DEPARTMENT OF ZOOLOGY
UNIVERSITY OF GHANA
LEGON, ACCRA
GHANA

This is to certify that this thesis has not been submitted for a degree to any other University. It is entirely my own work, and all help has been duly acknowledged.

S.B.V. Mkhize

(SHADRACK BEKI VUSUMUZI MKHIZE)

STUDIES ON THE LEPIDOPTERA OF COCOA FARMS IN GHANA

By

SHADRACK BEKI VUSUMUZI MKHIZE

A thesis submitted for the degree of Master of Science at the University of Ghana, 1971

SEPTEMBER 1971

CONTENTS

ABSTRACT

Fluctuations in populations of leaf-eating Lepidoptera at Aburi are not only tied up with availability of food in the form of flushes but to a certain extent also with the changes in seasons of the year. Flushing was greatest in February-March at the end of the dry sunny season getting into wet sunny. More caterpillars were seen on flushes at this time then in the dry months of October-December. Pod-boring caterpillars such as Characoma stictigrapta caused more damage in October-November when there were many pods available. The increase in numbers of Lepidoptera species is also associated with cocoa canopy: cocoa trees with a poor canopy harboured much higher numbers of some lepidopterous species such as Earias biplaga and Anomis leona than trees with a good canopy. Much larger numbers of caterpillars occurred in regularly sprayed areas such as at Kade and Tafo than at the rarely sprayed farms at Aburi. For instance, the incidence of the pod-husk miner, Marmara sp., was greatest in regularly sprayed farms, probably because, with the application of insecticides, the free-flying parasites of Marmara get killed thus upsetting the natural biological balance.

1. INTRODUCTION

Cocoa like many other plants of economic importance, has a host of its own attendant pests among which lepidopterous caterpillars feature fairly prominently. Early reports on entomological pests in West Africa (Lamborn, 1914-1915; Patterson 1914; Peacock, 1913) almost invariably included one or other lepidopterous pest attacking some part of the cocoa tree or seedling. Recent reports, too, abound in information on the problem of Lepidoptera on cocoa e.g. Entwistle (1960, 1962), Gerard (1962) and Alibert (1951).

The extensive use of insecticides in the control of other cocoa pests has indirectly and inadvertently increased the incidence of certain Lepidoptera (Johnson & Entwistle, 1959; Entwistle et al., 1959). It has also been observed that cocoa grown without overhead shade trees, as is often the case with young seedlings, suffers intensely from some lepidopterous caterpillars (Gerard, 1964, 1970; Leston, 1970). Some cocoa trees and seedlings may harbour a higher number of various species of lepidopterous larvae at certain times of the year than at others, especially after the rains following on the dry season when more food in the form of new leaves, pods and chupons is available (Gibbs & Leston, 1970; Lavabre, 1965; Leston & Gibbs, 1971; Smith, 1961).

Quantitative work on lepidoptera affecting cocoa has not been extensive and most of the available knowledge on seasonality and distribution of these pests, and of the damage they cause is based mainly on non-numerical data e.g. Smith (1965), Cotterell (1928) and others - Gibbs and Leston (1970) being an exception. In the present project, therefore, an attempt has been made at a numerical approach to the Lepidoptera problem, such that fluctuations in their numbers are viewed in relation to such factors as seasons of the year, cocoa flushing and production of new foliage, stems and pods. Further, upsurges in numbers of caterpillars after treatment of trees with insecticides as well as on cocoa growing in the sun have also been studied.

A working identification key of some of the caterpillars frequently encountered in cocoa farms has been prepared with a view to facilitating their quick recognition without the use of a microscope, particularly in the field. In addition, a list of the geographical distribution of Lepidoptera affecting cocoa in West Africa is presented and appended to this dissertation so that it may be available at all times for consultation.

Chapter 2: Methods

2. METHODS

2.1: Description of sampling sites

Four cocoa farms, A, B, C and D with varying degrees of shade were selected near Aburi, Akwapim, Eastern Region (Fig.2.1). Farmers were notified that their farms were being used for research purposes, and requested that they should not prune or cut away young chupons growing out at the bases of trees.

Farm A is about 1.60km from Aburi and is situated on the right-hand side on the road to Nsawam. It is a large farm composed of old tall cocoa trees most of which are multi-trunked due to early coppicing or lack of pruning. Spacing is random. The canopy on the whole is good on this farm, though there are areas where it is completely broken, with trees standing in the open. Where the canopy is broken small patches of cocoyam and cassava have been established by the farmers. Undergrowth is usually very thick and tall at places where the canopy is not completely closed, but suppressed and scattered where the canopy is good. There is a variety of shade trees rising well above the canopy.

Farm B is situated on a slope about 2.40km from farm A on the same Aburi-Nsawam road. The canopy on this farm is poor, but some of the cocoa trees receive shade from tall banana, palm and cotton trees. The undergrowth is very thick and is cut very irregularly. Leaf litter is abundant but is mostly obscured by the dense undergrowth.

Farm C is also very large and is located about 800 metres from farm A on the other side of the road. The canopy is good. Spacing is

2·1

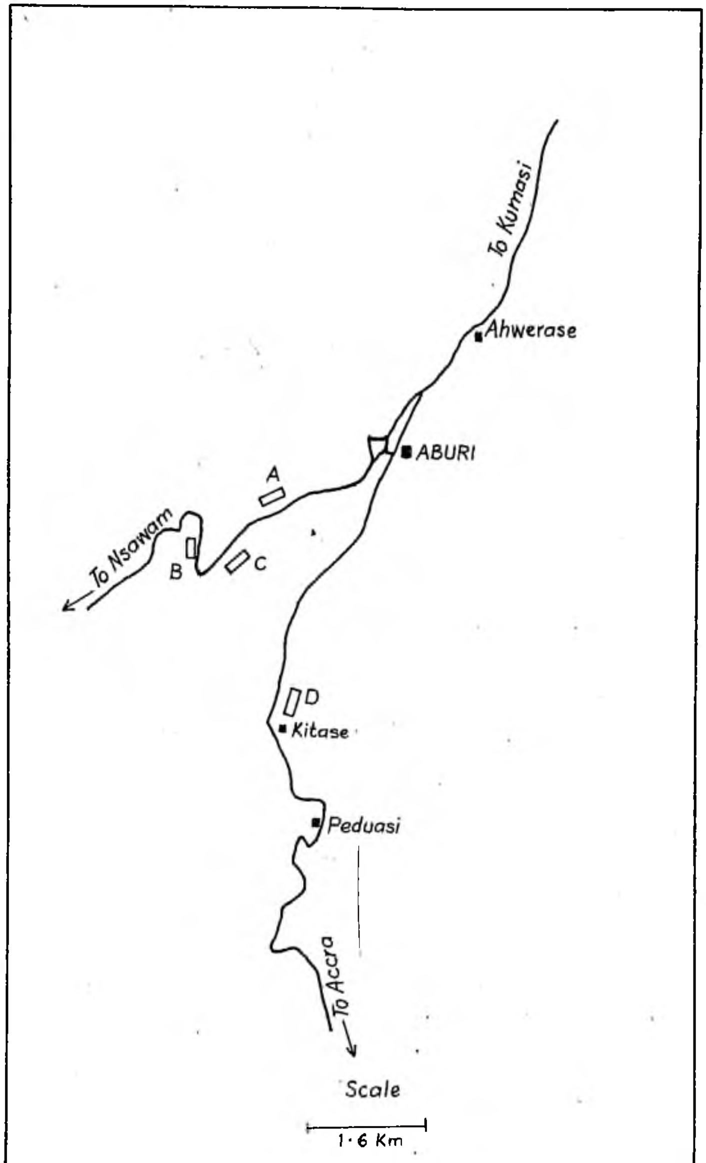


Fig. 2.1: Map showing location of farms A, B, C and D, where sampling was carried out.

random. The trees are old and tall, and quite a number of them have bent or broken stems, and where these occur the canopy is broken. Early coppicing has resulted in a few trees being multi-trunked. Shade trees are few. Leaf litter is abundant.

Farm D is much smaller in area than the other three farms. It is situated at Kitase, about 4.8km from Aburi on the Aburi-Accra road. Cocoa trees on this farm are also very tall and old. A few young trees which have not yet started to bear pods are interspersed among the older trees. The canopy is moderate, but is usually broken where trees are widely spaced. The undergrowth composed of ferns grows very profusely and is cut only very occasionally. Few shade trees are present.

At Kade the three plots that were surveyed are situated at the

Agricultural Research Station. Plots II and VIII have a moderate canopy and very few shade trees are present. Spacing is about 2.5 x 2.5 metres, but there are slight variations in spacing at certain points in each of these plots. Litter is abundant. Plot IVc on the other hand has a very poor canopy and the undergrowth is dense. Spacing is as in the other two plots.

At Amanokrom three farms were inspected, two of which have a good canopy and the other one a poor canopy. All three farms have tall cocoa trees. Spacing is random. Where the canopy is good the undergrowth is suppressed, but where the canopy is poor the undergrowth is fairly thick. Tall shade trees are present. Leaf litter is abundant, but rather obscured by dense undergrowth on the farm with a poor canopy.

To select sample trees, use was made of random numbers taken from a table in Campbell (1967). On each of the four farms these random numbers were used to give the number of steps to be taken from one tree to the next. At every tree reached, change of direction was effected by making alternate left and right quarter turns until the ten trees to be selected were marked using red paint. In this way the distribution of the 10 selected trees became automatically random in relation to shade.

Every week 20 other unmarked trees on one of the sites visited were selected in similar manner. Each farm was visited once every four weeks in rotation.

At Tafo, surveys were carried out on plot H.10 at the Cocoa Research Institute. On this plot there are cocoa seedlings grown under tall shade trees. The seedlings were invariably under heavy *Earias* and *Anomis* attack during the period of sampling. Apart from these seedlings there is also a portion where mature pod-bearing cocoa trees are grown. The canopy here is very good and there is virtually no undergrowth here as compared with what obtains on that part of the plot where the seedlings are growing.

2.2: *Selection of sample trees on each farm*

2.3: Sampling methods

Leaf area sampled was kept constant for each of the 10 or 20 trees, i.e. a maximum number of 20 leaves per tree were examined every time, starting with the top-most succulent flush leaves on accessible chupons and moving downwards to the hardened and the senescent leaves.

Leaves were classified in four categories: flush (red); post-flush (brown or green), tender limp and expanded; green partially hardened and horizontal; dark green, hardened and senescent.

In looking for caterpillars both upper and lower surfaces of leaves were examined, and where two or more leaves were held together with silk, they were separated to see whether caterpillars such as Tortrix dinota, Characoma stictigrapta, Archips occidentalis and others were present. Chupon tips were closely inspected for either Earias biplaga or C. stictigrapta.

To record the patterns of damage resulting from the feeding of the more important caterpillars, leaves on which the various species had been found feeding in the field were collected, tagged with the name of the caterpillar and noted for colour and age. They were then pressed between newspaper pages and left until dry. Diagrams of feeding patterns characteristic of each caterpillar were subsequently traced on translucent paper.

Pods in various stages of development e.g. cherelles and mature green pods, were examined for Marmara scribbling and Characoma stictigrapta damage. Records of numbers of accessible infested and uninfested pods were kept including the shade regime. Notes were also taken of any other caterpillars that were found feeding on the pod epicarp. Maps of farms where Marmara surveys were carried out were prepared, i.e. Kade and Amanekrom.

Old rotten pods left hanging on trees were brought down in order to check whether they harboured any Lepidoptera. Tree trunks, low-hanging branches, the undergrowth and leaf litter at the bases of sample trees were scrutinized for caterpillars that might have migrated there for pupation.

Caterpillars encountered were collected and placed together with part of the leaf on which they were feeding in a specimen tube. The colour of the head capsule and the rest of the body was recorded at the moment of collection, including the position of the larva on the leaf. All caterpillars were kept separately, labelled fully and brought back to the laboratory for purposes of identification and description as well as rearing to the adult stages. Reference specimens were preserved in 70% ethyl alcohol or in Pampel's fluid.

2.4: Weekly scoring of cocoa flushing

An arbitrary method for scoring the flushing of chupons on cocoa trees on the four sampling sites was adopted for the eight sample blocks, i.e. the four blocks of 10 and the four blocks of 20 trees. Every week, when one of the sites was visited the degree of flushing of the 10 and the 20 trees sampled was recorded. The scores for the 30 trees were lumped and a score of 1 was given to each tree that was in flush. If all the 30 trees were in flush, a total score of 30 was obtained, which signified 100% flushing.

2.5: Larval descriptions and chaetotaxy

Head capsule widths of all caterpillars caught in the field and of subsequent moults were measured in the usual way by means of an eye-piece graticule. The greatest width was taken through and including the genal ocelli. The measurements were subsequently converted to millimetres. Identification and naming of the caterpillars was done by following Smith's (1965) key as well as larval descriptions and diagrams in Alibert (1951). In critical cases the larvae were reared to adult. Description of the larvae was based on the colour of the head capsule, dorsal shield of the prothorax, thoracic legs, abdominal prolegs, integument and setae, especially where these were present in the form of tufts as in arctiids and lymantriids. The chaetotaxy of the prothorax, sixth and eighth abdominal segments was also studied and used in describing the larvae. The preparation of larval skins for the study of setal patterns of the more important Lepidoptera was done according to the method described by Hinton (1957). Setal maps were made with the aid of a camera lucida and an eye-piece graticule. In naming the setae Hinton's (1946) nomenclature was followed. Some of the diagnostic characters suggested by Gardner (1946) and Hinton (1943) were used in the making of larval identification keys. Much more emphasis has, however, been laid on those characters of the caterpillars that can easily be seen with the naked eye or with the aid of a hand lens in the field e.g. hairiness, general colour patterns, presence or absence of prothoracic verrucae, osmeteria and prolegs on the third, fourth and fifth abdominal segments.

2.6: Rearing methods

Larvae were reared in either tall 40 x 20cm rearing cylinders, marmalade jars, or 3.5 x 10cm specimen tubes. In the first two types of rearing apparatus leaves were supplied with their petioles dipped in water contained in small cotton wool stoppered specimen tubes. In the third type, which was found very convenient, leaves were provided without water; the tubes were corked loosely to permit air to circulate. Pupae were left in their rearing cylinders till emergence.

Chapter 3: Field Observations.

