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SEASONAL INCIDENCE, HOST RANGE AND CONTROL OF THE TEAK SAPLING BORER, SAHYADRASSUS MALABARICUS

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ABSTRACT

The life history, ecology, pest status and control of ***Sahyadrassus malabaricus*** (Moore) (Lepidoptera, Hepialidae), an insect borer of teak saplings in Kerala, were investigated.

The larva bores into the stem of saplings and lives in a tunnel along the pith. The mouth of the tunnel is covered by a thick mat of wood particles spun together with silk, underneath which the larva feeds on the callus tissue that grows as a result of continuous browsing.

The insect has an annual life cycle with most moths emerging in late April and early May. The moths do not feed and the female lays thousands of eggs soon after emergence. Circumstancial evidences suggest that the early larval instars survive on weedy ground vegetation, older larvae migrating to young saplings later, Most larvae are established in plantations by August although continued establishment may occur upto November.

S. malabaricus has a wide host range of over 40 species of woody shrubs and trees belonging to 22 families, of which Ulmaceae, Verbenaceae, Mimosaceae and Myrtaceae contain the most commonly attacked species. Among forest plantation species, saplings of ***Tectona grandis, Eucalyptus*** spp., ***Gmelina arborea, Anthocephalus chinensis, Sterculia companulata Albizia falcataria*** and ***Calliandra callothyrsus*** were attacked. In some 2 to 4–year old plantations of teak studied, 6 to 61 per cent of the saplings were attacked. ***Trema orientalis*** and ***Clerodendrum viscosum*** were the most attractive hosts, medium sized ***Trema*** trees supporting as many as 30 larvae per tree unlike others in which multiple infestation was rare. Occurrence of thesespecies in the vicinity and dense weed cover within the plantation favoured high incidence of the borer. Resistance of trees, intra-specific competition, predation by a bird and infection by a fungus were the main natural mortality factors operating after the larvae had established in saplings. Originally confined to mountainous forest areas, this species appears to be spreading gradually to the plains.

S. malabaricus is not a serious pest. As the larva feeds only on callus growth in the vicinity of the tunnel mouth, the damage caused is negligible. In rare instances, the stem is ring-barked, resulting in drying up of the sapling or the stem breaks off at the point weakened by feeding.

In experimental plantations, seed orchards, etc., where each sapling is valuable, attacked saplings may be protected by spot application of an insecticide, quinalphos. Ouinalphos (Ekalux), a contact cum stomach poison, may be applied at a concentration of 0.125% (active ingredient) solution using a brush, to the tunnel mouth region after pulling off the particle-mat cover. It gave complete control in comparison to Lindane, Carbaryl (Sevin), Sevimol and tar, all of which gave only partial control. HCH(BHC), at 0.5% concentration, was ineffective. A preparation of ***Bacillus thuringiensis*** was also ineffective by the method of application tested. A thick, nondrying formulation of insecticide, was developed in an attempt to increase the effectiveness of insecticides, but Ekalux was sufficiently effective even without adjuvants. In less valuable plantations, incidence of attack can be reduced by following some cultural practices which are described.

1 INTRODUCTION

The teak sapling borer, often called 'Phassus borer', is the larva of a moth, ***Sahyadrassus malabaricus*** (Moore), formerly known as ***Phassus malabaricus*** Moore (Lepidoptera, Hepialidae). The larvae cause damage to saplings of various tree species by boring into the stem, often leading to breaking off of stem at the point of attack (Figs. 1,2). Widespread incidence of this borer has been noticed in young plantations of teak, in recent years. Attacked saplings can be easily recognized **by** the dome-shaped mass of woody particles covering the point of attack (Fig. 3). On removal of this cover, a large borer hole can be seen (Fig. 4) which extend down along the central core of the stem.

Because of widespread occurrence in young plantations, easy noticeability of attack and fear of spread of attack to other saplings in the plantation, several instances of incidence have been reported to the Institute by the Forest Department in the past and recommendations for control sought. The present study was undertaken to investigate the biology and ecology of this pest, assess damage potential and develop suitable pest management strategies.

Beeson (1941), in his classical book on the forest insects of India, summarised the existing information on the life history and habits of this insect. No original work has been reported on ***Sahyadrassus*** since then.

The family Hepialidae (called swift moths) is a primitive family of Lepidoptera, characterised by the absence of frenulum (wings being interlocked by jugum), similar venation of fore- and hind-wings, and vestigeal proboscis. Of about 300 species of hepialids known in the world (Nayar *et at.,* 1976) only 14 have been recorded from India and neighbouring countries, (Hampson, 1892, 1896). The family is best developed in South America and Australasia (Mani, 1973). The larvae of most hepialids are borers of the stem of tree saplings or woody shrubs. Those recorded on forest trees in India are, apartfrom ***Sahyadrassus malabaricus*** (Moore), (1) ***Endoclita auratus*** (Hampson) attacking ***Alnus nepalensis, Cryptomeria japonica*** and ***Eucalyptus*** sp. in 'Bengal Himalayas', (2) ***E. punctimargo*** (Swinhoe), also attacking ***Cryptomeria japonica*** in 'Bengal Himalayas' and (3) ***E. signifer*** (Walker) attacking teak in Assam. In addition, one unidentified species each has been recorded on ***Lagerstroemia fios-reginae*** in Assam, ***Machilus edulis*** in Bengal and ***Strobilanthes neesianus*** in Bombay (apparently the then Bombay Presidency) (Beeson, 1941). Only ***S. malabaricus*** has so far been recorded from southern India.

Lefroy (1909) observed "the hepialids are found solely in the hills, none occurring, or very rarely, at low elevation or cultivated plains". However, Beeson (1941) recorded that ***S. malabaricus*** is distributed from sea coast upto about 2000m in southern India. It has been specifically recorded from Nilgiris (Lefroy, 1909) and Bangalore (Fletcher, 1914). Beeson (1941) listed 30 species of woody shrubs and tree saplings on which development of ***S. malabaricus*** occurred, showing that the species is polyphagous. Among the recorded hosts, forest trees of importance in Kerala are *Eucalyptus* spp. ***Gmelina arborea. Grewia tiliaefolia, Lagerstroemia mlcrocarpa*** and ***Tectona grandis.*** However, no detailed information is available on its pest status. According to Eeeson (1941) it is injurious in plantations of eucalypts and teak, which may be attacked at one year old, the nature of damage depending on the stem thickness and vigour of the plant and extent of girdling.

A general description of the insect and its life history has been given by Beeson (1941) along with figures of the moth and full-grown larva. Brief reference to the insect has also been made by Lefroy (1909), Fletcher (1914) and Ayyar (1940) The life cycle is reported to be annual, with moths emerging mainly in May and on into June.

Recommendations in the literature for control of ***Sahyadrassus*** or related. nsects include killing the larva physically by inserting a green twig or bamboo splinter through the borer hole, plugging the borer hole with tar, injecting a suitable insecticide into the hole followed by sealing, or using other host plants as 'traps'. (Beeson 1941; Kalshoven, 1924; Sonan, 1938). None of these methods are used, however, in forest plantations, generally.

In the present investigation, studies were made on the biology and ecology of the insect to build up necessary data base for developing appropriate methods for management of the pest. Most observations were made in young plantations of teak, but some plantations of eucalypts and other species were also examined. Several field trials were conducted to test insecticides and their methods of application. Some trials carried out after the formal expiry of the project period are also included in the report. Areas for future investigation are indicated.

For convenience, the term 'Sahya borer' will be used in this report, as a common name, for the larvae of ***Sahyadrassus malabaricus***

Fig. 1 A 3-yr old teak sapling in a plantation at Vazhachal broken off at the point of Sahyadrassus attack.

Fig.2. About **1-yr** old Eucalyptus grandis sanling, 2 m high, attacked by sahyadrassus and wind-thrown, in a plantation at Noolpuzha, Wynad.

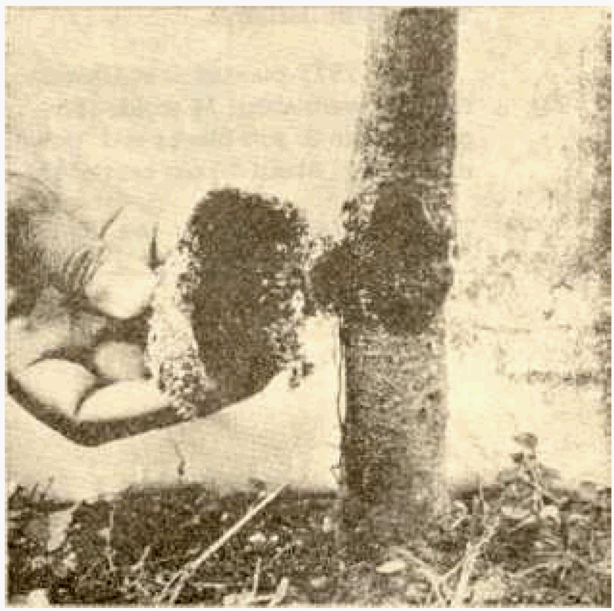


Fig.3 Sahyadrassus attack is characterised by a dome-shaped mass of woody particles covering the point of attack, as seen here on the stem of Cajanus cajan.

Fig.4 Cover removed to show the point of attack on a 2 - yr old Gmelina arborea sapling at Vazhachel.

I1 INCIDENCE OF INFESTATION IN VARIOUS PLANTATIONS

Several instances of Sahya borer attack were reported to the Institute by the Forest Department. These included incidence in plantations of teak at Parambikulam, Kallar Valley, Nilambur, Kothamangalam and Kalady; of eucalypts at Nilambur and Peermade; of ***Gmelina arborea*** at Kulathupuzha; and of ***Sterculia campanulata*** at Vazhachal. Some of these plantations were visited and assessment of the level of incidence was made. Most reports of damage concerned young plantation of teak, 1½ to 4½) yrs old. In addition, some plantations of teak and other species were visited when opportunities arose in connection with other field investigations.

