KFRI Research Report No. *ISSN*

DEVELOPMENT OF A PROPHYLATIC CONTROL STRATEGY FOR MANAGING THE MAHOGANY SHOOT BORER *HYPSIPYLA ROBUSTA* IN TRIAL PLANTATIONS

(Final report of the project KFRI 580/09)

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(An Institution of Kerala State Council for science, Technology and Environment)
Peechi 680653, Kerala, India

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Outline of the project proposal

1. Project Number : KFRI/580/09

2. Title of the project : **Development of a prophylactic control strategy for managing the Mahogany shoot borer *Hypsipyla robusta* in trial plantations.**

3. Objectives : 1. Monitor the pest incidence in younger plantation.

2. To try different control measures for the mahogany shoot borer *Hypsipyla robusta a*nd to standardize best among them.

3. To bring out a package of practices for the establishment of mahogany plantations

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Date of commencement : June 2009

Duration : 3 years

Funding Agency : KFRI Plan Fund

Investigators : K. Mohanadas
Thomas. P. Thomas
P. Rugmini

CONTENTS

ABSTRACT

Mahogany is one of the most valuable timbers of the tropics. In spite of excellent growth potential and adaptability to a wide range of conditions including degraded sites, the tree is susceptible to shoot borer attack by *Hypsipyla* species. Trials conducted in many countries to control the pest met with little success. Plantation with *Swietenia macrophylla* in Kerala by the Kerala Forest Department (KFD) though on a small scale, also was not a success story. Even mixed plantations started by the KFD at various forest circles could not save mahogany from the shoot borer attack.

Different experiments were hence conducted by KFRI to find out some suitable methods to save the mahogany plantations form the shoot borer attack and to bring out a package of practice to establish new mahogany plantations. In one of the study conducted earlier at KFRI, Peechi to study the effect of different shades to the mahogany seedlings on its growth and vigour it was observed that seedlings grown under 25 %, 50 % and 75 % shade nets were found promoting height increment as compared to control. Of the three shade 25 % was more effective in providing 66% more height and 26 % more growth in collar girth over the control seedling in the first year.

In the field experiments conducted at the KFRI Field Research Centre at Palappily, Veluppadam near Chimmini dam, Thrissur (2003-2008), the effect of improving the growth and vigour of mahogany in the field through integrated nutrient management, intensive weeding and the effect of two spacing levels (2x2 m and 3x3 m) on reducing the attack by the shoot borer were also studied.

The results showed the benefit of lateral shade provided through closer spacing in improving the growth and also in reducing shoot borer incidence. Trial conducted with two species of mahagony, namely, *Swietenia macrophylla* and *S. mahagoni* in the same design to ascertain the comparative resistance of these species to *Hypsipyla robusta* attack. The results showed that S. *mahagoni* was extremely slow growing and at the same time more susceptible to the shoot borer attack. This study clearly showed that of the two species studied for comparative resistance to *Hypsipyla robusta*, *S. macrophylla* is more resistant to and *S. mahagoni* is more susceptible to the shoot borer attack (Fig.5 & Fig. 6). This study also showed the effect of integrated nutrient management and intensive weeding on improving the growth and vigour of mahogany in the field. The effect of two spacing levels (2x2 m and 3x3 m) on faster growth and reducing the attack by the shoot borer were also very clearly brought out in this study (Figs 7&8, 10&11, 13&14, and 16 &17).

In this present study a package of practice is suggested to manage new mahogany plantations from the shoot borer, *Hypsipyla robusta*. This study was done at a six year old mahagony trial plots (both *S. macrophylla* and *S. mahagoni)* of KFRI, established for another earlier study by KFRI, by the same group of scientists, at the Field Research Centre (FRC), at Veluppadam in 2003. In this present study a three-way approach was attempted to manage the mahogany trial plots at FRC, Veluppadam. By following the ***Physical, Biological*** and ***Chemical tree-injection*** control methods it was found that the shoot borer incidence could be brought under control. In the ***Physical control*** the leading tender shoot of mahogany plants were covered with a hood made of bamboo frame and covered with fine nylon mosquito net. As long as this covering is maintained over the leading shoot, we could protect the leading shoot form the adult of *H. robusta* from being selected for egg laying, subsequent larval infestation damage and resultant branching. In the ***Bio-control*** method using weaver ants (*Oecophylla smaragdina*) along with their nest were collected from the neighbour hoods forest trees , from their naturally established trees and brought and released on the mahagony trial plots plants, thus allowed to establish their new nests on the young mahogany plants. These ants were provisioned initially with some food materials. Once the new nest was established, then theses weaver ant nested plants were connected to as much plants as possible with in the study plots, using some thick threads. This was to make sure these trees too under the surveillance of these ants. By doing so the weaver ants move to these surrounding trees along these treads and search for their food. The more the number of nests established and inter connected the better will be the result. Significant difference with respected to the infestation percentage was observed between the plants in the control plots and weaver ants established (treated) plots. In the ***Chemical tree-injection control*** method using systemic insecticide (Dimethoate 30% EC), hundred percent controls could be observed in all the three concentrations applied (0.1, 0.2 and 0.5 %), during the observation period. In all the treated plants up to 100 days no infestations occurred, with a single injection itself. Further observations are yet needed to suggest the frequency of treatment in giving continued protection of the plants. All these control methods can be applied as a package of practise for establishment of new mahagony plantations.

ACKNOWLEDGEMENT

We are grateful to Dr. J.K. Sharma and Dr. R. Gnanaharan, former Directors, for support and encouragement during the initial phase of the study and Dr. K.V. Sankaran, present Director, KFRI for continued support and guidance.

The strenuous field work of the project was made light by the contribution of all the staff of the Field Research Centre of KFRI at Veluppadam, especially Sri Unni K.K. who was in charge of the centre. The services of Sri. Rasmish .A.R, Research Fellow in the project deserves special mention for his hard work and sincerity. Sri John C.J. was very helpful in laying out the experimental plots in about 4 ha area and Sri. Thankachan, Sri. Zakkeer and Smt. Khadee along with other field workers are remembered with gratitude for their assistance in the field.

The whole hearted support received Dr. Maria Florence, Dr. R.C. Pandalai, Programme Co-ordinators of Extension and Training Division, Smt. Sarojam, Librarian, Hussain, K.H., Assistant Librarian, Smt. Divya , Smt. Sreeja daily wages worker at office during the preparation and finalization of the manuscript is greatly acknowledged.

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INTRODUCTION

Mahogany is an exotic evergreen tree attaining a height of about 30-40 m and a diameter of about 2.5-3.5 m within a span of 30-35 years, exhibiting bark peeling feature. Abundant growth occurs in places with average annual rainfall of 1500-5000 mm and in fertile soil. Though the trees are evergreen in nature, leaf fall occurs during the months of February, March. Red coloured young leaves appear to develop at about the beginning of April-May months. Pod maturation occurs in a year. *Swietenia macrophylla*, commonly known as big leaf mahogany, is a species of plant in the Meliaceae family. It is one of two species that yields genuine mahogany timber, the other being *S. mahago*ni. The tree is frost sensitive, somewhat shade tolerant, although extreme shade is detrimental.

Swietenia macrophylla is a large deciduous tree with an umbrella-shaped crown. Reaching heights of over 30 m and diameter at breast height (DBH) of more than 1.5 m. However, heights of 40–60 m and diameters of 3- 3.5 m were reported before the population was extensively logged (Lamb 1966). The trunk is straight and cylindrical, slightly grooved, with well-developed spurs. The crown of young trees is narrow, but old trees have a broad, dense and highly branched crown. The open, rounded crown has thick, rising branches and thick, dense foliage. The outer bark of older trees is shaggy, deeply longitudinally furrowed and brownish-grey to reddish-brown, and the inner bark is red-brown or pinkish-red. The leaves are usually par pinnate, sometimes imparipinnate, 12-45 cm long, and are made up of 3-6 pairs of lanceolate or ovate leaflets. The leaflets are asymmetrical, 5-12 cm long and 2-5 cm wide, with a whole margin and an acute or acuminate apex (Soerianegara and Lemmens 1993; Schmidt and Joker 2000). The flowers are unisexual, 0.5-1.0 cm in length, and are borne in large, branched inflorescences including both male and female. The fruits are capsular, oblong or ovoid, 11.6-38.7 cm in length, 6.7-12.0 cm in diameter and light grey to brown with. The seeds are samaroid, bulky at their base, 7-12 cm long and 2-2.5 cm wide including the wing (Soerianegara and Lemmens, 1993).

Easiest method of propagation is by using seeds. Seeds are obtained by drying the collected pods. Viability lasts for only up to 7 months. Seeds are placed in small pits at a distance of 7.0 x 7.5 cm or 10 x 10 cm. Germination starts within 2 weeks. Seedlings of height of 30 cm, 2 cm diameter with about 20 leaves are transferred to pits in the field. Direct sowing is found to be successful.

Seedlings can also be transplanted in polythene bags. Poly bagged seedlings having a height of 30 cm with 20 leaves are found be better planting material in the main field .Natural regeneration occurs by the germination of fallen seeds. Removal of shade is essential for its germination.

Planting is done in pits of 35cm, filled with top soil and 10 kg of Farm Yard Manure (FYM). Pits are taken and planting is done with the onset of monsoon, during June- July. Unlike other species, slightly wider spacing (3m x 3m) is required for this species mahogany. Can be cultivated as a mixed crop in teak plantations. Fertilization at the rate of 30-50 g Nitrogen(N), 40-50 g Phosphorus(P_2O_5), 50-70g Potash(K_2O), along with 20-30 kg Farm Yard Manure (FYM) per plant depending on size is good from second year onwards. (KFRI RR 448, June 2012).

Timber:

The wood is durable, one cubic meter of this timber with annual rings weighs about 560 kg , is of light reddish in colour, attractive and has high demand in the market.

Fig. 1 *S. macrophylla* King (Big- leaf mahogany**)**

Fig. 2 *S. mahagoni* Jacq (Small- leaf mahogany)

Wood is used for making furniture and oil from seed is used in soap industry. It is one of the best materials for staining and design works. The species is also known under other common names, including broad-leaved mahogany, Brazilian mahogany, Honduras mahogany, large-leafed mahogany, genuine mahogany, sky fruit, and tropical American mahogany, among others.

The shoot borer, *Hypsipyla robusta* (Moore) (Lepidoptera: Pyralidae) is a serious pest of meliaceous forest trees such as the exotics, *Swietenia macrophylla* King **&** *S. mahagoni* Jacq. and the native *Toona ciliate* M. Rome. The plantations raised by the forest department all over the State had suffered from this shoot borer attack during the sapling stage. Mahagony had no other

major insect pest problem. The mixed plantations raised by Kerala Forest Department also suffered from this shoot borer attack. The past works done in India on *H. robusta* had been reviewed by many researchers. The need for a collaborative effort to develop a pest management system with an Integrated Pest Management (IPM) approach is suggested by many.

A preliminary study was conducted by KFRI, during 1994-96 in selected young plantations of mahogany at Punalur and Nilambur and it was revealed in that study that generations of *H. robusta* are either continuous or overlapping. In some plantations, even up to 90% of the mahagony plants were affected by this borer. The pattern of infestation fluctuation depended on the availability or production of new shoots. This happens in the rainy season. The pest was found only on tender shoots and occasionally under bark, as this study was conducted in young plantation in Kerala. During this study a parasitic nematode, Hexamermis sp. (*Octomyomermis muspratti)* was found to attack and kill *H. robusta* larvae. Once infested by the shoot borer, the borer population spreads to the nearby mahagony plants, gradually. Age of the trees (trees less than 8 years of age were more infested) and availability of tender shoots were the two important factors which determine the survival and intensity of infestation of the shoot borer pest population. In older plantations (above 8 years of age) the population of the borer was not very conspicuous as evidenced by the lesser number of borer holes per tree. Evidence of a new infestation is the appearance of a sleeve-like structure made of frass and excreta at the base of new leaves on the tender shoot. Once established in the shoot, the borer continues to feed the inner part. The larvae come out of the infested shoots once it is older and if no tender shoots are available, they tunnel under the bark of the mahagony saplings. This is a grave situation for the plant also for the larvae. In case if this larval population continue under bark for a sufficient longer period the plant part above this attacked region will dry up. This in turn will affect the survival of the larvae. But for the plant, new shoots were found produced from below this dried portion, later.

In another study under taken by KFRI during 2003-2008 the objectives were:

1) To produce healthy seedlings in the nursery.
2) To standardize management practices such as spacing and manuring that can boost bio mass productions as well as reduce the shoot borer attack
3) To assess the comparative resistance of the two species of mahogany namely *Swietenia macrophylla* and *S. mahagoni* to this shoot borer. The result obtained for the first objective was: the best effect of manuring on growth of poly potted seedlings of mahogany (*S. macrophylla*) was

with 0.10 % each of N, P_2O_5, K_2O and $MgSO_4$ and 0.005% each of $ZnSO_4$ and BoO_3 supported maximum growth with seedling attaining 62.95 cm height with 4.12 cm collar girth. Growth of seedlings in nursery beds as influenced by manurial treatments was: 0.20% each of N, P_2O5, K_2O and $MgSO_4$ along with 0.005% each of $ZnSO_4$ and BoO_3 produced maximum height growth. The seedlings on an average recorded 69 cm height and 4.5 cm collar girth.

The effect of different shade nets on growth of mahogany seedling, in the first year in the nursery was also studied in this project. Both the species of mahogany seedlings were kept under different grades of shade nets and growth monitored up to 265 days (8.8 months). The growth of *S.macrophylla* seedlings was better under shade and was directly proportional to the extent of period under shade. All the three shade levels of 25, 50 and 75 % were seen to promote height increment compared to control, though height was more under 25% shade. Sixty six percent increases in height over the control was recorded under 25 % shade. Seedlings of *S. mahagoni* also showed similar growth trend under different grades of the shade nets. Maximum height was obtained with 25% shade which was followed by 50 and 75% shade. Thirty six percent increases in height over the control was recorded under 25 % shade in *S. mahagoni*.

In the silvicultural trials plots raised under this study with 2x2 m and 3x3 m spacing of both the species of mahagony, better growth was recorded in 2x2 m spacing in both the species (Fig. 5 & Fig. 6).In the case of comparative resistance of the two species of mahogany namely *Swietenia macrophylla* and *S. mahagoni* to this shoot borer *S. mahagoni* was found more susceptible to the shoot borer *H. robusta* attack in both the spacing plots.

The present study was under taken with the following objectives:

1) Monitor the pest incidence in younger plantation.
2) To try different control measures against the mahogany shoot borer *Hypsipyla robusta* and to standardize best among them.
3) To bring out a package of practices for the establishment of mahogany plantations.