3. FIELD OBSERVATIONS.

3.1: Seasonal changes in cocoa flushing

Results: It can be seen in tables 3.1 - 3.4 that at farm B few trees flushed as compared with those at the other three sites. In view of this any conclusions arrived at on the degree and pattern of flushing of cocoa trees at Aburi are therefore broadly based on what obtains on sites A, C and D only. In drawing the histogram (Fig.3.1) the actual numbers rather than percentages of flushing trees on sites A, C and D were used, those from B being excluded because it was realised that in certain weeks (Table 3.2) less than ten trees out of the thirty sampled were in flush on this site. It was felt therefore that such low numbers would affect the total pattern. There was a peak in weeks 9-12 (November-December) which was relatively small and insignificant in contrast to the latter one of weeks 21-28 (February-March). It can be noted further that there were two separate periods in which a higher number of trees on farms A and B were flushing at the same time, and this bimodal situation has come out clearly in Fig.3.2 which plots the polygons of the four sites separately. Site C and D, however, do not show this bimodality at all distinctly, though it may still perhaps be recognised as existing in the light of the position on the other two farms.

Tables 3.1 - 3.4: Weekly scoring of cocoa flushing: Numbers of trees flushing in the 10-tree and 20-tree blocks with totals, 1970-71.

Table 3.1 Site A

Date	Week	10 trees	20 trees	Total score	%
19/9	1	3	7	10	30
14/10	5	3	9	12	40
11/11	9	6	11	17	56.7
9/12	13	3	9	12	40
13/1	17	3	11	14	46.7
10/2	21	7	17	24	80
8/3	25	9	18	27	90
7/4	29	6	15	21	70
8/5	33	3	12	15	50

Table 3.2 Site B

Date	Week	10 trees	20 trees	Total score	%
25/9	2	0	6	6	20
21/10	6	2	10	12	40
16/11	10	1	7	8	26.7
18/12	14	1	5	6	20
19/1	18	3	13	16	53.3
16/2	22	4	13	17	56.7
17/3	26	6	16	22	73.3
16/4	30	4	12	16	53.3
14/5	34	3	7	10	33.3

Table 3.3 Site C

Date	Week	10 trees	20 trees	Total score	%
2/10	3	4	8	12	40
28/10	7	6	8	14	46.7
23/11	11	3	10	13	43.3
21/12	15	2	13	15	50
26 /1	19	7	16	23	76.7
23/2	23	8	16	24	80
23/3	27	7	18	25	83.3
23/4	31	4	11	15	50
20/5	35	2	10	12	40

Table 3.4 Site D

Date	Week	10 trees	20 trees	Total score	%
8/10	4	5	10	15	50
2/11	8	5	12	17	56.7
2/12	12	6	13	19	63.3
4/1	16	4	13	17	56.7
2/2	20	6	14	20	66.7
5/3	24	10	19	29	96.7
29/3	28	8	18	26	86.7
28/4	32	6	12	18	60
28/5	36	4	9	13	43.3

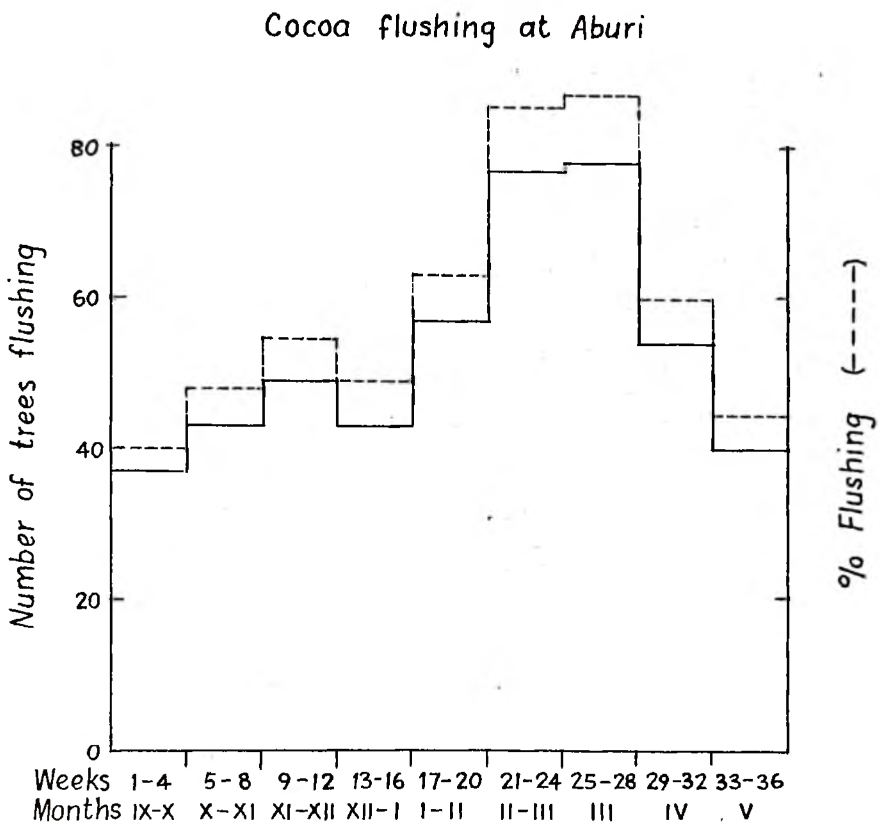


Fig. 3.1: Cocoa flushing at Aburi.

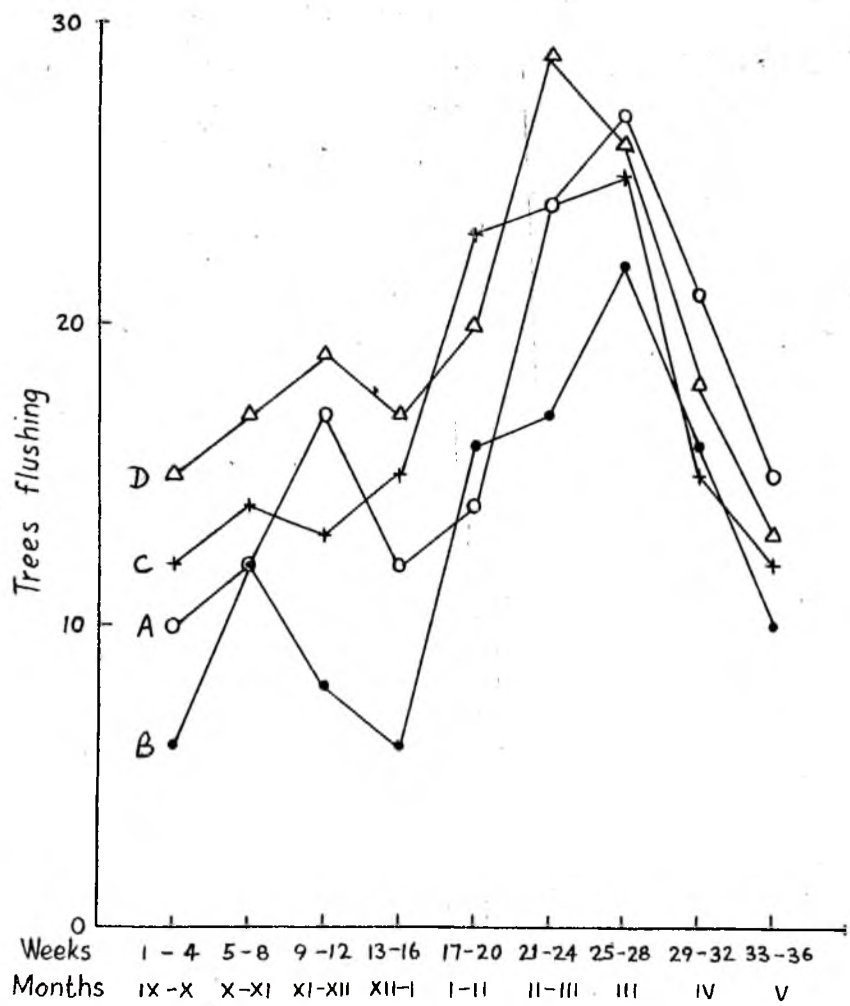


Fig. 3.2: Numbers of trees flushing on the sampling sites A,B,C and D at Aburi, 1970-71.

3.2: Seasonality of leaf-feeding lepidoptera

Results: Sampling results of the lepidopterous defoliators of cocoa at Aburi appear in table 3.5 and figures 3.3 - 3.25. Figure 3.21 gives kite diagrams depicting the distribution of the lepidoptera as percentages of the separate four weekly totals. Table 3.12 gives the record of rainfall in inches and equivalent metric units, millimetres, for Aburi for the year 1970 up to June, 1971. Rainfall figures for December, 1970 were not available at the Meteorological station. From the results it can be seen that various species could more or less be classified in the order of the times when each species was at its highest peak. For instance, there are some with early single peaks, double peaking periods and also others with relatively none, or with minor peaking.

Single early peak: Spodoptera littoralis (fig. 3.5, 3.21a) was absent in the first four weeks of sampling in September to October, only a few larvae being found between weeks 5 and 20 (October-February). The peak period of S. littoralis came in weeks 9-12 (November-December), which is at about the end of the wet sunny season and at the threshold of the dry sunny season. The average percentage distribution of this insect (fig.3.21a) in weeks 5-16 (October-January) was 6.2%, which was on the whole higher than that of some other equally less abundant caterpillars at the same period. Similarly Selepa leucograpta (fig.3.7, 3.21b) was not encountered in weeks 1-4 (September-October) but appeared in weeks 5-8, in fairly larger numbers than in the following eight weeks when there was a decline. No Selepa caterpillars

Table 3.5

The species of lepidopterous caterpillars encountered at the 4 sampling sites at Aburi, 1970-71.

	Species	Months / Weeks	IX-X 1-4	X-XI 5-6	XI-XII 9-12	XII-I 13-16	I-II 17-20	II-III 21-24	III 25-28	IV 29-32	V 33-36	Totals
	NOCTUIDAE											
1.	Anomis leona		23	21	30	44	68	115	120	94	21	536
2.	Characoma stictigrapta		7	3	11	17	28	37	43	48	13	207
3.	Selepa leucograpta		-	6	2	3	-	0	1	3	2	17
4.	Spodoptera littoralis		-	7	10	9	3	-	-	-	-	29
5.	Lophocrama phoenicochlora		2	1	2	4	7	6	3	1	-	26
6.	Earias biplaga		4	6	2	-	-	6	4	2	-	24
7.	Plusia chalcites		1	1	4	1	2	-	2	1	-	12
8.	Noctuid sp. 1		1	-	1	1	-	-	-	-	-	3
9.	Noctuid sp.2		-	-	1	-	-	-	-	-	-	1
	LYMANTRIIDAE											
10.	Euproctis xanthomelana		7	4	11	13	10	15	30	32	7	129
11.	E. melanopholis		1	6	3	5	8	8	12	20	4	67
12.	E. lepidographa		-	3	-	-	-	1	3	5	-	12
13.	E. dewitzi		-	-	3	-	-	-	3	1	-	7
14.	Orgyia basalis		3	6	1	1	2	4	8	3	2	30
15.	O. mixta		1	3	-	-	1	2	4	3	-	14
16.	Argyrostagma niobe		3	1	2	3	1	7	5	4	-	26
17.	Rhodogastria sp.		-	-	-	2	1	-	1	1	-	5

Table 3.5 (continued)

Species	IX-X 1-4	X-XI 5-6	XI-XIII 9-12	XII-I 13-16	I-II 17-20	II-III 21-24	III 25-28	IV 29-32	V 33-36	Totals
18. Lymantriid sp. 1	1	-	-	-	1	-	-	-	-	2
19. Lymantriid sp. 2	-	-	-	1	-	-	-	-	-	1
ARCTIIDAE										
20. Diacrisia auriantiaca	1	2	7	3	4	16	12	5	2	52
21. D. rattrayi	3	1	-	1	4	1	2	2	-	14
22. Diacrisia sp.	-	-	-	-	1	-	-	-	-	1
23 Arctiid sp. 1	1	-	1	-	-	-	-	-	-	2
SYNTOMIDAE										
24. Euchromia lethe	3	1	2	3	-	2	1	4	-	16
NOTODONTIDAE										
25. Graphidura sp.	-	-	1	1	-	-	-	-	-	2
GEOMETRIDAE										
26. Neocleora sp.	3	4	2	1	3	6	8	4	1	32
27. Ascotis reciprocaria	2	2	3	2	1	2	1	-	-	13
28 Colocleora divisaria	2	4	6	3	2	2	3	5	-	27
29. Hyposidra smithi	-	-	-	1	2	-	1	-	-	4
30. Geometrid sp. 1	2	-	-	-	-	-	-	-	-	2

Table 3.5 (continued)

	Species	IX-X 1-4	X-XI 5-6	XI-XII 9-12	XII-I 13-16	I-II 17-20	II-III 21-24	III 25-28	IV 29-32	V 33-36	Totals
	LYCAENIDAE										
31.	Hypokopelates eleala	-	-	2	6	-	1	-	-	-	9
32.	Lycaenid sp.1	-	-	-	1	-	-	-	-	-	1
	LASIOCAMPIDAE										
33.	Leipoxais peraffinis	-	1	5	3	1	2	-	-	-	12
34	L. rufobrunnea	1	-	-	4	-	-	1	-	-	6
35.	Lasiocampid sp.	1	1	-	-	-	-	-	-	-	2
	TORTRICIDAE										
36.	Tortrix dinota	2	3	9	5	2	11	7	5	-	44
37.	Archips occidentalis	1	2	-	1	1	-	3	3	-	11
	PSYCHIDAE										
38.	Eumeta rougeoti	7	9	8	13	15	19	37	21	16	145
39.	Psychid sp. 1	13	8	11	10	12	32	23	21	12	142
40.	Psychid sp. 2	4	4	6	3	14	21	17	8	18	95
	LIMACODIDAE										
41.	Cosuma rugosa	-	1	-	-	-	-	-	-	-	1
42.	Teinorrhyncha pyrosomoides	-	-	-	-	-	-	1	-	-	1
43.	Limacodid sp.1	-	1	-	-	1	-	-	-	-	2
44.	Limacodid sp.2	-	-	1	-	2	1	-	-	-	4
	Total individuals	100	112	147	165	197	317	356	296	98	1788
	Total no. of species	27	28	28	30	27	23	28	24	11	
	α ≃	12	10	10	10	7	4	5	4	4	

Table 3.12

Record of rainfall at Aburi for the periods January-December, 1970 and January-June 1971.

