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DEMONSTRATING THE EFFECT OF CONTROLLING TEAK DEFOLIATOR ON VOLUME INCREMENT IN TEAK IN THE PERMANENT PLOT ESTABLISHED AT NILAMBUR

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ABSTRACT OF THE PROJECT PROPOSAL

Project No:	RP 399/2003
Title:	Demonstrating the Effect of Controlling Teak Defoliator on volume increment in Teak in the Permanent Plot Established at Nilambur
Objectives:	to demonstrate the effect of protecting the teak trees from the defoliator to integrate teak defoliator control operations with teak plantation management practices
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Study area:	Nilambur Teak Plantation

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ABSRACT

Two permanent demonstration plots of half a hectare of teak plantation were established in 1993 at Panayamgode, Nilambur North Forest Division. This is inorder to get the exact and unsurpassed estimate about the benefits of control measures against *Hyblaea puera* attack on teak plantation. While routine management practices were adopted in both the plots, teak trees of one of the plantation were protected by pesticide application while those in the other plot were left unprotectd. In the current report the tree measurement data collected during the period 1994 - 2013 were analysed. Tree height, GBH, tree stocking and tree forking of the two plots were analysed to get the accurate figures. Tree height was measured by using Suunto Optical Reading Clinometer. Sunnato Clinometer is used to measure a point's degree from horizontal and a surface slope in percent or slope angle. Girth at Breast Height (GBH) was calculated using a measuring tape at 1.37 meters above from the ground. Tree forking and broken tree in the unprotected plot is 9.8 percentage , while it is 2.4 percentage in protected plot. Tree survival is 6 percentage more in proteted land compare to the unprotected area. At the end of the experiment period an average additional increment of 3.3 cm in GBH and 1.5 m in height is attained the trees in the protected land. The analysis concluded that protecting teak trees from *Hyblaea* attack is worthwhile when considering and comparing the quality and quantity of teak wood from protected and unprotected plots.

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DEMONSTRATING THE EFFECT OF CONTROLING THE TEAK DEFOLIATOR ON VOLUME INCREMENT IN TEAK IN THE PERMANENT PLOTS ESTABLISHED AT NILAMBUR

1. Introduction

The quality and quantity of the end products from plantations depends on several factors. Amongst insects play a key role along with things like nutrition, fire, animal and climatic conditions. In Kerala Teak plantations are growing extensively both in forest and private sectors. The insect *Hyblaea puera* is recognized as a serious pest of teak plantation since it causes complete defoliation of teak trees and damage to the terminal shoots. In order to estimate the impact of *Hyblaea* infestation on teak trees a continuous observation on four years old teak plantation had done (Nair, 1985). This study was estimated that *Hyblaea* infestation brings 40 percent reduction in potential wood volume increment (Nair et al., 1985). Considering the value of teak wood this study on loss estimate brings new light to the authorities. Several studies on control strategies of *Hyblaea* (Sudheendrakumar et al., 2004; Biji et al., 2006) spatial distribution (Sajeev, 2000), molecular studies (Chandrasekhar et al.,2000) artificial rearing (Mathew et al., 1990) standardization of artificial diet (Bindu et al., 2009), relationships of *Hyblaea* and teak leaves maturity (Bindu et al., 2004), veritical and horizontal transmission of diseases and colour dimorphism (Bindu et al., 2012) had been completed and other studies are going on. The major milestone of these studies is the development of Hybchek – a biopesticide against teak defoliator. The active ingredient of Hybchek is the *Hyblaea puera* nucleo polyhedrosis virus (HpNPV) and the product is patented by KFRI on 2005 (Nair, 2007; Sudheendrakuma *et al* .,2004).

Two permanent demonstration plots of half a hectare of teak plantation were established in 1993 at Panayamgode, Nilambur North Forest Division. This is inorder to get the accurate and best estimate about the benefits of control measures against *Hyblaea puera* attack on teak plantation. Since 1993 onwards one of the plantations were protected from teak defoliator attack while the other was left as unprotected. The past years analysis results show that the protected plot attained more height and GBH than the unprotected trees. Present project is the extension study on the effect of controlling teak defoliator on volume increment and quality of teak wood in two demonstration plots. The main objective of this work is the comparison on quantity and quality of teak wood in protected and unprotected plantations. This long term study report on the impact of Hyblaea attack on teak plantation will generate exact initiatives that have to be taken in pest control methods in teak plantations.

2. REVIEW OF LITERATURE

2.1 BIOLOGY AND SEASONAL INCIDENCE OF TEAK DEFOLIATORS

Amongst the insects that have been found associated with the teak tree (Mathur and Singh, 1960), four are considered to be serious pests- two of which are defoliators and the other two, stem borers. The defoliators are *Hyblaea puera* and *Eutectona macheralis* (commonly called the teak skeletonizer) and stem borers are *Cossuss cadambe* (Moore) (teak trunk borer) and *Sahyadrassus malabaricus* (Moore) (the teak sapling borer). Based on the quantum of economic loss, *Hyblaea puera* is recognized as the most important pest of the teak tree (Nair *et al.,* 1985). *H. puera* was documented as a pest of teak as early as 1898, when outbreaks (Fig. 1.1 a and b) of this insect were observed in Konni forest division of Kerala state (Bourdillon, 1898). In Kerala, repeated outbreak take place every year, with two or three defoliations during the early part of the growth season. A silvicultural-cum-biological control program was advocated to manage the pest in the past (Beeson, 1941). These recommendations were seldom practiced due to a variety of reasons including the inability of the parasitoids to respond numerically to massive increase of the pest population. The problem sustained and aerial application of chemical pesticides was carried at Jabalpur in Madhya Pradesh (Singh *et al.,* 1978) and at Konni in Kerala (Basu-Choudhary, 1971) as an experimental basis.