Teak

The borer was noticed in most young plantations throughout Kerala although the intensity of incidence varied. Plantations at Parambikulam, Kallar valley, Kothamangalam and Kalady were examined in detail. Observations are given below along with details of the plantations and the method of survey which differed slightly. In all the tables, Row. No. 1 denotes the first observation row selected at random from among the first 20 rows.

1. Parambikulam

A 1977-plantation at Orukombankutty was surveyed in October 1978. The saplings were about 1½ yr old. The plantation area of over 60 ha was arbitrarily divided into 3 sub-blocks and the middle row of saplings in each sub-block was examined. About 10 per cent of the saplings were found attacked (Table 1).

Table 1. ***Incidence of the Sahya borer in a teak plantation at Parambikulam***

Sub-block No.	No. of saplings examined	No. of saplings attacked
1	43	4
2	73	11
3	55	3
Total	171	18 (10.5%)

In a plot selected for insecticide trials within the same plantation, 75 out of 931 saplings (8%) were attacked.

2. **Valley**

A 1976-plantation in Kallar Range was surveyed in April 1979. The saplings were 3yrs old. All saplings in every 20th row of the 6 ha plantation were examined; about 13 per cent were attacked (Table 2).

Table 2. ***Incidence of the Sahya borer in a teak plantation at Kallar Valley***

Row No.	Total No. of saplings	No. of saplings attacked
1	21	2
21	13	5
41	39	14
61	40	4
81	60	0
101	65	16
121	27	1
141	39	5
161	15	0
181	39	1
Total	358	48 (13.4%)

3. Kothamangalam

A 1975-plantation in Kothamangalam Range (Kaliar ,series) was surveyed in December 1979. The saplings were 41/2yrs.old. All saplings in every 20th row of the 26 ha plantation were examined. About 32 per cent of the saplings were attacked (Table 3).

Table 3. ***Incidence of the Sahya borer in a teak plantarion at Kotharnangalam***

Row No.	Total No. of saplings	No. of saplings attacked
1	30	7
21	35	17
41	53	16
61	81	30
81	84	28
101	227	82
121	230	64
141	250	86
161	242	62
Total	1232	392 (31.8%)

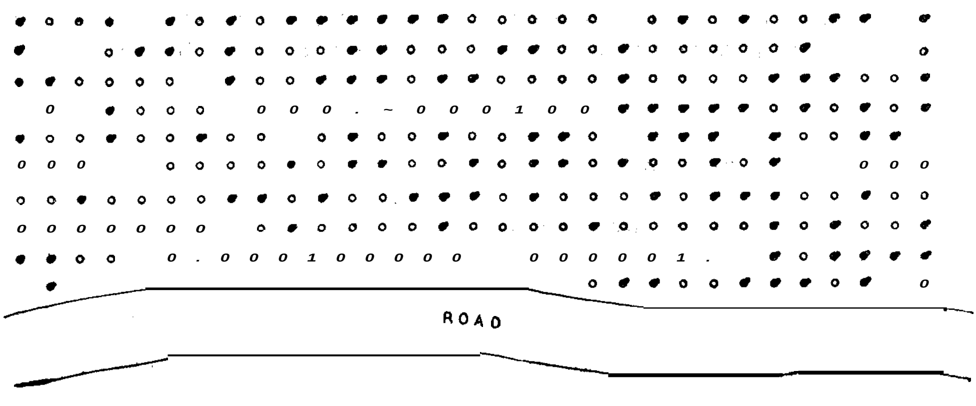
4. Kalady

A 1976-plantation at Athirapally in Kalady Range was surveyed in December 1979. The saplings were about 3½ yrs old. An 18 ha compartment within a 156 ha plantation was covered by enumerating attacked plants in every 20th row. Nearly 61 per cent of the saplings were attacked (Table 4).

Table 4 ***Incidence of the Sahya borer in a teak plantation at Kalady***

Row No.	Total No. of saplings	No. of saplings attacked
1	194	122
21	264	165
41	198	130
61	264	128
81	84	65
Total	1004	610 (60.8%)

In an adjacent compartment in the same plantation, all saplings were examined in each of two plots selected for insecticide trials. In one plot 55 out of 242 saplings (23%) and in the other, 120 out of 266 saplings (45%) were attacked. The distribution of attacked saplings in the latter plot is shown in Fig. 5.



Fig, 5. Diagram showing distributinn of Sahya borer incidence in a selected plot in a 3½-yr old teak plantation at

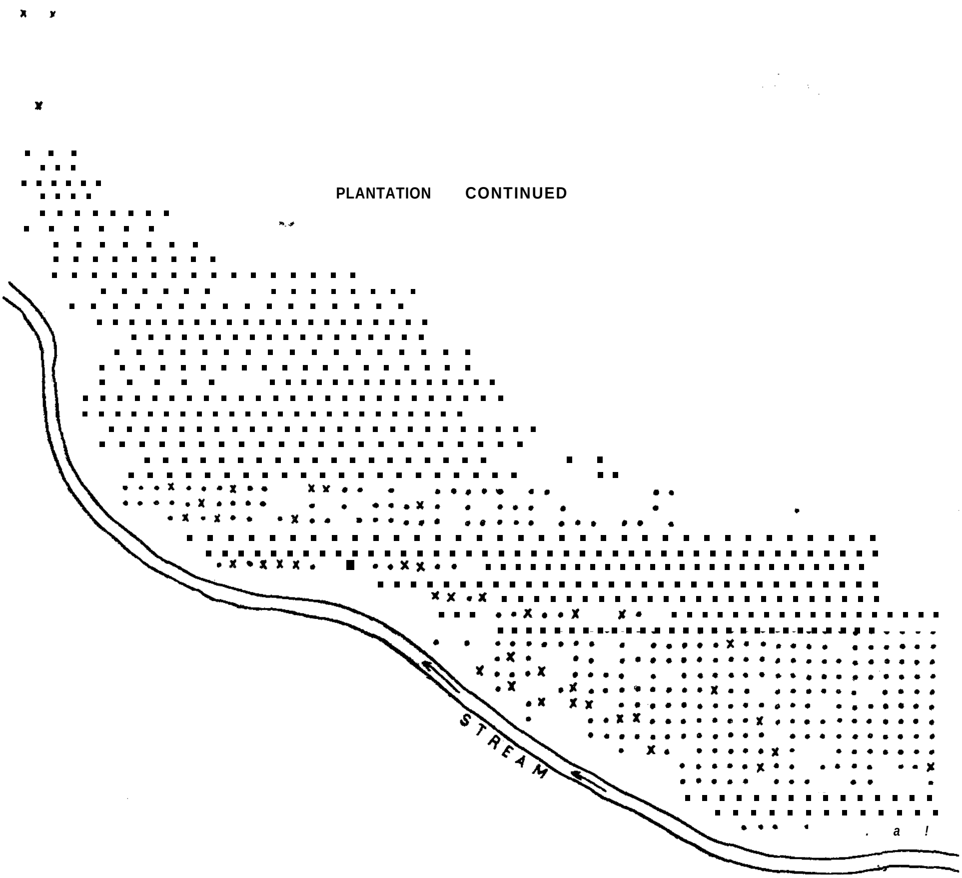
Each sapling (planted at an espacement of 2 rn by 2 m) is represented by a circle; attacked saplings are shown In black with a projection to represent the PMC. The plot is surrounded by saplings of the same age all around, with a narrow approach road on one side.

In an adjacent 4½ yr-old plantation (77 ha) examined at the same time, borer incidence appeared to be less severe. In a random row of saplings examined across the plantation only 4 out of 210 saplings were attacked

5. Arippa

A 16-month old KFRI seed orchard plantation was examined in November 1982. Out of about 500 'plus tree' saplings planted in 1.8 ha area, 30 were attacked (6%).

Considering all the teak plantations surveyed, incidence of borer attack varied from 6 to 61 per cent. Most young plantations, particularly 2 to 4 yrs old, were nfested throughout Kerala. Within a plantation, incidence of attack appeared to be greater near stream banks, wherever they occurred. This general observation



Fig, 6 Distribution of Sahya borer incidence near stream border in an year-old teak plantation at Orukombankutty, Parambikulam.
Attacked saplings are denoted by X. unattacked ones by dots. and missing ones by blank space. Spacing was 2 m by 2 m
Note greater incidence of attack near the stream border

was supported by data in one instance where detailed enumeration was made (Fig. 6). Other than this effect, no particular trend was noticeable in the infestation pattern, the distribution being more or less uniform within a given plantation, particularly when the incidence was heavy (Fig. 5). Factors influencing the level of infestation will be discussed in the next section.

The impact of Sahya borer on teak plantation was generally negligible. In rare instances, the saplings dried up above the point of attack because of ring barking or the stem broke off at that point, but usually coppice shoots developed (see Section III for more details of the damage).

Eucalyptus

Attack of Sahya borer was noticed in several young plantations of both ***Eucalyptus grandis*** and ***E. tereticornis,*** throughout Kerala. Generally, the level of infestation as judged from casual observation was lower than in teak but comparatively more saplings broke off at the point of attack. Specific observations are given below.

1. Wynad

A 1978-plantation of ***Eucalyptus grandis*** at Noolpuzha was examined in March 1980. The saplings were about 2 yrs old. Three plots of 400 saplings each were selected within the 12 ha plantation and all saplings within the plots examined. About 11 per cent of the saplings were attacked (Table 5).

Table 5. ***Incidence of Sahya borer in an eucalypt plantation at Noolpuzha***

Plot No.	Total No. of saplings	No. of saplings attacked
1	400	34
2	400	51
3	400	47
Total	1200	132 (11%)

2. Peermade

About 2-yr old coppiceshoots of ***E.grandis*** at Pambanar were enumerated for Sahya borer incidence in March 1976. The coppice shoots were about 3 m high and 20 - 25 cm in girth; mostly with 3 shoots per stool. Two randomly selected plots, 50 m x 20 m, were examined. Out of 446 stools examined. only 5 saplings' (1.1%)) were attacked.

In October 1982, about 18 ha, planted in 1981 with 3 different species of eucalypts, as part of silvicultural research trials of the Forest Department, was examined. Borer incidence was assessed by examining at least every 5th row (20 per cent of saplings) in each plot. In some plots all saplings were examined.

