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Preliminary Study on the Outbreaks of Teak Defoliator (*Hyblaea puera*) in Teak Plantations

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ကျွန်းစိုက်ခင်းများတွင် ကျွန်းရွက်ကြွေပိုးကျရောက် ဖျက်စီးမှု အခြေအနေကို ပဏာမ စူးစမ်းလေ့လာခြင်း

ဒေါ်ဝင်းဝင်းမြင့်၊ B.Ag., M.Agr.st. (The University of Queensland, Australia)
ကထိက၊ သစ်တောတက္ကသိုလ်၊ ရေဆင်း။

စာတမ်းအကျဉ်းချုပ်

သစ်တောကာကွယ်ရေး ဌာနစုမှ မိုးစွေဒေသရှိ ကျွန်းခင်းများတွင် ကျွန်းရွက်ကြွေပိုးကျရောက် ဖျက်စီးမှုကို ပထမအဆင့် စူးစမ်းလေ့လာမှု အနေဖြင့်ဆောင်ရွက် ခဲ့ပါသည်။ တောင်ညို ကြိုးဝိုင်း၊ အကွက်နံပတ် (၅၆) မှ ၁၄-၁၅ နှစ်သား အသက်အရွယ်ရှိ ကျွန်းစိုက်ခင်း ဧက (၂၀၀)တွင် ၎င်းပိုးကျရောက်မှု ပမာဏကို ကိုယ်စားပြု တိုင်းတာ နိုင်ရန်အတွက် အပတ်စဉ် ပိုးနမူနာ ကောက်ယူမည့် အမြဲတန်း အကွက် (၂)ကွက်ကို ၎င်းဧရိယာ အတွင်းတွင် ရွေးချယ်ခဲ့ပါသည်။ ၁၉၉၆ ခုနှစ်၊ ဩဂုတ်လမှ နိုဝင်ဘာလအတွင်း အပတ်စဉ် ပိုးနမူနာ ကောက်ယူမှုကို ဆောင်ရွက်ခဲ့ပါသည်။ ကျွန်းရွက်ကြွေပိုးများ ဖျက်စီးမှု ပမာဏနှင့် အတူ နမူနာပင်များ၏ ကျွန်းရွက်နုများ ထွက်ရှိမှု ရာခိုင်နှုန်းကို အပတ်စဉ် ကိန်းဂဏန်းများ ကောက်ယူ မှတ်တမ်းထားရှိခဲ့ပါသည်။ ကောက်ယူရရှိသော ကိန်းဂဏန်းများအား ဆန်းစစ်ချက်အရ ၎င်းဧရိယာတွင် ကျွန်းရွက်ကြွေပိုးကျရောက်မှု ပမာဏလွန်စွာ နည်းပါးကြောင်း တွေ့ရှိခဲ့ရပါသည်။ သို့ရာတွင် တောင်ညို သစ်တောကြိုးဝိုင်း၊ အကွက်အမှတ် (၅၉)အတွင်း ကျွန်းစေ့ထုတ် ဧရိယာတွင် ၁၉၉၆ ခုနှစ်၊ ဩဂုတ်လ အတွင်း၌ ကျွန်းရွက်ကြွေပိုးများ ရုတ်တရက် ဆိုးရွားစွာ ကျရောက်ဖျက်စီးခဲ့ပါသည်။ သစ်တောကာကွယ်ရေး ဌာနစုမှ လေ့လာမှုနှင့် ပိုးနမူနာ ကောက်ယူမှု ကိန်းဂဏန်းများ ဆန်းစစ်ချက်အရ ၎င်းဧရိယာ အတွင်းရှိ ကျွန်းပင်များအနက် ပျမ်းမျှ ၃၆%မှာ ကျွန်းရွက်ကြွေပိုးများ ဆိုးရွားစွာ ကျရောက်ဖျက်စီးခြင်း ခံခဲ့ရကြောင်း တွေ့ရှိရပါသည်။ နောက်ဆက်တွဲ အကျိုးဆက်အားဖြင့် ၎င်းပိုးများ ဆိုးရွားစွာ ကျရောက်ခြင်း ခံရသော ကျွန်းပင်များတွင် အောင်မြင်သော ကျွန်းသီးများ တင်ရှိမှု ပမာဏ လွန်စွာ နည်းပါးကြောင်း တွေ့ရှိ ရပါသည်။ ယခုနှစ် လေ့လာမှုမှာ အကြောင်းအမျိုးမျိုးကြောင့် (၄)လသာ ဆောင်ရွက်နိုင်ခဲ့သဖြင့် နောက်နှစ် များတွင် ကျွန်းရွက်ကြွေပိုး ကျရောက်မှု ဖြစ်စဉ်နှင့် ၎င်းကျရောက်မှု ဖြစ်စဉ်သည် ရာသီဥတု အခြေအနေ၊ ကျွန်းပင်များ ရွက်နုထွက်သည့် အချိန်ကာလ စသည်တို့နှင့် ဆက်နွယ်ပတ်သက်မှု ရှိမရှိကို ဆက်လက် လေ့လာ စူးစမ်းမည် ဖြစ်ပါသည်။