Year	Month	Rain days	Rain fall	
			inches	mm
1970	January	2	1.85	46.99
	February	3	2.30	58.41
	March	4	1.87	47.49
	April	6	4.94	125.4
	May	9	12.19	309.5
	June	8	10.04	255.0
	July	6	3.48	83.39
	August	5	1.27	32.25
	September	15	2.24	568.9
	October	15	10.11	256.7
	November	12	3.86	98.04
	December	-	-	-
1971	January	2	2.27	57.65
	February	6	4.79	121.6
	March	4	2.98	75.68
	April	5	5.07	128.5
	May	8	3.75	95.23
	June	12	9.50	241.3

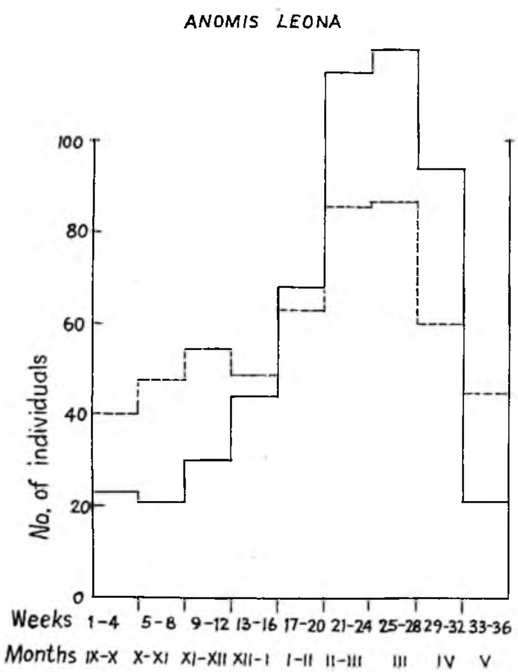


Fig.3.3

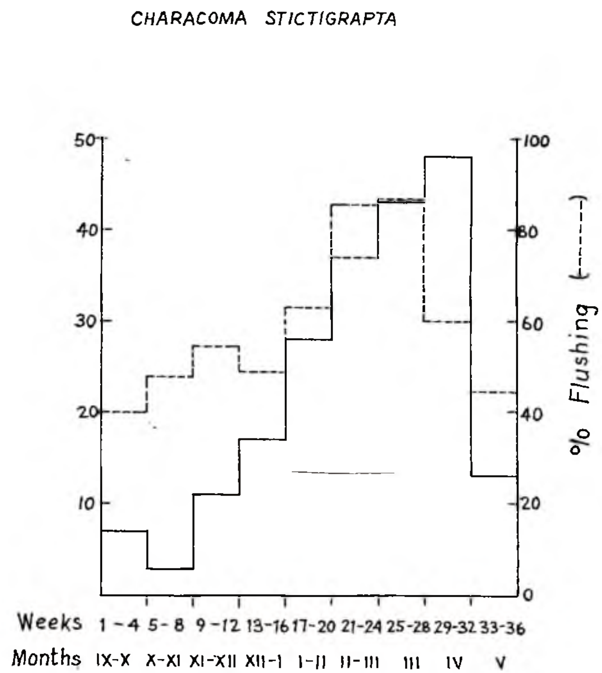
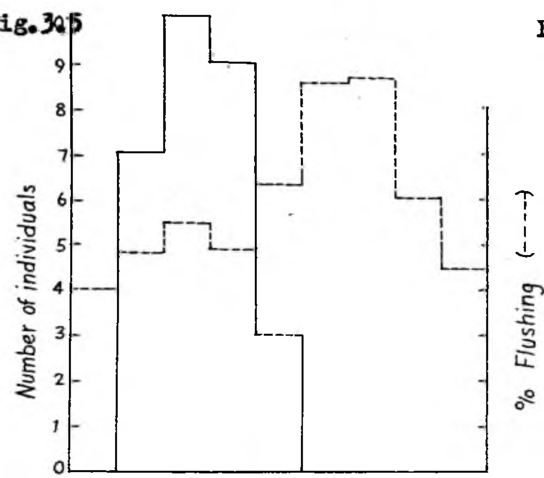


Fig. 3.4

Seasonal changes in numbers of lepidopterous larvae at Aburi, 1970-71 (solid line) and percentage flush (dashed line)

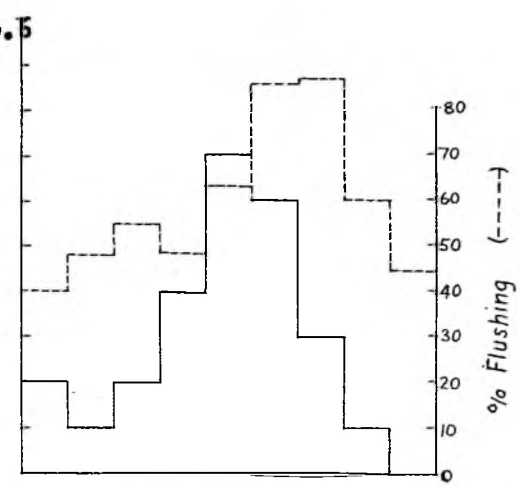
SPODOPTERA LITTORALIS

Fig.3.5



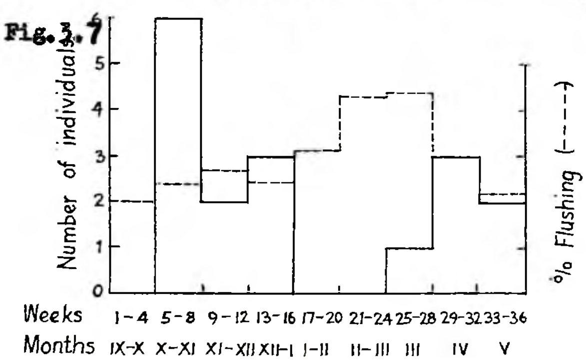
LOPHOCRAMA PHOENICOCHLOLORA

Fig.3.6



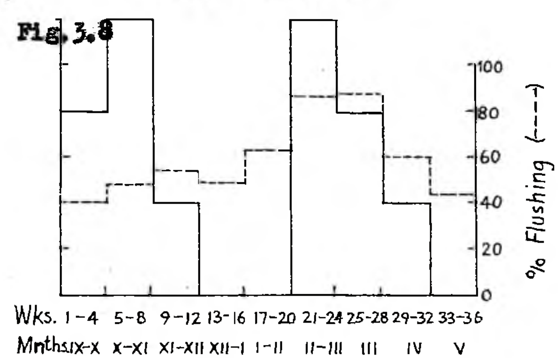
SELEPA LEUCOGRAPTA

Fig.3.7



EARIAS BIPLAGA

Fig.3.8



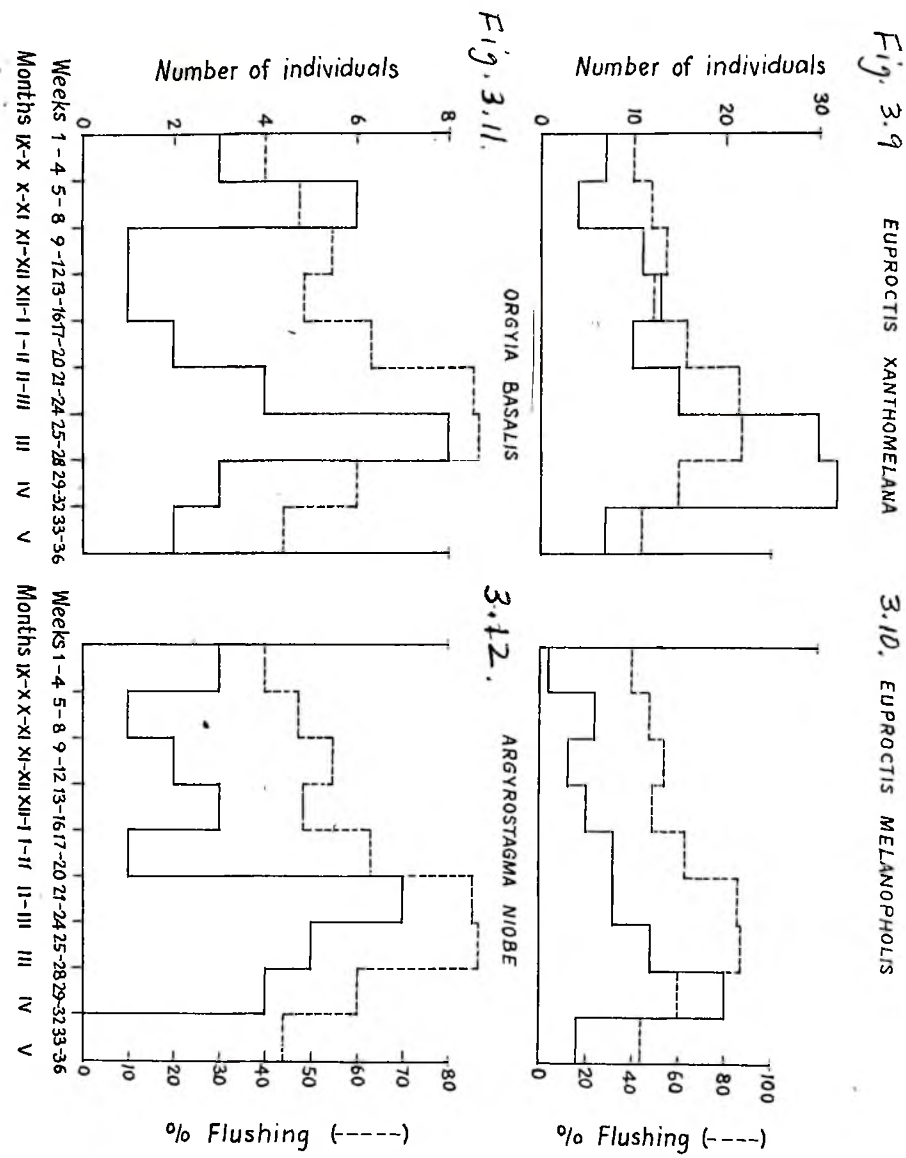
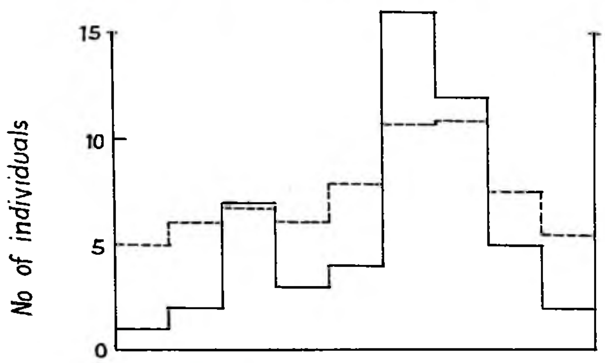


Fig. 3.9
EUPROCTIS XANTHOMELANA
3.10. EUPROCTIS MELANOPHOLIS
Fig. 3.11.
ORGYIA BASALIS
3.12.
ARGYROSTAGMA NIOBE
Number of individuals
Number of individuals
% Flushing (----)
% Flushing (----)
Weeks 1-4 5-8 9-12 13-16 17-20 21-24 25-28 29-32 33-36
Months IX-X X-XI XI-XII XII-I I-II II-III III IV V

Fig. 3.13. DIACRISIA AURIANTIACA



3.14. TORTRIX DINOTA

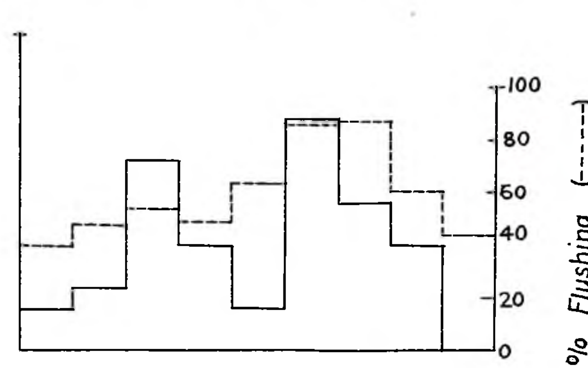
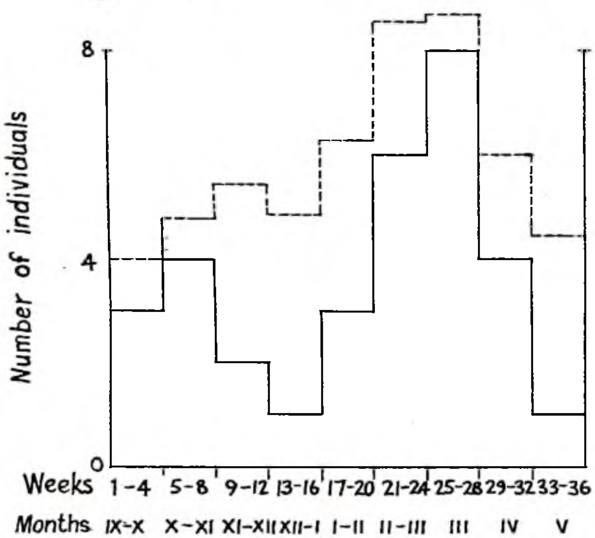


Fig. 3.15. NEOCLEORA sp.