3.3: Insect pest of mahogany

A number of insects attacking mahogany have been reported from all over the world (Table1). However, the shoot borer, *Hypsipyla grandella* (Zeller) and *H. robusta* (Moore) (Lepidoptera: Phycitidae) are the major pests. *H. grandella* is found throughout Central and Southern America (except Chile). It also occurs in many Caribbean Islands and southern tip of Florida (Entwistle, 1967). The closely related *H. robusta* is widely distributed throughout West and East Africa, India,

Indonesia, Australia and South East Asia (Entwistle, 1967) and in Western and Central Solomon Islands (Oliver, 1992). Mahogany plantations in Kerala were found to be severely affected by *H. robusta* during the present study. A number of studies have been made on the pest status, distribution, biology and control aspects of this shoot borer (Atuahene and Souto, 1983; Bennet and Grijpma, 1973; Gupta and Lamba, 1982; Kandasamy, 1969; Kirsten, 1988; Leugo, 1989; Mathur, 1967; Mishra, 1993; Roberts, 1965; 1968). More than 20 alternative host plants (Appendix1) have been reported (Ardikoesoema and Dilmy, 1956; Beeson, 1919; Brunck and Fabre, 1974; Fletcher, 1914; Ramaseshiah and Sankaran, 1994).

Trees below 8 years (< 7m in height) of age were heavily infested and the intensity of damage decreased with the increase in age and height of trees. Close spacing (1m x 2m or closer) has been advocated to encourage height growth and thereby reduce the period of ement systems, susceptibility to *H. robusta* (Suratmo, 1977). In one of KFRI's earlier studies (2003-2008, KFRI Research Report 448) this was found that in 2x2 m spacing plots of mahagony *H. robusta* infestation rate was comparatively less in all the four years we observed, in both the species of *S. macrophylla* and *S. mahagoni*, compared to 3x3 m spacing plots of these species. This result are summarized in this study to make the problem more clear and to show the relation of rainfall and subsequent production of new shoots and the continuation of shoot borer infestation in mahagony plots.

H.robusta infestation on mahogany has also been reported from the Philippines (Leugo,1989). The serious threat of this pest had been recognized long back and attempts have been made to evolve control measures through standardization of silvicultural, biological and chemical methods. Roberts (1965) reported that chemical control of *H. robusta* was impracticable in view of the continuous attack by this shoot borer. He also found that the biological control of this shoot borer using parasites was not possible because of the low rate of parasitization.

Fungi like *Botryodiplodia theobromae* and *Colletotrichum gloeosporioides* produce leaf spot disease. This can be controlled by spraying Carbendazim 0.05 per cent.

Table 1. Pests reported on mahogany

Insect	Country	Source
Ambleypelta cocophaga (Heteroptera : Coreidae)	Solomon Islands	Oliver,1992
Egchiretes nominus (Lepidoptera)	Belize, Honduras	Stevenson,1944, Chable,1967
Diaprepes abbreviatus (Coleoptera:Curculionidae)	Puerto Rico	Bauer, 1987
Dysercus longiclaris (Coleoptera:Curculionidae)	Malaysia	Streets,1962 , Ata and Ibrahim,1984
Catopyla dysorphnaea (Coleoptera:Curculionidae)	Malaysia	Brunck and Mallet,1993
Gyroptera robertsii (Eugyroptera robertsii)	Malaysia	Brunck and Mallet,1993
Crossotarsus externedentatus (Coleoptera:scolitidae) *Platypus gerstaeckeri* (Coleoptera: scolitidae)	Fiji	Roberts,1977
Coptotermes sp. *Neotermes samoanus* *N. papua* *Procryptotermes* spp. (Isoptera)	Fiji, Sri Lanka, Solomon Islands, Belize	Oliver,1992 Stevenson,1940 Kamath *et al*., 1993 Kamath *et al*., 1995
H. robusta in (S. macrophylla)	West Java, and Indonesia	Suratmo(1976) and Suharti and Santoso (1990)

1. Biology of *Hypsipyla robusta:*

Adults are typically nocturnal and mate within six days of emergence, only once. Females lay 200-450 eggs over a period of five to eight days. Eggs are deposited singly or occasionally in clusters of 3-4 on the shoots, stems and leaves, particularly the upper surface on young leaves. Eggs may be laid at all heights on the host tree usually in leaf axils or in crevices in the bark or on fruits (Griffiths, 2001). After three to five days, the eggs hatch and the larvae tunnel in the developing shoots and sometimes also feed upon the flowers, fruit and bark of host trees (Griffiths, 2001). Pupation takes place either in the twigs, shoots or in the soil. A generation usually takes 1-2 months for completion but may extend to five months if larvae diapause which has been reported

from areas of low temperature or rainfall, and occurs immediately after fruit-feeding despite apparently suitable climatic conditions (Griffiths, 2001).

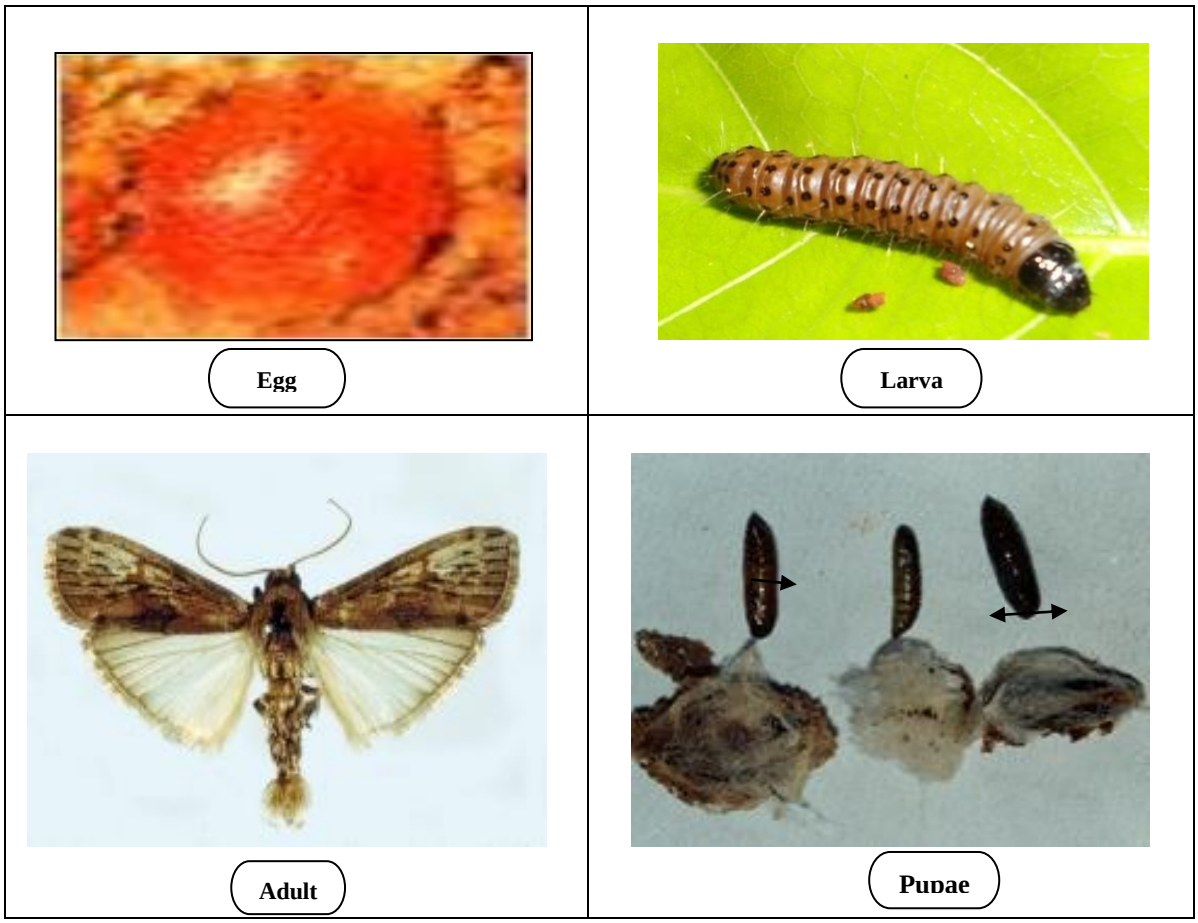

Figure 3. Life history stages of *Hypsipyla robusta*

3. Objectives

3. 1. Monitor the pest incidence in younger plantation.

3. 2. To try different control measures for the mahogany shoot borer *Hypsipyla robusta* and standardize the best among them.

3.3. To bring out a package of practices for the establishment of new mahogany plantation

3.1.1. Pest incidence in younger plantation.

Materials and Methods

Study area:

The study was carried out in field station of KFRI at Veluppadam, Thrissur, Kerala, which was originally a degraded deciduous forest .Here the experimental trial pot of mahagony was established in 2003.The mahagony plants were planted with 2x2 m and 3x3 m spacing. Two species of mahagony namely *Swietenia macrophylla* and *S. mahagoni* were planted here to study the comparative resistance of these two species to the shoot borer *Hypsipyla robusta* infestation.

Experimental design:

Both *Swietenia macrophylla* and *S. mahagoni* plants were planted in this study area at **F.R.C. (Field Research Centre), Veluppadam,** at 2x2 m and 3x3 m spacing in the year 2003. Each species had three blocks, each block consisting of 12 plots and one control plot. There were 25 plants in each plot. This present study was conducted in this already established young trial plots. This study period was from 2009-2012.

Materials and methods

The study site was at FRC, Palappilly. Experimental plots, with two levels of spacing viz., 2x2 m and 3x3 m, of the two species of mahogany viz., *Swietenia macrophylla* and *S. mahagoni* already established in 2004 for another study were considered for the present project. There were 39 plots under each spacing level. Observations on the number of fresh shoot produced and number of shoots attacked were recorded periodically for 18 months. Five trees along the diagonal of each plot containing 25 plants were considered for taking observations on infestation aspects.

Chi-square test was performed to test whether there were any significant differences between the number of infected shoots found in different months. For this the null hypothesis stated was the number of infected shoots is the same in all months and hence derived the expected frequencies in different months accordingly. This test was done separately for each spacing level and also for pooled data set, under each species.

The test statistic used was $x^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}$ (1)

Where O_i = Observed number of infected shoots in the i^{th} month

E_i = expected number of infected shoots in the i^{th} month

k = number of months

Proportion of infestation was also calculated for each period for two spacing levels. *Z* test was performed to find whether there is any significant difference between the proportions of infestation under two spacing levels. This test was carried out separately for each species.

$$z = \frac{p_1 - p_2}{\sqrt{\frac{p_1 q_1}{n_1} + \frac{p_2 q_2}{n_2}}}$$

Where p_1 and p_2 are proportion of infestation in two spacing levels.

$q_1 = 1- p_1$ and $q_2 = 1- p_2$

Five plants representing each plot, in the diagonal line of each of the plot, were observed for the pest incidence. Observations were made in each month and the data recorded in the data sheets designed for this purpose. From each plant the total number to tender shoots and the number of shoots infested were recorded. The different larval instars were also collected and reared in the lab. The rain fall data from 2003-2005 and its influence on shoot production, the shoot borer incidence in these trial plots during 2003-2005 were summarised here , the rain data during this study period were also taken from the data recorded and maintained in the Field Research Centre ,Veluppadam.

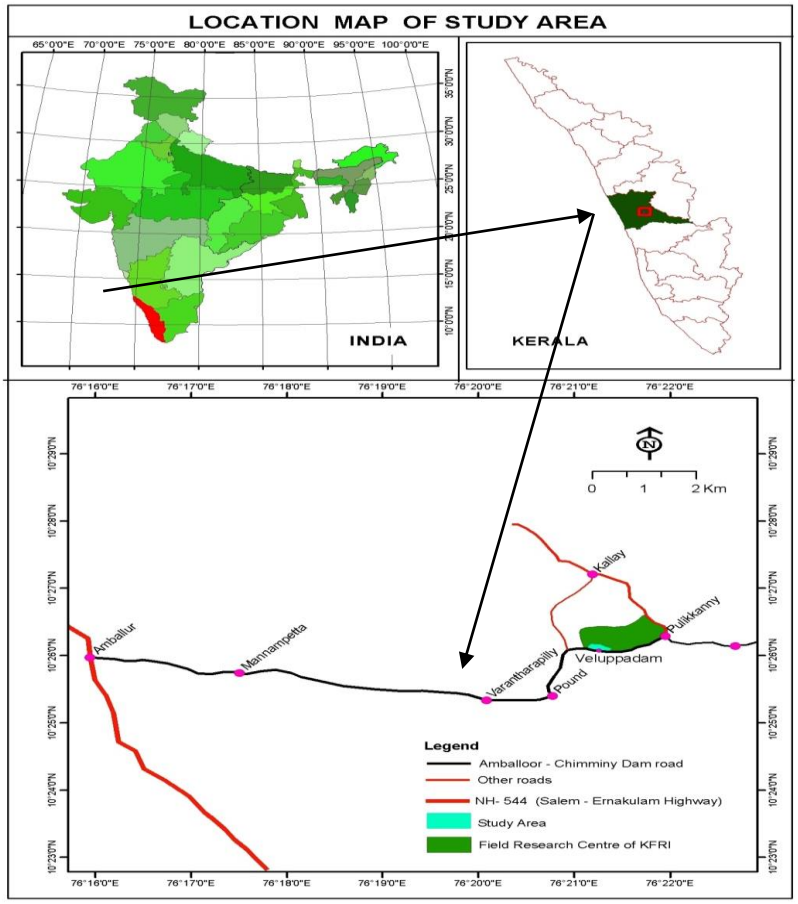

Fig. 4. Location map of the study plot at F.R.C. Veluppadam.

Both these data from this study plots were recoded during 2005- 2008 period from KFRI's one earlier project were used here in this study just to see whether there is any correlation existing between the pattern of rain , the availability of new shoots and the occurrence of the shoot borer incidence. The summery data was used here to support the first objective of this project.

1. Pest incidence in young plantations.

Observations in trial plantations have shown that unless effective control measures are adopted the shoot borer infestation continues throughout the year .This is primarily due to the damaged plants continue to produce new shoots to overcome the damage occurred to the leading shoot and it was observed that the shoot borer populations were continuously occurring with an interval of 35 to 40 days. In no plantations a management practice is done meticulously so as to eradicate this pest. This had resulted in total failure of mahogany plantations. As a result no new plantations are initiated by the Forest Department.

This present study was undertaken to understand the reasons for the shoot borer incidence holistically and to come out with a package of practices to manage mahogany plantations in the initial years.