Normally, the life cycle of *H. puera* is completed in 2 to 4 weeks. Climatic conditions, particularly, the temperature affects the length of life cycle. The female moths lay about 500 to 600 eggs on an average during a period of about a week. The eggs are laid singly on tender leaves near the veins. The first and second instars feed on the leaf surface and it is scrape feeding. From the third instar onwards the larva cuts out a leaf flap, folds it over and fastens it with silk and feeds from within. There are 5 larval instars, the 5th entering pupation. The pupation occurs within a triangular leaf fold cut specially and strongly spun together; between juxtaposed leaves or leaf skeletons bound by silk. If host leaves are completely stripped, pupation can observe on other foliage in the undergrowth in the soil cover (Nair et al., 1985).

The neonate larvae of *H. puera* survive on tender leaves only. Two types of populations were identified in the case of *H.puera as* low density population (with less than two insects per shoot) and high density populations (up to fourteen insects per shoot). Although defoliator outbreak is a regular annual feature in teak plantations throughout Kerala, it is extremely difficult to predict the exact time and places of occurrence of these outbreaks. Recent research has indicated that the outbreaks begin in small epicentres during the pre-monsoon season (Nair *et al*, 1994: Nair and Mohanadas, 1996). Evidences obtained in earlier studies (Nair and Sudheendrakumar, 1986) indicated habitual, short-range, gypsy type movements of emerging moth populations, suggesting that these populations spread to larger and larger areas, generation by generation, affecting the entire teak plantations. On the Other hand, early outbreaks were found strongly correlated with the occurrence of pre-monsoon showers.

2.2 Effects of Defoliation on Growth of Teak

In the earlier period it was generally believed that loss due to defoliation amounted to between one third and one half of the potential volume increment (Beeson, 1928; Minchin, 1929). These were not based on scientific analysis but the opinions influenced by the devastated appearance of heavily defoliated plantations.

The earliest attempt to calculate the economical loss resulting from defoliation was that of Mackenzie (1921). Using arbitrarily estimated values for the loss in wood increment, he showed that defoliation may result in significant economic loss. According to him 8.3percent of the annual increment in volume was lost due to defoliation in Burma and 6.6%, in Nilambur, India. But his assumptions were also not acceptable because of the absence of experimental or observational evidence.

Another evaluation of loss due to defoliation is that of Beeson (1931. 1941) and he made a trivial improvement over Mackenzie’s estimate. Beeson replaced Mackenzie’s assumption on defoliation by observation. He made monthly visual estimate records of the intensity of defoliation during the 8-9 months of growth season for each of the 350 compartments of teak plantations in Nilambur covering an area of about 2000 ha for a period of 4 years from 1926 to 1930. Out of 11,700 observations thus obtained he found that the frequency of occurrence of severe defoliation was 8.2 per cent. This amounts to about 3 severe defoliations within a 4-year period, in contrast to Mackenzie's assumption of one severe defoliation within a period of 6 to 7 years.

Another reported study on increment loss due to defoliation is that of Champion (1934 b). He selected hundred saplings from a three-year-old teak plantation in Dehra Dun, classified them into four comparable sets of twenty five saplings each and subjected them to different levels of artificial defoliation. Control was the non defoliated saplings. Experiments were conducted based on measurements like diameter at breast height, basal area and height of the experimental saplings. The conclusion was that three complete strippings of- leaves in the same season (on 13 June, 9 July and 17 August) caused a loss of 65% of the normal increment. He also reported that in addition to loss of increment, repeated heavy defoliation resulted in weakening of leading shoot with consequent forking and even mortality. Taking a mean annual increment of about 100 c.ft. per acre for quality Class I (Bourne's yield table volume for Nilambur) and an average royalty of ₹ 2-00 per c.ft. of timber, Champion calculated that the loss amounted to ₹130 per acre per year of severe defoliation. There are several drawbacks in this calculation and are the followings

1. The experiments were performed on 3-year-old saplings, about 5 cm in d.b.h. and 3.6 m height. The results cannot be applied to plantations of all ages.
2. Dehra Dun, where the experiments were conducted, is outside the natural teak-growing belt and the stress due to defoliation may misinterpret with stress due to other factors such as low temperature during winter.
3. Artificial stripping of leaves, however carefully performed, cannot simulate natural insect defoliation.
4. Under plantation conditions, the magnitude of loss will depend on several factors - the age of the plantation, the time of defoliation in relation to the seasonal

growth pattern of teak, the frequency and duration of the leafless periods, the quantity of foliage lost in relation to the total quantity of foliage, etc.

Hence Champion (1934 b) himself stressed the need for further investigations to derive more conclusive and dependable results.

Another study about this was from Beeson in 1931. He calculated the loss due to defoliation amounted to 8.2 per cent of the annual volume increment. Beeson himself discussed the many assumptions implicit in such a calculation and stated "these assumptions invalidate the conclusions drawn, but by making them, the conclusion becomes one stage better than a guess". Further Observations in the same area by Beeson in 1941 (a total of 16,300 observations) revealed that severe defoliation occurred nine percent of the time and he revised his earlier estimate of the loss to 13per cent of the normal current annual increment and gave some financial loss figures. He did not explain the basis for such an upward revision of the estimate. Although Beeson's estimate of 13per cent loss has been repeatedly quoted by subsequent writers and has received wide recognition, it is clear that this study do not have a realistic estimate of the loss in increment in plantations under natural conditions of insect defoliation.