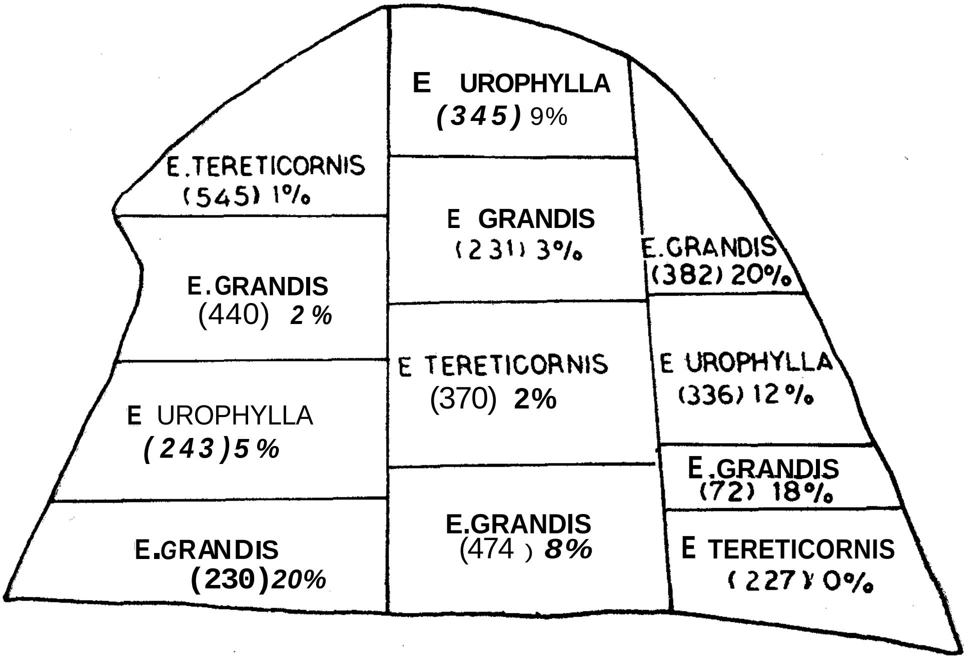


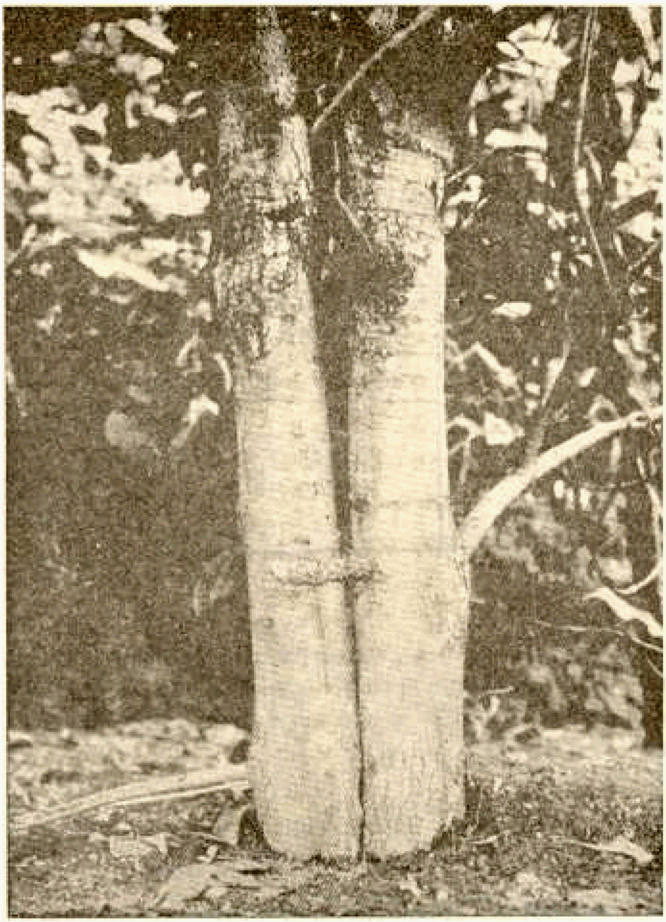
Fig. 7. Diagram showing the field lay-out of experimental eucalypt plantings (1981) made by the Silvicultural Research Wing of the Forest Oepartment at Peermede. Percentage of saplings attacked by Sahya borer in each plot is given. Figures in parentheses are estimated number of saplings in each plot.

Incidence of attack varied from O to 20 per cent (Fig. 7). All the three species, viz' ***Eucalyptus grandis. E. tereticornis*** and ***E. urophylla*** were attacked; ***E. tereitcornis*** appeared to be less susceptible.

Other Species

Infestation was also noticed in plantations of ***Albizia falcataria, Anthocephalus chinensis, Calliandra callothyrsus, Gmelina arborea*** and ***Sterculia companulata.*** Mostly, these were experimental-scale plantations of limited extent except for ***Albizia falcataria.*** In ***A. fa/cataria*** low level infestations were noticed, in 2 to 3-yr-old plantations at Vazhachal, Kollathirumedu and Kulathupuzha.

In *Gmelina arborea* the incidence was somewhat higher. In a provenance trial undertaken at Nilambur by the Silviculture Division of KFRI, 20 to **37** per cent of 2-yr-old *Gme/ina arborea* saplings were attacked; incidence was! low during the first year and from third year onwards (K.C. Chacko, pers. comm.). In all other species, only a few instances of attack were noted.



Fig, 8. **Sahya borer attack of a 5-yr old clove plant at Azhakiyapandiapuram, Kanyakumnri District, Tamil Nadu. Note the girdling-type of attack**

Comparatively high incidence :of attack, most often leading to drying up of plants due to ring barking, was noticed in 4- to 5-yr-old plantations of clove ***(Eugenia ceryophyllata)*** at Azhakiyapandiapuram: Range in the Clove Plantatio Division of Kanyakumari District in Tamil Nadu (Fig. 8).

III LIFE HISTORY AND ECOLOGY

Except for the general information given by Beeson (1941), there is no published literature on the life history, biology and ecology of ***Sahyadrassus malabaricus.*** In the present study, information was gathered on all these aspects, by field observations as well as investigations under controlled conditions.

Methods of Study

Field observations were made throughout Kerala, mainly to identify host plants. This was facilitated by the many field trips made in pursuance of several projects of study, including this. Observations on seasonal development and behaviour of larvae and occurrence of parasites and predators were made mainly on larvae infesting teak and ***Trema orientalis*** at Vazhachal, Athirapally and Kaliar (Chalakudy and Kothamangalam Forest Divisions). To determine the adult emergence period, moth traps were set up in infested teak saplings. A simple trap was developed for

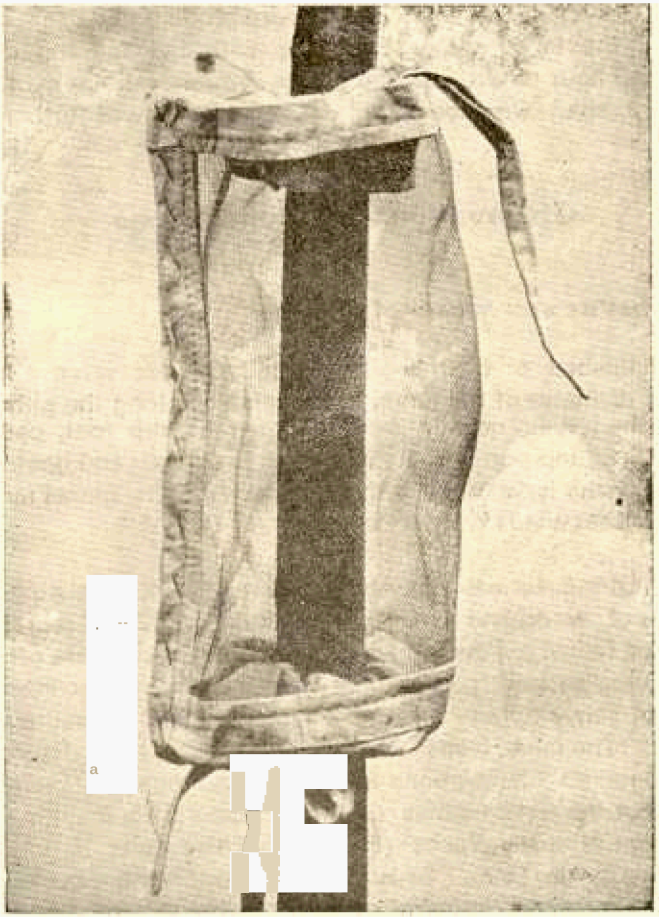


Fig. 9. Moth trap tied in position on a

this purpose. It consisted of a piece of plastic netting, stitched with cloth borders and provided with strings on two sides. It was tied around the stem of the infested sapling and the open end held together by staples (Fig. 9). The only disadvantage of this trap was that in some instances where the plastic netting rested close to the surface of the dome-shaped cover of the borer hole, the larva nibbled a hole in the netting across the mouth of the tunnel, usually just before pupation. through which the emerging moth escaped. This could be prevented by making the trap loose.

Field observations were supplemented with observations made on larvae rehabilitated on saplings of ***Trema orientalis*** growing within the KFRI Campus. Larvae of all ages, irrespective of the original host tree, could be successfully established on ***Trema*** saplings by the following procedure. A hole was drilled on the main stem of the sapling, at right angle to the stem, using a mechanical drill. The diameter of the hole was just sufficient for easy entry of the larva and the depth, just sufficient to accommodate the length of the larva. The larva readily accepted the hole and entered into it moving forwards or backwards depending on the end that was placed near the hole. After preliminary probing and deepening of the hole when necessary, the larva entered the hole with the tail-end downwards and usually, within an hour or two, clused up the entrance hole with a mat-work of wood particles and silk. On subsequent days, the cover was further extended.

