punjab. *Punjab Horticultural Journal,* 27(3-4): 255-259.

Sharma, D.D. and Kumar, H. 1986. How to control bark eating caterpillars'? *Indian Horticulture,* 31 (1): 25.

Sharma, S.K. and Verma, A.K. 1987. Insect pest complex of apricot, *Prunus armeniaca* L. in Himachal Pradesh. *Bulletin of Entomology,* 28(2): 115-123.

Shevale, B.S. 1991. Control of bark eating caterpillar, *Indarbela quadrinotata* (Walker) in pomegranate through insecticidal sprays. *Plant Protection Bulletin,* 43(3-4):31-32.

Sidabutar H. and Natwiria, D. 1973. Percobaan penggunaan Dimecron 100 untuk memberantas hama *Xystrocera festiva* Pascoe pada *Albizia falcataria* (L.) Fosberg. *Direktorat Jenderal kehutanan Lembage Penelitian Hutan Laporan No.* 174. 20 p.

Sidhu, M. and Poon C.K., 1983. Efficacy of insecticide soaked cotton plugs against caterpillars of *Indarbela* sp. (Lepidoptera: Metarbelidae) infesting guava trees. *Pesticides,* 22 (9): 19-20.

Singh, M.P. 1984. Field screening of some jujube cultivars against the attack of the bark eating caterpillar, *Indarbela quadrinotata* (Walker). *Madras Agricultural Journal,* 71(6): 416- 417.

Singh, U.C. and Dhamdhere, S.V. 1989. Field screening of some guava varieties against the bark eating caterpillar, *Indarbela quadrinotata* (Walker). *Indian Journal of Entomology,* 51(2): 216-217.

Verma. T.D. 1985. Incidence and chemical control of bark- eating caterpillar, *Indar bela quadrinotata* Walker on plum trees. *Indian Journal of AgriculturaI Sciences.* 55(2): 131-132.