A Preliminary Study on the Outbreaks of Teak Defoliator (*Hyblaea Puera* Cramer) in Teak Plantations

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Abstracts

The study was undertaken as a first step towards exploring the outbreaks of teak defoliator in plantation at Moeswe region. Two permanent sample plots were demarcated from the 200 acres of the 14-15 year old teak plantations, located in the Compartment number 56 of Taung Nyo Reserve Forest. Sampling was taken at weekly intervals for 4 months (from August to November, 1996). At every sampling, the extent of defoliation by *Hyblaea puera* the percentage of tender leaves flushed were estimated by observing and giving scores according to pre-defined data sheets. Based on the weekly observations at the permanent plots, no major outbreak occurred during these months. However, during August 1996, a sudden, heavy infestation occurred in the seed production area within the Compartment number 59, Taung Nyo Reserve Forest. According to the observations and sampling in this area, an average of 36% of the teak trees were severely defoliated by *H. puera*. Moreover, due to severe defoliation, consequent reduction in teak fruit production was found in those trees. Further investigations will be carried out to decipher the pattern of defoliator outbreaks and its correlation with the climatic and tree phenological parameters in these teak plantations.

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1. Introduction

Teak is presently the most important forest resource of Myanmar. One of the major constraints in the economic gain from the teak tree is the attack of leaf feeding caterpillars of *Hyblaea puera*, commonly called as the teak defoliator. Defoliation by *H. puera* has always been suspected to cause loss of volume increment. Based on the field studies conducted in 4-9 years old teak plantations at Nilambur, India, over a 4 year period, it was estimated that the impact of *H. puera* defoliation on volume increment of teak is of high economic significance since about 44% of the potential increment was lost (Nair *et al*,. 1985). Krisnamara (1982) also stated that the teak defoliators, *H. puera, and Eutectona machaeralis,* cause heavy defoliation of teak which lead to substantial growth as well as flower and seed reduction in Thailand. In Myanmar, however, no attempt was made in the past on the impact of *H. puera* defoliation by Forest Research Institute except of some early report of frequent outbreaks of *H. puera* in teak plantations and financial loss estimated by Mackenzie in 1921 (Beeson, 1941).

Although *H. puera* has long been recognized as an important teak pest, attempts at controlling this pest is presently far from successful due to the inability to predict the outbreaks well in advance. Because, changing in sizes of population are variable between the localities and between years so that sudden appearance *of H. puera* population followed by serious outbreak was unpredictable. Recently, studies on the spatial and temporal pattern of outbreaks in Kerala State. India, has given indications of its possible correlation with pre-monsoon wind. After almost absolute absence for a period of at least 6 months (usually October to March), sudden appearance of *H. puera* coincided with pre-monsoon showers as it is the time of occurrence of the first phase (Nair et. al., 1995). The seasonal growth pattern of teak (tree phonology) can also be expected to influence the magnitude of *H. puera* populations particularly in the early stages of larval development since their feeding mainly depend on the supply of the quantity of flush of the tender foliage of teak trees (Nair et. al., 1985).

The present study was originally designed to cover the following objectives: (1) a basic population unit which would represent the absolute population of *H. puera* during outbreak season for 200 acres of 14-15 years old teak plantations at Moeswe region, (2) the population trends of *H. puera* at different points of time in this region. The information on the climatic and tree phenological parameters in relation to the pattern of defoliator outbreaks in teak plantations were also intended to be gathered this year.,

However, due to un-anticipated various reasons, the sample plots can only be established in July, 1996 as it was 4 months later than the proposed schedule. The studies were undertaken for only 4 months from August to November. Therefore, the occurrence of the initial population build-up during outbreak season and that of residual population during off-season cannot be investigated in the study area. Only the estimates of weekly population between August and November in the study area can only be investigated for this year. In this study, two permanent plots were established to sample the immature stages of *H. puera* (especially different ages of larvae) at weekly intervals in the 14-15 years old teak plantations of the Compartment number 56, Taung Nyo Reserve Forest, at Moeswe region. At every sampling, intensity of defoliation by *H. puera* and percentage of tender leaves flushing were visually observed and scored according to the pre-defined data sheets. In the permanent plots, no major outbreak occurred during these months.

However, severe infestation occurred in some discontinuous patches of 30 years old teak plantations within the seed production area. According to the visual observations followed by giving the scores for the intensity of defoliation at the temporary sample plots, an average of 36% of the teak trees in this area were severely defoliated (i.e. 51% to 100%). Moreover, based on the pupa sampling, high density population was also found in the discontinuous patches of the study area. As a result, it was found that teak fruits did not successfully developed on the severely infested trees due to heavy defoliation.

Further investigations would be needed to obtain a through understanding of the population dynamics of *H. puera* pertaining to weather system, particularly intensity and occurrence of pre-monsoon rains, seasonal growth pattern of the teak tree, and migratory behavior of the teak defoliator, etc., in the teak plantations of Myanmar.

2. Literature Review

Studies on the biology, seasonal incidence and population dynamics of this pest will be reviewed and summarized briefly.