3.16 3.16. COLOCLEORA DIVISARIA

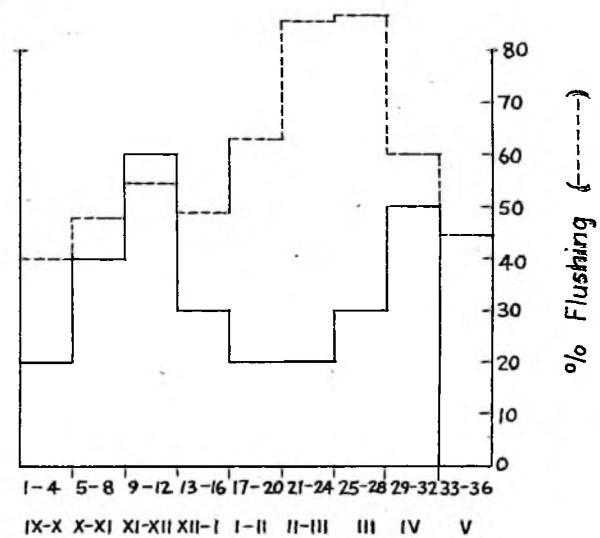
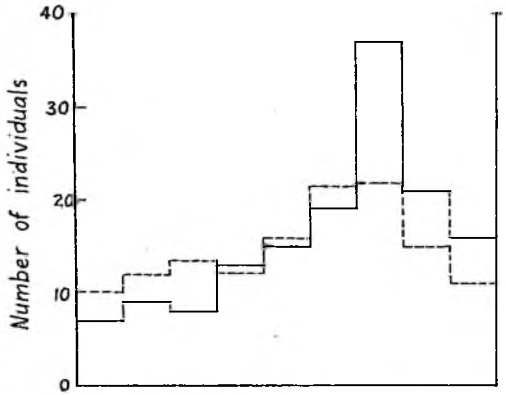


Fig. 3.17. EUMETA ROUGEOTI



3.18. PSYCHID Sp. 1

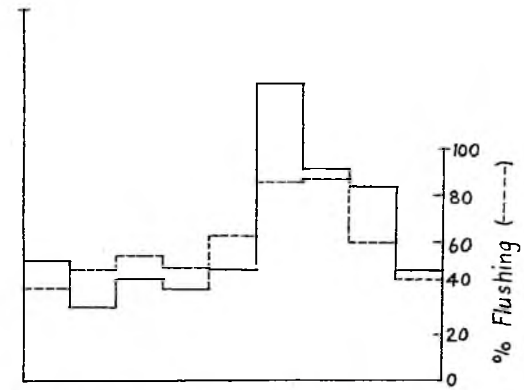
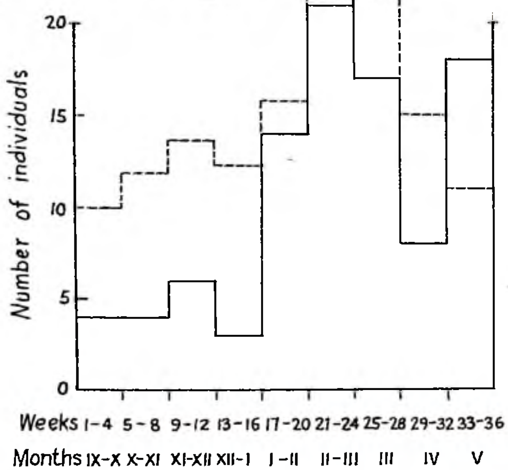
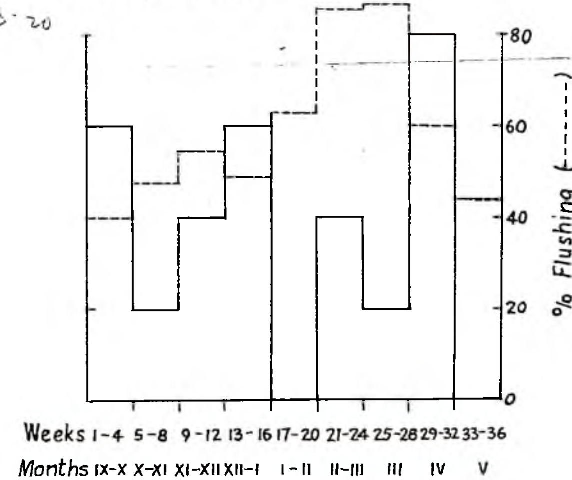


Fig. 3.19. PSYCHID Sp. 2



3.20. EUCHROMIA LETHE



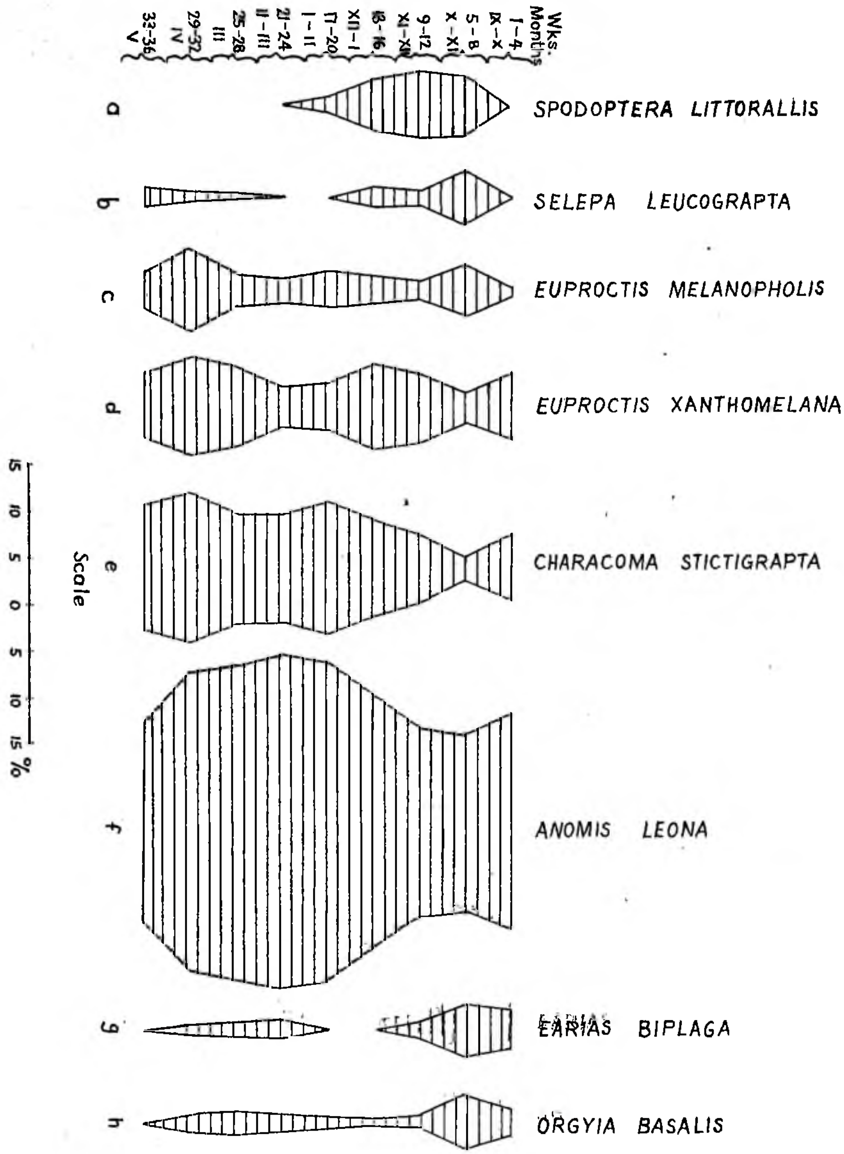
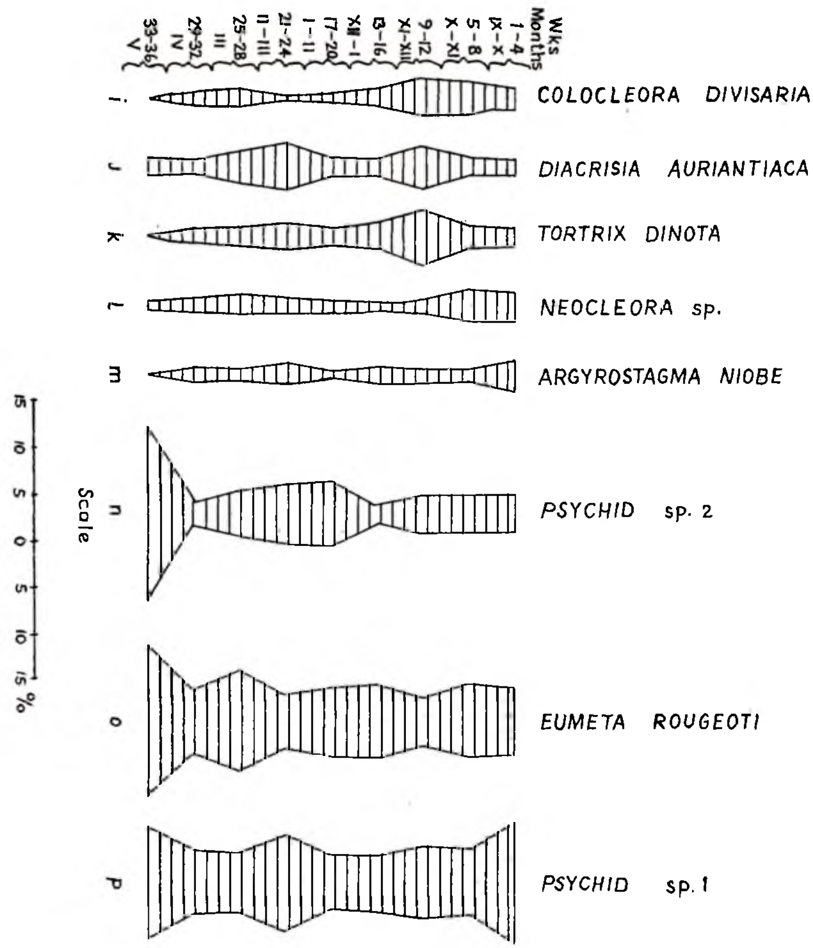
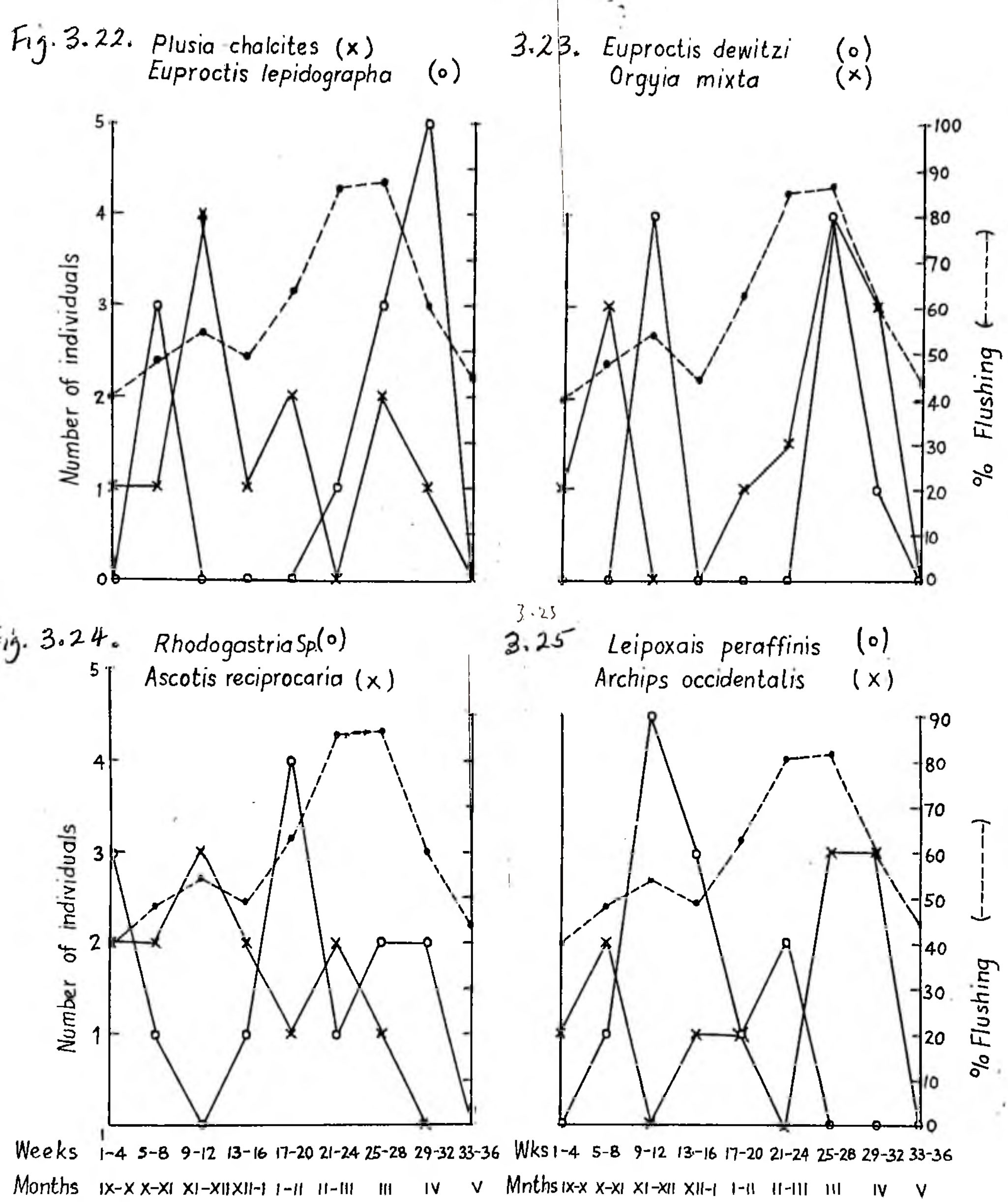


Fig. 3. 21: Kite diagram showing percentage distribution of the more important lepidopterous species at Aburi.


Wks
Months
Scale
i. COLOCLEORA DIVISARIA
j DIACRISIA AURIANTIACA
k TORTRIX DINOTA
l NEOCLEORA sp.
m ARGYROSTAGMA NIOBE
n PSYCHID sp. 2
o EUMETA ROUGEOTI
p PSYCHID sp. 1



Seasonal changes in numbers of some less important species, Aburi, 1970-71, and percentage flush (dashed line) were seen in weeks 17-24 (February-March) but smaller numbers were counted from weeks 25-36 (March-May).

Late single peak: Numbers of Euproctis xanthomelana were highest in the weeks 25-32 (March-April) well within the season of greatest flushing at Aburi (Fig.3.9). In Fig.3.21d, it can be seen that this caterpillar formed 10.8% of the total larvae sampled in April, and ranked as the third commonest lepidopterous larva in that period. Euproctis melanopholis peaked at the same time (Fig.3.10) and with 8.5% abundance rate (Fig.3.21c) was the next caterpillar after E. xanthomelana with most numerous individuals at the same period. A higher number of Lophocrama phoenicochlora individuals was seen in weeks 17-20 (February-March than in other weeks. Though the numbers of larvae sampled were not greater than ten in any week (Fig.3.6) this core is seen as representing a peak at that time. With Characoma stictigrapta (Fig.3.4) the population steadily and continuously increased with practically no drops in numbers until a peak was reached in April when 16.2% of the total number of caterpillars counted during that month were Characoma individuals (Fig.3.21e). There was a sharp slump in numbers in weeks 33-36 (May) when also at the same time fewer trees were flushing. Anomis leona on the other hand peaked a little earlier than Characoma in weeks 21-28 (February-March). Of the total number of caterpillars scored for this period, Anomis accounted for an average of 34.9% individuals (Fig.3.21f). It can be seen that among the commonly occurring caterpillars at Aburi, Anomis was by far the most plentiful.