Observations and Conclusions

Larval feeding habits and nature of damage

When established on host saplings, the larva excavates a long cylindrical tunnel, about the diameter of the larva, longitudinally along the pith (Figs. 10, 11). At the bottom, the tunnel usually extends into the tap root, particularly if the sapling is small. The top portion of the tunnel is curved and opens to the outside (Fig. 10). Normally the larva rests with head towards the tunnel mouth. It moves either forwards or backwards with equal ease.

The mouth of the tunnel is covered by a mat-work consisting of coarse saw-dust like particles of wood and bark, spun together with silk secreted by the larva (Figs. 3,4). Dried faecal pellets and moulted head capsule are often attached to this mat. This dome-shaped 'particle-mat cover' (PMC) is a conspicuous sign of infestation by the Sahya borer. Initially small, the PMC is gradually extended to cover more area. The larva feeds on the callus tissue that develops around the tunnel mouth. Detailed observations on ***Trema*** saplings artificially infested with larvae showed that the larva nibbles on the bark in such a way that the lower bark layers are left intact in many places (Fig. 12). This results in good callus growth which is consumed by the larva. By not consuming the entire thickness of the bark, the larva ensures sustained growth of new tissues to feed upon. The mode of feeding is similar in other host trees. The tunnel is used mainly as shelter. Feeding

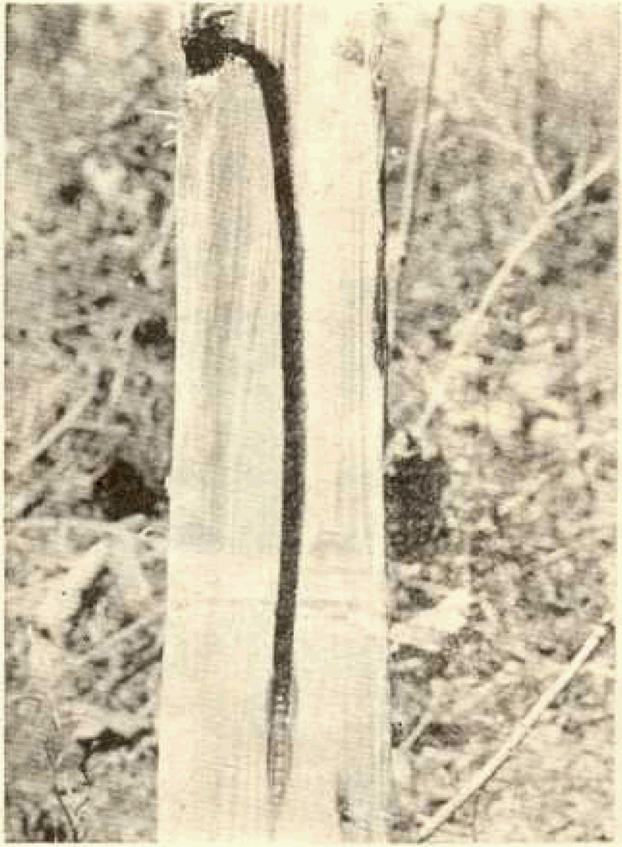
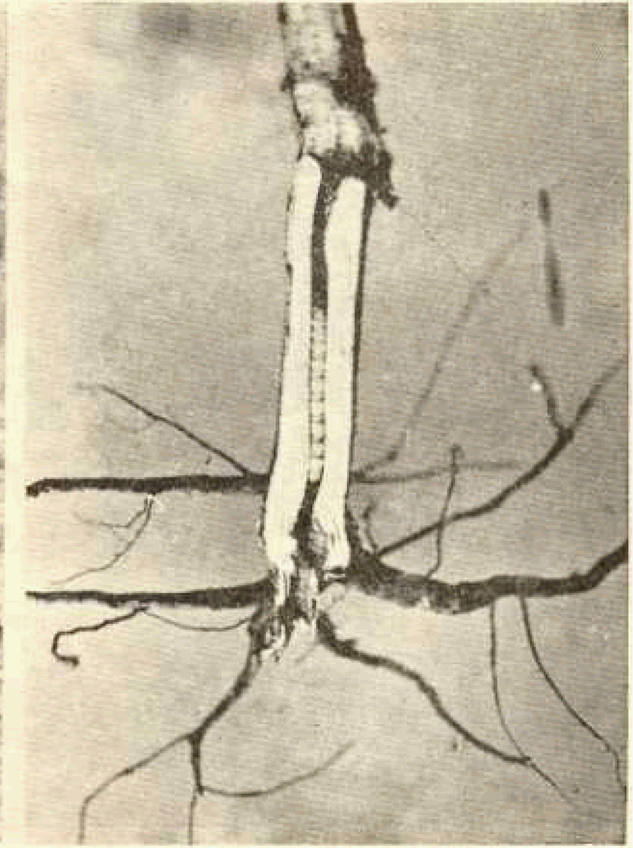


Fig. 10. L. S. of attacked portion of a teak sapling showing the larval tunnel and larva at the bottom.



Fjg. 11. A full-grown larva of S. **malabaricus** inside a longitudinally split sapling of **Clerodendrum viscosum**. Note extention of tunnel into the root.

Fig. 12. PMC lifted up to show feeding on the bark of a sapling of *Trema orientalis*.
a. tunnel mouth; b, fresh feeding; c, new callus growth partly eaten up.

Fig. 13 A 16-month old teak sapling ring-barked by Sahya borer. The PMC has been removed; note the central tunnel mouth and intense callus growth.

takes place at night, under cover of the PMC.As feeding progresses, the PMC is extended to cover the browsed portions. If the PMC is removed, it is rebuilt within a day. Rebuilding usually takes place at night; apparently the larva is inactive and rests at the bottom of the tunnel during the day time.

In some cases, the bark is browsed in a ring around the entire girth of the sapling (Fig. 13). In very rare cases, the entire thickness of the bark is eaten, resulting in death of the portion above the ring-barked area. In most cases, however, feeding is confined to a patch around the tunnel mouth, or an incomplete ring. Some of these saplings break off at the point of feeding. Such instances were generally rare, although some were noticed in young plantations of teak and eucalypts (Figs. 1, 2). In most cases, the damage consisted simply of localised bark feeding (the feeding wound heals up later) and tunnelling of the central pith, which may have caused some growth retardation. In addition, some epicormics often developed below the point of attack

Comparatively high incidence of attack by the Sahya borer in some plantations combined with the easy noticeability of attack, the large size of the larva and the fear that attack may spread to other saplings in the plantation has often created scare amongst forest managers. But in most cases, the real damage is negligible inspite of rare knock-down of some vigorous saplings. Control is necessary, however, in experimental plantations, seed orchards, etc., where each sapling is important.

Life history

In central Kerala, the moths emerged between mid-March and mid-May, most emergence occurring in late April and early May. Beeson (1941) observed that moths emerged mainly in May and on into June, apparently based on observations made elsewhere.

The moths are large and greyish brown in colour, with characteristically mottled forewings (Fig. 14). Measurements of a typical field-trapped female moth were: wing span 11 cni and body length from head to abdomsn, 5.5 cm. There is considerable size variation among individuals, some being almost half the above size. Small pupae were often collected from small saplings, particularly of ***Clerodendrurn viscosum.*** Mouth parts of the moth are vestigeal with atrophied proboscis. Antennae are bare and pointed, with 22 visible segments. Legs are flattened and possess characteristically arranged tufts of hairs. Two black, well developed claws are present in each leg. The third pair of legs are atrophied and are only about 1.5 cm long about two third length of the first two pairs. In the male the third pair of legs possess scent producing glands. They produce a sharp pungent smell which apparently attracts the female for mating. The diagnostic features of the moth have been described by Hampson (1892).

Fig. 14. *Sahyadrasrus malabaricus* adult (moth) in the characteristic resting position.

At rest, the moth hangs vertically (Fig. 14), supported by the first two pairs of legs. In this posture it vaguely resembles a dried leaf. Moths kept in laboratory cages are sluggish and do not fly during the day even when disturbed; they are active during night. According to Beeson (1941) the moth is active for a short period at dusk. The vestigeal mouth parts suggest that the moths do not partake any food. In laboratory cages, the moths lived for 3–5 days without: food. Newly emerged females laid eggs when disturbed, often when held by thorax between fingers. Eggs were laid in train at great speed; 5 to 6 eggs could be seen sticking out at a time in a row when laying. While laying, there were intermittent pauses and theabdomen was often rotated in a circle, apparently to disperse the eggs. Eggs were cream coloured when laid, turning black within an hour or two, spherical and about 0.5 mm in diameter. In one instance, an unmated female laid 4, 166 eggs in laboratory cage. Evidently they are capable of laying several thousands of eggs. In most hepialids the eggs are believed to be scattered broadcast by the female while in flight; some species are credited to produce as many as 40,000 eggs per female (Beeson, 1941).

Field observations revealed that all the moths had emerged by mid–May, in most years. However, it was only by mid–August, that is, about 3 months later, that larvae of the new generation were found established in plantations. By then the larvae were already 1.5 to 2 cm long. Inspite of reasonable search, smaller larvae were not located during June–July. The habits and habitat of the early stage larvae remain unknown. It is possible that early larvai life is spent in soil or on weedy ground vegetation. In some years, comparatively small larvae were found in August, on small branches of ***Trema orientalis,*** at which time no larvae were present on the main trunk. A few months later large numbers of bigger larvae were found established on the main trunk. Sometimes, comparatively small larvae were found as late as November, inside short bore holes on the stem of teak saplings. They occurred at several points on the same tree, mostly below the leaf node and sometimes at the junction of branches. These observations and other circumstantial evidence ***(Vide infra)*** suggest that early stage larvae thrive on weedy ground vegetation and migrate to other host saplings later. Since such behaviour was not suspected earlier, systematic observations could not be made on ground vegetation. More detailed observations are necessary to establish the habits and habitat of early stage larvae.

Full–grown larvae (Fig. **15)** are large, conspicuous caterpillars measuring 6 to 10 cm in length. They are yellowish white in colour with deep black head capsule. The first thoracic segment, parts of the 2nd and 3rd thoracic segments and some dorsal sclerites on the abdomen are brownish (Fig. **15).** Rarely, blackish larvae were encountered. They occurred side by side with the other larvae in the same locality. The significance of this colour variation is not clear; it can be understood only by rearing each type separately and examining the moth.