2.1 Biology of *H. puera*

The teak defoliator, *Hyblaea puera*, belongs to Family Hyblaeidae of the Order Lepidoptera. This species is distributed in the Asia Pacific and Australia regions, in South Africa, part of East Africa and West Indies (Beeson, 1941; Browne, 1968). It completes the life cycle within a month, passing through 5 larval instars, and in the tropical part of India and Myanmar about 14 generations per year have been recorded in field insectaries (Beeson, 1941).

Teak is its principal food plant although it has several alternative hosts on which it survives, grows and can regularly breed (Beeson, 1941) and 37 tree species have been recorded as its alternative host (Beeson, 1941; Mathur, 1960; Hutacharan, 1990). *H. Puera* is a highly fecund insect as a maximum of 1000 eggs (average 500 eggs) are laid per female. The female moths usually lay their eggs on the underside of tender foliage. Subsequently, the newly hatched larvae mainly feed on tender foliage and usually make small leaf folds at the margins of the leaves. From the third instar onwards, the larvae consume the entire leaf leaving only the major veins and petioles. Thus feeding by *H. purea* leads to defoliation because the heavily damaged leaves fall off after a few days. The entire larval period lasts for 8-14 days mainly depending upon weather conditions. The mature larvae pupate on the ground and make use of soil or leaf debris together with silk for cocoon. According to Beeson (1941), they sometimes pupate on the leaf in a triangular leaf fold cut specially and strongly spun together or sometimes a naturally curved leaf or justaposed leaves or several parts of eaten leaves entangled in silk are utilized. The average pupal period lasts 6-8 days under optimal conditions. The male and female usually fertilize 2-3 days after emergence and eggs are laid a night or two later.

2.2 Population dynamics of *H. puera*

The studies on the population dynamics of *H. puera* have not been completed yet but a number of reports for the possible population dynamics in India has been published. According to the reports, usually one or two major epidemics of this

species was a regular feature between late April and July which are followed in some years by a smaller build up between August and October. The insect was then not measurable until next February-March. In India, this cycle of ups and downs is repeated every year. Of importance to studies on the population trends of *H. puera,* there have been different suggestions between theoretical development and observations. Theoretically *H. puera* can pass through at least 14 generations per year (Beeson, 1941), but they almost totally disappear in some months in nature. Aestivation or diapause in summer and hibernation in winter have been suspected by Chatterjee (1932) and Beeson (1941) for the explanation of disappearance of *H. puera* at certain times. However, detailed observations of these habits in this insect are lacking. A number of authors have also argued that the occurrence of a residual population during off-season can be taken as evidence against diapause and hibernation. (Vaishamanpayan & Bahadur, 1983; Vaishamanpayan et. al., 1984; Nair & Sudheendrakumar, 1986). According to them, if the insects have been in diapause or hibernation, within a locality, they should become active at about the same time and be distributed more uniformly. On the other hand, they have agreed with the interpretation of population dynamics of *H. puera* in relation to migratory behaviour and have presented some supportive evidences. Based on the analysis of spatial and temporal distribution of *H. puers* infestations and certain behavioural characteristics of moths and larvae, it was stated that the moths are able to migrate at least 20 Km and probably more (Vaishamanpayan & Bahadur, 1983; Vaishamanpayan et. al., 1984) but they usually migrate for a short range distance of about 5-10 Km when suitable host trees are available within this distance (Nair & Sudheendrakumar, 1986).

Based on these assumptions, Nair & Sudheendrakumar (1986) proposed a population model for changing the population size over years. In the proposed model, during off-season, a residual active population of the insect exists on host trees which possess tender foliage suitable for oviposition and survival of the early larval instar. Such a population is more likely to occur in natural forests mainly due to continuous availability of tender foliage and occurrence of alternative hosts. Then, the population starts increasing generation by generation from February-March because most trees flush new tender foliage at that time in the plantations. When the population density reaches a critical level, the migratory behavior is triggered within the population. Subsequently, the population build-up may continue in the general direction of early flushing to late flushing areas. In July, most trees have fully mature leaves in the plantations so that the conditions are no longer suitable for sustaining a large population of larvae, particularly the early instars. Since then, the population decreases to the very low level up to next February-March except some peaks in August- September. However, there has not been enough evidences to support this proposed model.

Nair (1980) also pointed out the role of natural controlling factors including climate and natural enemies which cause the reduction of pest population. A record of 34 species of insect parasites and predators attacking on *H. puera* and the adverse effects of heavy continuous rainfall on the survival of *H. puera* may reduce the population after heavy infestation (Nair, 1985). Probably due to combined action of these mortality factors and the migratory behaviour of this pest, the populations chrushes down and return to the residual level usually by July and sometimes after another peak in August-September.

3. Materials and Methods

3.1. Study sites

The study sites are located in the Compartment number 56 and 59 of Taung Nyo Reserve Forest, at Moeswe region. Two permanent sample plots were established within the 200 acres of 14-15 years old teak plantations in the Compartment number 56. The temporary sample plots were conducted in 30-31 years old teak plantations of the compartment number 59, Taung Nyo Reserve Forest.