When this study was undertaken at the Field Research Centre, Veluppadam, this mahogany trial plots was already at 6th year. This mahogany trial plots were established in 2003 by KFRI for another earlier project at FRC, Veluppadam. During that project period the same group of scientists had generated and recorded the data on the *H. robusta* infestation and rainfall from this mahogany plots. These data on the shoot borer infestation and rainfall were interpreted here to show the relation of rainfall pattern, news hoot formation and continued existence of the shoot borer in the mahogany plantations. The variation in the susceptibility of the two species of mahogany to this shoot borer is also clear from the data.

***Fig.5. S. macrophylla* in 2x2m spacing**

***Fig.6. S. macrophylla* in 3x3m spacing**

Infestation by the shoot borer in the year 2005 when the plants were 3 year old is given in Figure 7. It can be seen that maximum attack was during the rainy season and the infestation of the new shoots were in the range of 40-60 percent in the case *Swietenia macrophylla* in 3x3 m spacing plots. In the case of *S. mahagoni* infestation of new shoots ranged between 45-73% during the months of April to October 2005. The mahogany plants were infested in all the months though attack was comparatively less in January and February (10-12 %).The lowest percentage of attack was observed in March (6-8 %), when rainfall was scanty and there were only few new fresh shoots on the mahogany plants. Infestation was less in 2x2m spacing in all the months (Fig. 8).

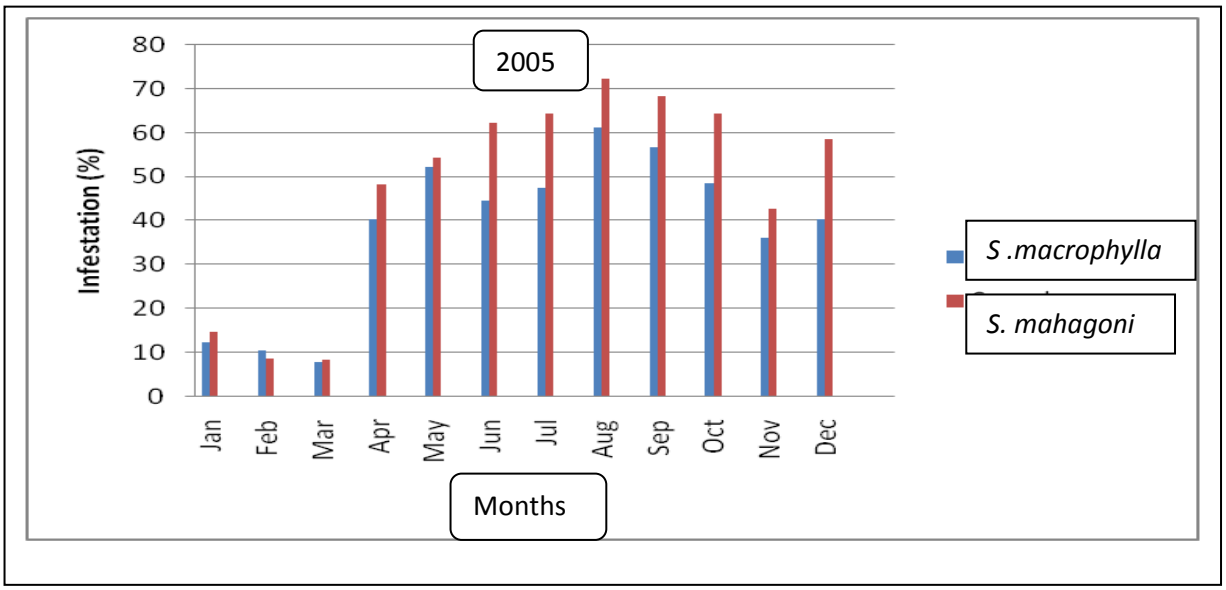

Fig. 7. *Hypsiphyla robusta* infestation status in plots of 3 x3 m spacing in 2005 .

Comparative resistance of the two mahogany species in 3x3 m spacing against the shoot borer during 2005 is shown in Fig. 7. It can be seen that both *S. mahagoni and S. macrophylla were* attacked by the shoot borer *Hypsipyla robusta* throughout the year. In the beginning of the year January to March the rate of infestation is found very low due to dry period and the non availability of new shoots. But the infestation gradually builds up from April to Aug. and then declined till Dec. This may be due to the summer rains and followed by the rainy season (Fig.9), the availability of fresh shoots were ensured in the mahogany plantations. The Fig. 9 shows the general pattern of rain in the study area in 2005. In both the species the rate of infestations were more in 3x3m spacing plots (40-61 % in *S. macrophylla* and 41-71 % in *S. mahagoni*) than in 2x2 m spacing plots.

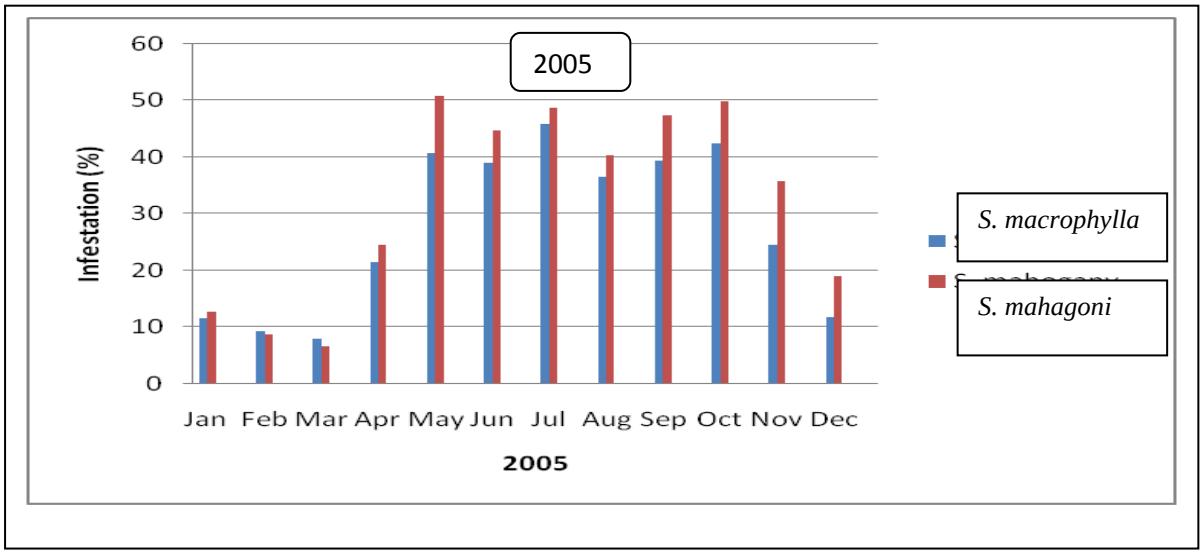

Fig. 8. *Hypsiphyla robusta* infestation status in plots of 2 x2 m spacing in 2005

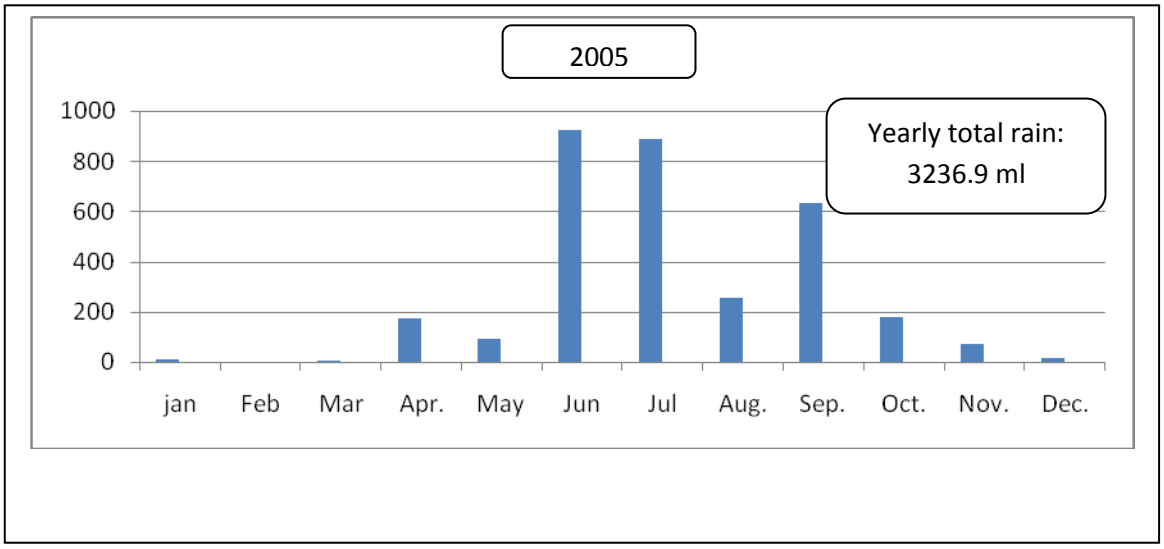

Fig.9. Rain fall data in ml, from the Field station at, Veluppadam, 2005

The infestation was severe during the months of April to December. During the year 2005 *S. macrophylla* suffered around 21-45 percent infestation in 2x2 m spacing plot (Fig.8). *S. mahagoni* showed comparative more susceptible than *S. macrophylla*. In the 2x2 m spacing plots(Fig. 8) in the same year (2005) both the species showed comparatively less infestation(21-45 % in . *S. macrophylla* and 23-51 % in *S. mahagoni).*

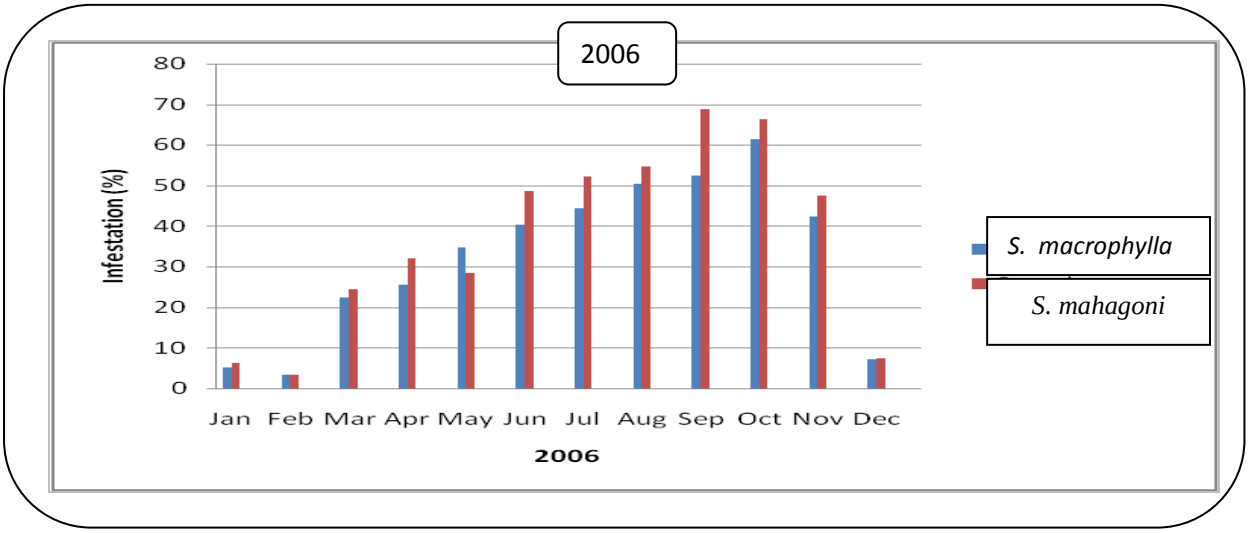

Fig 10. *Hypsiphyla robusta* infestation status in plots of 3x3m spacing 2006

The infestation was severe during the months of April to December. During the year 2005 *S. macrophylla* suffered around 21-45 percent infestation in 2x2 m spacing plot (Fig.. *S. mahagoni* showed comparative more susceptible than *S. macrophylla*. In both the species the rate of infestations were more in 3x3m spacing (40-61 % in *S. macrophylla* and 41-71 % in *S. mahagoni*) In the 2x2 m spacing plots(Fig. 8) in the same year (2005) both the species showed comparatively less infestation(21-45 % in . *S. macrophylla* and 23-51 % in *S. mahagoni).*