2.3 Studies on the seasonal incidence of defoliators and their effect on volume increment by Kerala Forest Research Institute

The teak defoliator research took a new momentum, when the Kerala Forest Research Institute (KFRI) started the study on the impact of teak defoliation on volume increment in teak plantations. The study in KFRI has revealed that a loss of 44 per cent of the potential volume increment is occurring in young teak plantations in Kerala (Nair *et al.*, 1985). Detailed observations on the population dynamics of the pest and mapping of outbreak zones were conducted during the following periods (Nair, 1986; Sajeev, 2000). KFRI is being continuing the study on defoliation and effect of volume increment of teak trees.

The study on the seasonal incidence of defoliation and its effect on growth of teak plantations were conducted at Nilambur, Kerala and started in early periods of 1980s.

Experimental plots were established in a 4-year-old plantation at Karimpuzha in the Karulai range of Nilambur forest division. The experiments were laid out in two blocks of plantation. Amongst one plot is protected against defoliator attack and another one was left as unprotected over a period of 5 years. The defoliation trend was studied fortnightly by visual scoring. Measurements made on trees felled during the first and second mechanical thinning were used to establish empirical mathematical relationship between GBH and height on the one hand and volume on the other. Using this relationship, the volumes of the experimental trees were determined at the beginning and end of the experiment. Increments were compared using statistical methods in which the initial volume and the number of neighbours of each tree were used as covariates.

The study comes up with a conclusion that *H. puera* infestation brings loss of 44 per cent of the potential increment in volume during the experimental period. When the gain due to protection is expressed as percentage increase over the normally realized unprotected yield, it amounted to 80 per cent. The general applicability of this estimate and its practical significance were discussed. It is concluded that because of changes in stand dynamics brought about by improved growth, it is not possible to quantify the benefit in terms of volume gain for the entire rotation, until adequate models of stand dynamics have been developed. However, the study showed that the benefits are so large that attention must now be focused on development of suitable methods of protection, rather than more precise estimation of the benefits. Control of *H. puera* is worthwhile, and protection during the early years will be more beneficial because of the greater absolute increment.

The experiment for the study was started when the first mechanical thinning of the plantation was carried out in the 4th year, during which half the number of trees were felled as per standard silvicultural practice. Detailed measurements were made on felled trees from which the volume of each tree was calculated. Then the mathematical relationship between volume on the one hand and GBH and top height on the other was determined empirically. Using this function, the initial volume of the standing experimental tree was estimated. The treatments were continued until the next mechanical thinning was carried out at the end of the 8th year and the tree volumes were again determined. Fresh measurements were made on trees felled at this time to derive volume-GBH-top height relationships applicable to 8-yr-old standing trees. The plots established for these measurements were also used for measurement of defoliation levels and observations on insect activity.

In 1978, all measurements were made between 20 June and 6 July, during which period the first mechanical thinning was carried out. The breast height (1.37 m above ground) of all trees were marked and GBH measurements were taken with a tape. Thinning was then carried out by the Forest Department as usual, as part of the regular thinning of the entire plantation. The measurements were taken on the felled trees are - (i) top height, i.e., height upto the tip of the leading shoot, measured with a tape, (ii) under bark girth of the main bole and of all branches, at every 50 cm interval, down to 1 cm over bark girth. After the thinning, top heights of the standing trees were measured with a tape attached to a reed pole. In all plots receiving complete protection, the GBH of each tree was measured at monthly intervals for about three growth seasons to determine the normal growth pattern. In addition, the GBH of all experimental trees were measured annually at the end of the growing season, to make interim comparisons. Final measurements were taken in the last week of December 1982, when the regular second mechanical thinning was carried out. Thus the total experimental period encompassed nearly 5 growth seasons, from July 1978 to December 1982. The same measurements taken in 1978 were repeated in 1982 on both standing and felled trees. For measuring the top height, many trees had to be climbed part way to reach the reed pole to the top.

2.4 Maintenance of plots

The plots were maintained by keeping free from weeds, wild animals, and grazing and forest fire for several years. The trees including one row of border trees were fenced with barbed wire, after the first mechanical thinning. Before fencing, wild elephants destroyed a few experimental trees in some plots. The fencing was mainly intended to prevent cattle grazing and human disturbances but may have deterred elephants also. The plots were weeded annually in November-December to prevent wild fire. The fence was temporarily removed during the second mechanical thinning, but has been replaced, so that the plots can be identified for future observations, if necessary.

Pest incidence in 1994

Regular observations on pest incidence were started from March 1994 onwards. *H. puera* attack was not observed during these periods in the two plots. Therefore, no control measure was needed. Weeding was carried out in both the plots.

Pest incidence in 1995

During 1995, defoliator incidence was noticed six times, in May (two times), Auguest, September and October (two times). In May and October, control operations like spraying of Ekalux were required twice in each month.

Pest incidence in 1996

In 1996, pest incidence was noticed twice and control measures were adopted. The first attack occurred during the first week of May as in the previous year. The second occurred in the last week of October. On both occasions, the attack was effectively controlled by an one-time application of Ekalux 25EC.