An appreciable decline in numbers of Anomis larvae followed in April and the numbers dropped to a mere trickle in the last four weeks of the sampling period in May when it became practically impossible to get any larvae on flushes. The psychid, Eumeta rougeoti (Fig.3.17) was present in relatively high numbers throughout the period of sampling. Its highest peak was in March, and it coincided with the period of greatest flushing at Aburi when about 87% of the trees had bright red crowns. Psychid 1, too, had its highest numbers at this time (Fig.3.18).

Double-peaking caterpillars: Earias biplaga had two population peaks (Fig.3.18), the first occurring in weeks 5-8 (October-November) when flushing was about 40%. The second peak in weeks 21-24 (February-March) followed a period between weeks 13-20 (December-February) when Earias was scarcely to be found due perhaps to lower numbers of flushing chupons. Numbers of Earias gradually decreased from the second peak until May when no more larvae were seen. Psychid 2 had two periods of peaking, one in weeks 21-24 (February-March) and another in May following on a sharp drop in numbers in April (Fig.3.19). Of the total number of caterpillars sampled in May 18.7% were Psychid 2 individuals and after Anomis this psychid was the second most plentiful species in that month (Fig.3.21n).

Minor or relatively no peaking: Generally, Orgyia basalis, Argyrostagma niobe, Diacrisia auriantiaca, Tortrix donota, Neocleora sp. and Colocleora divisaria (Fig.3.11-3.16) occurred in such low numbers that it would not be meaningful to recognise as significant peaks any slight increases in their numbers. Diacrisia, however, may be an exception in that some fifteen individuals of this species were seen in weeks 21-24 (February-March) thus signifying some minor peaking (Fig.3.13). The kite diagram for Diacrisia (Fig.3.21j) also shows that this insect was commonest among the other rarely occurring Lepidoptera during that period. In like manner Tortrix could be seen as having had a minor peak at the same time as Diacrisia (Fig.3.14). The kite diagrams of O. basalis, C. divisaria, Neocleora sp. and A. niobe (Fig.3.21) show also that these Lepidoptera were frequently in low percentages of the total population counts made in the various months of the sampling period. Among the caterpillars with relatively no peaking could also be included Plusia chalcites, Euproctis lepidographa, E. dewitzi, O. mixta, Rhodogastria sp. Ascotis reciprocaria, Leipoxais peraffinis and Archips occidentalis (Figs.3.22-3.25) which were rare and were encountered only very occasionally in field. The rest of the others in this category including also those which were encountered on not more than three occasions appear in Table 3.5.

3.3: Seasonality of pod-feeding and pod-boring caterpillars

Methods: In carrying out this survey, only those pods on which live caterpillars were found at the time of inspection were scored. The others were not, even if there were signs that a pod had been freshly eaten possibly by a caterpillar found on an adjacent pod. This precaution was taken for the reason that caterpillars are not alone involved in causing this damage but also some Eumolpid beetles such as Paraivengius sp.

No sampling was done in the period December-February because, as most pods had ripened, harvesting was then fully under way, and as a result there were virtually no mature green pods available apart from very small newly-forming ones which were not inspected.

Results: Table 3.6 summarizes the results of an inspection of green pods at Aburi for pericarp damage by lepidopterous caterpillars that eat away surface tissue of pods. Table 3.7 on the other hand gives the data on the damage done by the pod-borer Characoma stictigrapta. The caterpillars that were found during this period were Anomis leona, Argyrostagma niobe and Euproctis melanopholis. The latter two species were seen on pods examined in November, March and May, while Anomis dominated the scene in the other months. E. melanopholis was found on the two pods growing on unshaded cocoa, and also on three out of the five pods in the shade during sampling in November. In March, two of the three pods had E. melanopholis while A. niobe was on the remaining one. The May sampled four pods had three Euproctis larvae in the sun and one A. niobe on shaded cocoa.

3.4: Seasonality of the pod-mining gracillarid, Marmara sp.

Methods: At Aburi pods were sampled alternately on the four sample sites through four weeks, but at both Amanokrom and Kade sampling was done intensively only occasionally and was designed to coincide with the time when pods were most plentiful, as in November, March and April. After sampling a runs test for randomness (Langley, 1968) was used to

Table 3.6

Numbers of lepidoptera found eating superficial tissue at Aburi, 1970-1971

	1970						1971					
	September		October		November		March		April		May	
	Shade	No shade	Shade	No shade	Shade	No shade	Shade	No shade	Shade	No shade	Shade	No shade
Total pods inspected	211	202	297	189	229	201	381	206	400	369	461	355
No. of pods with larvae	3	1	4	1	5	2	-	3	2	-	1	3
No. of larvae per pod	1	1	1	1	1	1	-	1	1	-	1	1

Table 3.7

Numbers of pods attacked by the pod-borer *Characoma stictigrapta* at Aburi, 1970-1971.

	1970				1971					
	October		November		March		April		May	
	Shade	No shade	Shade	No shade	Shade	No shade	Shade	No shade	Shade	No shade
Total pods inspected	295	212	289	223	393	233	494	383	472	345
No. of pods infested	148	99	116	82	101	78	156	98	199	123
% pods infested	49.6	46.7	40.5	36.7	25.9	33.1	31.8	25.5	42.7	35.6
Overall % damage	48.2		37.7		24.5		29.1		39.7	

estimate the amount of clustering of observations on each of the plots inspected. The observed distribution of runs in all plots will be random if z is less than 1.96.

Results: Table 3.8a-e give a summary of results of sampling of mature green pods at Aburi, Amanokrom and Kade for the occurrence of Marmara, the micro-lepidoptera that mines beneath the epiderm of pods. Figs. 3.26-3.28 and 3.29-3.31 are maps of parts of the plots and the farms inspected at Kade and Amanokrom respectively. The results of the runs test to estimate the amount of clustering of observations on plots II, IVe and VIII at Kade are as follows: z = 0.57, 0.32 and 0.59 respectively. The observed distribution of runs in all three plots is random because z is less than 1.96. Similarly, at Amanokrom the value of z is less than 1.96 i.e. 0.73, 0.61 and 0.55 respectively; hence the distribution of runs is also random. In Table 3.8a it can be seen that at Aburi there was a greater prevalence of Marmara at the time when more pods were available, that is, in October-November. Similarly in April-May more and more pods were being infested as they became maturer. In Table 3.8d is shown the results of an attempt at counting the larvae of the miner by carefully peeling off the raised epiderm to locate them beneath. This was, however, abandoned because it was felt that the very minute first instar larvae were possibly being missed in this way. The results do, however, show that as many as fifteen of the easily visible later instar larvae could be found on a single pod. At Amanokrom (Table 3.8b) and at Kade (Table 3.8c) more pods were infested in the fruiting season of cocoa.

3.5: Influence of shade and spraying

Methods: Sampling at Aburi, Amanokrom, Kade and Tafo was carried out with another aim also of finding out whether shade and spraying had any effects on populations of Lepidoptera. The shade regime and the spraying history of almost all the farms visited were thus recorded. For instance,

Table 3.8a

Numbers of mature green pods infested with <u>Marmara</u> at Aburi, Amanokrom and Kade

Table 3.8a

Aburi

	1970						1971					
	September		October		November		March		April		May	
	Shade	No shade	Shade	No shade	Shade	No shade	Shade	No shade	Shade	No shade	Shade	No shade
No. of pods inspected	211	273	202	298	322	313	217	364	331	295	301	299
No. of pods infested	29	88	43	91	74	112	48	99	69	107	96	111
% pods infested	13.7	32.2	21.4	30.5	23	35	22.1	27.2	20.8	36.3	25.8	37.2
Overall % infested	22.9		25.9		29		24.6		28.5		31.5	

Table 3.8b

Amanokrom, 2.IV. 71

	Farm 1	Farm 2	Farm 3	
Canopy	Good	Moderate	Poor	
No. of pods inspected	888	551	737	
No. of pods infested	118	88	202	
% pods infested	13.3	16.0	27.4	$X^2 = 41.01$

Table 3.8c

Kade, 25.III.71

	Plot II	Plot IVc	Plot VIII	
Canopy	Moderate	Poor	Moderate	
No. of pods inspected	429	596	499	
No. of pods infested	126	300	187	
% pods infested	29.4	50.3	37.5	$X^2 = 41.01$

Table 3.8d

Numbers of *Marmara* larvae on pods in Plot VIII (D.D.T. sprayed) at Kade, 15. XI.70

No. of pods inspected	319
No. of pods infested	152
% pods infested	47.6
No. of larvae in infested pods	364
Mean no. of larvae per infested pod	2.4
Range	0-15

Distribution of larvae in the 319 pods

Larvae per pod	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
No. of pods	167	64	40	24	11	3	3	0	3	0	1	1	0	1	0	1

Table 3.8e

Comparison of numbers of pods infested with Marmara on one unsprayed plot and two sprayed ones at Kade, 16.XI.70.

	Plot I		Plot IVA		Plot VI	
	Unsprayed		D.D.T. sprayed		D.D.T. sprayed	
	Shade	No shade	Shade	No shade	Shade	No shade
No. of pods inspected	266	305	312	393	201	198
No. of pods infested	58	122	114	199	72	99
% pods infested	29.3	40	36.4	50.8	35.9	49.7
Overall % infestation	34.7		43.6		42.8	

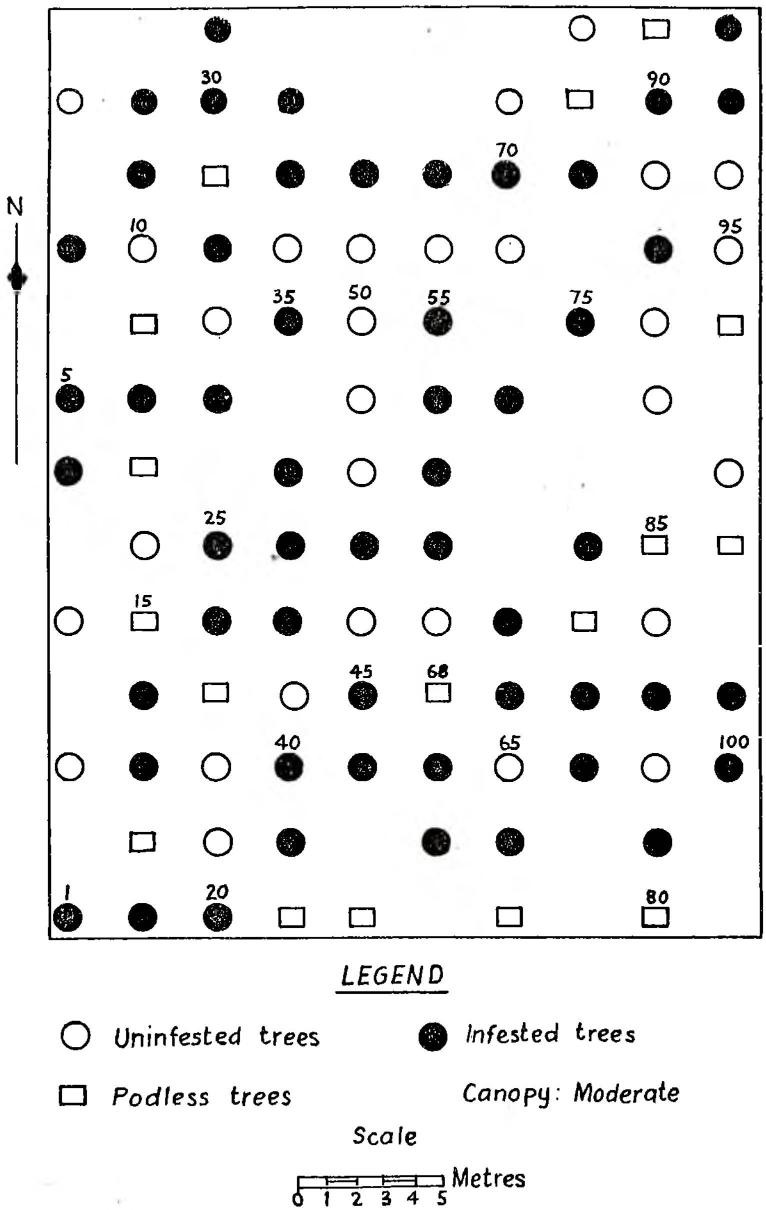


Fig.3.26: Map of trees inspected for Marmara infested on Plot II at the Agricultural Research Station, Kade, 25.III.71. Trees numbered 1-100.

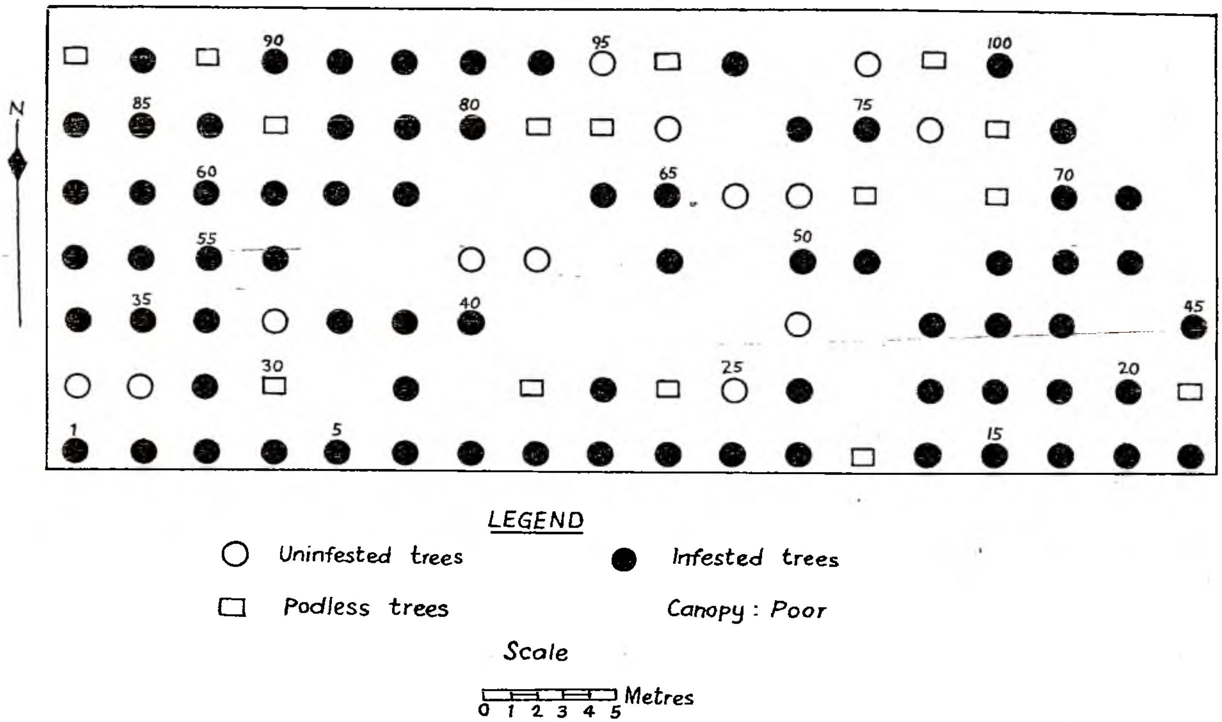


Fig.3.27: Map of trees inspected for Marmara infestation on Plot IVc at the Agricultural Research Station, Kade, 25.III.71. Trees numbered 1-100.