3.2. Tree samples

50 sample trees were randomly selected from each permanent plot (1.5 acres each and namely plot A and B). In these plots, tree were marked, numbered serially and then the sample trees were randomly selected from those and locations were marked in the chart. The location of the permanent plots are shown in the map (Figure 3.1).

In the temporary sample plots, a close group of 10 trees were considered as one plot and altogether 20 sample plots were chosen from various places to cover all of the seed production area (within SPA 1/65-37 acres and SPA 1/66-50 acres) as shown in the map (Figure 3.2).

3.3. Observations and sampling in the permanent plots

Two permanent plots were established in July and the sampling was started in the first week of August at these plots. Pre-defined data sheets were prepared before the samplings were started. Each sample tree was visually observed and scored for defoliation, at weekly intervals from August to November, 1996. Scores were assigned to indicate the gross percentage of tree foliage loss due to *H. puera* : score 1 represented 0% (no foliage loss); 2 : 1-5% foliage loss; 3 : 6-25%; 4 : 26-50%; 5 : 51-75%; 6 : 76-100%. To distinguish between the damage symptoms of *H. puera* and those of other insects like grasshoppers, beetles and weevils and to predict the different ages of the defoliator, the various sizes of leaf folds such as small, medium, and large made by *H. puera* are counted if they were present. At every sampling, the percentage of flushed tender foliage was also estimated by counting the number of tender and total leaves per shoot, approximate number of shoots per branch and number of branches per tree. The same scores as intensity of defoliation were also given (score 1:0% (no flush tender leaf); scores 2:1-5%; score 3:6-25%; 4:26-50%; 5:51-75%; 6:76-100%).

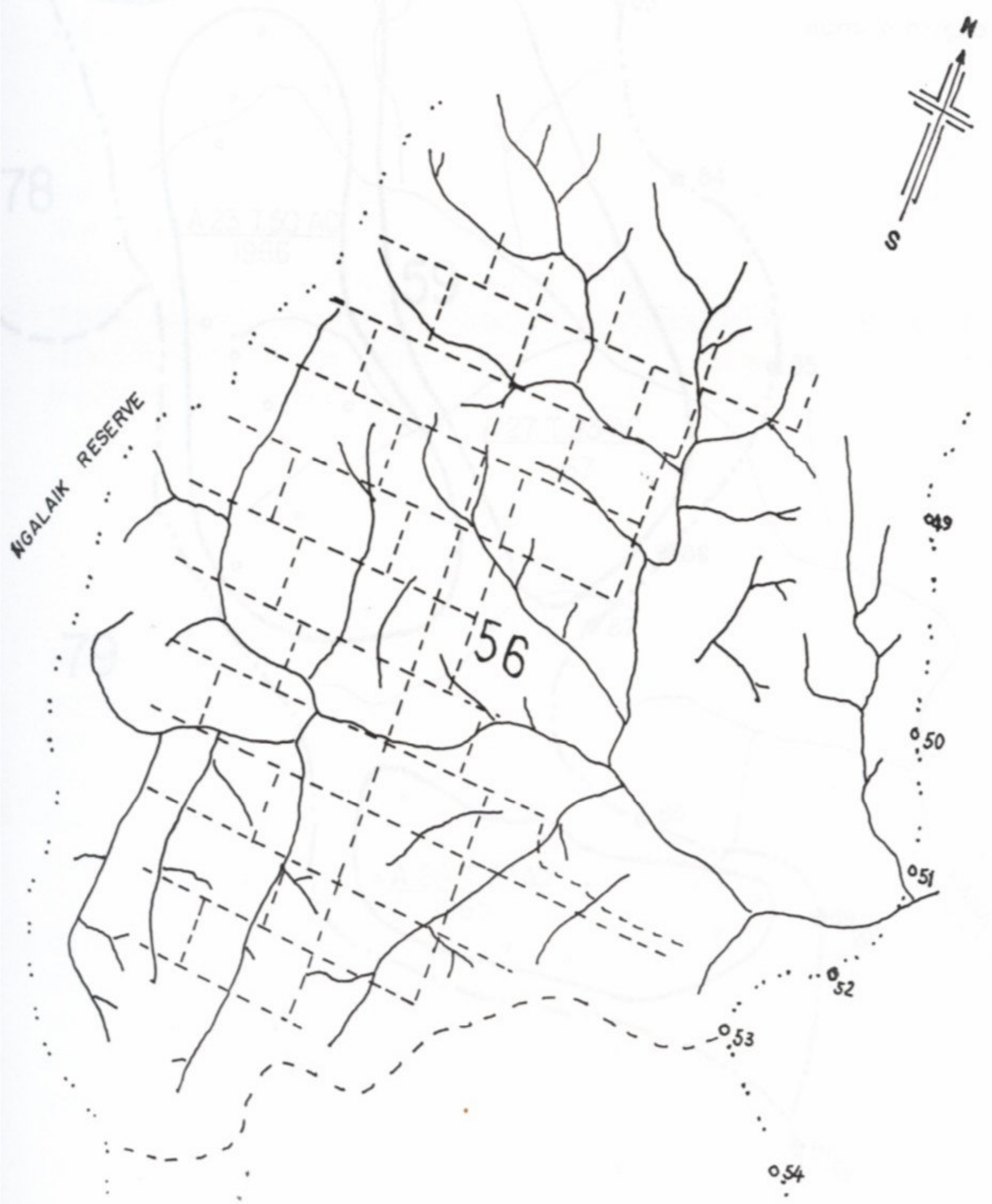

Figure 3.1 Location of the permanent sample plots in the Compartment Number 56, Taung Nyo Reserve Forest at Moeswe Region.