Pest incidence in 1997

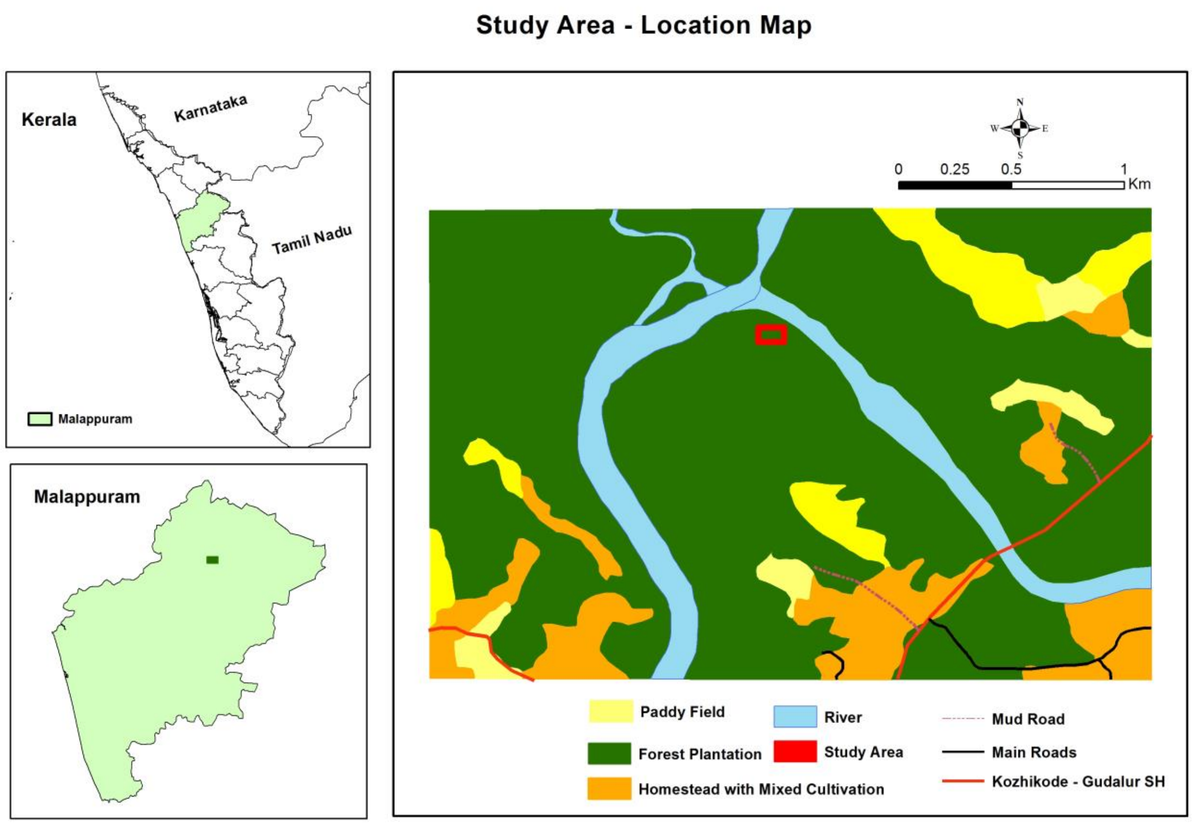
H. puera attack occurred twice during the year**.** The first incidence occurred in May, and the second in June. On both the occasions, the pest was effectively controlled by applying a commercially available *B. t.* preparation, Biobit, through an one-time application @ 1 g of Biobit per litre of water. A Stihl sprayer (Mist blower) AU 8000 spray head was used for applying the *B.t.* preparation.

The studies of KSS Nair, VV Sudheendrakumar, RV Varma, KC Chacko on the seasonal incidence of defoliators and the effect of defoliation on volume increment of teak in 1985, R.V. Varma ,V.V. Sudheendrakumar, K.S.S. Nair, K. Mohanadas on establishment of permanent plots to demonstrate the effect of protected teak plantations from the teak defoliator in 1998 emphasis the need of controlling teak defoliator in teak plantations. Present work is the follow up of the above mentioned studies to assess the loss on wood volume increment due to the infestations of Hyblaea attack.

3. MATERIALS AND METHODS

3.1 Study area (Demonstration plots of teak)

The study area selected was one hectare teak plantation at Panayamgode , Nilambur Forest Range, Nilambur North Foest Division. This plantation was raised by Kerala Forest Department in the year 1993 at an espacement of 2m X 2m. 60 rows with 50 trees in each row were selected for the experiment. First 25 rows were timely protected from defoliator attack and the last 25 rows remained naturally without any pest control practices. A buffer area of 10 rows of teak trees were maintained in between the two plots. The layout of the experimental area is shown in Figure 1



3.2 Maintenance of plots

The plots were weeded properly inorder to avoid other animals, borer attack and fungus or bacterial diseases. Thinning and forking had done in both plots in prescribed or required time periods. Fire line had taken around the plots to protect the plantation from forest fire. Human interaction is minimum as the plots are away from people houses. Mistletoe attack is observed in the two plots and the possible ones were removed mechanically.

3.3 Monitoring of *Hyblaea* attack

Hyblaea puera was documented as a pest of teak as early as 1898 when outbreaks of this insect were observed in Konni forest division of Kerala state. In Kerala, repeated outbreak of *Hyblaea* take place every year, with two or three defoliations during the early part of the growth season. At Nilambur this outbreak often occurs during the periods of February to October.