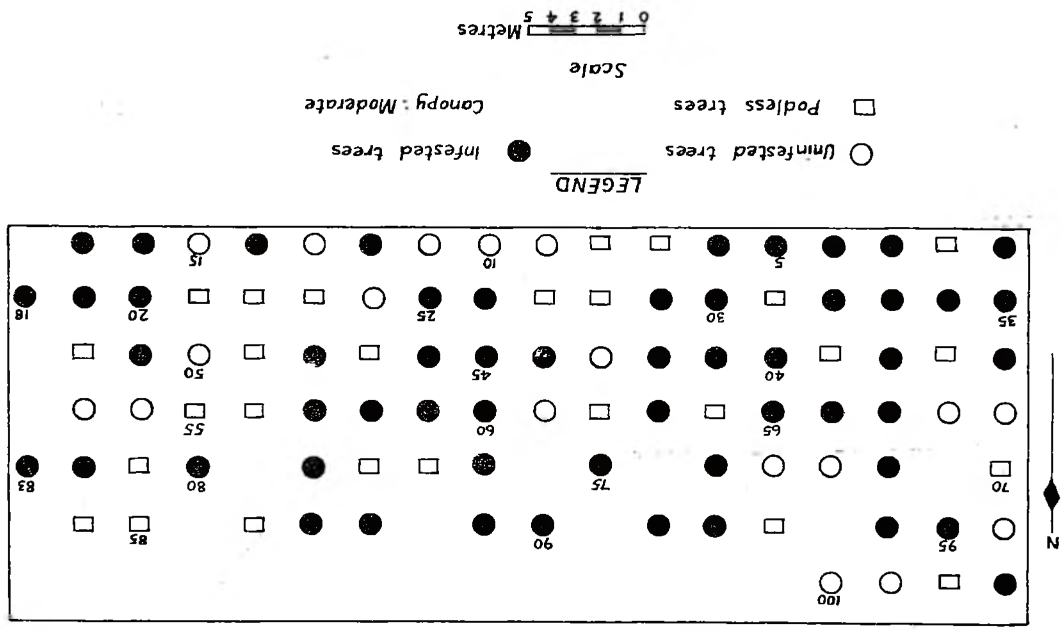


Fig.3.28: Map of trees inspected for Marmara infestation on Plot VIII at the Agricultural Research Station, Kade. 26.III.71. Trees numbered 1-100

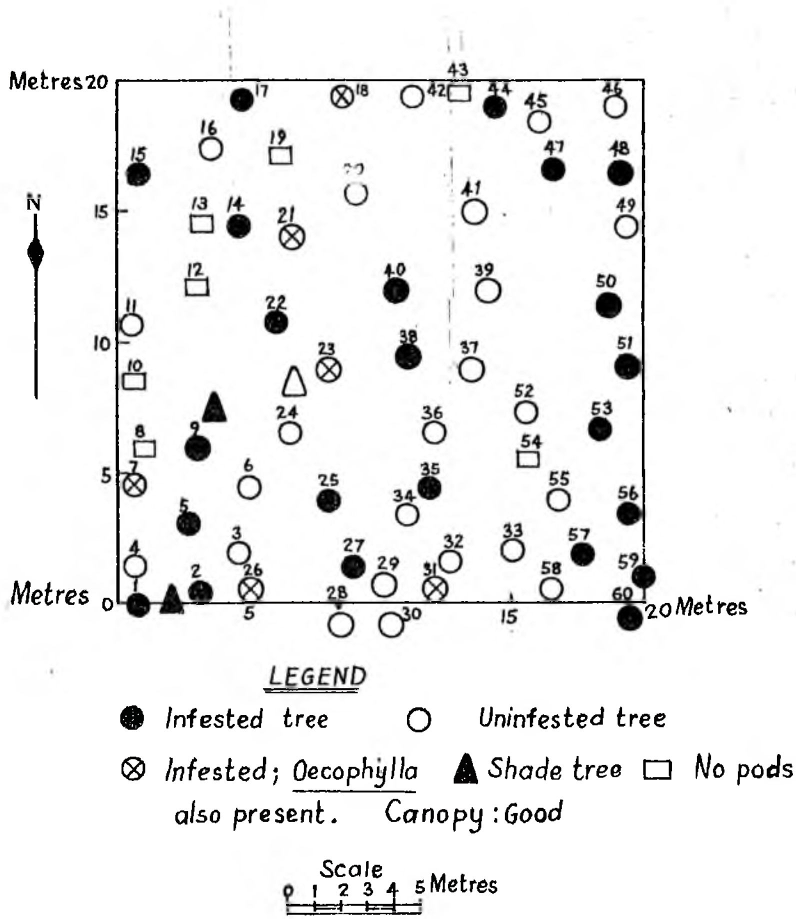


Fig.3.29: Map of trees inspected for Marmara infestation at an area of good canopy, Amanokrom, Akwapim, Eastern Region, 2.IV.71. Numbers: tree identification.

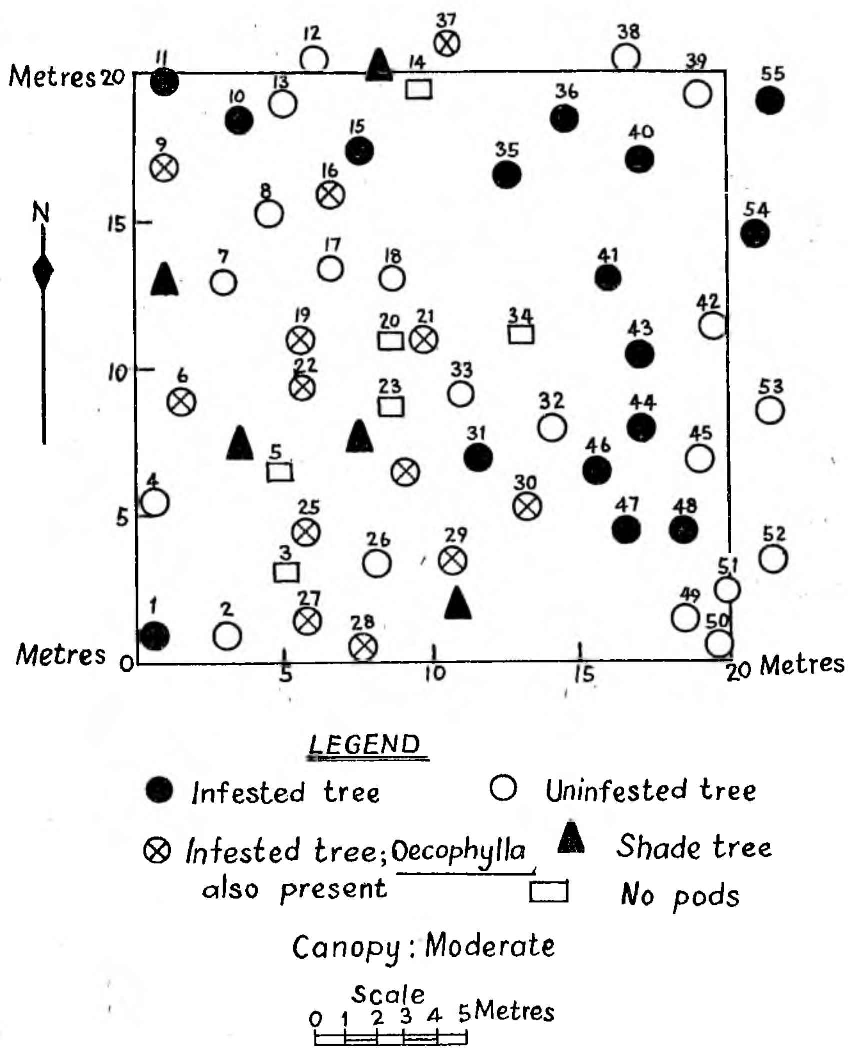


Fig.3.30: Map of trees inspected for Marmara infestation at an area of moderate canopy, Amanokrom, Akwapim, Eastern Region, 2.IV.71. Numbers: tree identification.

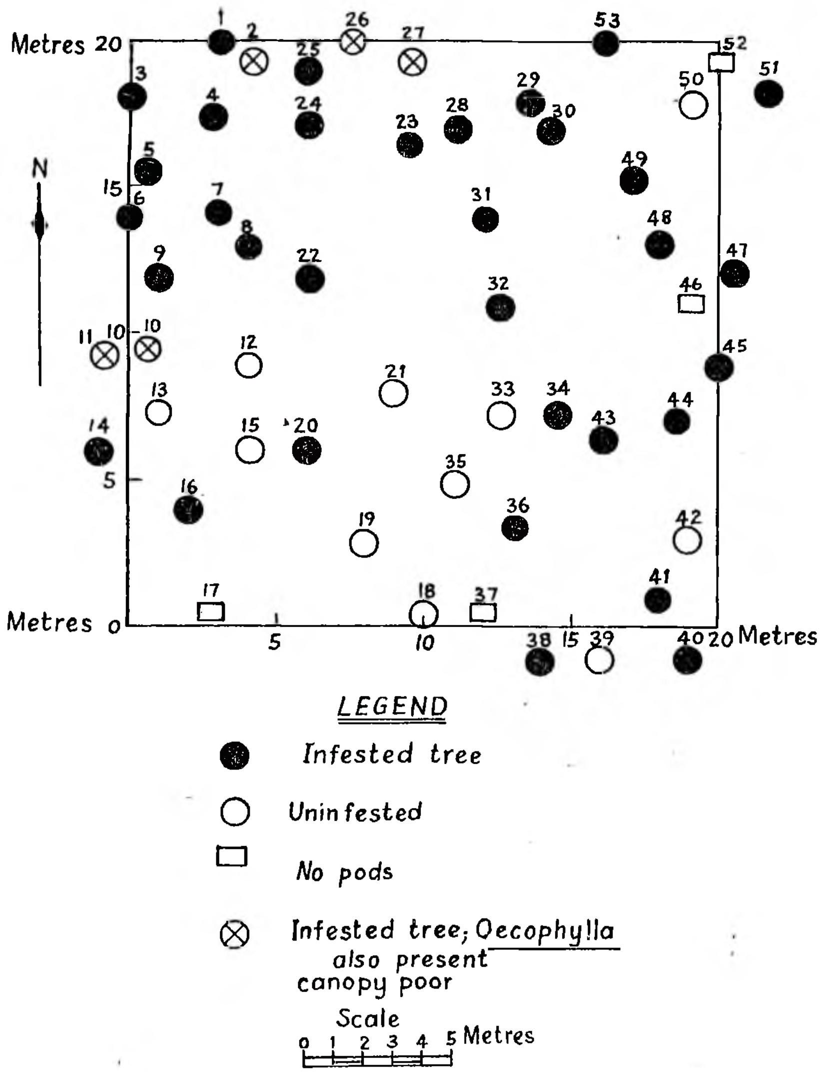


Fig. 3.31: Map of trees inspected for Marmara infestation at an area of poor canopy, Amanokrom, Akwapim, Eastern Region, 2.IV.71. Numbers: tree identification.

plots at Kade had practically all been sprayed with DDT, with the exception of plot number one, which was left unsprayed during the intensive November and February spraying operation (Table 3.11). Similarly at Tafo some experimental plots have been under routine spraying with a variety of insecticides. Farms at Aburi and Amanokrom, however, received virtually no spraying during the year. At Tafo sampling for the common Lepidoptera was done once monthly and more or less on the same lines as at Aburi. Twenty trees each were randomly selected on each of two plots, one with shaded trees and seedlings and another with little or no shade. A constant number of ten leaves per tree was inspected.

Results: In Table 3.6 with the exception of Table 3.8d, which summarizes results of a survey carried out exclusively in the shade, a distinction is made between sampling done in the shade and in the sun. Lepidoptera found eating superficial tissue e.g. Anomis leona, Argyrostagma niobe and Euproctis melanophelis (Table 3.6) occurred mostly in the shade in September-November and on poorly shaded cocoa in March and May. With Characoma stictigrapta at Aburi (Table 3.7) there is a fairly significant difference between the amount of damage done by this caterpillar to pods on shaded cocoa and those on trees with a poor canopy, though results for March show a slightly higher percentage damage to pods on unshaded than on shaded cocoa. Marmara on the other hand seems to thrive on unshaded pods (Fig.3.8a). At Aburi a greater number of pods on trees with a poor canopy was infested than those that grew on shaded trees. Similarly at Amanokrom (Table 3.8b) it is

Table 3.11

Record of dates on which DDT insecticide was applied at various cocoa plots at the Agricultural Research Station, Kade, in November, 1970 and February, 1971.

Plot	Date sprayed	Plot	Date sprayed
IV C	2.XI.70	VII	12.XI.70
IV B	4.XI.70	C.C.6&7	13.XI.70
II	5.XI.70	VI	16.XI.70
II	6.XI.70*	I X A	9.II.71
IV A	9.XI.70	VIII	17.II.71
C.C. 2	10.XI.70	IX B	18.II.71
C.C. 2	11.XI.70*	VIII	19.II.70

*Date on which spraying was done to completion.

clear that Marmara infestation in the case of trees growing in the shade is negligible in contrast to the condition on isolated trees whose pods are frequently under heavy attack from Marmara. A chi-squared test of the results gave a value 54.8, proving a highly significant association between unshaded cocoa and a high rate of Marmara infestation ($p \ll 0.1$). An almost equally high chi-squared value of 41.01 was obtained from the Kade sampling results (Table 3.8c). In Table 3.9 is shown the distribution of the more commonly occurring lepidoptera at Aburi in relation to shade categories. While C. stictigrapta, D. auriantiaca and E. rougeoti occurred mostly in shaded areas, it can be seen that the rest were found mainly in the sun. Results of sampling done at Tafo appear in Table 3.10, from which it can again be noticed that, with the exception of a few species such as C. stictigrapta, E. xanthomelana, O. basalis, D. auriantiaca and T. dinota, which were found constantly in the shade most caterpillars occurred in the unshaded plot. In Tables 3.5 and 3.10 it can be seen that regularly sprayed farms such as at Tafo and Kade showed much higher numbers of lepidoptera than the rarely sprayed peasant farms at Aburi. For instance, Anomis and Earias occurred in much higher numbers at Tafo than at Aburi in the same period. Marmara infestation at Kade (Table 3.8e) was more marked in plots IVA and VI than in plot I which had not been sprayed for a long time. Further, the incidence of Marmara at Aburi was still lower (Table 3.8a).