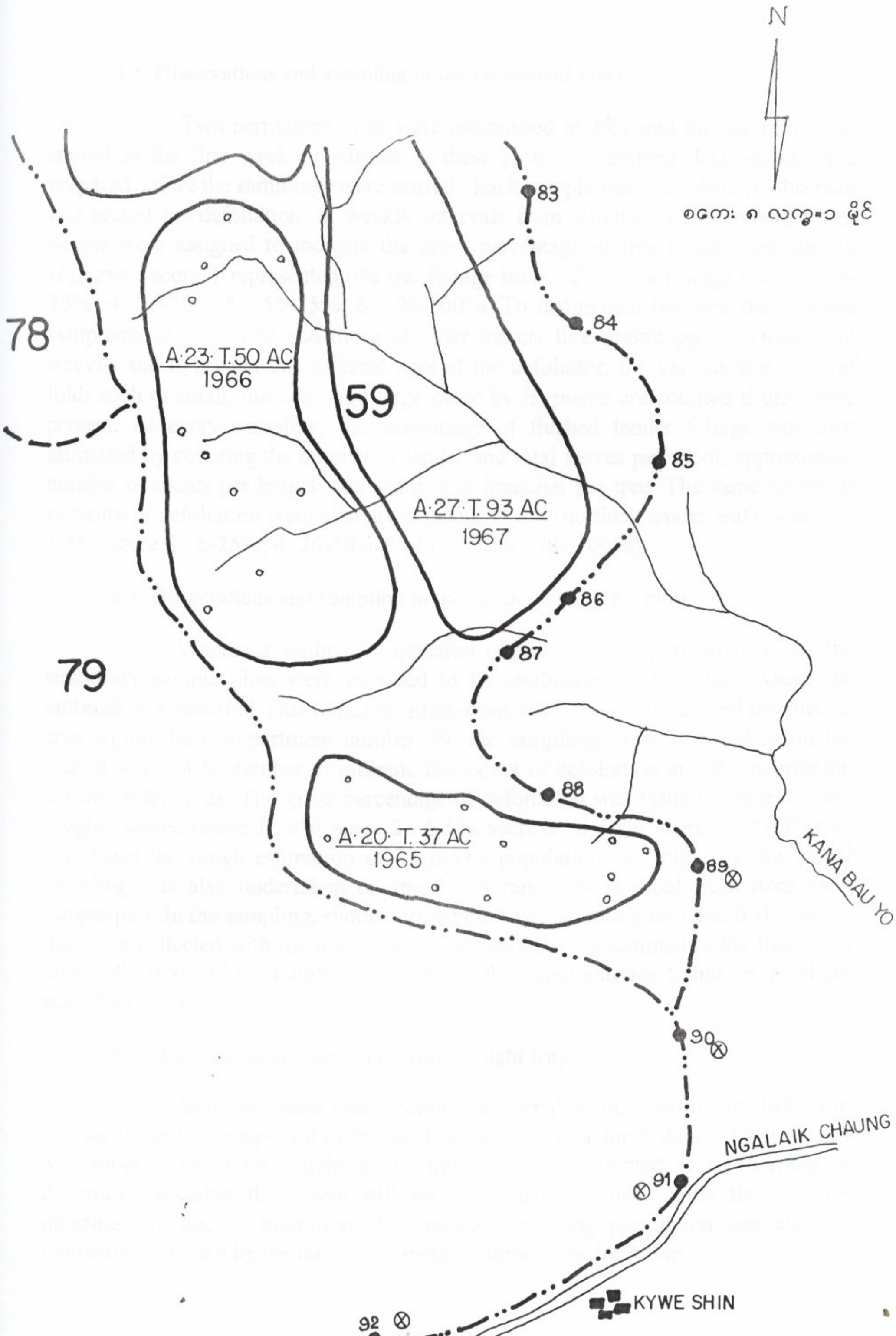

Figure 3.2 Location of the temporary sample plots in the seed production area of the Compartment Number 59, Taung Nyo Reserve Forest at Moeswe Region.

3.4. Observations and sampling in the temporary sample plots

Whenever outbreaks appeared outside the two permanent plot, the temporary sample plots were intended to be established at the place where the outbreak has occurred. Due to heavy infestations of *H. puera* in the seed production area within the Compartment number 59, the samplings were undertaken on the second week of September to estimate the extent of defoliation and the population density in this area. The gross percentage of defoliation was visually observed and roughly scored (score 1 : 0%, score 2:1-5%, score 3 : 6-50%, score 4 : 51-100%). To obtain the rough estimation of *H. puera* population in this area, the pupal sampling was also undertaken on the 2 to 3 randomly selected trees from each sample plot. In the sampling, shoots formed the basic sampling unit and 6 shoots per tree were collected with the tree pruner. Each shoot was examined in the field soon after collection and the number of pupae or the pupal exuviae found on the shoot were then recorded.