Routine observations were made in the experimental plots in an interval of two weeks. When information about the *H. puera* outbreak from any part of Nilambur was reported, then daily observations were started in the plots. This helps to implement proper control strategies on time to prevent the attack of *Hyblaea* in experimental plots. This timely management was helped to protect the foliage and prevented damage to the tender shoots by *Hyblaea* attack.

3.4 Controlling Teak Defoliator

Teak defoliator attack on experiment plot was carried out by spraying pesticides. Pesticide applications were carried out whenever the presence of *Hyblaea* was observed in the protected plot. Either chemical (Ekalux 25 EC) or biopesticides (Biobit) were used to control the defoliator attack in protected plot. Active ingredient of Ekalux is 25 per cent O, O-diethyl-O [quinoxalinyl-(2)] -thionophosphate and Biobit is *Bacillus thirungiensis*. Biobit is more often used in the plantation as it has narrow host spectrum and safe when compare to Ekalux 25 EC. But whenever urgent need comes Ekalux was used to control the defoliator. Biobit was not always available in the local market.

Pesticide application had done using a mist blower (Stihl SR400 with AU 8000 spray head) during the initial stage of the study. But during this project period motorised high volume sprayer (Birla Yamaha make) was used to reach the pesticides on the foliage of twenty years old tall trees.

3.5 Tree measurements

Height and GBH of trees in two plots were measured every year during the months of January or February. Twenty years data, from 1993 onwards regarding the tree height and GBH had collected and compiled to know the difference of trees in two plots.

Height Meassurements

Tree height was measured by using Suunto Optical Reading Clinometer. Sunnato Clinometer is used to measure a point's degree from horizontal and a surface slope in percent or slope angle. For taking an optical reading stood 20km away from the prescribed tree. Then kept both eyes opened and aligned clinometers cross hairs on the very top of the tree. then read the scale. then tilted the clinometers till get a number from the scale that coincides with the tree meet the ground. then using the equation "[Total height = (Top measurement – Bottom measurement) X 0.20]" final height of the tree was calculated.

GBH Calculation

Girth at Breast Height (GBH) was calculated using a measuring tape. Measurement of the tree girth had taken at 1.37 meters above from the ground. GBH of the entire tree in the two plots had taken in the same way.

3.6 Observation on Tree Status

Forking is a major constraint to the growth and quality of trees. *Hyblaea* attack at the tender teak trees may cause tree forking and reduces the quality of teak. Tree diseases, other structural deformities and tree death were observed and recorded during the project period.

4. RESULTS AND DISCUSSION

Results of the experiment from 1993 onwards was analyzed and compared to get an accurate state and consequences of *Hyblaea* infestation on teak trees. The results and their explanations are documented below. The results were analysed mainly by using tree height and girth at breast height (1.37m). Forking is also considered as a factor in analysis.

4.1 Pest incidence

Since 1993 onwards repeated outbreak take place every year in the experimental plots, with two or three defoliations during the early part of the growth season. A total of around 40 outbreaks occurred during these periods. Majority of the infestation happened during the months of June and July. In some years late outbreak also took place in the month of August and September. All infestations were caused by early stages of the insect. when we look on to the topography of the plots protected plot is near to other teak planatation while two sides of the control plot is facing to the river Chaliyar. Hence protected plot seems to be more prone to insect attack than the control one. Even though *Hyblaea* infestation occurred at equal intervals and same time in both the plots as *Hyblaea* cover vast area in a night.

4.2 Controlling of teak defoliator

Control options were adopted suddenly whenever *Hyblaea* infestation occurred in the protected plot. Biobit (Bacillus thuringiensis) was used in majority of the applications in the protected area. In the absence of Biobit , Ekalux also was used. Both the control options adopted were successful since no foliar damage was noticed after each control steps in the protected area. Timely chemical application had done in protected plot whereas in the control plot the *Hyblaea* infestation suppressed normally after the defoliation of each attack.

4.3 Present Condition of Trees at Experiment Plot

Table 1: Present details of trees at protected and control plot

Sl No	Treatment			Control		
	Specification		Number	Specification		Number
1	Stocking		245	Stocking		175
2	Forking		2	Forking		9
3	Disease/Weak/Brocken		3	Disease/Weak/ Brocken		8
4	GBH (cm)	30 -40	30	GBH (cm)	30 -40	21
		41- 50	63		41- 50	43
		51 - 60	74		51 - 60	48
		61 - 70	43		61 - 70	28
		71 - 80	21		71 - 80	13
		81 - 90	5		81 - 90	7
		91 – 100	4		91- 100	--
5	Height (m)	10 - 15	9	Height (m)	10 - 15	8
		16 -20	56		16 -20	84
		21 - 25	177		21 - 25	75

At present the protected plot contains a total number of 245 teak plants and control plot have 175 trees. Amongst the 245 plants in the experimental plot, 2 have bifurcation in the trunk and three of them are broken. Trees having 30cm to 100cm in GBH and 15m to 25m in height were documented from protected plot. More trees comes under 51cm to 60cm GBH. Remarkable quality trees with 96 cm to 100 cm in GBH and 23.5 m to 24.5 m in height without any forking are there in the experimental plot.

Tree forking is comparatively more in the control plot and is 9 from 175 trees. Eight of the trees were broken. GBH of trees in the experimental plot comes in between 30 cm to 90 cm. the heights of the trees are in between 15 m to 23 m. More trees are in a rage of 51 cm to 60 cm GBH range. In the experimental plot no trees were attained GBH of above 90 cm.