The mouth of the tunnel is generally situated about 30 cm above ground, but this may vary from 5 to 60 cm. Mature larvae have never been observed on high branches.

There was no overlapping of developmental stages at any given point of time, although there was some Variation in measurements of the larvae. For example, all 19 insects collected from the weed host, ***Clerodendum viscosum*** in late February 1980 at Kaliar, Kothamangalam Forest Division, were in the larval stage and measured 4 to 8 cm (5.9 $\pm$ 1.3 *) in body length. The width of head capsule at the broadess point varied from 0.5 to 0.9 cm *(0.70* $\pm$ 1.1). These and other observations showed that only one generation of the insect occurred each year. Variation in body length of larvae could be accounted for by different growth attainments, apparently due to the condition of the host plant. This was also reflected in the size of the adult, as mentioned earlier. Variation in head capsule width was more or less continuous and not discrete (step–wise), suggesting that the larvae may undergo a variable number of moults, resulting in unsystematic (continuous) variation in head capsule width.

Pupation takes place between about mid–February and early April. Before pupation the larva makes a hole in the PMC across the tunnel mouth and spins a spiral of coarse silken thread along the tunnel. The hole in the PMC facilitates

* Standard deviation of

Fig 15. A full–grown larva of *Sahyadrassus malabaricus*, about 9 cm long.

emergence of the moth. The larva retreats to the bottom of the tunnel for pupation. This portion of the tunnel is lined with a sparse layer of silk, with a plug of brownish silken threads at the bottom. The last larval exuvia is pushed to the bottom. Apparently, the pharate adult wriggles its way up the tunnel prior to the pupal–adut moult, with the help of ridges and asperities present on the pupal cuticle (Beeson, 1941). After emergence of the moth, the pupal exuvia can generally be seen sticking out of the PMC, or sometimes fallen on the floor. The pupal exuvia is almost as big as the larva, generally 6 to 9 cm long.

The pupal period was not determind exactly, but lasts between 3 and 5weeks. It can be taken as about a month on the averge, from early April to early May.

The life cycle is thus annual. Good synchronisation was noticed in the emergence of the moth population.

Host Range

Sahyadrassus larvae accept a wide range of hosts consisting of woody shrubs or climbers and saplings of trees. Beeson (1941) listed about 30 hosts. About a dozen additional host species were recorded in this study; these are listed in Table 6, arranged under the plant family, along with those recorded by previous authors.

Table 6. List of host trees of Sahyadrassus malabaricus

Acanthaceae
Strobilanthes callosus[1]

Boraginaceae
Cordia myxa[1]

Caesalpineaceae
Cassia hirsuta

Casuarinaceae
Casuarina equisetifolia[1]

Compositae
Chromolaena odorata
(Syn. *Eupatorium odoratum)*

Euphorbiaceae
Bridelia retusa[1]
Macaranga indica
Mallotus philippinensis'

Gyrocarpaceae
Gyrocarpus americanus[1]

Labiatae
Ocimum gratissimum[1]

Lythraceae
Lagerstroemia microcarpa'

Malvaceae
Abutilon crispurn[1]

Mimosaceae
Acacia mearnsi[5]
A. pennata
A. intsia
Albizia falcataria
Calliandra callothyrsus

Myrtaceae
Eucalyptus grandis
E. multiflora[5]
E. robusta[1]
E. tereticornis
Eugenia caryophyllata

Papilionaceae
Cajanus cajan
Deomodium cephalotus
Erythrina sp.[2]

Rhamnaceae
Zizyphus horrida[1]

Rosaceae
Pyrus communis[3]
Rosa sp.[1]

Rubiaceae
Anthocephalus chinensis

Sapindaceae
Filicium decipiens[1]
Sapindus trifoliatus[1]

Solanaceae
Solanum indicum
S. melongena
S. torvom
S. verbascifolium[1]

Santalaceae
Santalum album[5]

Sterculiaceae
Sterculia companuluta

Tiliaceae
Grewia tiliaefolia[1]

Theaceae
Camellia thea

Ulmaceae
Trema orientalis

Verbenaceae
Callicarpa lanata[1]
Clerodendrum
Gmelina arborea
Tectona grandis

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1. Beeson (1941); 2. Ayyar (1940); 3, David and Kumaraswami (1978); 4, Lefory (1909); 5, Browne

It was found that attacks were most prevalent on ***Clerodendrum viscosum*** and Trema orientalis. ***C. viscosum*** (syn. ***C. infortunatum)*** is a common shrubby weed, prevalent in most natural forests in Kerala, particularly in open areas. It usually occurs gregariously, in patches. In a typical observation, one patch of ***C.viscosum*** along the boundary of a 1978-plantation of ***Eucalyptus grandis*** at Noolpuzha was examined in December 1978. Out of a total of 29 plants, 4 to 7 cm in girth, 21 plants were attacked by the borer; two of them had two larvae per plant and one three larvae. Such high incidence was common in this species.

Fig. 16. Multiple infestation of *Trema orientalis* by Sahya borer. The black line along the main trunk is *a* termite tunnel.

Another host which harboured a large population of ***Sahyadrassus*** larvae was ***Trema orientalis,*** a coloniser species, common in open forests. Whereas in other tree species only saplings harboured the larvae, in the case of ***Trema,*** both saplings and older trees supported them. Some medium-sized trees had as many as 30 larvae per tree (Fig. 16). In ***Trema,*** multiple infestation was the rule rather than exception, unlike in other tree species. For example, about two dozen roadside trees along Vazhachal-Orukombankutty road (used for insecticide trials in Feb. 1981) harboured an average of 10 larvae per tree, with a range between 2 and 20. The high suitability of ***Trema*** appears to be due to its high potentiality for bark regeneration and comparatively soft wood which facilitate tunnelling. In older trees of ***Trema,*** the tunnel was shorter and confined to the superficial layers of wood.

Trees (saplings) belonging to 22 families were attacked by ***Sahyadrassus*** (Table 6). Absence of bark exudates is a common characteristic of these families (a characteristic, favourable to the insect) with the exception of Euphorbiaceae. Plants most commonly attacked belong to the families Ulmaceae, Verbenaceae, Mimosaceae and Myrtaceae. ***Trema orientalis*** (Ulmaceae) was, by far, the most acceptable. Except in ***Trema,*** most attacked saplings had a stem girth of about 7-11cm.

Geographical distribution

In Kerala, this insect is widely distributed in hilly forest areas. It has also been recorded in the plains, particularly in ***Trema orientalis.*** During this study, it was recorded specifically from Kulathupuzha, Punalur, Achencoil, Kallar Valley, Devikolam, Kaliar (Kothamangalam), Pamba, Vazhachal, Athirapally, Kalady, Trichur, Parambikulam, Peechi, Wadakkanchery, Nilambur, Noolpuzha (Sultan's Battery), Wleenangadi, Chandanathode and Manantody, and outside Kerala in Azhakiyapandiapuram Range of Kanyakumari District in Tamil Nadu. Other authors have recorded it from Coorg, Bangalore, Nilgiris, Kodaikanal, and the former presidencies of Madras and Bombay (Hampson, 1892; Lefroy 1909; Fletcher 1914; Beeson 1941; David and Kumaraswami, 1978). Its known distribution is confined to Peninsular India. According to Beeson (1941) ***Endoclita signifer*** (Walker) or a related undescribed species replaces S. ***malabaricus*** in Assam and Burma as a borer of teak and ***Gmelina*** saplings.

It appears that ***S. malabaricus,*** originally confined to mountainous forest areas (Lefroy, 1909), is spreading gradually to the plains, aided by the colonization of cleared forest areas by plant species like ***Trema orientalis*** and ***Clerodendrum v/scosum*** and plantations of teak and eucalypts.

Natural regulation and conditions favouring infestation

In spite of the potential of each female moth to produce many thousands of eggs, no epidemic build–up of ***S. malabarlcus*** populations has been noticed. Evidently, considerable mortality occurs between the egg stage and the establishment of larvae in host saplings, As discussed earlier, it appears that the eggs are broadcast from above by the flying moth and the early larval instars develop in ground vegetation before thay migrate to saplings. There was considerable variation in the percentage of infested saplings in various teak plantations (Section II) Overall observations indicate that incidence is greater in plantations with dense weed cover. Most often infestation was noticed when weed growth was cleared. In many infested plantations, the incidence appeared to be more towards the natural vegetation boundary where most often ***Clerodendrum viscosum*** was prevalent. There was also some indication that incidence was greater towards stream banks where miscellaneous weeds occurred and favourable moisture conditions prevailed (**Fig.** 6). These general observations, which cannot be quantified, suggest that survival of the early instars and its successful establishment on saplings are dependent on adequate vegetation cover of ground.

Known mortality factors are the following.

1. Tree resistance

In many cases, teak saplings which showed signs of initial establishment of larvae, did not harbour live larvae and showed regeneration of wounded tissues. While the exact cause of larval mortality is not known, it appeared that some saplings were capable of resisting establishment of the larvae.