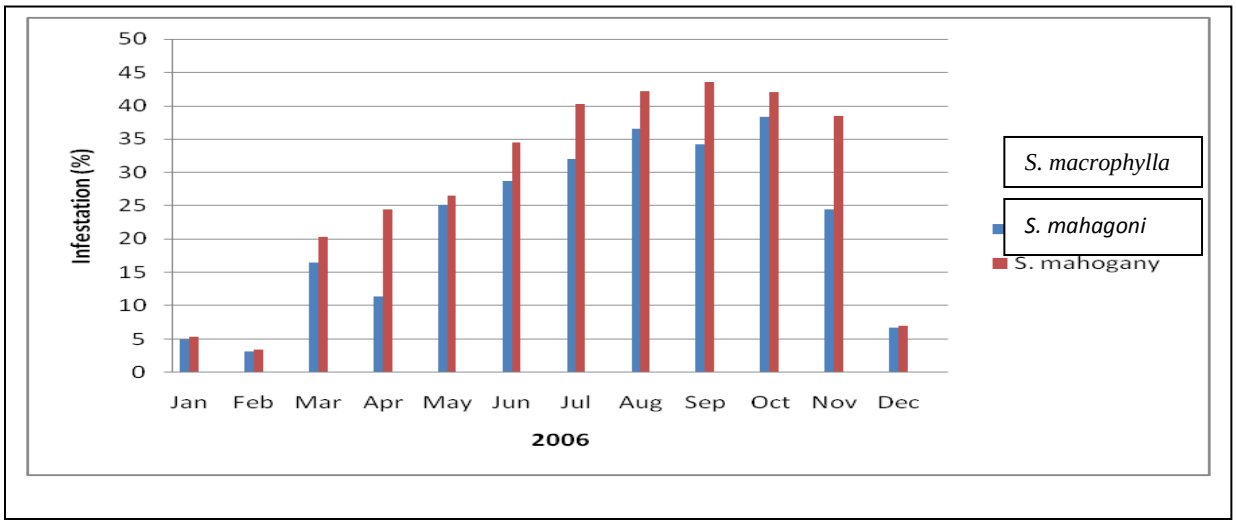

Fig 11. *Hypsiphyla robusta* infestation status in plots of 2x2m spacing 2006

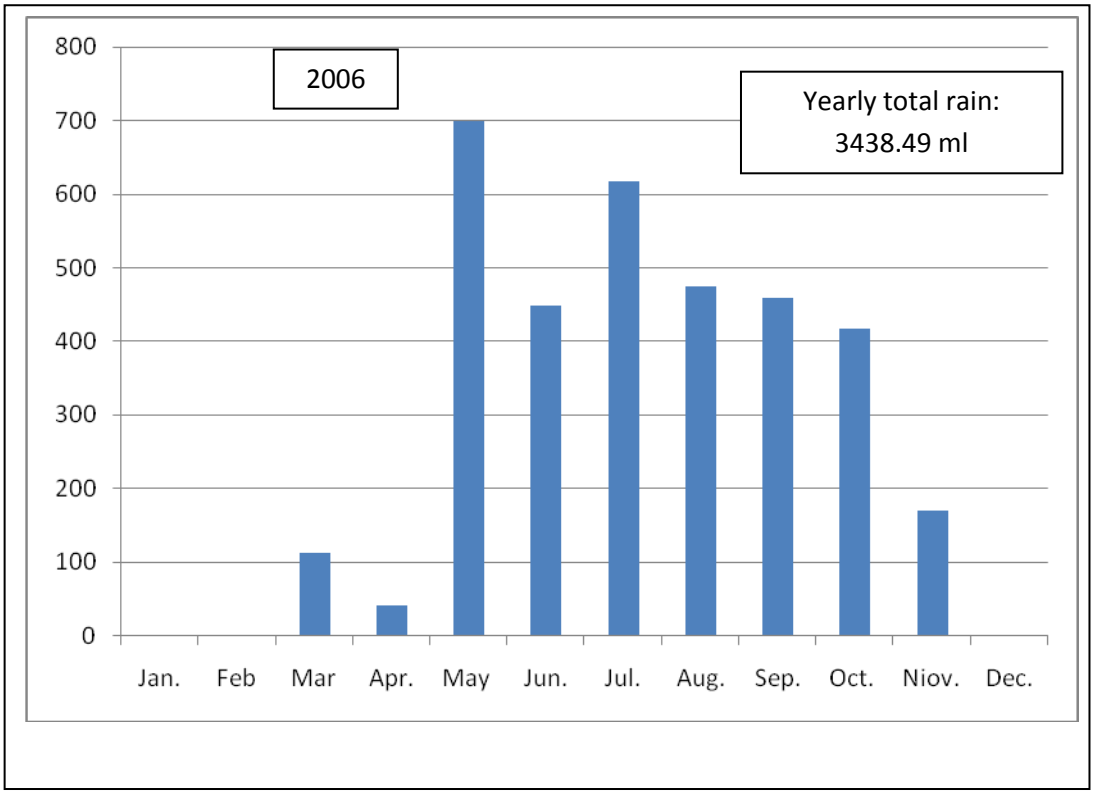

Fig.12. Monthly rain fall data in ml, from the Field Research Centre station at F.R.C., Veluppadam 2006.

Data on the shoot borer infestation during 2006 showed a similar pattern of infestation of the previous year. S. *mahagoni showing* relatively higher susceptibility compared to S. *macrophylla,* in all the months. During April to November around 12 to 37 percent of the *S. macrophylla* and 20 -47 percent of the new shoots of *S. mahagoni* plants suffered damage by *H. robusta* infestation in 2x2m spacing (Fig.10). In the 3x3 m spacing plots during the same year in both species the intensity of infestations were more compared to 2x2 m spacing plot(22-61 % in *S. macrophylla* and 23 to 69 % in *S. mahagoni*). In 2006 year there occurred summer rains (fig. 11) in the month of March, resulting in availability of new shoot and subsequently *H. robusta* infestation started from March onwards(Fig. 10 &11). The rain data recorded from FRC, Veluppadam (Fig. 12) clearly shows the influence of rain on new shoot production and *H. robusta* infection pattern and its intensity.

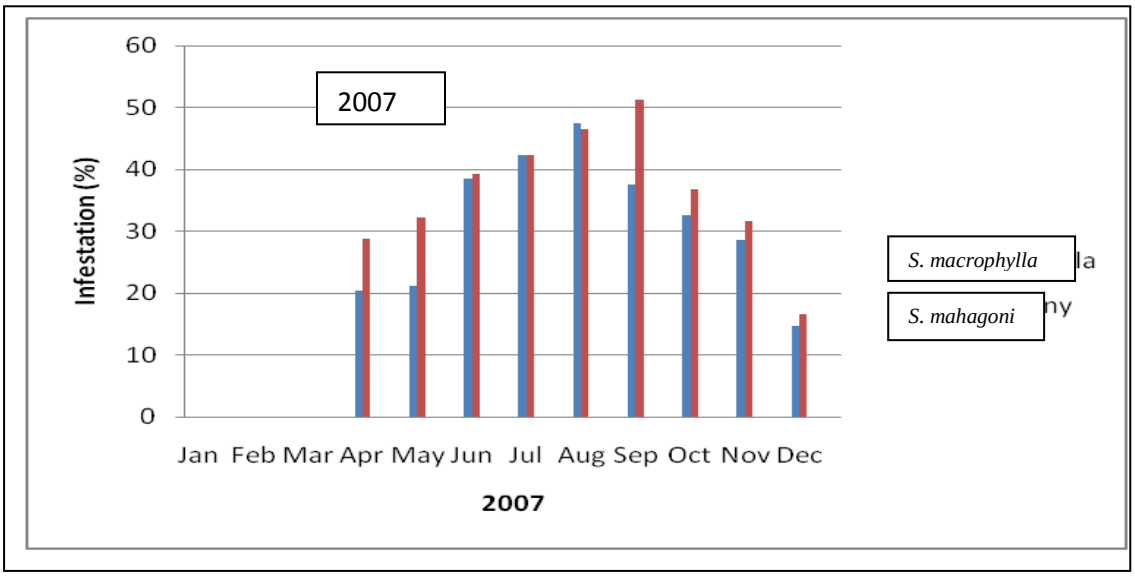

Fig 13. *Hypsiphyla robusta* infestation status in plots of 3x3m spacing 2007

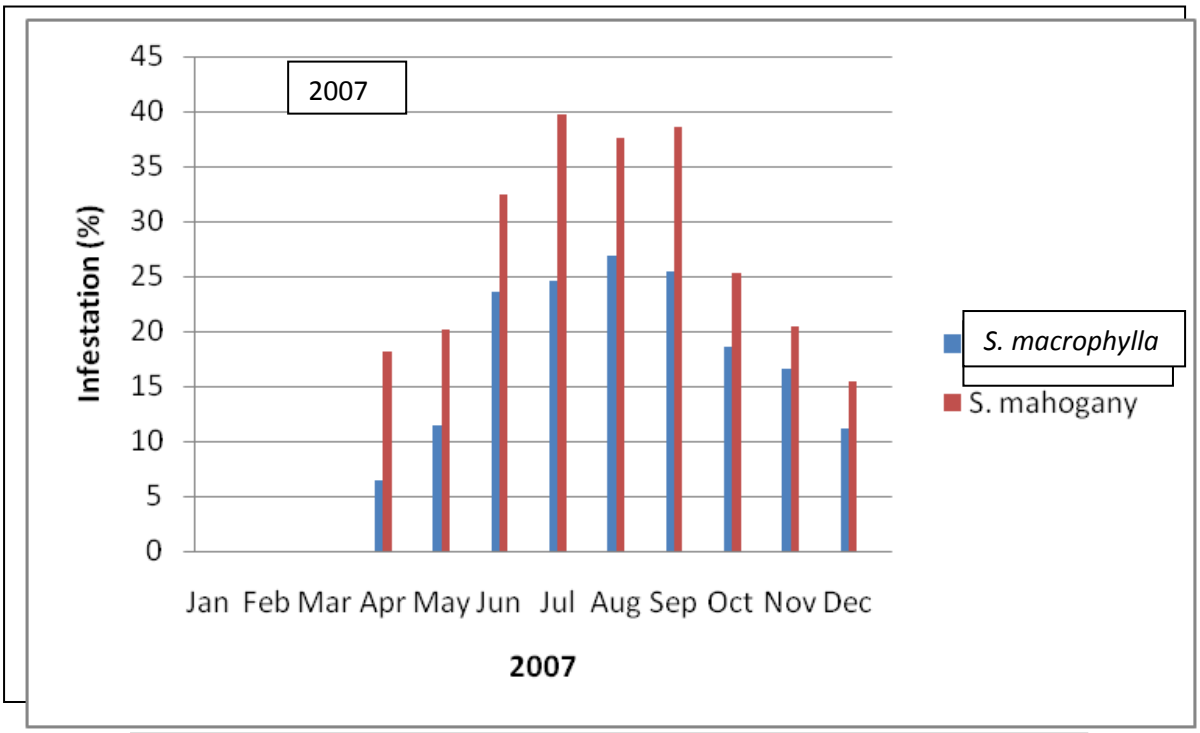

Fig. 14. *Hypsiphyla robusta* infestation status in plots of 2x2 m spacing 2007

Hypsiphyla robusta infestation in the year 2007 in 3x3 m spacing plots (Figure 12) of *S. mahagoni* in 2x2 m spacing plots (Figure 13) showed that there was some reduction in the overall rate of infestation when compared to the previous years, still the pattern was almost similar. The rain fall pattern in 2007 (Fig. 14) started in March and lasted up to Nov., but the infestation was noticed from the month of April onwards. This infestation persisted up to Dec. The infestation in S. *mahagoni ranged* from 29 -51 percent (Fig. 12.) in 3x3 spacing plots where as the infestation in *S. macrophylla* it ranged from20-48 percent only. In the 2x2 m spacing plots(Fig. 13) the infestation in *S. mahagoni* plots ranged from18 to 40 percent and in *S. macrophylla* plots infestation varied from 6 to 26 to percent only.

The pattern of rainfall in 2007(Fig. 14) showed similarity to 2006 and this also supported the infestation of *H. robusta* .