4.4 Growth parameters

Tree GBH and height had taken to assess and compare the growth rate of trees in the two plots. A comparison study was conducted with the help of these growth parameters to know the effect of defoliation and tree forking caused by *Hyblae* infestation. At the beginning of the project in the year 1994 protected and unprotected plots have a total of 1147 and 1141 teak tree consecutively. In the beginning period only 3 per cartage trees were lost from the protected plot while it was 17 percentage in control plot. After 10 years period 11 percentage deductions happened in the protected plot and at present this area is having 21 percentage of standing trees. Tree stocking is only 15 percentages in the unprotected land. A remarkable reduction in tree stocking had happened at the initial stages of tree growth.

The height and GBH measurements of trees in the two plots over the period 1994 – 2013 are given in table 2 and 3. graph against corresponding data are also plotted below.

Table 2: Mean GBH of trees during 1994 – 2013 in the protected and unprotected plots

Category	**Mean GBH**			
	1994-1998	**1999-2003**	**2004-2008**	**2009-2013**
Protected	17.66 (1115)	26.47 (1130)	29.41 ()	58.01 (245)
Unprotecetd	13.88 (965)	20.37 (799)	24.13 ()	54.71 (175)

Figures in the parenthesis indicate the number of trees in the plot

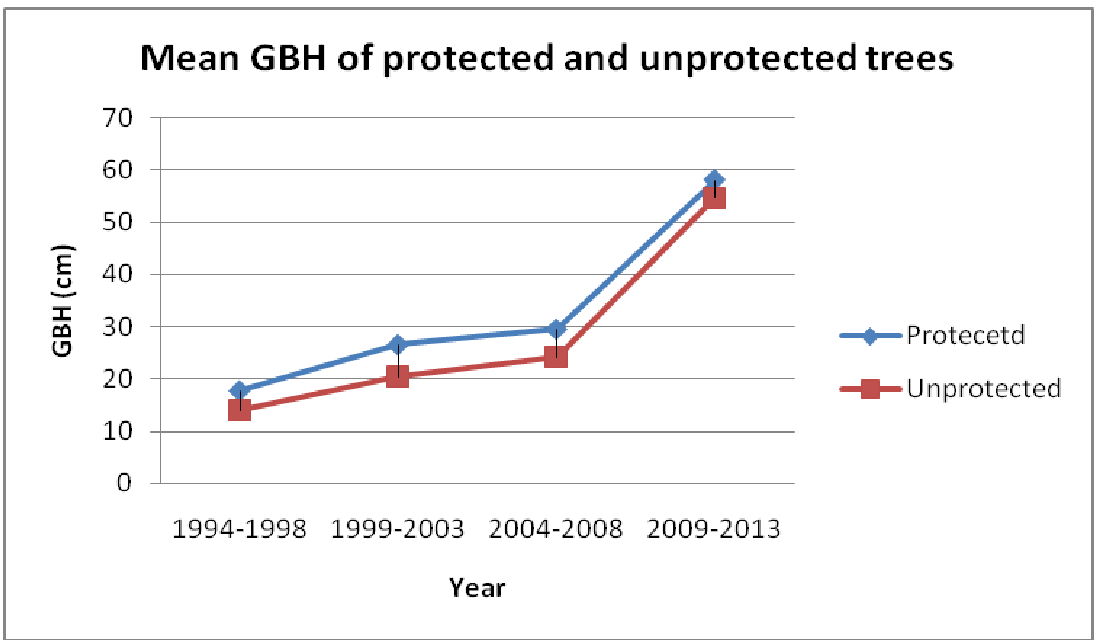


Figure 2: Graph showing mean GBH of trees (cm) in Proteceted and unprotecetd plot since the year 1994

From the starting of the experiment there was notable increment in the GBH of trees in the protected plot. That scenario continues till the end of the project period. From the Table and the graph it is evident that the GBH of the teak trees in the protected area has a steady increase all through the period. At the end of the project period the trees in the protected plot gained an average GBH of 58.01 cm against the trees in the unprotected area with an average of 54.71cm. An average of 3.3 cm increase in the GBH is attained the trees of protected plot.

Table 2: Mean height of trees during 1994 – 2013 in the protected and unprotected plots

Category	**Mean height (m)**			
	1994-1998	**1999-2003**	**2004-2008**	**2009-2013**
Protected	4.26 (1115)	2.67 (1130)	11.08()	20.01(245)
Unprotected	1.91 (965)	5.44 (799)	7.63()	18(175)