2. Intra-specific Competition

Larvae kept together in petri–dishes were found not to tolerate each other In some cases where detailed observations could be made, it was found that when the host sapling was small, only one of several larvae which attempted to establish on it succeeded (Fig. 17). Multiple infestations were rare in teak and other trees, although common in ***Trema orientalis.***

3. Predation

There is evidence of predation by a bird, possibly a wood–pecker. In some cases, peck-holes similar to that made by a wood-pecker was found on the stem of attacked saplings at some distance down the tunnel mouth. No larva was found inside the tunnel on examination. It was evident that a bird had extracted and consumed the larva, although the act of predation was not observed. Apparently, the hole is made at the bottom of the tunnel where the larva rests during the day. Only those larvae which remain above the soil surface level can be extracted thIs way. Infestation at lower levels of the stem with the tunnel extending down the root thus confers adaptive value to the insect against bird predation. Bird predation

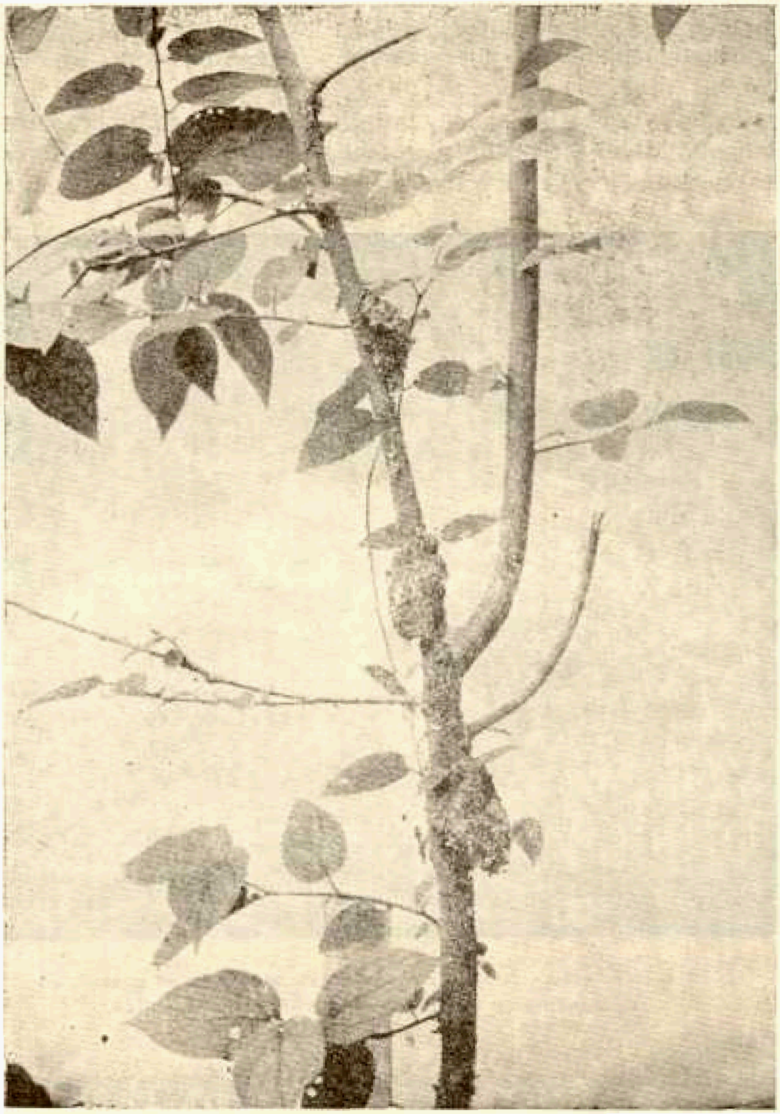

Fig 17. Of 3 larvae initially established on this small sapling of *Trema* orientalis only the one at the bottom survived- The stouter branch on the right hand side developed after infestation and became the main stem in course of time; that On the left broke down at the point of forking and dried up.

was recorded at Athirapally (Kalady Forest Division) and Kaliar (Kothamangalam Forest Division). At Athirapally, 7 out of 177 infested saplings examined in February 1980 showed evidence of bird predation. An additional sapling showed a bird peck hole, but the larva had built a PMC over the hole, apparently an instance of unsuccessful predation attempt. At Kaliar, 2 out of 80 infested saplings examined showed evidence of bird predation. Evidence of bird predation was also found on infested saplings of ***Clerodendrum viscosum*** and ***Albizia falcataria*** occasionally.

Sahyadrassus larvae are readily attacked by many different species of ants, when in the open. The PMC affords protection against ants and other predators and parasites, once the larvae are established in saplings.

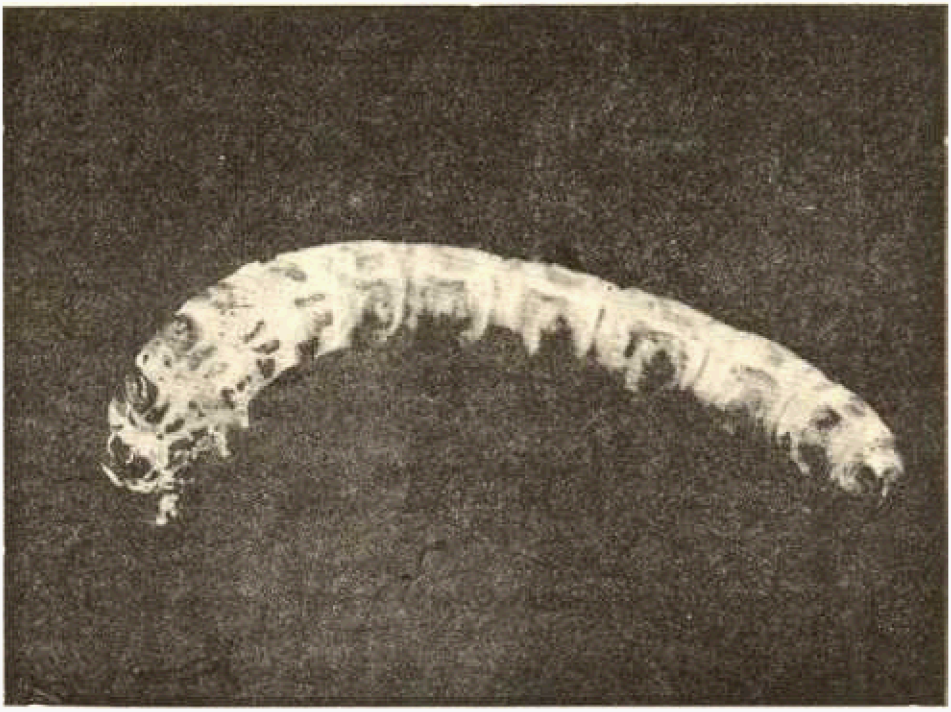

Fig. 18. A full - grown larva of S. malabaricus killed and mummified by infection ot the fungus Metarhizium anisopliae.

4. Parasitism

Incidence of a fungal parasite was noticed. The fungus caused mummification of nearly mature larvae. The rate of parasitisation was very low—1 out of about 180 larvae on teak at Kalady in February 1980 and 2 out of about 200 larvae on ***Trema*** at Vazhachal in February 1981. The mummified larvae partly projected out of the tunnel mouth inside the intact PMC; two were curved slightly and one was coiled like a millipede. When kept in the laboratory, white fluffy mycelial growth appeared on the surface of the mummified larvae (Fig. 18). Conidial scrapings from such larvae were sent to Dr. Jaroslav Weiser (Dept. of Insect Pathology, Institute of Entomology, Chechoslovak Academy of Sciences) who obtained colonies of ***Metarhizium anisopliae*** by culturing in appropriate media. This fungus, used for control of the Rhinoceros beetle, is more or less a secondary, nonspecific invader (Dr. Weiser, Pers. Comm.). Further studies are required to assess the usefulness of ***M. anisopliae*** as a bio-control agent and to examine possible involvement of other fungi.

IV CONTROL TRIALS

Methods recommended in the past for control of the teak sapling borer or related species (Kalshoven, 1924; Sonan, 1938; Beeson, 1941) fall under 4 categories- (1) Allowing naturally growing saplings of more attractive host trees to remain in the plantation area to act as trap trees and destroying them later, (2) Killing the larva physically by inserting a twig or sharp wire into the borer hole, (3) Plugging the borer hole with tar and (4) Injecting an insecticide into the borer hole by means of a syringe. The first is a preventive measure, while others are curative or remedial. No experimental evidence of the effectiveness and suitability of these methods have been reported. Each of the above methods has certain limitations as discussed below.

The most common naturally occurring, preferred host is ***Clerodendrum viscosum.*** Since in most cases, the larva bores down the tap root of this species, cutting back alone will not destroy the larvae, although it may reduce its chances of survival. Uprooting the saplings is a difficult operation. On the other hand, retaining ***Trema*** saplings and cutting them back later should prove beneficial. However, in view of the uncertainty of natural occurrence of these favoured species in the plantation area, the first method cannot be depended upon solely, although it could be used to reduce the risk of incidence of attack. The second method, viz., physical killing' may not be practicable in all cases due to difficulty of reaching the larva through the sharply bent initial portion of the tunnel (Fig. 10). Also, this method is more difficult in the early stages of attack when the larval tunnel is narrow. Tar plugging, the third method, may prove effective but is cumbersome and has not been field-tested. The last method, injection of insecticide into the borer tunnel, is also cumbersome; in addition, there has been no experimental evaluation of various insecticides against this insect, although most insecticides may be expected to be effective.

Observations made in this study, on the behaviour of ***Sahyadrasuss*** larvae (Section III) suggested that spot treatment of the tunnel mouth with a suitable insecticide after removal of the PMC could prove effective. When the PMC is removed, the first reaction of the larva is to rebuild it. For this purpose, the larva gnaws out small pieces of bark and wood from the area surrounding the tunnel mouth. During this process, the larva comes in close contact with the treated surface. In addition, if the larva survives this initial contact exposure, further poisoning could take place through the stomach when it feeds on the treated bark. Experiments were therefore conducted to test the effectiveness and feasibility of this method of control using some common insecticides.

Materials and Methods

The insecticides and their methods of application were evaluated under field conditions. Most experiments were run on young teak plantations and some on ***Trema orientalis.***

General experimental procedure was as follows. Experiments were laid out in heavily infested plantations identified in reconnaissance surveys. Within the selected plantation, starting from a convenient row, each sapling in several consecutive rows was examined and sufficient number of infested saplings identified by tagging a blank aluminium label. The marked saplings were examined one day prior to application of treatment, and those in which the PMC was rebuilt indicating presence of live larvae were used for experiment. Before treatment, the freshly built PMC was again pulled off and discarded and the treatment code marked on the aluminium tag.