3.5 Moth population sampling with the light trap

As the *H. puree* moth exhibits nocturnal habits, a temporary light trap was set up in the compound of the seed production area for 5 days (from 9 to 13 September). The moths caught in the light trap were counted every morning to determine whether they were still present nearby or away from the recently infesting site due to migration. The recently infesting population can also be indirectly estimated by the number of moths caught in the light trap.

4. Results

4.1. Observations and sampling in the permanent plots

In this year study, the results showed that no measurable defoliation occurred in the permanent plots during the outbreak season. Therefore, no data was available in estimating the intensity of defoliation and pest population for this year. The percentage of tender foliage flushing at every sampling was also very low on the sample trees of the permanent plots. At the first sampling dated on 7.8.96, out of 50 sample trees, the new flushes of 14 and 23 trees were rated in the score 2 (1-5%) and those of 36 and 27 trees rated in score 3 (6-25%) in the plot A and B respectively. After the third sampling, the rate of flushing become lower and thus the new flushes were mostly rated in the score 2. From mid September onwards, no more flush appeared and the majority of the trees were rated in score 1 except a few number were rated in the score 2. Score 4 and above were never rated on almost all sample trees during these 4 months. (Appendix 1).

4.2. Observations and sampling in the temporary sample plots

4.2.1. Intensity of defoliation

Table 4.1 and 4.2 show the intensity of defoliation in the sample plots of SPA 1/65 and 1/66 by the average percentage. According to the sampling in each plot, an average 36% of the teak trees were severely defoliated at both plots within the range between 51% and 100%. Apart from that, an average of 37% of the teak trees were moderately defoliated (within the range between 6% and 50%), and that of 21% of the

sample trees were slightly defoliated (within the range between 1% and 5%) in the SPA 1/65. Only 6% of the sample trees were free from defoliation in the SPA 1/65. Similarly, an average of 47% of the teak trees were also moderately defoliated and that of 17% of the sample trees were slightly defoliated in the SPA 1/66. No observed trees were free from attack of *H. puera* in the SPA 1/66.

Table 4.1. The average percentage of defoliated teak trees by *H. puera* at temporary sample plots (SPA-1/65 37 acres) on 9-13 September, 1996.

Plot. No	Average percentage of defoliation			
	0%	1-5%	6-50%	50-100%
1	20	30	20	30
2	0	30	30	40
3	40	60	0	0
4	0	20	20	60
5	0	10	20	70
6	0	0	50	50
7	0	0	90	10
8	0	20	50	30
9	0	30	20	50
10	0	10	70	20
Mean	6%	21%	37%	36%
sd (δ)	13.50	17.92	27.51	22.21

Table 4.2 The average percentage of the defoliated teak trees by *H. puera* at temporary sample plots (SPA-1/66 acres) on 9-13 September, 1996.

Plot. No	Average percentage of defoliation			
	0%	1-5%	6-50%	50-100%
1	0	10	50	40
2	0	30	30	40
3	0	50	40	10
4	0	10	40	50
5	0	10	80	10
6	0	20	60	20
7	0	30	50	20
8	0	10	70	20
9	0	0	0	100
10	0	0	50	50
Mean	0%	17%	47%	36%
sd (δ)	0	15.67	21.00	25.77

4.2.2. Population sampling

In the temporary sample plots, the density of recently infesting population was also estimated by sampling the number of pupae or pupal exuviate per shoot on the randomly selected trees of each sample plot. Table 4.3 and 4.4 show the average number of pupae or pupal exuviate per shoot as a plot mean and the total mean number of pupae per shoot for all sample plots of the SPA 1/65 and 1/66. According to the sampling in SPA 1/65, the total mean number of pupae per shoot was 10.098

although high density population with up to the average of 22.38 and 24.05 pupae per shoot were particularly found in the sample plot number 2 and 4. However, there were very low density population with the average 0.78 pupae per shoot found in the plot number 3. Thus it can be seen that heavy infestation was not continuously occurring in this study area. In the SPA 1/66, the average number of pupae per shoot (i.e.5.821) was lower than that of the SPA 1/65 as shown in the Table 4.4. Only the trees located in the plot number 2 and 9 were observed to have high density populations and those in the plot number 8 (nearest to the plot number 9) were entirely free from defoliation. Similarly, very low population density with the average number 0.33 pupae per shoot was found in the plot number 3 and again it was observed that with an average number of 1.16 pupae per shoot was present on the trees of the plot number 5. Therefore, the similar pattern of infestation (i.e. defoliation occurring in discontinuous patches) was also found in the SPA 1/66. Moreover, the population density of the SPA 1/65 was significantly higher than that of the SPA 1/66 with 96% confidence level according to the results of the Paired t-test (Table 4.5).