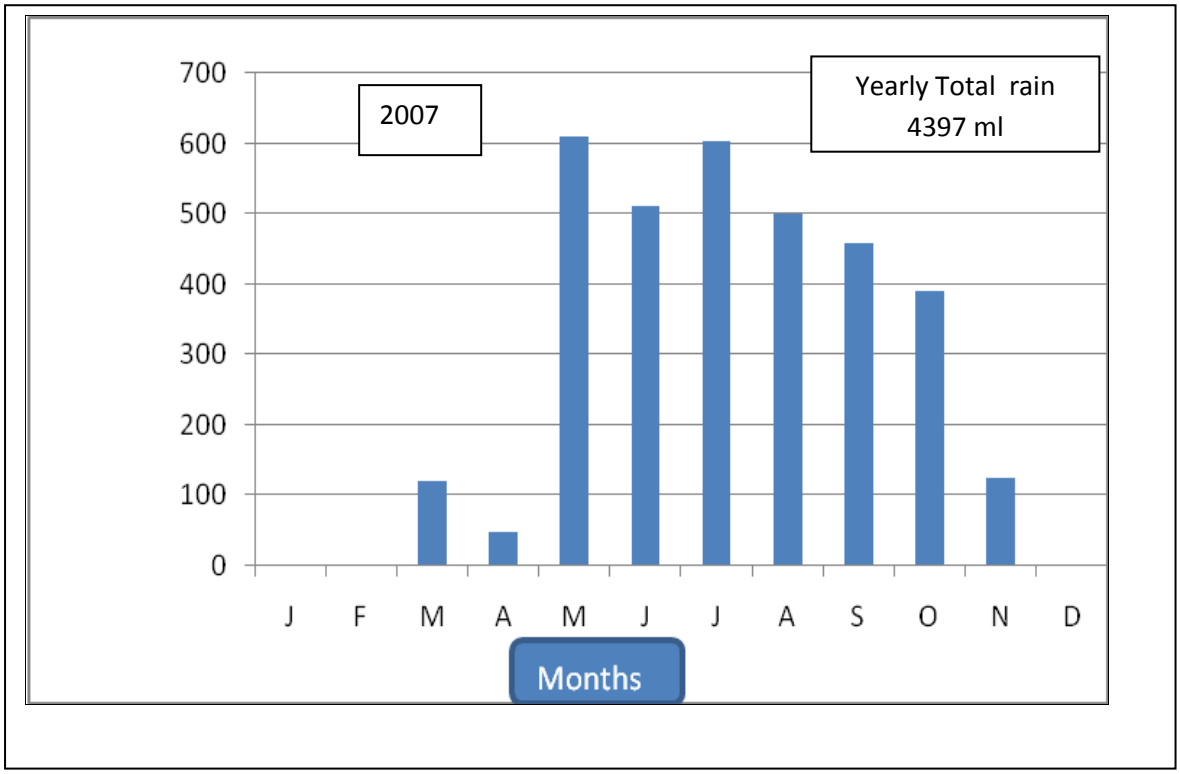

Fig.15. Rainfall data from the Field station at Veluppadam in 2007

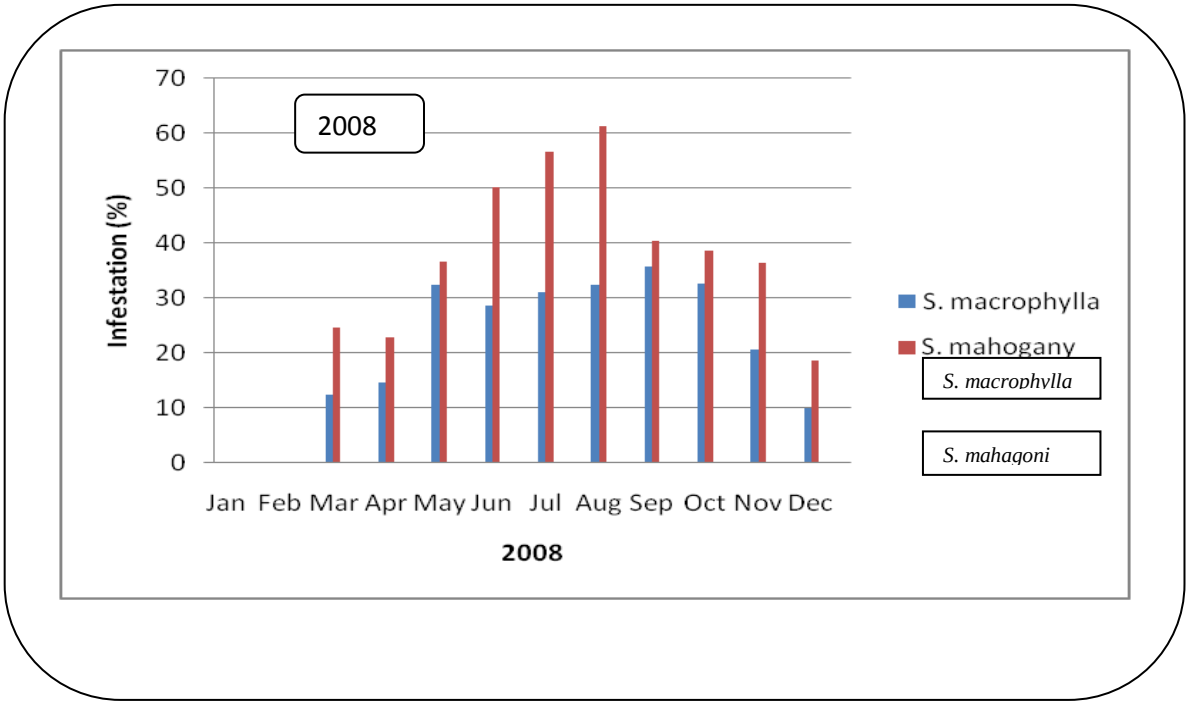

Fig. 16. *Hypsiphyla robusta* infestation status in plots of 3x3 m spacing 2008

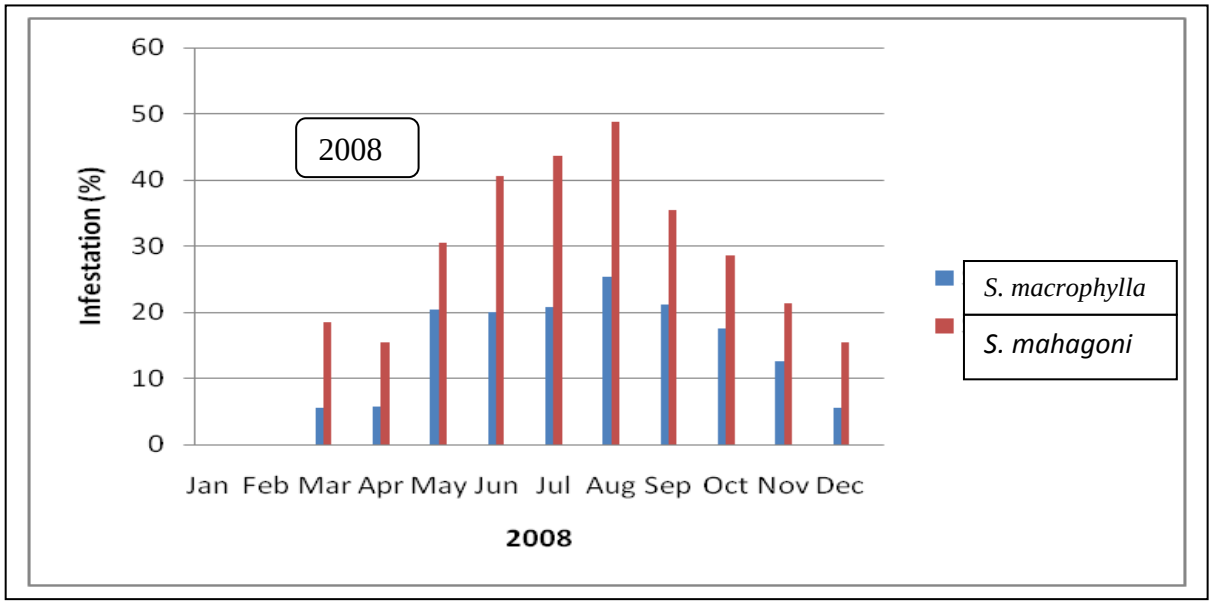

Fig 17. *Hypsiphyla robusta* infestation status in plots of 2x2 m spacing 2008

Hypsiphyla robusta infestation in the year 2008 in 3x3 m spacing plots (Figure 16.) of *S. mahagoni* and in 2x2 m spacing plots(Figure 17.) showed that there was some reduction in the overall rate of infestation when compared to the previous years, still the pattern was almost similar coinciding with the rain pattern. The rain fall pattern in 2008 (Fig. 18) started in March and lasted up to October. The infestation *by H. robusta* was noticed from the month of March onwards. This infestation persisted up to Dec. The infestation in S. *mahagoni* plots ranged from 25-61 percent (Mar. To Aug.) (Fig. 16) in 3x3 m spacing plots and it persisted up to Dec. The infestation in *S. macrophylla* it ranged from12- 35 (Mar. To Sep.) percent only. This infestation persisted up to Dec. and then reduced .

In the 2x2 m spacing plots (Fig. 17) in the same year 2008 the infestation in *S. mahagoni* plots ranged from 18 to 49 (Mar. To Aug.) Percent and decreased to 5 percent in Dec. In the 2x2 m spacing plots of S. *macrophylla* infestation was only 5 to 25(Mar. To Aug.) percent and then reduced to 5 percent(Dec.). This year also though the pattern of infestation showed a similar trend .

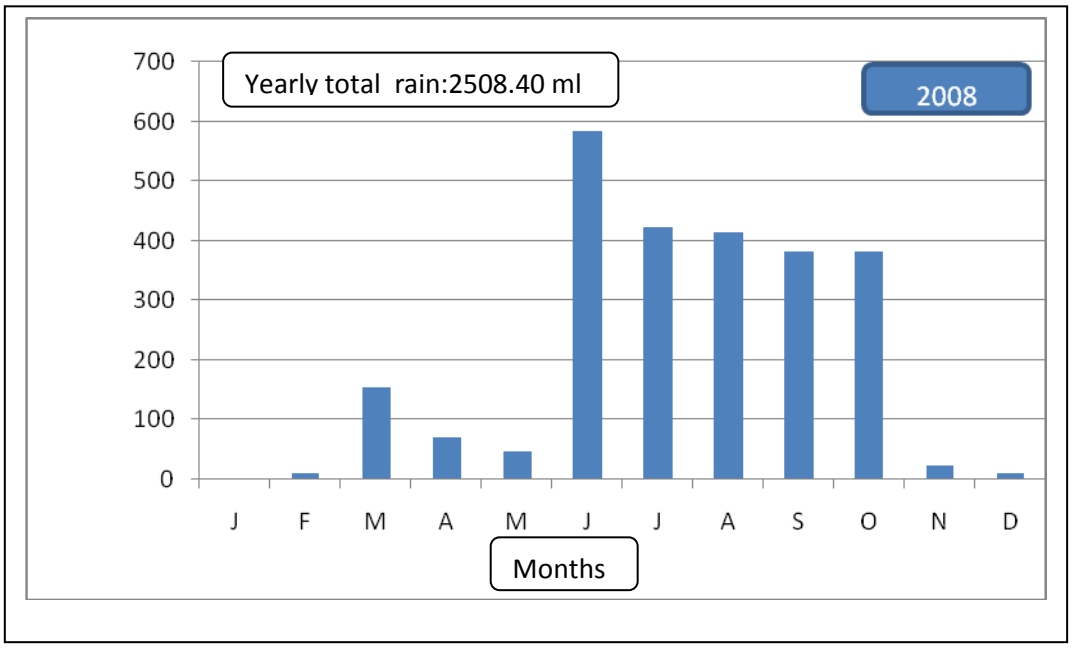

Fig.18.Monthly rainfall data from FRC Veluppadam for the years 2008

This year the over all rain pattern remained the same (Fig.18). Compared to last year the rain was less in the first two months (Mar. To May). But July onwards it was almost similar to the previous year , though with little variation in the total quantity of rain obtained.

Materials and methods

The study site was at FRC, Palappilly. Experimental plots, with two levels of spacing viz., 2x2 m and 3x3 m, of the two species of mahogany viz., *Swietenia macrophylla* and *S. mahagoni* already established in 2004 for another study were considered for the present project. There were 39 plots under each spacing level. Observations on the number of fresh shoot produced and number of shoots attacked were recorded periodically for 18 months. Five trees along the diagonal of each plot containing 25 plants were considered for taking observations on infestation aspects.

Chi-square test was performed to test whether there were any significant differences between the number of infected shoots found in different months. For this the null hypothesis stated was the number of infected shoots is the same in all months and hence derived the expected frequencies in different months accordingly. This test was done separately for each spacing level and also for pooled dataset, under each species.

The test statistic used was $x^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}$ (1)

Where O_i = Observed number of infected shoots in the i^{th} month

E_i = expected number of infected shoots in the i^{th} month

k = number of months

Proportion of infestation was also calculated for each period for two spacing levels. *Z* test was performed to find whether there is any significant difference between the proportions of infestation under two spacing levels. This test was carried out separately for each species.

$$z = \frac{p_1 - p_2}{\sqrt{\frac{p_1 q_1}{n_1} + \frac{p_2 q_2}{n_2}}}$$

Where p_1 and p_2 are proportion of infestation in two spacing levels. q_1 = 1- p_1 and q_2= 1- p_2

SUMMARY

The data from this earlier study from FRC, Veluppadam summarised here as part of monitoring the pest incidence in younger plantation. The result of this study clearly shows the influence of climatic conditions (mainly rain pattern) in supporting the tender shoot production and shoot borer population in young mahagony plantations. *Swietenia mahagoni* (*S. microphylla*) was much more susceptible than *S. macrophylla* throughout the earlier study period (2003to 2008). This study also showed that irrespective of spacing, infestation was more in *S. mahagoni* plots. Shoot borer damage was more in young age group (second year to sixth year) plantations. Infestation decreased with age of plants in both the species. The pattern of rain support new flushing of mahogany shoot which in turn supported the *H. robusta* infestations beginning , persistence and continuation till the end of the year.(KFRI R.R.No. 448)

Table 1. Infestation percent in two spacing levels observed in *S. mahagoni* and *S. macrophylla*, during June 2010 to Jan.2012

Period	***S. mahagoni***		***S. macrophylla***	
	2 x 2 spacing	**3 x 3 spacing**	**2x2 pacing**	**3 x 3 spacing**
	Infestation per cent	**Infestation per cent**	**Infestation per cent**	**Infestation per cent**
June 2010	33.53	13.29	32.75	14.04
July 2010	43.27	16.78	20.47	51.46
Sept. 2010	50.88	14.77	17.54	18.71
Oct. 2010	20.47	3.38	16.96	8.77
Dec. 2010	11.11	4.76	23.39	25.73
Jan. 2011	6.96	1.89	23.39	28.40
Feb. 2011	20.51	25.93	55.56	47.34
Mar.2011	11.54	3.70	65.50	59.17
Apr.2011	38.06	11.28	14.04	17.75
May 2011	25.97	16.03	37.82	43.20
June 2011	35.53	29.69	20.59	29.07
July 2011	29.82	42.26	29.82	42.26
Aug. 2011	19.61	9.30	10.53	22.09
Sept. 2011	19.21	2.46	18.71	24.42
Oct. 2011	26.85	30.30	59.06	76.16
Nov. 2011	28.77	16.67	33.92	64.53
Dec.2011	28.57	21.95	39.77	34.30
Jan. 2012	17.69	4.17	19.88	18.02

Results

The infestation percentage observed in *S. mahagoni* and *S. macrophylla.* during June 2010 to January 2012, planted in two spacing is reported in Table 1

The chi-square test revealed that the infestation status is not the same in all months under two spacing levels in both the species. The *Z* test also indicated that there is significant difference between the proportions of infestation for the two spacing levels under the same species and also for the two species under the same spacing level.

The rain data recorded and maintained at the Field Research Centre, Veluppadam, was very much useful to co-relate the shoot borer incidence at the experiment mahogany trial plots with the production of new tender shoots. All These years rain data shows that in the months of Jan. ,Feb. and March there was no rain or very little rain and very less tender shoots and shoot borer population was almost nil on the shoots and only a few were found surviving in some cases under the bark of some of these plants. A summary of rain fall data (2003-2012) and figures (19, 20, 21&22) showing monthly rain fall and the yearly total rain recorded during this study period (2009-2012). Figure 23. Shows the yearly total rain fall recorded at FRC, Veluppadam

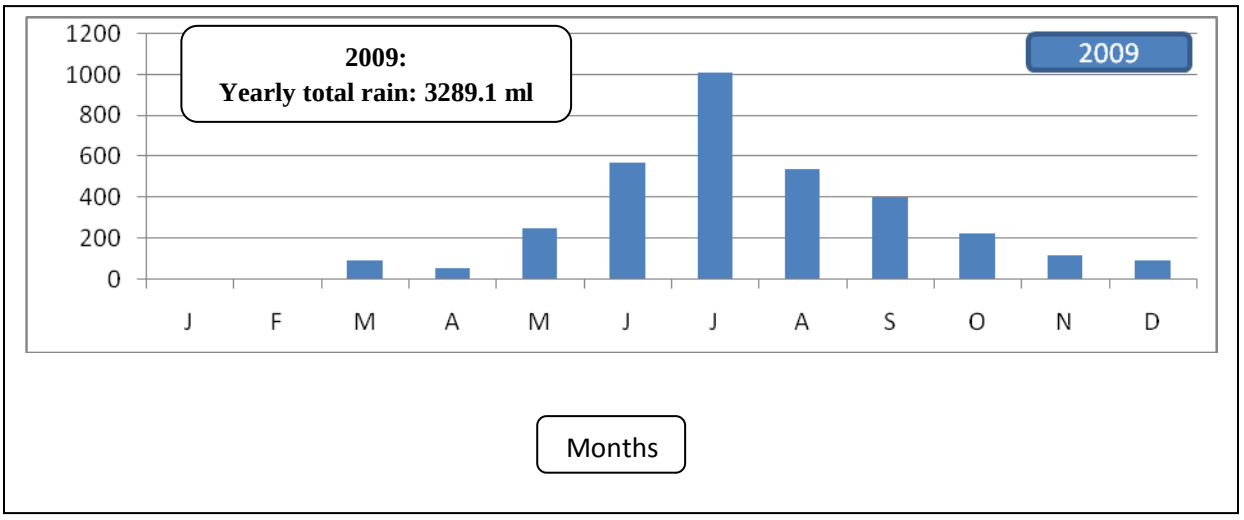

Fig. 19: Monthly Rainfall data in ml, from FRC, Veluppadam , during 2009.