All insecticides, whether EC or dust, were applied as water emulsion. A sticker-spreader, Triton X or Triton AE (Rohm & Hass Co.) or Sandovit (Sandoz India Ltd.), was added except when other experimental adjuvants were used. The insecticide solution was liberally brushed on to the area surrounding the tunnel mouth using a 4 cm paint brush. For untreated check (control), water was applied in place of insecticide in the same manner. Using one sapling per treatment at a time, the complete set of treatments was replicated sequentially along the consecutive rows.

Larvae which failed to rebuild the PMC in the final observation were considered dead. Final observations were usually made about a month after treatment or earlier in some cases. For observations, the PMC, if any, was pulled off and rebuilding recorded the following day. When observed on the next day after treatment, in some cases, the PMC was rebuilt loosely with a few strands of silk and sparse wood particles. This indicated unsuccessful rebuilding due to quick effect of insecticide.

The significance of the differences in mortality between treatments was tested statistically using the Chi-square test. Further details of methods are given along with the results of each experiment.

Results

Experiment I – Parambikulam, 1978-79

The experiment was conducted in 1½-yr old teak saplings. The insecticides tested were lindane (20 EC, PNM Co. Ltd., Erode) and Sevimol (40 LV w/w, Union Carbide India Ltd.), each at 0.5% concentration. A total of 51 attacked saplings were used. Unlike in later experiments, the treatments were applied on the first day itself, immediately after removal of the PMC and in the final observations presence of PMC was taken as evidence of survival of larva. Treatments were applied in December 1978 and final observations made in February 1979.

Seven out of 17 larvae were dead (Table 7) in the untreated control where only water was applied. The cause of this substantial mortality could not be ascertained. Both lindane and sevimol caused high mortality, but a few larvae survived.

Table 7. ***Effect of Lindane and Sevimol on*** Sahyadrassus malabaricus, ***when applied to tunnel mouth***

Insecticide	concn. (% a.i.)	No. of larvae in expt.	No. dead	% Mortality
Nil (Control)	–	17	7	41
Lindane	0.5	17	15**	88
Sevimol	0.5	17	16**	94

** **Difference between the treatment and control significant at 1% level.**

Experiment II - Kothamangalam, 1979-80

This experiment was conducted in 4i-yr old teak saplings at Kaliar in Kothamangalam Range, The insecticides tested were HCH (BHC) (50 WDP, Rallis India Ltd.) and Carbaryl (50 WDP, Paushak Ltd.), each at 0.5% concentration in water. A total of 66 attacked trees, some with multiple infestations, were used. The treatment was carried out in December 1979. Sicce the final observations were vitiated by ground fire which caused damage to some saplings, conclusions were based on observations made on rebuilding of PMC on the day following treatment. That this gave a good indication of the final mortality was shown by later experiments (see Table 9).

Table 8. Effect of HCH and Carbaryl on *Sahyadrassus malabaricus* when applied to tunnel mouth

Insecticide	Concn. (% a.i.)	No. of larvae in expt.	No. of larvae that had not rebuilt or imperfectly rebuilt the PMC next day after treatment
Nil (Control)	–	24	4 (17%)
HCH (BHC)	0.5	24	2 (8%)
Carbaryl	0.5	22	13** (59%)

** **Difference between the treatment and control significant at 1% level.**

Treatment with carbaryl caused significant mortality but HCH was totally ineffective (Table 8). Although carbaryl was better than HCH, it did not provide sufficient protection, as about 40 per cent of the larvae survived the treatment.

Experiment I11 – Athirapally, 1980

All insecticides tried in the previous two experiments were tested again in this experiment conducted in a $3\frac{1}{2}$- yr old plantation at Athirapally in Kalady Range. In addition, treatment with tar was tested. Locally purchased, commercial tar was used without dilution and applied with a brush in the same manner as insecticide solution. In the case of untreated control, no operation was carried out except removal of

PMC. The experimental saplings were chosen from two adjacent plots, each containing about 300 saplings. Where multiple infestation occurred, the same treatment was applied to all infestation points on the same sapling. Thus the number of larvae per treatment varied slightly. The treatments were carried out in February 1980 and final observation made about a month later.

HCH (Hexidole 50 WDP) was obtained from Rallis India Ltd.; Lindane (20 EC) from Bharat Pulverising Mills Ltd.; Carbaryl (50 WDP) from Paushak Ltd.; and Sevimol (40 LV) from Union Carbide Ltd.

The results are presented in Table 9. None of the treatments gave complete control. The highest mortality was obtained with Sevimol (83%), followed by lindane, carbaryl and tar, in that order. HCH was ineffective.

Observations made next day after treatment (Table 9) gave a good indication of the final results; where the treatment was effective, the larvae either failed to rebuild the PMC altogether or made only a loosely-knit PMC.

In tar treatment, most larvae rebuilt the PMC initially but it was confined to the mouth of the tunnel, not extending to the surrounding treated area. Later, as tar dried up, in some cases, the mat was extended to the tar-treated area. Some larvae made unsuccessful attempts to open up alternative hole beside the normal opening or at the bottom of the tunnel.

Table 9. Effect of some insecticides on *Sahyadrassus malabaricus*, when applied to the tunnel mouth

Insecticide	Concn. (% a,i.)	No. of larvae in expt.	No. of larvae that did not rebuild PMC plus No. that rebuilt PMC imperfectly, next day after treatment.	No. of larvae dead in final observations	% mortality
Nil (Control)	-	19	1+2 = 3	3	16
Sevimol	0.5	12	7+2 = 9	10**	83
Carbaryl	0.5	15	5+6 11	9**	60
HCH	0.5	14	0+3 = 3	5	36
Lindane	0.5	14	2+6 = 8	10**	71
Tar	Concentrate	14	5+6 = 11	8*	57

** Difference between the treatment and control significant at 1% level.
* Difference between the treatment and control significant at 5% level.

Experiment IV-Vazhachal, 1980

Since complete control was not obtained in any of the previous trials, an attempt was made to give a thick coat of insecticide at the tunnel mouth. For this, the insecticide solutions were thickened by addition of wheat flour at the rate of 10g per 100ml. Both HCH and carbaryi were tested. In addition, a commercial preparation of *Bacillus thuringiensis* var. *thuringiensis* (Bactospeine, 2000 IU/mg/A. K, Unit, Biochem Products Ltd.) was tested in the same manner, at a concentration of 10,000 IV per ml.

The experiment was conducted on larvae infesting ***Trema orientalis*** at Vazhachal. The treatments were given in March 1980 and final count of mortality was made three weeks later.

Table 10. Effect of some insecticides on *Sahyadrassus malabaricus*, when applied to the tunnel mouth after thickening with wheat flour

Insecticide	No. of larvae in expt.	No. dead	% mortality
Nil (Control)	23	3	13
Carbaryl, 0.5%,a.i.	25	20**	80
HCH, 0.5% a.i.	21	5	24
Bactospeine, 0.5% dust	21	4	19

** **Differencs between treatment and control significant at** *1%,* **level**

The results (Table 10) were not encouraging. Carbaryl thickened with wheat flour gave about 80 per cent kill; apparently wheat flour did not substantially improve its effectiveness. Ineffectiveness of HCH was further confirmed. The bacterial preparation was also ineffective.

Development of a thick non–drying formulation *of* insecticide

Since complete control remained elusive in spite of several field trials, it was assumed that the method of application did not ensure adequate exposure of the larva to insecticide. Attempts were therefore made to develop a thick, non-drying formulation of insecticide which might stick to the legs and mouth parts of the insect during tts effort to rebuild the PMC. If the medium was sufficiently sticky, it was, hoped, it could be used even without admixture of insecticide to trap and kill the insect. The aim was to develop a non-drying paint, but no suitable formula could be arrived at in spite of laboratory trials with many concoctions. Among other formulae tried, a recipe containing "maida" (fine wheat flour), glycerol and water gave the desired consistency of a thick, sticky solution which did not dry up quickly. Maida, cooked in water, gave the desired consistency and admixture of glycerol prevented quick drying. Addition of 'jaggery' (cane sugar molasses) to the above mixture improved its effectiveness as shown by field trials ***(vide infra),*** probably by stimulating feeding. The final recipe arrived at was as follows.

Composition of Intseticide formulation

Maida	....	50 g
Jaggery	....	200 g
Glycerol	....	200 ml
Water	....	1 litre
Insecticide	......	required quantity of dust or EC

Maida and jaggery are mixed with water and heated to boiling in a suitable container. When the slurry begins to thicken, the container is taken off the flame, glycerol added with stirring and the mixture allowed to cool. When cooled to room temperature, the desired quantity of insecticide is added and mixed thoroughly. It is now ready for use.

Experiment V – Vazhachal, 1981

This experiment was conducted to test the new formulation. Using the same insecticide, viz. carbaryl (50 WDP), the effectiveness of different formulations were compared. The insecticide concentration was raised to 1% from 0.5%. The experiment was run on larvae infesting ***Trema orientalis*** at Vazhachal. Two hundred larvae infesting about **23** trees were used. The infestation points were marked on the trunk by nailing number plates near the tunnel mouth. Treatments were made in February 1981 and final observations taken three weeks later.

Table 11. Effect of Carbaryl formulated in different ways on *Sahyadrassus malabaricus,* when applied to the tunnel mouth

Insecticide formulation	Initial No. of larvae	NRB + LRB on the day following treatment	No. of larvae dead in final observation	% mortality
Nil (control)	50	1+1 = 2	0	0
Carbaryl 1% in water	50	5+14=19	13**	26
Carbaryl 1% with maida and glycerol	50	10+9=19	334*	66
Carbaryl 1% with maida, glycerol and jaggery	50	22+6=28	44**	88

NRB. PMC not rebuilt **when observed next day of treatment.**

LRB, PMC loosely rebuilt when observed next day *of* treatment.

** **Difference between treatment and control significant at 1% level.**

The results are given in Table 11. While no larva died in the water treated control, significant numbers died in all insecticide treatments. The insecticide formulation containing 'maida', jaggery and glycerol gave the highest mortality (88%). This was followed by the formulation containing only maida and glycerol (66%). There was significant difference between the two ($P<0.01$). The insecticide alone gave only 26% mortality, significantly lower than the above two ($P<0.01$), but significantly higher than the water treated control.