Table 4.3. The average number of pupae or pupal exuviate per shoot in each sample plot of the SPA-1/65 (37 acres) from 9 to 13 September, 1996.

Plot No.	Number of tree	Number of shoot	Total no. of pupae per plot	Average no. of pupae per shoot
1	3	18	120	6.66 ± 8.37
2	3	18	*433	*24.05 ± 17.95
3	3	18	14	0.78 ± 1.03
4	3	18	*403	*22.38 ± 16.57
5	3	11	51	4.64 ± 3.89
6	2	12	*158	*16.o ± 30.63
7	3	18	36	3.0 ± 2.80
8	3	18	87	6.85 ± 16.60
9	3	18	85	6.54 ± 6.94
10	2	12	*121	*10.08 ± 7.26
Total mean			1478	10.098 ± 7.63

Table 4.4. The average number of pupae or pupal exuviate per shoot in each sample plot of the SPA-1/65 (50 acres) from 9 to 13 September, 1996.

Plot No.	Number of tree	Number of shoot	Total no. of pupae per plot	Average no. of pupae per shoot
1	2	12	*110	*9.17 ± 9.43
2	2	12	*156	*13.0 ± 15.48
3	3	18	6	0.33 ± 0.58
4	3	18	145	8.06 ± 6.58
5	3	18	26	1.16 ± 2.14
6	2	2	41	3.50 ± 4.13
7	3	18	40	2.22 ± 2.72
8	3	18	0	0
9	3	18	*265	*14.72 ± 8.82
10	3	18	109	6.05 ± 5.89
Total mean			898	5.821 ± 5.014

Table 4.5. Comparison of the population density between SPA 1/65 and 1/66 of the compartment number 59, during September, 1996.

	Variable 1	Variable 2
Mean	10.098	5.821
Variance	64.707	27.903
Observation	10	10
Hypothesized mean difference	0	
d.f	9	
t. Stat	1.913	
P (T ⇐ t) one-tail	0.044	
t Critical one-tail	1.833	

4.3 Sampling of moth population

The number of moths caught in the temporary light trap was shown in Table 4.6. Only a few number of moths were caught on each date. According to the data, it may be indicated that after heavy infestation in the seed production area, the newly emerged moths seemed to migrate to the other areas. Only a few moths emerged from a residual late-aged population by the that time may be caught in the light trap.

Table 4.6. The number of moths caught in the light trap temporarily set up in the compound of seed production area from 9 to 13 September, 1996.

Date	9.9.96	10.9.96	11.9.96	12.9.96	13.9.96
No. of moths caught in trap	27	32	17	24	21

5. Discussion

The present studies showed that, during 4 months, no major infestation occurred in the study area of the Compartment number 56 as the leaf folds made by larvae were rarely found in large number and the damages were also negligible. During a 4 month period of sampling, some other defoliators such as Geometric and Pyralid caterpillars, Cerambycid bettles, Curculionid weevils, short-horned and long-horned grasshoppers feeding on the trees were occasionally found at the plots but no measurable defoliation was seen during these months. No other information was also available on the defoliator infestation in these plantations. Generally, it can be determined that the teak trees in the study area were free from the attack of defoliator for this year due to either asynchrony between the flushing time and insect population cycle or less preference to the young aged plantations. Nair *et. al.* (1985) stated that under normal conditions, the moths lay eggs only on tender leaves and the newly hatched larvae survive only if such leaves are available for initial establishment and feeding. In these study plots, the teak trees may exhibit either early or late seasonal growth pattern which did not coincide with initial build up of population for this year. The pre-monsoon showers mainly occurred during. May every year but non-seasonal

rains had frequently occurred since February-March this year so that the majority of the new tender leaves would have flushed earlier than last years. During the period of the samplings, most leaves were already fully matured but no serious damage symptoms of *H. puera* was found on the sample trees and other neighbouring trees at the plots as well. On the other hand, Beeson (1941) assumed that the frequency of severe defoliation by *H. puera* was highest in 21-30 years old plantations and that of light defoliation was higher in under 20 years old plantations according to his observations in India and Myanmar. In this study, the permanent plots were selected from 14-15 years old plantations due to the accessibility. Moreover, the plantations of other tree species like. *Pterocarpus macrocarpus*, *Gmelina arborea* and *Chukrasia tabularis* are present only 1 mile away from the study area so that this situation seem to be a considerable barrier *for H. puera* to infest the study area. Finally, the other alternative reason may be that, in some years, some areas of the plantations are entirely free from the defoliation by *H. puera* as Nair (1988) mentioned that the spatial distribution of the patches or the plantations is not constant over years.

The observations conducted this year were not sufficient to draw any conclusion because the seasonal growth pattern of the teak and its correlation with the occurrence of initial population build up have not been investigated yet. The meterological data was not also fully available for this year to correlate the outbreaks of *H. puera* with the intensity of rainfall in this area. According to Nair *et. al.* (1985), under plantation conditions, the magnitude of loss will depend on several factors: the age of plantations, the time of defoliation in relation to the seasonal growth pattern of teak, the frequency and duration of the leafless periods, the amount of foliage lost in proportion to the total amount of foliage, etc.. Based on these assumptions combined with the knowledge gained from this year study, the sample plots should be selected from different ages of teak plantations in Moeswe region and the duration of sampling should also be lengthened for more than one year. If it is possible, observations should be made on its migratory behaviour and other possible mortality factors to predict the population trends of *H. puera* within the region.