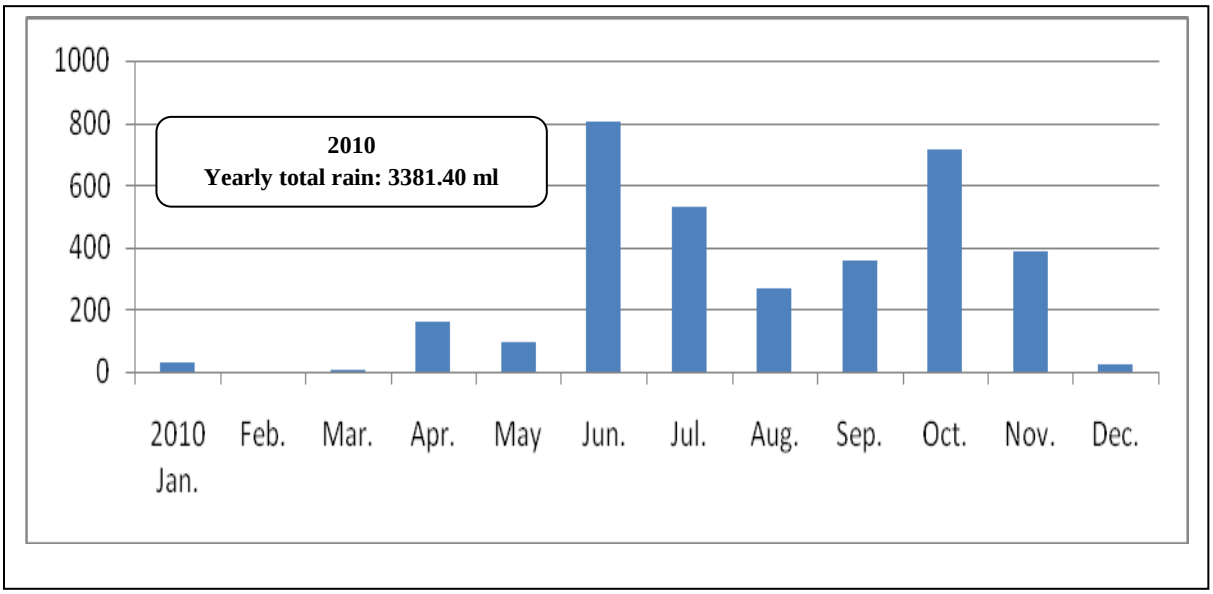

Fig. 20: Monthly rainfall data in ml, from FRC ,Veluppadam ,during 2010.

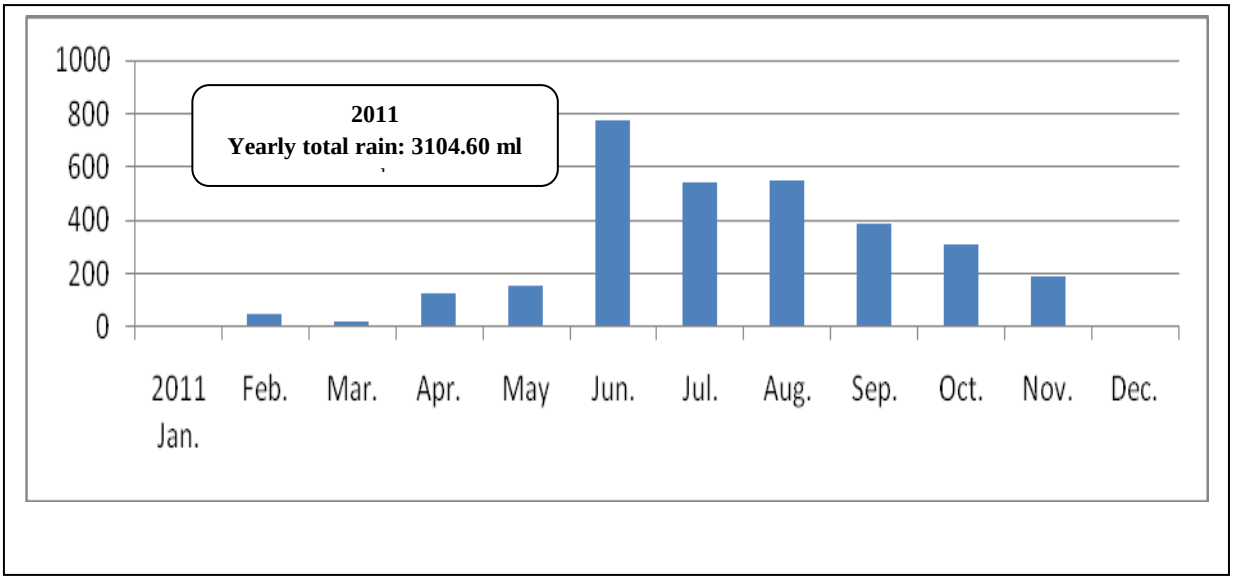

Fig. 21 : Monthly rainfall data in ml , from FRC ,Veluppadam ,during 2011.

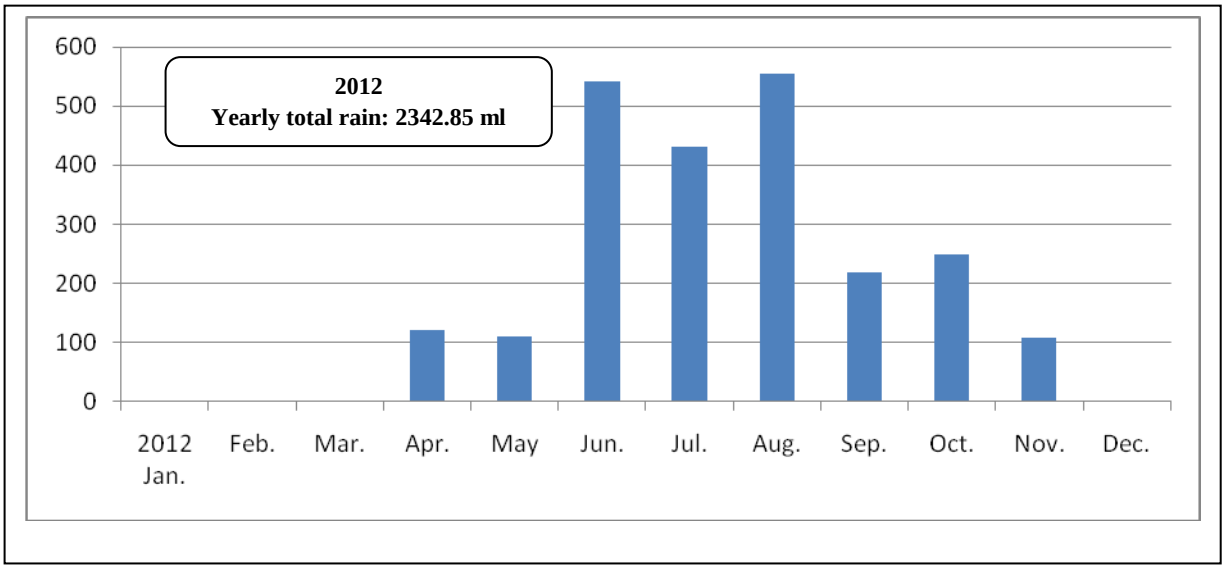

Fig. 22: Monthly rainfall data in ml, from FRC, Veluppadam, during 2012.

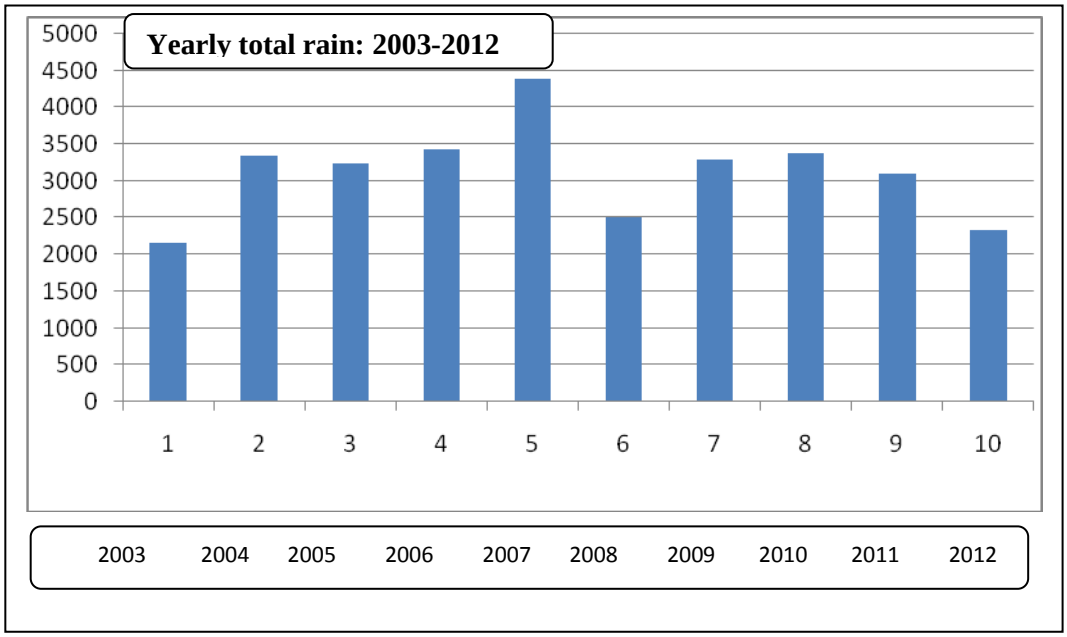

Fig. 23.Yearly total rain fall in ml, at FRC , Veluppadam during 2003- 2012.

Table 2. Showing the monthly and year total rainfall data from the experimental trial plots at FRC, Veluppadam 2003-2012

year	Jan	Feb	mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Des	Yearly Total rain fall ml
2003	0.00	111.0	35.80	130.00	42.20	440.50	410.10	411.60	102.00	453.00	11.20	10.10	2157.50
2004	0.00	0.00	19.40	34.20	550.60	943.80	427.90	542.70	224.80	502.40	101.70	0.00	3347.50
2005	10.40	0.00	3.00	173.30	91.90	923.20	888.90	253.50	634.00	177.20	67.50	14.00	3236.90
2006	0.00	0.00	112.80	41.50	698.40	448.00	618.00	474.10	458.90	416.80	169.90	0.00	3438.40
2007	0.00	0.00	0.00	78.20	180.60	803.30	1292.10	693.80	679.00	566.60	87.40	16.00	4397.00
2008	0.00	3.00	170.20	98.40	73.40	605.60	468.60	425.00	239.00	407.00	11.20	5.00	2506.40
2009	0.00	0.00	79.50	57.90	285.30	546.10	1052.60	477.00	381.10	226.00	137.50	46.10	3289.10
2010	30.40	0.00	8.90	160.70	97.50	802.90	530.30	269.70	358.00	715.00	384.00	24.00	3381.40
2011	0.00	52.00	19.00	126.00	153.00	773.70	541.20	548.70	388.30	311.50	191.20	0.00	3104.60
2012	1.50	0.00	0.50	121.50	111.00	542.00	431.25	555.00	220.00	249.50	109.20	1.40	2342.85

5.2. **Pest management studies**

5.2.1 Physical Control:-

5.2.1.1 Methodology:

This is a method Hypsiphyla *robusta* moths were physically prevented from reaching the tender shoots of mahogany plants using a physical barrier. For this the tender shoots were covered with a bamboo frame over which is covered with a fine nylon mosquito net. This experiment was conducted at the study plot of FRC, Veluppadam on selected plants with fresh tender shoots. The results observed were recorded regularly. This data was analyzed statistically to understand the significance this method in controlling the shoot borer damage. Though the preparation of the bamboo frame and net coving was little time consuming this method was found hundred percent effective in preventing the shoot borer incidence. (Table 1).The percentage of infestation was

calculated by dividing the total number of damaged fresh shoots with the number of total fresh shoots in the plot sampled and then multiplied this value with 100. Representing the plot five plants in the diagonal line of each of the plots were sampled and data so collected were used for this calculation.

$$\text{Note:- \% of damage} = \frac{\text{No. of damaged fresh shoots}}{\text{Total No. of fresh shoots}} \times 100$$

Constructed bamboo hoods with nylon net covering to cover the tender shoots that can block the moths from laying eggs on these tender shoots. (See fig. 26). This trial was conducted in *S. mahagoni* belonging to 2m x 2m spacing. For this physical control experiment a control plot and net covered plot (treated plot) were kept for recording observations on infestation. The observations were recorded from October 2011 onwards. Chi-square test was performed to test whether there were any significant differences between the numbers of infected shoots found in different months in control plot as well as in net covered plot separately. *Z* test was carried out to find whether there is any significant difference between control plot and treated plot with respect to proportions of infestation.

Fig. 24. A susceptible new tender shoot of *Swietenia macrophylla*

Fig. 25. A general view of the *mahogany* study plot in the Field Research Centre at Veluppadam

Fig. 26. The hood used for covering the leading shoot of *mahogany* plants.

Data on infestation of shoot borer in protected (shoots covered with net) and unprotected (without net covering) plants is given in Table 2 and Figure 27.

Month	% of damage in *Swietenia microphylla* plants with net covering	% of damage in plants without net covering
Oct. (29-10-11)	0	18
Nov. (28-11-11)	0	11
Dec. (27-12-11)	0	36
Jan. (27-01-12)	0	10

Table 2. Comparison of shoot borer damage in *Swietenia mahogani* plants *with* and without net covering, at FRC, Veluppadam, during Oct. 2011 to Jan. 2012.

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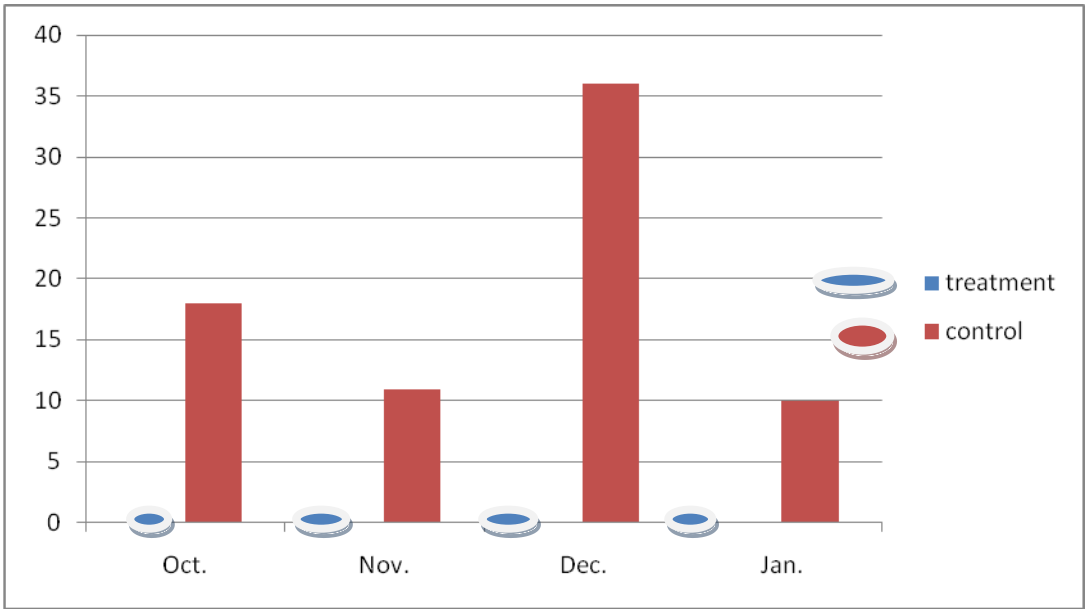

Fig.27. Comparison of shoot borer infestation in plants with net covering (treatment) and without net covering (control), at F.R.C., Veluppadam during Oct. 2011 to Jan. 2012

5.2.1.2 Result:

The physical control method followed in this study gave full protection to the young mahogany plants in the study plots. Though the preparation of bamboo hood with nylon net to cover each plant's leading shoot was time consuming the result was rewarding .There was absolute protection of plants from the shoot borer in the protected plants compared to the unprotected ones. This method is also an eco friendly one. The infestation percentage observed in *S. mahagoni* during October 2011 to January 2012, planted in 2 m x 2m spacing is reported in Table2. There is no attacked shoots in all the months in net covered plants. Hence this method is found to be effective. The chi-square test revealed that occurrence of number of infested shoots in different months is not the same in the control plot.