Figures in the parenthesis indicate the number of trees in the plot

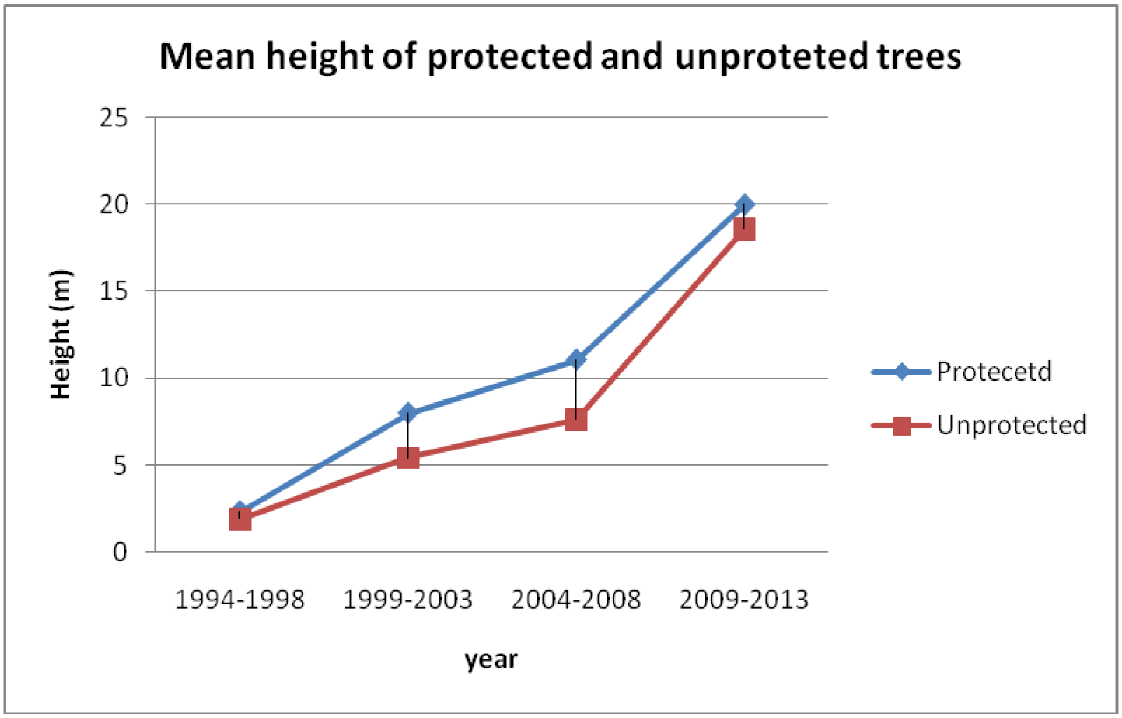


Figure 3: Graph showing mean height of trees (m) in proteceted and unprotecetd plots since the year 1994

Teak trees in the protected plot has attained more height than the trees in the unprotectd plots. From the beginning year onwards trees show this difference and continues till the end of the project period. At the end of the observation period the mean height of trees in the protecetd plot is 20.01m and trees in the unprotecetd plot is 18.57m. An avarage of 1.5 m increase in height is observed in protected plots.

4.6 DISCUSSION

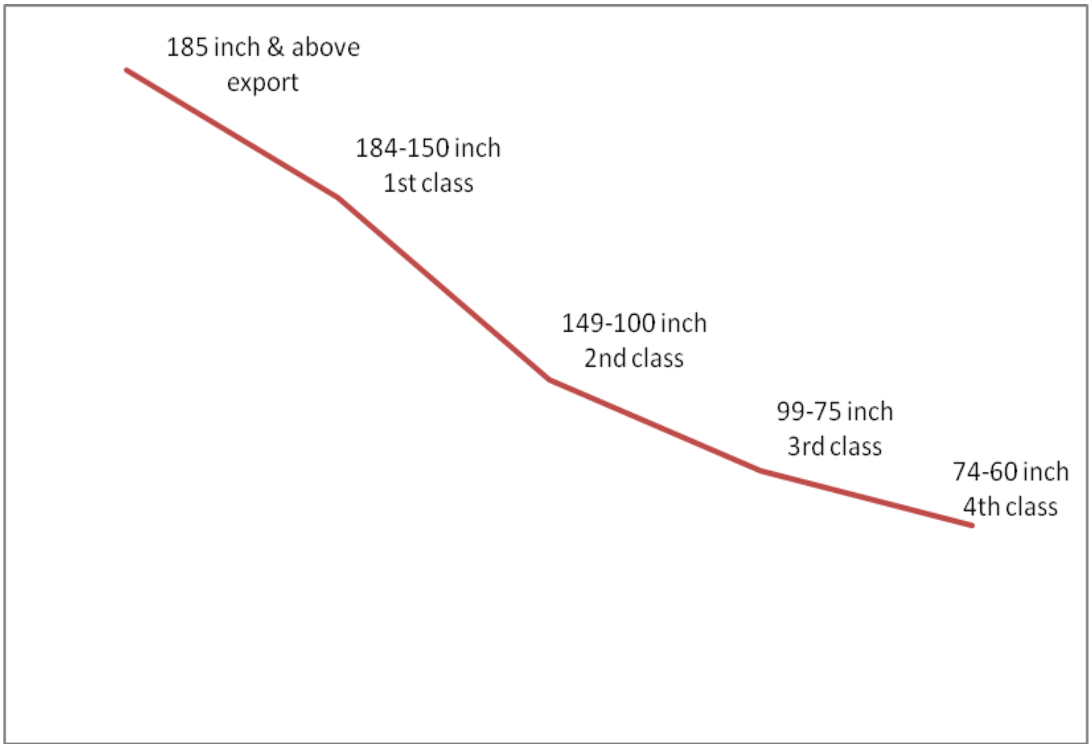
GBH, Height and Tree Value

The volume of wood in a tree and the type of product made from the wood are based primarily on the tree's height and diameter. Volume alone does not determine value or the products that could be produced; tree quality is also very important. As tree DBH increases, value shifts from pulpwood to sawtimber and finally to veneer depending on stem quality. The value of higher-quality desirable hardwood tree species can increase dramatically over time as it adds additional diameter growth. The quality of trees is described by standardized tree-grading rules used to assess value. Tree grades are determined by the diameters and the number of clear faces in the first log (i.e., the lack of defects such as branches, knots, cracks on the log surface). Most of the value in a tree is in the first 16 to 20 feet (the butt log).