3.6: Seasonal changes in diversity

Results: Table 3.5 shows seasonal fluctuations in the diversity of

Table 3.9

Distribution of some of the commonly occurring lepidoptera with respect to shade at Aburi, 1970-71

Months	IX-X		X-XI		XI-XII		XII-I		I-II		II-III		III		IV		V			
Weeks	1-4		5-8		9-12		13-16		17-20		21-24		25-28		29-32		33-36		Totals	
Species	Sh	Sun	Sh	Sun	Sh	Sun	Sh	Sun	Sh	Sun	Sh	Sun	Sh	Sun	Sh	Sun	Sh	Sun	Sh	Sun
Anomis	9	14	10	11	13	17	17	24	23	45	38	77	51	72	41	53	12	9	214	322
Characoma	5	2	3	-	9	2	7	10	17	11	22	15	28	15	20	28	10	3	121	86
Selepa leucograpta	-	-	1	5	-	2	-	3	-	-	-	-	1	-	3	-	-	2	5	12
S. littoralis	-	-	2	5	3	7	-	9	-	3	-	-	-	-	-	-	-	-	5	24
L. phoenicochlora	-	2	-	1	-	2	2	2	2	5	2	4	-	3	-	1	-	-	6	20
E. biplaga	-	4	2	4	-	2	-	-	-	-	2	4	-	4	-	2	-	-	4	20
E. xanthomelana	3	4	-	4	3	8	5	8	4	6	9	6	11	19	13	19	-	7	48	81
E. melanopholis	1	-	1	5	3	-	5	-	1	7	-	8	5	7	8	12	4	-	28	39
Orgyia basalis	3	-	2	4	-	1	1	-	2	-	3	1	3	5	3	-	-	2	17	13
D. auriantiaca	1	-	2	-	5	2	3	-	3	1	12	4	9	3	5	-	2	-	42	10
Neocleora	-	3	4	-	-	2	-	1	-	3	4	2	3	5	0	4	-	1	11	21
Eumeta rougeoti	4	3	6	3	2	6	8	5	11	4	7	12	24	13	9	12	11	5	82	63
Total	26	32	33	42	38	51	48	62	63	85	99	133	135	146	102	131	39	29	583	711

Table 3.10

Distribution of some of the commoner species of Lepidoptera with relation to shade at Tafo, 1970-1971.

MONTH	SHADE	ANOMIS	EARIAS	CHARACOMA	SPODOPTERA	LOPHOCRAMA	PLUSIA	SELEPA	NEOCLEORA	COLOCTEORA	EUPROCTIS XANTHOMELANA	E. MELANOPHOLIS	O. BASALIS	D. AURIANTIACA	TORTRIX	EUMETA	TOTAL
Oct	-	9	11	3	10	13	1	4	1	1	2	-	-	1	2	-	58
	+	6	3	6	5	1	-	-	5	4	4	1	-	4	5	2	46
Nov.	-	8	14	2	12	5	1	1	7	-	4	4	1	5	1	1	66
	+	11	5	6	2	-	-	-	4	-	-	-	4	2	1	4	39
Dec.	-	10	7	2	6	1	-	1	1	4	1	-	1	-	-	2	36
	+	12	4	9	2	2	-	-	-	-	-	-	4	5	1	6	45
Jan.	-	15	12	5	-	5	-	-	2	1	1	-	-	-	-	4	45
	+	7	3	9	-	-	1	1	-	-	1	1	-	1	-	1	25
Feb.	-	8	15	-	-	6	-	-	4	1	1	1	-	-	1	6	43
	+	2	3	7	-	1	-	-	-	-	-	-	-	5	2	1	21
Mar.	-	13	9	3	-	5	-	-	1	-	-	-	1	-	-	7	39
	+	6	4	8	-	2	-	-	0	1	2	-	-	3	-	3	29
Apr.	-	7	13	-	-	11	-	1	5	2	-	-	2	1	1	-	43
	+	5	8	5	-	3	-	-	3	-	-	-	-	-	5	-	29
May	-	10	16	2	-	6	-	-	1	-	-	-	-	-	1	1	37
	+	7	9	9	-	2	-	-	2	-	4	-	1	3	-	-	37
Total	-	80	97	17	28	52	2	7	22	9	9	5	5	7	6	21	367
	+	56	39	59	9	11	1	1	14	5	11	2	9	23	14	17	271

species of Lepidoptera that were found at Aburi during the period of sampling. Figs. 3.32-3.34 are histograms depicting the number of species in separate four-weekly scores each of weeks 1-4 (September-October), 21-24 (February-March) and 25-28 (March), when the number of individuals ranged from 23-1, 115-1 and 120-1 respectively. The resulting curves approximate to log normal distribution curves as the number of individuals per species gradually thins down to two or one individual as the rarer species show up. The index of diversity was not calculated but was read off from Williams (1964).

<u>Discussion</u>: This index of diversity parameter, α , has been used by many authors in comparing different trap catches of Lepidoptera either at various sites or in different seasons (Williams, 1964; Owen, 1969). It can be seen from the results that there was a greater variety of species in weeks 1-4 (September-October) in spite of the fact that there were fewer individuals, as compared with weeks 21-24 (February-March) when individuals were more plentiful, about three times as much as in September-October, yet the number of species was very low and not very diversified. Similarly, in Sierra Leone, Owen (1969) found that diversity was high when sphingids were least abundant and low when they were most abundant. The largest numbers of sphingids occurred with the onset of the rains in May-June but there was only a small increase in the numbers of species and a drop in diversity. At Aburi numbers of caterpillars increased during the flushing season of cocoa in weeks 21-24 (February-March) but there was

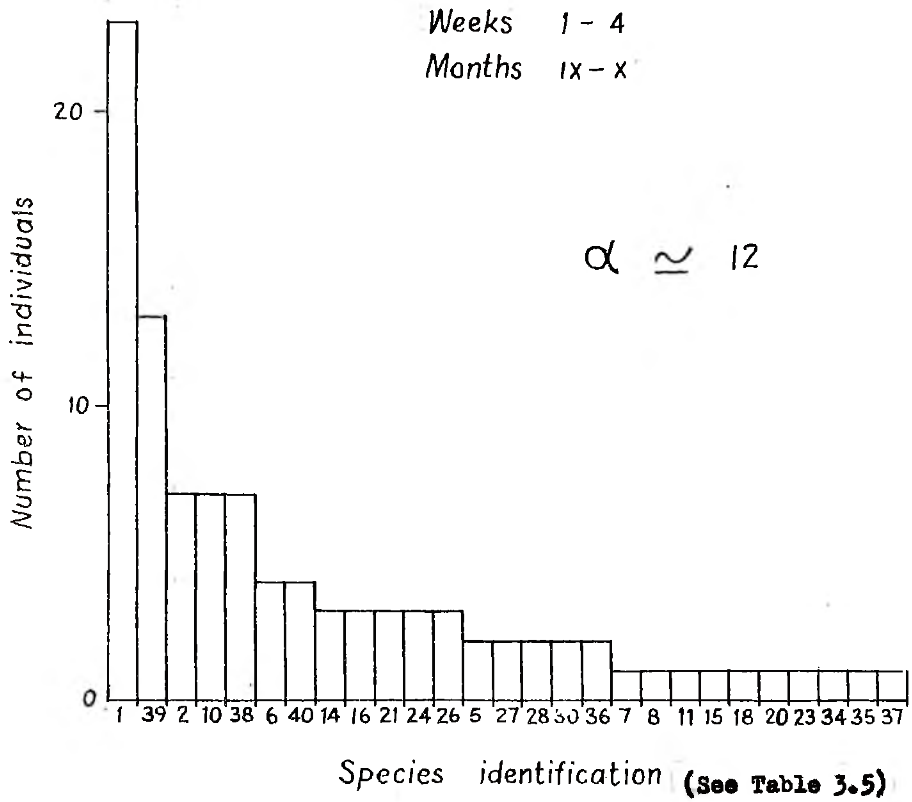
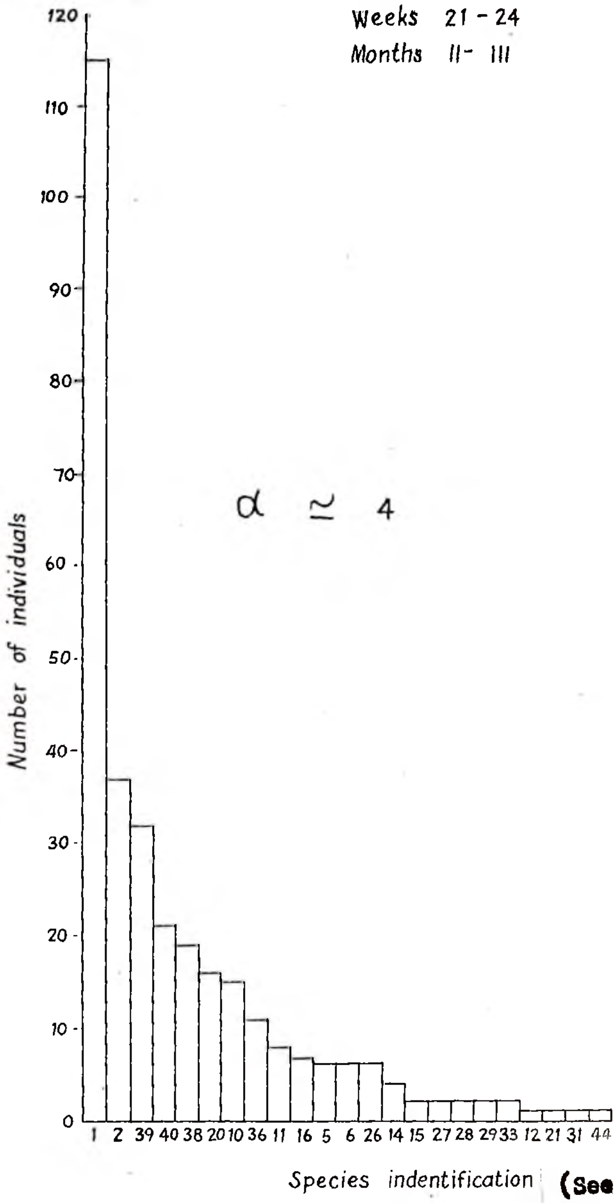
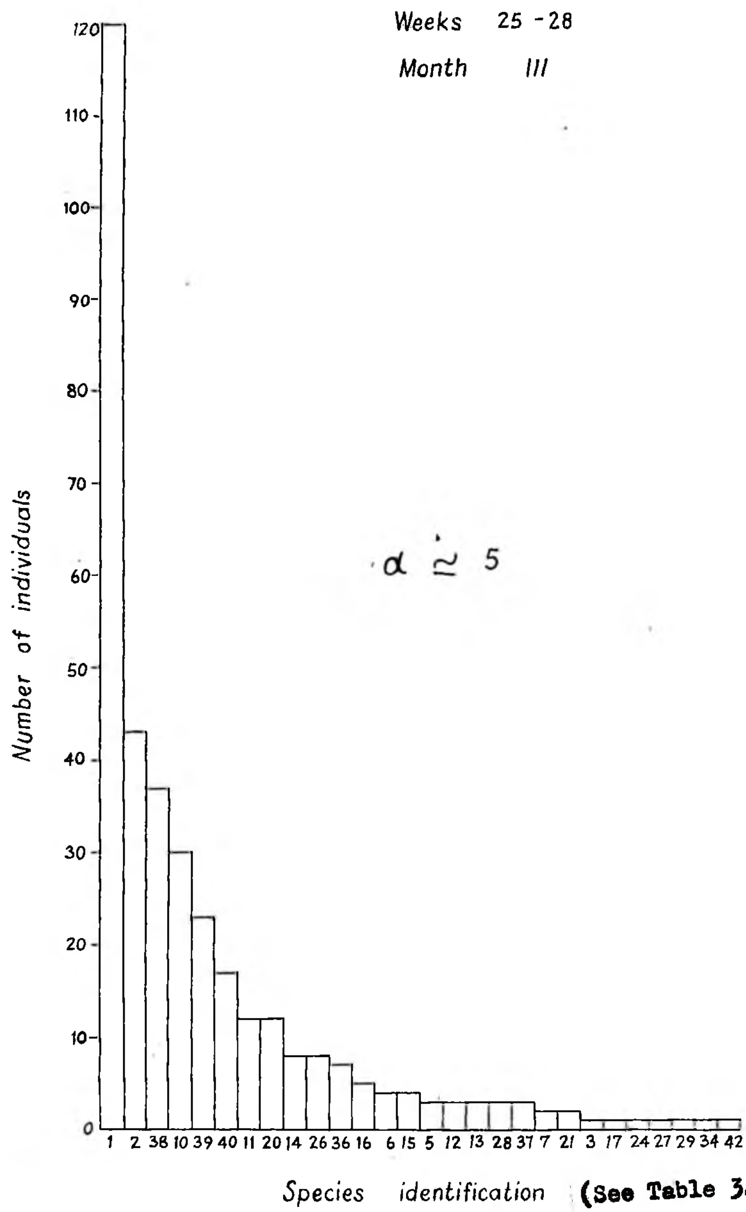


Fig. 3.32: Diversity of species of lepidopterous larvae at Aburi in September-October 1970



(See Table 3.5)

Fig.3.33: Diversity of species of lepidopterous larvae at Aburi in February-March, 1971.



(See Table 3.5)

Fig.3.34: Diversity of species of lepidopterous larvae at Aburi in March, 1971.

no appreciable increase in the number of species and diversity was low. From the results it could be concluded that species diversity is inversely correlated with abundance of individuals in a tropical environment (Owen, 1969) in contrast to temperate conditions (Williams, 1964) where diversity increases with seasonal abundance of individuals. The biological explanation for this inverse correlation between species diversity and abundance of individuals at Aburi is likely to be that when flushing was low especially in the drier parts of the year the majority of caterpillars that normally feed on flush leaves became very scarce while the other group of caterpillars which feed mainly on hardened leaves, such as Psychids, Limacodids, Lasiocampids, and Notodontids were commoner. The latter group, probably because of their fairly large size or in the case of Psychids, the added weight of the cases they carry, may prefer harder and more robust leaves to support their weight. The soft pliable flush leaves may not be suitable in this respect. It should be noted, however, that though the flush-eating Lepidoptera were relatively few in the dry season their numbers were still higher than those of, say, the Limacodids, Lasiocampids, and Notodontids, which on the whole were rarely represented by more than one individual.