The Z test also indicated that there is significant difference between the control and treated plot with respect to proportions of infestation in all the four months.

5.2.2: **Biological Control**

Oecophylla smaragdina weaver ants (Hymenoptera: Formicidae) were used as a bio-control agent for the control of the pest of many fruits trees in other countries(Chen, S. (1991) ; Offenberg, J. *et al*., (2004) ; Peng, R. *et al*., (2007); Van Mele, P.and Vayssières, J.F. (2007) ; Peng, R. K. and Christian, K. (2008) ; Van Mele, P. (2008) ; Offenberg J and Wiwatwitaya D, 2010). Offenberg, J. and Fir, J. (2015)). In this study the effectiveness of weaver ants (O*ecophylla smaragdina*) as a bio-control agents for managing the mahogany shoot borer *H. robusta* was attempted in the mahagony trial plots at FRC, Veluppadam.

5.2.2.1: Methodology:

Weaver ant's nests are common on forest trees. These nests were identified and collected with the help of expert tree climbers. The nests were kept in cloth bags and brought to the study plots and ants were released on the mahogany plants. Soon these ants come out of their nests, moved around and located appropriate site for establishment. Within one to two hours they constructed a new nest and settled. Instances of deserting the mahogany plants were also noticed. In order to enhance establishment of ants, food supplements in the form of fish and chicken waste were also

provided which was found to be useful in sustaining the ants colonies on the mahogany plants initially.

Fig. 19. Weaver ant weaving the leaves together for making the nest, holding the immature stage of weaver ant.

Fig.20. The mature queen of weaver ant (*Oecophylla smaragdina)*

5.2.2.2: Result

The data generated on the efficiency of weaver ants in managing the shoot borer incidence is given in table No. 3.,Fig.21. This data shows that weaver ants were able to manage the shoot borer incidence to a substantial level. During the nine months observation period the rate of damage of new tender shoots on the control plants varied between nil to 63 percent. Whereas the incidence of shoot borer on the treated plants during the same period was only between nil to 14 percent. (See table 3.)

Observation period	% of damage in weaver ant nested plants (plot value)	% of damage in control plants-without weaver ant nesting (plot value)
May.2011 (27-05-11)	0	30
Jun.2011 (29-06-11)	6	25
Jul.2011 (29-07-11)	**0**	**0**
Aug.2011 (31-08-11)	0	38
Sep.2011 (25-09-11)	13	14
Oct.2011 (29-10-11)	13	19
Nov.2011 (28-11-11)	14	63
Dec.2011 (27-12-11)	8	13
Jan.2012 (28-01-12)	7	17

Table 3. Comparison of the percentage of shoot borer infestation data collected form the weaver ant nested mahogany plants and control plants within the study plot at FRC, Veluppadam

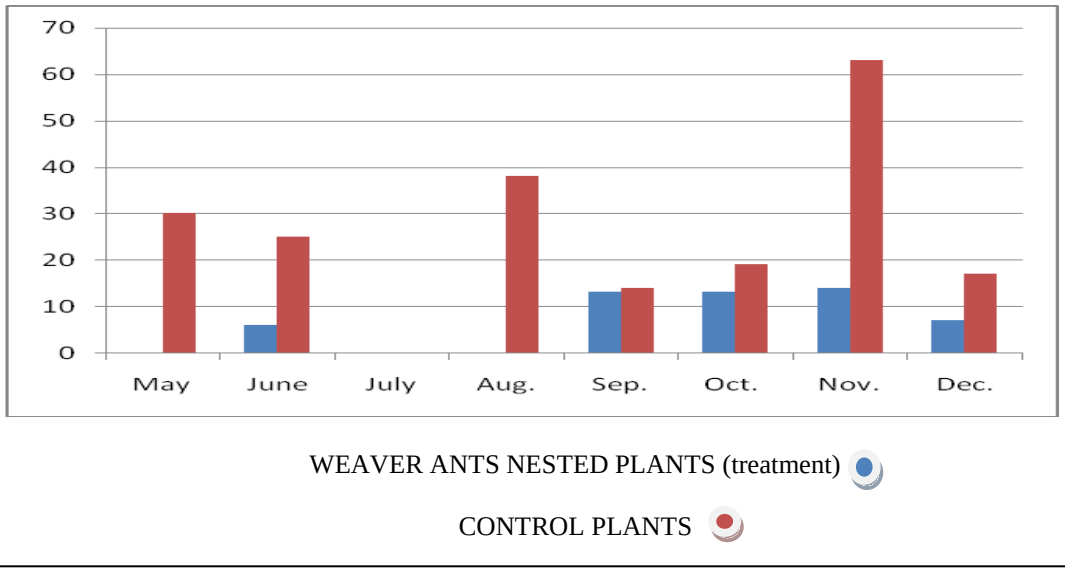

Fig. 21. Comparison of the percentage of shoot borer infestation form the weaver ant nested mahogany plants (treatment) and control plants within the study plot at FRC, Veluppadam

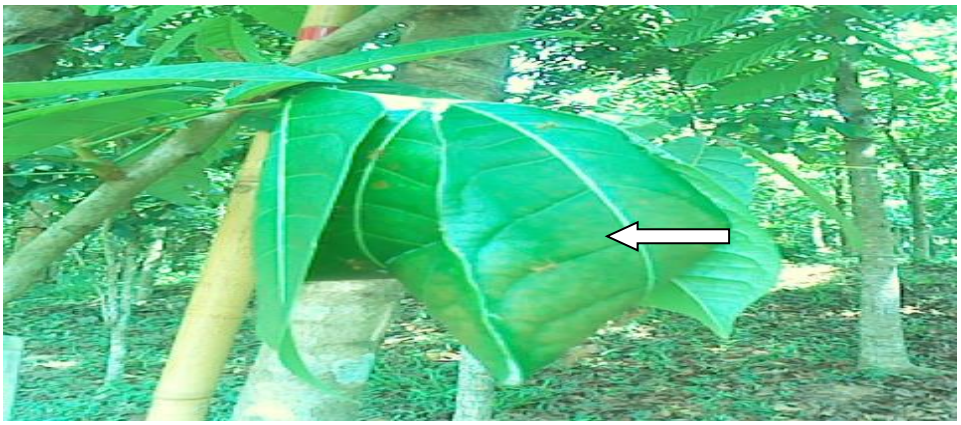

Fig.22. New nest of weaver ants maid on mahogany plant leaf at FRC Veluppadam

Fig.23.New multiple nets of weaver ants maid on the mahogany plants leaves at FRC,

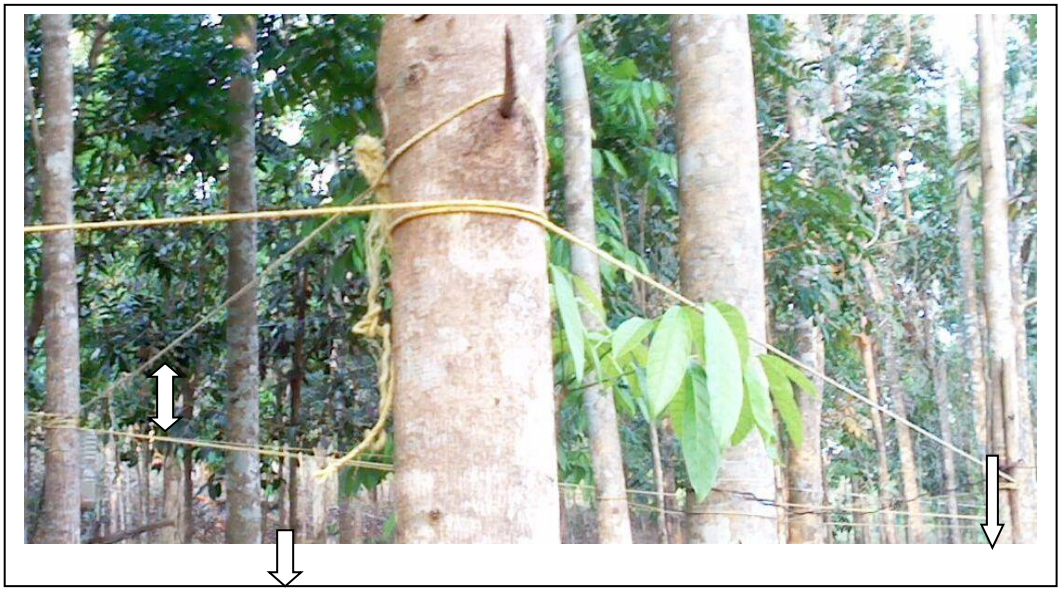

Fig.24.Weaver ant nested mahogany plants within the study plot were connected to all surrounding mahogany plants, using thick thread . This helped to bring all mahogany plants under the surveillance of weaver ants from the nested plants.

Fig.25.Weaver ant nested mahogany plants within the study plot were connected to all surrounding mahogany plants, using thick thread. This helped to bring all mahogany plants under the surveillance of weaver ants from the nested plants. See the movement of ants between the plants along

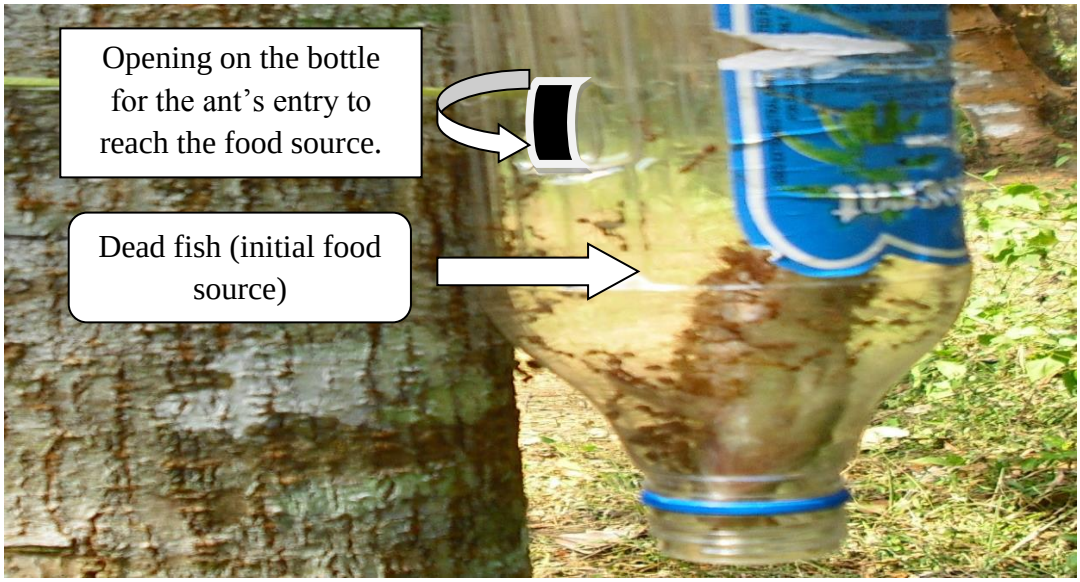

Fig.26. Mahogany plants within the study plot provided with a plastic bottle with a dead fish as initial food source, to support the newly established weaver ants.

Fig.27.Weaver ants sharing the fish (food source) kept in side the plastic bottle attached to the mahogany plant.

5.2.3: Chemical tree injection

5.2.3.1. Methodology:

Dimethoate (Rogor, Cygon, Hexagor-trade name) is a systemic and contact poison. In the present study this insecticide was used against the shoot borer management. In order to find the effectiveness against the shoot borer *Hypsipyla robusta*, five different concentrations of the systemic pesticide Tafgor (Dimethoate 30%EC) was prepared. One ml of Dimethoate 30%EC was added to 100ml of water. This formed the first solution, (C1). One ml of this C1 was added to a second set of 100 ml water and stirred well. This formed the second concentration C2. In this way from C2 to C3, C3 to C4, C4 to C5 dilutions were prepared. (Tab.4). Freshly collected tender mahogany shoots of *S. macrophylla* were kept with it' s bottom cut edge alone dipping in the pesticide solution , in separate test tubes, for half an hour. Some larvae of *Hypsipyla robusta*, in different age group (with different body weight) were collected from the mahogany plants in the study plot. These larvae were then released to the different set of treated shoots. The establishment of theses larvae on the treated shoots on the subsequent dates were then observed (Tab.5, Tab.6.).

5.2.3.2. Laboratory test (Dimethoate 30.E.C)

C_1	1 ml/100 ml
C1 to C_2	1 ml/1000 ml
C2 to C_3	1 ml/10000 ml
C3 to C_4	1 ml/100000ml
C4 to C_5	1 ml/1000000 ml

Table 4: The table showing the preparation of different concentration of Dimethoate 30 %EC for the lab test

Sl. N O.	Larval no. (larval body weight)	Conc. no.	Dosage
Set-1	1, (0.01gm) , 2(0.949gm), 3(0.0977gm)	C_1	1 ml/100 ml
Set-2	4(0.01620gm), 5(0.085gm) , 6(0.0799gm)	C_2	1 ml/1000 ml
Set-3	7(0.0177gm) , 8(0.0401gm), 9(0.0817gm)	C_3	1 ml/10000 ml
Set-4	10(0.0135gm) , 11(0.0474gm) ,12(0.0925gm)	C_4	1ml/100000 ml
Set-5	13(0.0277gm) 14(0.1746gm) 15(0.0949gm	C_5	1ml/1000000 ml

Table 5: shows the different size (body weight) of larvae used in different concentrations of Dimethoate prepared for laboratory test.