There are different criteria for the classification of teak considering straightness, soundness, girth and length of teak logs. According to the straightness and soundness teak timber comes under different grades like grade A, B, C and D. Girth classes of teak are divided as export, class 1, class 2, class 3 and class 4. Likewise length classes are described as SL, LL and LLL.

Straight and sound teak log without any defects are graded as A, fairly straight and sound logs are in B, defective and crooked logs are in grade C and highly defective and crooked logs are in grade D. *Hyblaea* feeds on the apical shoot causes forking which reduce timber quality. Its infestation causes death of the leading shoot and result in formation of epicormic branches. Thus the *Hyblaea* affected teak could not be fall in to top wood grades. The teak log sale report show an average difference of Rs 5000 for each grade. When considering the yield from large area teak plantation the wood quality depreciation and the loss due to *Hyblaea* infestation will be huge.

Similarly girth of teak trees in protected plot and unprotected plot shows observable difference. An average of 3.3 cm reduction was observed in unprotected area. The classification details of teak according to the girth range are described in the following diagram.



Severe infestation of *Hyblaea* on teak results complete defoliation. Tree utilize extra energy for rebuilding of the leaves. The energy required for budbreak and leaf expansion, causes further depletion of stored food reserves. The inability of the tree to manufacture food (energy) together with the depletion of stored food weakens the tree and results in reduced growth, stunted, pale-green new leaves and possibly twig and branch dieback. Mortality of small feeder roots also frequently occurs (Bruce 2011). The tree also is changed physiologically from defoliation. The production of protective substances that aid in disease resistance may be inhibited. Natural growth regulators also may be modified which may delay dormancy. These changes result in increased susceptibility to certain insects and diseases again. Defoliation due to Hyblaea attack happens in the early growing season just after the natural defoliation and refoliation process. Defoliation early in the growing season when leaves just reach full expansion is most detrimental. At this time, considerable energy has been expended in budbreak and leaf development, but food reserves are not replenished by photosynthesis due to the foliage loss. Refoliation usually occurs following heavy defoliation early in the season, which will further weaken the tree. Complete defoliation causes reduced stem growth for the two subsequent years following the event.

Three length classes of teak trees (SL, LL, LLL) are there and the ranges are listed in the below table (Teak Net).

Sl no	Length Class	Length in meter
1	SL	Above 1 and below 2.5
2	LL	2.5 m to 7.3
3	LLL	Above 7.3

The main effect of *Hyblaea* attack on teak trees are the formation of epicromic branches. This insect feed on the apical shoot of the tree. The plants in the protected area have long straight stem compared to the plants in the unprotected area. If we observe the length classes of teak the straight stems give more economy than others. There is an average of 1.5 m height attainment came about in protected area than the unprotected area.

On the other hand, defoliation may also cause hormonal imbalances that in turn can impede or limit growth (Kulman, 1971; Boege, 2005). Leaves exert a strong hormonal control on budburst, so leaf removal may stimulate renewed growth of buds (i.e. flushing) that otherwise would break in the following season (Collin et al., 2000). This would limit the bud availability in the following season. Indeed, we observed premature budburst in defoliated trees. It has also been indicated that the utilization of photosynthates for stem growth is regulated by hormones produced in the foliage (Kulman, 1971).

5.CONCLUSION

The main intention of this project was to study the impact of defoliator attack on teak growth increment and change in physical properties of trees after *Hyblaea* attack. Since the demonstration plot is in the forest land controlling climatic factors and soil nutrient profiles are not possible. It is minimized in this study by selecting a single stretch of 1 hectare land with almost same topography. The selection of a buffer area in between the two plots neutralized the effect of control measures in the protected land and kept the unprotected plot naturally.

Hyblaea attack causes complete defoliation of teak trees. The plant leaf functions primarily in the manufacture of sugars and carbohydrates. These substances are the basic food or energy sources for all metabolic processes in the plant including growth, root development, flower and seed production, disease resistance, etc. When the defoliation happened at very early stage of growth the consequences occur in plant growth will be more. The mean tree height and mean GBH of teak trees in the experiment plot also shows the same result. The protected land attained more GBH and Height against the trees in the unprotected land. Defoliation also reduces or inhibits the production of protective substances in leaves (Bruce, 2007). This situation leads the trees more susceptible for diseases and insect attack. Present study shows that tree death or disease are less in the protected teak plantation when compare to the trees in the unprotected plantation. Tree forking is another important factor has to be considered while developing a plantation. Infestation of *Hyblaea* on teak trees at early stage of growth will cause damage to the tender shoot. This may causes the bifurcation of stem. This affects the quality of wood and brings economic loss. Tree forking is more prevalent in unprotected plantation than the protected one. Teak trees in the protected area are seems to be healthier than the trees in the unprotected land.

Tree forking and broken tree in the unprotected plot is 9.8 percentage , while it is 2.4 percentage in protected plot. Tree survival is 6 percentage more in proteted land compare to the unprotected area. At the end of the experiment period an average additional increment of 3.3 cm in GBH and 1.5 m in height is attained the trees in the protected land.

The result analysis of present study on the protected and unprotected land emphasized the need of applying control methods against *Hyblaea* attack. The study articulates that protecting teak plantation from *Hyblaea* attack is worthwhile if sufficient monitoring program is adopted.

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