Much of the increased mortality resulting from addition of maida, glycerol and jaggery was not reflected in the rebuilding of PMC on the day following treatment (Table 11). It occurred later, evidently due to continued exposure to insecticide, facilitated by the adjuvants.

Complete mortality was not obtained, however, with any of the formulation of carbaryl even with increased contact ensured by the adjuvants. It was clear that carbaryl, a contact insecticide was not sufficiently toxic to ***Sahyadrassus*** larvae. Further trials were made next year with another insecticide.

Experiment VI- Arippa, 1982

This experiment was undertaken to test a new insecticide, quinalphos (Ekalux EC 25, Sandoz India Ltd.) which has both contact and stomach action and is known to be effective against many lepidopteran larvae. Preliminary tests on larvae rehabilitated on ***Trema*** saplings in the KFRI campus indicated effectiveness. Field tests were carried out at Arippa near Kulathupuzha in Trivandrum Forest Division on larvae infesting $1^1/_2$yr old teak saplings in a seed orchard established by the Genetics Division of KFRI.

Table 12. Effect of Quinalphos (Ekalux) on *Sahyadrassus malabaricus*

Insecticide formulation	Initial No. of larvae	RB/RBL	No. of larvae dead in final observation	% mortality
Nil (Water only)	8	7/0	Nil	Nil
Ekalux, 0.5% (0.125% a. i.) with Sandovit	8	6/2	8	100
Ekalux 0.5% (0.125% a. i.) with maida, jaggery and glycerol	8	1/7	8	100

RB, PMC found rebuilt normally on the day following treatment.

HBL,PMC found loosely rebuilt on the day following treatment.

The treatments were applied in November 1982 and observations made on the day following treatment as well as 10 days later. Twentyfour infested saplings were used for three treatments. The results (Table 12) showed that 0.5% Ekalux emulsion (about 0.125% a. i. of quinalphos) gave 100 per cent control with or without the addition of adjuvants. Addition of adjuvants, however, resulted in quicker death, as indicated by loosely rebuilt PMC on the day following treatment (Table 12) in comparison to the normal PMC made by larvae treated with Ekalux alone.

Discussion

All preparations tested in this study for control of ***S. malabaricus*** were tested by a particular method of application which was considered to be simple enough for practical application under field conditions, i.e. brush coating at the tunnel mouth after removing the particle-mat cover (PMC). Had they been tested by injection into the tunnel, permitting direct contact with the insect body surface, the results would have been different, most preparations probably proving more effective.

The bacterial preparation, bactospeine, was not effective at all (Table 10). Although ***Bacillus thuringiensis*** has a wide spectrum of effectiveness among Lepidoptera, the biological activity of different commercial preparations (at least a dozen are in the market, made in 5 countries) shows considerable variation (Falcon, 1971). It should also be noted that in this study bactospeine was tested mixed with wheat flour; the effect of this admixture is not known. Final conclusions on effectiveness of ***B. thuringiensls*** should therefore be made only after more elaborate trials.

Tar, the other unconventional insecticide tested, also did not afford sufficient protection by the method of application employed here.

The remaining 5 insecticidal chemicals tested fall essentially under three categories.

(1) HCH (BHC) and Lindane

Both belong to the group of organochlorine insecticides and the active component is the'same. HCH is a mixture of several isomers, of which **y** HCH is the most active. Lindane consists of y HCH only. HCH was totally ineffective as shown repeatedly (Tables 8, 9, 10). Lindane was tested only once, at 0.5% concentration (Table 7), when it proved effective, although 100% control was not obtained. Since it has both contact and stomach action, it is possible that with the addition of adjuvants which facilitate greater contact/intake, it may prove more effective. Lindane was not subjected to further tests because it was not commonly available in the market.

(2) Carbaryl (Sevin) and Sevimol

Both belong to the group of carbamate insecticides and the active component is the same; Sevimol is a combination of carbaryl and molasses. Sevimol was tested only once, at *0.5%* concentration (Table 7). It was fairly effective, but 100% control was not obtained. Carbaryl was tested repeatedly (Tables 8, 9, 10, 11). but satisfactory con'rol was not obtained, even when the concentration was raised to 1%. Addition of adjuvants (maida, glycerol and jaggery) improved its effectiveness, apparently by facilitating greater contact of the chemical with the larva (Table 11), but complete control was still not obtained. Since Carbaryl is known to, possess only contact toxicity, the adjuvants, inspite of promoting the intake of the chemical, could not increase its effectiveness through stomach poisoning. Carbaryl is therefore not suitable for control of this borer.

(3) Quinalphos (Ekalux)

It belongs to the organophosphate group and possesses both contact and stomach toxicity. At a concentration of about 0.125% a. i., (as against 0.5% or higher of other chemicals) it gave complete control, both with and without adjuvants. Death was quicker when the adjuvants were used.

It is clear that among the insecticides tested, quinalphos (Ekalux EC 25) is the most effective against the Sahya borer. Although greater effect could be obtained by addition of adjuvants, from practical point of view, it is more convenient to use the insecticide alone. However, a sticker-spreader, like Sandovit or Triton must be used, when adjuvants are not added. When a sticker-spreader is not readily available, glycerol may be used with advantage at 10 to 20% concentration.

In view of the comparatively low economic significance of ***Sahyadrassus.*** attack (see Section 3), in most large-scale plantations no control operation is necessary. Where control is necessary, as in experimental plantings, seed orchards and other valuable plantations, it is posslble to control the insect by using Ekalux, as above. In highly valuable plantations such as clove, the plantation must be surveyed frequently and insecticide application made when fresh infestations are detected. From currently available information, fresh infestationsmay occur from about mid-August to late November. Pest management practices for high value crops may include allowing growth of ***Trema orientalis*** and ***Clerodendrum viscosum*** within the area and cutting them in late November. Their presence within the plantation is expected to attract the larvae towards them in preference to cultivated tree species, and cutting them in November will, by reducing the larval survival, help to reduce the next year's population of moths.

As discussed earlier, infestation was high in plantations in which there was dense weed cover. Clean cultivation, with timely weeding, is fherefore expected to reduce the incidence of attack.

V CONCLUSIONS AND RECOMMENDATIONS

The study has revealed that the teak sapling borer, larva of the hepialid moth, ***Sahyadrassus malabaricus*** (Moore) is prevalent in young plantations of teak in Kerala. In some plantations examined at Parambikulam, Kaliar, Athirapally, Achencoil and Arippa, 6 to 61 per cent of 2-to 4-yr old saplings were infested. The insect is distributed throughout Kerala and hasa wide host range of over 40species belonging to 22 plant families including woody shrubs and tree saplings. Most commonly attacked plants belong to the families Ulmaceae, Verbenaceae, Myrtaceae and Mimosaceae. Among forest plantation species, in addition to teak, ***Eucalyptus*** spp., ***Gmelina erborea, Anthocephalus chinensis, Sterculia companulata, Albizia falcataria*** and ***Calliandra callothyrsus*** were attacked. ***Trema crientalis*** was, by far, the most preferred host. In this species alone, older trees are attacked in addition to saplings, some trees harbouring as many as 30 larvae. The second most attacked species was the shrubby weed, ***Clerodendrum viscosum***

The damage caused by this insect is not serious. The larva lives inside a tunnel along the pith of the sapling and feeds on the bark and callus tissue around the tunnel mouth under cover of a thick mat of wood particles spun together with silk. In rare cases, the stem is ring-barked resulting in drying up of the sapling, or the stem snaps at the tunnel mouth region. Although, in most cases the damage is economically negligible, in experimental plantations, seed orchards, etc., where each sapling is important, control measures become necessary.

The insect has an annual life cycle, with moths emerging between mid-March to mid-May. The habits and habitat of early stage larvae remain unknown. More detailed investigations are necessary to shed light on these aspects. Circumstantial evidences suggest that early instars survive on weedy ground vegetation and migrate to young plantations later. Most larvae establish in saplings by mid-August, although migration may continue upto November. Infestation was heavier in plantations that had dense weed growth. Within plantations, the incidence was heavier near stream banks. Occurrence of the preferred hosts, ***Trema orientalis*** and ***Clerodendrum viscosum*** within the plantation or along the borders increased the risk of infestation. Originally confined to mountainous forest areas, ***Sahyadrassus malabaricus*** appears to be spreading gradually to the plains, aided by the colonization of cleared forest areas by plant species like ***Trema orientalis*** and ***Clerodendrum viscosum*** and plantations of teak and eucalypts.

Resistance of trees, intraspecific competition, predation by a bird and infection by a fungus were the main natural mortality factors after the larvae became established in saplings.

Generally it is difficult to control borers because insecticides cannot reach their concealed habitat easily. Methods recommended against this borer in the past included physical killing with a wire probe, injection of insecticide into the tunnel tar plugging, etc. In this study, observations on larval behaviour were made use of to devise a simple method of poisoning the larva. It consisted simply of applying the insecticide at the tunnel mouth after pulling off the particle–mat cover. The insecticide acts as contact poison when the larva works on the treated surface to rebuild the cover and later, as a stomach poison, when it feeds on the treated surface. Among several insecticides tested, quinalphos (Ekalux) was the best. It ensured complete mortality when applied at the tunnel mouth at a concentration of about 0-125% a. i. (0.5% of Ekalux EC 25). HCH (BHC) was ineffective at 0.5% concentration. Lindane and Sevimol at 0.5% concentration and Carbaryl (Sevin) at upto 1% concentration or tar gave only partial control. Although a thickened, slow-drying formulation of insecticide developed in this study increased the effectiveness of insecticides, Ekalux proved sufficiently effective even without the adjuvants.

As noted above, insecticidal control is necessary only in high value plantations. Cultural practices may be employed to reduce the incidence of attack. These include the following two measures. (1) Avoid excessive weed cover, particularly during June, July and August. (2) Where ***Trema orientalis*** and ***Clerodendrum viscosum*** occur within or in the vicinity of the plantation, retain them until late November to attract the larvae and then cut back ***Trema*** and uproot ***Clerodendrum*** to destroy the larval population.

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