Conc. applied	Establishment of larvae on the treated shoot	Treatment started date: 22/03/2012. Observation dates		
		23/03/12	24/03/12	26/06/12
C_1	Established	1 Dead,2 live	2 Dead,1 live	3 Dead
C_2	Established	3 live(2 pre pupa)	3 live(2 pre pupa)	3 live(2 pre pupa)
C_3	Established	3 live	3 live(1 pre pupa)	3 live(1 pre pupa)
C_4	Established	3 live	3 live	3 live(1 pre pupa)
C_5	Established	3 live(2 pre pupa)	3 live(2 pre pupa)	3 live(2 pre pupa)

Table 6: shows the impact of different concentrations of Dimethoate 30% EC on the shoot borer larvae in the laboratory feeding test.

5.2.3.3. Result:

The result of the treatment showed that except the one concentration (C1= 1 ml in 100 ml water) no other dilution had any controlling effect on the shoot borer larvae. The larvae released on the treated shoots all got established and started feeding on them. Of the five dilutions prepared and treated only C1 (1ml Dimethoate 30%EC in 100 ml water) had a controlling effect on the established larvae Table 6) . All the other dilution had no impact on controlling the shoot borers. All the larvae released on the shoots treated with other dilution of the insecticide did not have any

impact on the growth of the shoot borer larvae. All the larvae in these shoots advanced to pre pupal stage.

5.2.3. 4. Tree injection:

5.2.3.4.1. Methodology

In order to find out the water absorption time by mahogany trees, mahogany trees in the KFRI campus were selected and given injection with water from morning 7.30 am to 3.30pm in five days time. Knowing the water absorption time by mahogany plants is a prerequisite before going to the real chemical tree injection operation. Water injection was given to six trees during the above time period and the data recorded. There was a lot of variation in the quantity of water absorbed among the trees, depending on the climate, tree size and height of the plant injected. In order to standardise the experiment tree injection time was fixed as 30 minutes for each tree irrespective of its height, girth and climate and the quantity of water absorbed was recorded. The data recorded during this experiment is given in the table below (Table 7.) During this water injection operation at KFRI the tree injection methods were also modified and standardized.

The tree injection unit consist of an mechanical tree driller , tree injection unit, different sizes of rubber plugs for placing into the drilled hole on the plant, during the tree injection time and for closing the tree hole after the injection operation, a pressure developing pump, a measurement marked jar with a connected delivery tube to connect the insecticide solution containing jar to the injecting syringe unit, a plastic bottle with water, different containers with the different systemic insecticide concentrations prepared, a measuring jar, a bucket , a plastic mug for preparing and pouring the insecticide formulations to the marked jar and a small hammer.

Three concentrations of the Dimethoate 30% EC were prepared by adding 3.5 ml,7ml and 17 ml insecticide in to three containers with one litre water each, for preparing 0.1%,0.2% and 0.5% insecticide solutions of Dimethoate.

The mahogany plants with fresh tender shoots were identified, selected and marked for tree injection in the study plot, at Veluppadam.

The duration for tree injection was fixed for 30 minutes for each tree, irrespective of the tree size and the quantity of solution absorbed during this time recorded.

The tree height of the selected trees varied 625 cm to 1110cm, GBH varied between 21 cm to 44cm. six trees were selected and marked for the water absorption operation.

All the trees in the study plot were 9 year old (2003 year plantation) at the time of the tree injection.

On the selected trees for the tree injection using a hand operated driller a hole of 2 cm size was drilled, on the bark, below chest height. While drilling the hole on the bark, water from the two litter plastic bottle was continuously poured slowly to the point of drilling along the bark, from above. This was done to prevent air getting into the xylem vessels while making the hole using the driller, which may block the insecticide up taking process during the tree injection time. On reaching the sufficient depth the driller was removed and a rubber plug was inserted into the hole, while pouring of water was continuing.

This tree is now ready to receive the tree injection. The container containing the insecticide solution is now connected to the injection unit. The free flow of the insecticide is checked by opening the valve on the injection unit. Now this unit is connected to the pressure developing pump. The injection needle is now inserted into the rubber plug on the tree hole. The pump is now operated mechanically to develop 2 unit pressures. Now the system is ready for the tree injunction. By opening the valve on the injection unit, focus on the insecticide containing jar's measurement for half an hour and see how much insecticide solution was taken in the tree injected. The quantity of insecticide absorbed by the tree after 30 minute was noticed in the data sheet. After thirty minutes the injection unit valve was closed and the syringe removed from the rubber cork.

The quantity of insecticide solution absorbed into the injected tree was recorded in the data sheet. Thus one tree injection was over. Now move to the next tree selected for tree injection and the process repeated till all the selected trees were given the injection.

Date	Time of tree injection	Tree-1 Height(H)=7m Gbh:29c m	Tree -3 H=8m Gbh:29cm	Tree-2 H=11m Gbh:37 cm	Tree-5 H=11.5m Gbh:39.5 cm	Tree-4 H=12.5m Gbh:42.5cm	Tree-6 H=13.5m Gbh:43.5cm
10/08/12	7.00-7.30 am	5 ml					
10-08-2012	7.30-8.00 am					500ml	
	8-8.30 am				220 ml		
	8.30-9.00 am					400ml	
	9.00-9.300 am				100ml		
07-08-12	9.30-10.00 am	60ml					
	10..00-10.30 am			280ml			
	10.30- 11.00 am	15ml					
	11.00-11.30am		280ml				
11-08-12	11.30-12.00 noon					310ml	
	12.00-12.30 pm				130ml		
	12.30-1.00 pm						
	2.00—2.30 pm						400ml
	3.00-3.30 pm			160ml			

Table 7: This table shows the quantity of water absorbed by different mahogany plants at KFR, date and time of injection, during the 30 minutes tree injection time, fixed for each trees.

Date of treatment 18-09-2012	Concentration of insecticide applied 0.1 %						Result observed Date 29-12-2012(after 102 days)	
Plot / Tree no	Time	Volume of insecticide absorbed	Tree height (cm)	GBH (cm)	Infested shoot	Un infested shoot	No. Fresh shoots	No. Fresh shoots attacked
1/10	9.30-10am	140m l	1100	41	o	1	1	0
1/11	10-10.30am	300 ml	950	42	0	1	2	0
1/9	10.45-11.15 am	160 mi	1000	40	1	1	1	0
11/16	11.25-12.00 noon	170 ml	880	26	0	1	2	0
9/3	12.05_12..35pm	160 ml	625	25	0	1	1	0

Tab.8. Data sheet for Chemical tree injection with 0.1% Dimethoate 30% EC solution in *Swietenia macrophylla* at FRC, Veluppadam- 2012. Year of Planting: 2003, Spacement: 3x3m

Based on the experience gained from the tree injection observations done at KFRI, Peechi, tree chemical injection treatments were conducted at FRC, Veluppadam and the data recorded. These data are shown in the tables below.

Date of treatment 18-09-2012	**Concentration of insecticide applied 0.2 %**						**Result observed Date 29-12-2012 (after102 days)**	
Plot/Tree no	**Time**	**Volume of insecticide absorbed**	**Tree hight (cm)**	**GBH (cm)**	**Infested shoot**	**Un infested shoot**	**No. Fresh shoots**	**No. Fresh shoots attacked**
9/16	2.20-2.50pm	90 ml	725	23	0	1	0	0
11/19	3.00-3.30 pm	350 ml	860	38	0	1	2	0
11/17	3.35-4.05 pm	180 mi	725	25	0	2	2	0
11/25	4.10-4.40 pm	110 ml	750	32	1	1	7	0
9/3	4.42-5.12 pm	90 ml	790	33	0	1	1	0

Table: 9 Data sheet for Chemical tree injection with 0.2% Dimethoate 30% EC solution in *Swietenia macrophylla* at FRC, Veluppadam- 2012. ,
Year of Planting: 2003, Spacement: 3x3m

Date of treatment 18-09-2012	**Concentration of insecticide applied 0.5 %**						**Result observed Date29-12-2012 (after102 days)**	
Plot/Tree no	**Ttime**	**Volume of chemical injected**	**Heig ht (cm)**	**GBH (cm)**	**Infested shoot**	**Un infested shoot**	**No. Fresh shoots**	**No. Fresh shoots attacked**
11/9	07.40-08.10 am	150ml	800	41	Nil	Seven	*2*	0
11/11	08.15-08.45 am	190ml	900	44	Two	Three	*8*	0
12/18	09.00-9.30 am	50ml	725	21	Nil	Three	0	0
12/3	09.40-10.10 am	180ml	815	31	Nil	Two	0	0

Tab.10. Data sheet for Chemical tree injection with 0.5% Dimethoate 30% EC solution in *Swietenia macrophylla* at FRC, Veluppadam -2012. ,

Date of treatment 18-09-2012	Control (No treatment with insecticide)			Result observed Date29-12-2012 (after102 days)	
Plot No.	**Tree no.**	**Height (cm)**	**GBH (cm)**	**No. Of fresh shoots**	**No .of fresh shoots attacked**
12	16	700	29	0	0
13	24	700	21	2	2 (100%)
11	13	900	43	4	1 (25%)
4	19	810	26	1	0
5	8	470	15	3	1(33%)

Table: 11. Data on the incidence of shoot borer incidence on the control mahogany plants at the Field research Centre, Veluppadam 2012. Year of planting 2003 Spacement: 3x3 m.

5.2.3.4.2: Results:

Water absorption by mahogany plants (*S. macrophylla*) at KFRI campus was recorded during 07-08-12 to 11-08-2012. Tree injection time was from 7.30 am to 3.30 pm. It was observed that mahogany trees absorb water from morning to evening and the quantity absorbed depends up on the climate, size (GBH) and height of the plants. It was understood from the experiment that there is on fixed time during day for water absorption by mahogany trees. It was found to absorb water throughout the day time. There is no peek time of water absorption during day time. Anyhow Tree no.4(table 7.) was found to absorbed 500 ml at 7.30 to 8.00 am, 400 ml at 8.30 to9.00 am and 310 ml at 11.30 to 12 noon. This showed a peek absorption time in the morning and gradual decreasing trend towards the evening. Of the three above observations the first two were recorded on one day (10-08-12) and the third observation on the second day (11-08-12). It was seen from the data that the quantity of water absorbed increases from morning till evening (400 ml in Tree no. 6 at 2.00 to 2.30 pm) and then it decreased. Within the 30 minutes fixed for each tree injection, the quantity of water absorbed varied from 15 ml to 500ml, among the injected trees. This variations may be depending on the size of the tree, climatic conditions and the water requirement of each trees due to the climatic conditions .Tree no. 4(GBH=42.5cm & height 12.5

m) absorbed 5oo ml at 7.30-8 am, 400 ml at8.30-9 am and 310 ml at 11.30 am-12 noon. This tree no.4 absorption pattern indicate that more water is absorbed in the morning hours and the water requirement come down towards evening .Tree no.6 with little more height and GBH had absorbed 310 ml water by 2.00-2.30 pm .This indicate that bigger trees (of the 6 trees observed in this observation) had more water requirement compared to trees with smaller height and lesser GBH.

Three concentrations of Dimethoate 30% EC was prepared and injected in to the selected mahogany plants with tender shoots at the field research centre, Veluppadam. Observations continued since the treatment on 18-09-2012 up to 29-12-2012 (102 days). In all the plants treated with three different concentrations of Dimethoate 30% EC(0.1 %,0.2% and 0.5%) no further shoot borer attack occurred.(Tabs. 8,9 &10 ,column No.9., No. of fresh shoots attacked)) .At the same time in the control plants up to 40 % of the tender shoots had been found infested by the shoot borer. (Tab. 11).


5
18/9/2011 12:11


6


7
18/9/2011 11:38


8

Fig.28. 1: Drilling the selected mahogany plant with tender shoot for chemical tree injection, using a simple mechanical driller machine.

Fig.28.2: Pouring water from above the drilling point while drilling is progressing, to prevent air intake in to the xylem vessels, which may block the water uptake.

Fig.28.3: Once the drilling is sufficient the driller is withdrawn and the hole is plugged with a special rubber plug. This permit the syringe of the tree injection unit into the xylem vessels.

Fig.28.4: Filling the jar with selected measured quantity of Dimethoate 30% EC solution before connecting to the tree.

Fig.28. 5: Develop 2 + unit of pressure in the jar containing the insecticide solution using the pump. Checking the out flow of the solution, by opening the valve correct the pressure to 2 unit in the meter.

Fig.28.6: Inserted the syringe in to the rubber plug and opened the valve to allow the out flow of pesticide into the tree.

Fig.28.7: Waiting for the thirty minutes time fixed for each tree injection.

Fig.28.8: After the thirty minutes injection time the valve is closed and the quantity of insecticide solution injected into the tree noted and recorded.

Fig.28.
9 &10 : After the injection procedure is over the syringe is removed from the rubber plug. The rubber plug is also removed from the tree gradually, while removing the rubber plug water is poured again from above the tree hole. As soon as the plug is removed the hole is closed with our finger and a broad cello tape is used to cover the tree hole

GENERAL CONCLUSION

Mahogany is an ideal plantation species in many respects since raising seedlings in the nursery is very easy and seedlings grow fast. The species tolerates wide range of site conditions and grows satisfactorily even on degraded sites. But the tree is almost always infested by the mahogany shoot borer, *Hypsipyla robusta*, that tunnel down the apical shoot causing its breakage and encouraging lateral branching. Loss of the main leader and resultant low branching drastically reduce timber value. Silvicultural techniques that reduce attack by the shoot borer and assist recovery after attack are the only strategies that are feasible. Closer spacing of 2x2m that create lateral shade restricting development of lateral branches and promoting vigorous vertical growth has been found to improve growth of trees and also reduce shoot borer infestation (KFRI R.R.448) Manuring has been found to support the plants in this respect, but to a lesser extent as compared to spacing which was shown to have significant impact. The Physical, (Tab.2, FIG.27) Biological, (Tab.3, Fig.21) Silvicultural (KFRI R.R.448) and Chemical tree injection methods (Tab.8, 9, 10, 11) suggested in this study will be a base for the package of practices for establishing any future mahogany plantations.

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APPENDIX I

Alternative host plants of *Hypsipyla robusta* Moore (Lepidoptera: Pyralidae : Phycitinae)

1. *Canarium schueinfurthii*
2. *Carapa guianensis*
3. *Cedrela australis*
4. *C. mexicana*
5. *C. multijuga*
6. *C. odorata*
7. *C.sureni*
8. *C. toona*
9. *Chukrasia tabularis*
10. *C. velutina*
11. *Entandrophragma angolense*
12. *E. utile*
13. *Khaya anthotheca*
14. *K. ivorensis*
15. *Soymida febrifuga*
16. *Swietenia candollei*
17. *S. macrophylla* King
18. *S. mahagoni* (L.),Jacq.
19. *Toona ciliata*
20. *Xylocarpus guianensis*
21. *X. moluccensis*