Although not all the objectives have been accomplished, investigations were made on some other aspects, particularly the sudden, heavy infestation of trees, in the seed production area within a short period. In this area, there would be no measurable defoliation by *H. puera* before August since many teak trees were found to be free from attack of *H. puera* at the time of investigation. From second week of August onward, however, the heavy defoliation would have occurred in discontinuous patches within the area. Because once we have noticed the symptoms of heavy infestation on first week of September , only the pupae and some of the pupal exuviae within the triangular leaf folds were mainly found in the lower branches of the infested trees. The new flushes on entirely defoliated trees also clearly indicated that infestation had occurred 2 or 3 weeks earlier. Therefore, it can be determined that the active feeding stages (larval stages) must have occurred at about mid-August. The density of recently infesting population was roughly estimated by sampling the remaining pupal population on the teak trees. The pupae were also found in the leaf folds made on the weeds like Thekke (*Imperata cylindrica*) and Zamini (*Hiptage candicans*) although they were not counted. Since a large population of pupae was present in this area., it can be assumed that a much bigger population must have been present 2-3 weeks earlier.

During investigation, it was found that only a small, uneven-aged population existed in this area and they confined their feeding chiefly to the coppices of the understory. Nair (1988) stated that after heavy infestation, successive generations of

the insect do not inhabit the same; place thus no significant reinfestation occurs in or around recently defoliated area even when trees possessing suitable tender foliage are present. Instead, a small number of uneven aged larvae may be seen in the area, feeding mostly on tender leaves of teak coppice in the understorey and occasionally the lower branches of the bigger trees. Such an occurrence has been found in our study. According to the evidences of small residual population presented and only a few moth being caught in the light trap after heavy infestation, it can be assumed that the newly emerged moths would have migrated somewhere but the direction and distance of their movement were not known. Further investigations will be made in further to draw the final conclusion for this study.

Apart from seed production area, our team also inspected other areas within the Compartment number 59 and severe infestations were also found in the discontinuous patches while some area were free of infestation. Thus it can be assumed that defoliation occurred in the whole area of the Compartment number 59 at about the same period. It was also peculiarly noticed that all of the severely infested trees in the seed production area failed to produce successful fruit formation. Consequently, it would be difficult to established extensive areas for the purpose of seed production in such aged plantations if proper preventive and control measures cannot be performed.

In Myanmar, large area of teak plantations have been establishing since 1980 and a total of 255,711 acres have been raised up to 1996. As a consequence, the teak defoliator outbreaks would be a regular phenomenon in the near future. The proper control strategies for this pest without damaging the ecosystem should be developed other than the conventional method using chemical insecticides in the plantations. In conclusion, the knowledge of population dynamics of this pest is a necessary first step in the development of the proper control strategies in Myanmar.

Appendix 1. **Average percentage of the flushed tender foliage at permanent plots on specified dates in 1996.**

Sampling date	Plot no.	Score 1 0%	Score 2 1-5%	score 3 6-25%	Score 4 26-50%	Score 5 51-75%	Score 6 76-100%
7.8.96	A B	-	n = 13 n = 23	n = 36 n = 27	n = 1		
14.8.96	A B	n = 9 n = 2	n = 22 n = 20	n = 18 n = 28	n = 1		
21.8.96	A B	n = 4 n = 3	n = 35 n =17	n = 11 n = 30			
28.8.96	A B	n = 30 n = 13	n = 18 n = 32	n = 2 n = 5			
4.9.96	A B	n = 9 n = 14	n = 31 n = 32	n = 10 n = 4			
11.9.96	A B	n = 27 n = 16	n = 21 n = 28	n = 2 n = 6			
19.9.96	A B	n = 37 n = 31	n = 12 n = 23	n = 1 n = 27			
26.9.96	A B	n = 33 n = 24	n = 14 n = 25	n = 3 n = 1			
2.10.96	A B	n = 40 n = 32	n = 10 n = 17	n = 0 n = 1			
9.10.96	A B	n = 41 n = 34	n = 9 n = 13	n = 0 n = 3			
16.9.96	A B	n = 42 n = 33	n = 7 n = 14	n = 1 n = 3			
23.10.96	A B	n = 45 n = 39	n = 5 n = 8	n = 0 n = 3			
30.10.96	A B	n = 47 n = 42	n = 3 n = 5	n = 0 n = 3			
6.11.96	A B	n = 45 n = 43	n = 5 n = 7	n = 0 n = 0			
15.11.96	A B	n = 50 n = 42	n = 0 n = 7	n = 0 n = 1			
20.11.96	A B	n = 48 n = 44	n = 2 n = 4	n = 0 n = 2			
27.11.96	A B	n = 50 n = 45	n = 0 n = 3	n = 0 n = 2			

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