3.7: Seasonal migration in butterflies

Early in April, about the middle of the wet sunny season, *Libythea labdaca* (Libytheidae) was seen in large numbers flying southwards near Aburi, Amanokrom and Koforidua districts. The butterflies avoided the forests and cocoa farms and flew in the clear of highway. As far as could be ascertained (Leston, 1971) L. labdaca is in no way connected with cocoa, and has been included here for the reason that it shows a migratory pattern directly geared to the seasons of the year. Farquharson (1922), Leston (1971) and William (1930, 1958) have reported that L. labdaca is a regular migrant in West Africa, migrating from the Northeast towards the south in the two wet sunny seasons. It returns flying to the North towards the end of the rainy season.

Chapter 4: Experiments with caterpillars.

4. EXPERIMENTS WITH CATERPILLARS

4.1: Food preferences

Methods: A few experiments were performed in the laboratory to find out whether cocoa leaves, especially flush leaves which are almost always preferred by leaf-eating caterpillars, have any substances in them that attract caterpillars. In the first experiment flush and green tender leaves of cocoa were used. They were crushed separately in a mortar and thereafter small pieces of Whatman No.1 filter paper were soaked in the resulting liquid pulp, and then used in place of actual leaves as food for caterpillars. Eleven caterpillars, namely five Anomis leona, one Neocleora sp., two Diacrisia auriantiaca and three Euproctis xanthomelana were used in the test. The caterpillars which had first been starved for about 12 hours were divided into two groups such that one group received the flush-soaked filter paper and the other group the green-leaf-soaked paper. Medium sized glass bowls, were turned over the caterpillars and the soaked filter papers to restrict the movement of the former. Caterpillars were either placed directly onto the soaked filter papers before covering them or at some distance from the papers. Observations were made at 5 minute intervals.

Results: It was soon observed that the caterpillars that had been placed directly onto the flush-soaked paper, namely, two Anomis larvae and one Neocleora after crawling or looping on the flush-soaked paper for about three minutes, stopped to eat off small notches at the edges of the paper. On the other hand Diacrisia, a naturally fidgety and active caterpillar, never settled on the paper for any length of time, but just moved about alongside the rim of the overturned bowl. On re-encountering the soaked paper, however, it paused for a while and brought its mouth parts and antennae close to the paper without starting to eat. After this it continued wandering around until after about five minutes when it stopped moving and remained at one place. It quickly moved off when disturbed.

The same caterpillars after being starved for a further three hours were placed a few centimetres away from the flush-soaked paper to see whether they would move in its direction. One of the Anomis larvae, after crawling about for about three minutes was seen to approach the soaked paper. Without climbing on to it it started to eat a small part off the paper from the side. It did not stay long at the paper. It left to move about a little, but finally came to rest at one spot not far from the paper and remained there for over six minutes. The other Anomis eventually reached the filter paper, its final arrival at the paper being seemingly undirected. It climbed onto the paper, first walking across it towards the edges along which it moved keeping its mouth parts and antennae very close to the paper. It began to eat the paper for about three minutes after which time it had eaten a sizeable area. It remained on the paper for a long time but did not continue eating. Neocleora remained quiet at one place after taking a few short "loops" around, but not in the direction of the soaked paper. It straightened itself into its characteristic stick-like stance with its thoracic legs folded against the ventral part of the thorax. It was prodded several times to encourage it to move so that it would eventually approach the flush-soaked paper. After taking a few loop-walks about it stopped at one place and assumed a half-loop or twig-like resting poise. Finally it was moved to within 1cm of the paper and watched for its reaction. Without actually climbing onto the paper *Neocleora* started to nibble at the margin of the paper and eventually ate away fairly large portions. *Diacrisia* as usual first scurried about for some time and seemed to be attracted towards the flush-paper which it first felt with its mouth parts and antennae after reaching it and then quickly passed on again without eating any part of it.

The second group of caterpillars namely three *Anomis* larvae and one *Diacrisia* were each given green-leaf-soaked papers under similar conditions as for the first group. When placed flush on the paper one of the three *Anomis* larvae began to eat the paper; the other two moved about on the paper or occasionally got off and moved about under the bowl. Alternatively, they remained at one place either on the paper itself or off it. *Diacrisia* immediately moved off the paper and started its usual energetic rovings. It did not eat the paper even after feeling it for some time on re-encountering it.

After an hour the caterpillars were removed from under the bowl and kept in large specimen tubes for about two hours without food. Fresh green-leaf-soaked filter papers were prepared and the procedure repeated with the caterpillars placed a few centimetres away from the papers. *Diacrisia*, still fairly active, was seen to reach the paper earlier than the others but it did not appear as if it were attracted towards the paper. It started to feel it and ended up eating small areas along the margin. It kept at this intermittently for about three minutes before moving away again in the usual fashion. One of the Anomis larvae on reaching the paper climbed onto it, moved along its margin and stopped for a few minutes to eat some of the paper. It moved onto another part of the paper where it again nibbled at the paper.

When the second Anomis eventually arrived at the paper it began to feel the paper in the usual way after which it ate some parts of the paper. The third Anomis remained stationery at one spot for a long time and wriggled violently when prodded in an attempt to get it moving. It was later realized that it was in the process of moulting. It was therefore removed and placed in a large specimen tube and left there until it had completely moulted. When placed on a green-leaf-soaked paper this freshly moulted larva immediately started to eat and kept at it for about three minutes. It continued to eat also when transferred to a flush-soaked paper. The two Anomis larvae that were on the green-leaf-soaked paper made no further attempts at eating the paper, although they kept on feeling it as they moved about on its surface.

The Euproctis xanthomelana larvae at first made feeble attempts at feeding on the flush-soaked paper, biting off small areas at the margins, but were apparently unmoved by the green-leaf-soaked paper. These caterpillars, however, became increasingly lethargic and when examined under a dissecting microscope it was found that they were heavily parasitised.

4.2: Selection of feeding leaves

Methods: In the second series of experiments an attempt was made at finding out whether the caterpillars selected the kinds of leaves they fed on.

This time the feeding material was given in four different combinations: a, b, c and d. First, the leaves including the soaked filter papers were numbered serially as follows:

(1) Flush-soaked paper,

(2) Green-leaf-soaked paper,

(3) flush leaf and

(4) Green tender leaf.

The caterpillars were presented with these in turn as shown below. (Table 4.1). Four Anomis and four E. xanthomelana larvae which had been initially starved for about 12 hours were used in the experiment. Observations were made after every five minutes for one hour. Two caterpillars were used with each combination of the feeding material prepared. The variously combined treatments were presented alternately so as to afford better observation. Four rectangular plastic dishes with lids were procured, in which the various food materials were placed in such a way that they could be suspended in a triangular array from cords such that their free ends touched the base of the dish to enable caterpillars to climb onto them with ease.

Results: Two Anomis larvae were placed in the dish with combination a and watched for their reactions. First the caterpillars moved about at the base of the dish. After about two minutes one of the larvae

Table 4.1

The four different combinations in which the feeding materials were presented to caterpillars.

Combinations

a	b	c	d
1	1	1	2
2	2	3	3
3	4	4	4

reached the flush-soaked paper and after feeling it for some time it climbed onto it and began eating the margins. The second Anomis climbed onto the flush leaf on which it first moved along its edge for a little less than one minute before starting to feed on it near the petiole. After about twenty-five minutes both larvae had eaten fairly large areas from the various feeding substances chosen except that the caterpillar on the flush-soaked paper had not eaten very much in comparison with the other. After another 35 minutes the larva on the flush leaf had almost eaten the whole leaf up leaving only part of the midrib and a few veins uneaten.

For combination b two E. xanthomelana caterpillars were used. Instead of climbing directly onto the leaf or paper first encountered these moved about for some time, then from one leaf or paper to another before finally settling on one. One of them climbed onto the green tender leaf and walked along its margin bobbing its head up and down, and feeling the leaf with its antennae and mouth parts. It descended again without having eaten any part of the leaf. It moved about for a few minutes until it came into contact with the green-soaked paper from which it also descended after being on it for a little less than a minute. It then stopped at one spot without moving, for about four minutes. The second E. xanthomelana mounted the flush-soaked paper, fed on it continually for about two minutes, climbed down again and moved about for a minute before encountering the green tender leaf on which it fed and rested for over fifteen minutes. The first

E. xanthomelana was seen to move straight towards the flush soaked paper as if it were attracted. It fed on the paper for some time and remained feeding on it intermittently till the end of the one hour observation period.

One Anomis and one E. xanthomelana were used in combination c. It was soon observed that both caterpillars moved in the direction of the flush-soaked paper and flush leaf respectively. Anomis fed on the paper for some time and then moved off and after briskly wandering about it finally reached the green leaf. It did not climb onto this but ate away small areas from it while standing on its prolegs at the base of the dish. E. xanthomelana remained feeding on the flush leaf till the end of the one hour of observation time.

For combination d one Anomis and one E. xanthomelana larvae were used. It was interesting to note that Anomis first made feverish searching movements by swaying its anterior end from side to side as well as by keeping its antennae close to the base of the dish. When it encountered the flush leaf it climbed onto it and began to feed on it ravenously. E. xanthomelana remained at one spot for some time before moving in the direction of the flush leaf, on which Anomis was already feeding. It began feeding on it too, slowly moving up towards the petiolar end on the margin opposite to that on which Anomis was. As feeding progressed a point was reached when the two larvae touched. Anomis immediately wriggled off the leaf and fell to the bottom of the dish where it continued to writhe for some time. According to Minnich (1925) this kind of behaviour is likely because certain non-hairy caterpillars are very sensitive to touch. It paused for a while, then moved about a little, until it reached the green leaf on which it fed. The results of the above experiments are summarized in Table 4.2 below. The plus sign signifies those leaves and papers which were either wholly or partially eaten.

4.3: Discussion

From the experiments (Table 4.2) it can be seen that green-leaf-soaked papers were not touched nor were there any larvae that moved in their direction. The general behaviour of the caterpillars, that is, their active use of antennae and mouth parts seems to suggest that the caterpillars depend to a certain extent on some odour probably emitted mainly by the flush leaves. Wigglesworth (1965) states that the sense of smell is of some importance in caterpillars. When, however the various cocoa leaves used in the experiment were smelled to find out whether any scent was given off by them none could be detected. Further in this connection Wigglesworth (1965) does mention that the scents in question may not be perceptible to man, although, on the other hand, Dethier (1937) feels that the relationship between the olfactory thresholds of man and caterpillars remain the same for practically all odorous substances; plants that appear odourless to man are probably odourless to caterpillars. The question remains then as to how caterpillars that feed on flushes distinguish them from other maturer leaves. It is still possible that the flush leaves of cocoa contain some odour slightly different from, though related to, that of other cocoa leaves, which attracts caterpillars more. It is

Table 4.2

Apparent selection by caterpillars of feeding material presented in four different combinations to them.

	Feeding material presented to caterpillars			
Combinations	Flush soaked paper	Green-leaf soaked paper	Flush leaf	Green leaf
a	1	2	3	4
a	+	-	+	
b	+	-		+
c	+		+	+
d		-	+	+

Caterpillars used:

For a, c and d: *Anomis leona* and *Euproctis xanthomelana*

For b: *Euproctis xanthomelana* only.

worth noting, too, that larvae placed some distance away from the leaves never seemed to be attracted towards the leaves from that distance as judged by their initial non-directional wanderings before reaching the leaves. This may be explained by the fact that the sense of smell in caterpillars has a short range, which is correlated with the fact that they move about with their olfactory receptors, the antennae, exceedingly close to the source of the stimulus, the leaf (Dethier, 1937). Alternatively, however, contact chemoreception, a sense fairly distinct from smell and functionally concerned principally and immediately with the act of feeding are possibly stimulated as soon as the caterpillar has mounted the leaf. Though the regions concerned with contact chemoreception lack easily recognized sense organs to which a chemoreceptive function can be confidently assigned, Dethier (1937) and Dethier & Chadwick (1948) observed that longer and shorter thin-walled spines are the only types of sense organs common to the epipharyngeal and hypopharyngeal surfaces of the preoral cavity in lepidopterous larvae. Since these were the only areas which yielded a response to contact chemical stimulation, they concluded that one or both are among the specific receptors involved; the removal of antennae was without effect. In the foregoing experiments it was seen that in a number of cases the caterpillars placed some distance away from the leaves wandered around without shwwing signs of being attracted towards the leaves or soaked papers. They might possibly have been responding to other external stimuli such as light, moisture and gravity, rather than to odours, if any, given out by the leaves.

It would appear therefore that direct contact with the leaf is necessary before feeding actually starts; smell probably plays a minor role.

Chapter 5: The identification of larvae.

5. THE IDENTIFICATION OF LARVAE

5.1: Larval descriptions

Methods: The main aim was to provide means of identification of caterpillars in a form suitable for use by field assistants. In describing the various commonly occurring species of lepidopterous larvae (Table 3.5 and Fig.3.21) attention has thus been paid mainly to obvious characters such as hairiness, colour of head capsule, integument, setal tufts and thoracic legs, and the shape of the body where it seemed to deviate from the normal, uniformly cylindrical form. The chaetotaxy of the various species was also studied, and the segments used for this study were the prothoracic, the sixth and the eighth abdominal segments. In hairy larvae the chaetotaxy of the prothorax was not studied. Figs.5.1a-b are general diagrams of the chaetotaxy of the prothorax and abdomen of an unhairy caterpillar. Fig.5.2a-b shows the arrangement of verrucae or setal tubercles on an abdominal segment of a hairy larva. In the descriptions that follow reference will be regularly made to these diagrams, except in cases where the setal patterns are different from the ones depicted in the above diagrams, such as in _Earias biplaga_, where certain setae arise at apices of fleshy projections. In such instances separate diagrams have been provided for clarity. The names of the setae proposed by Hinton (1946) appear in Table 5.1 together with other abbreviations used in the text. In order to distinguish the setae of the caterpillars, it was necessary to stain and mount the cuticle as described

5·1

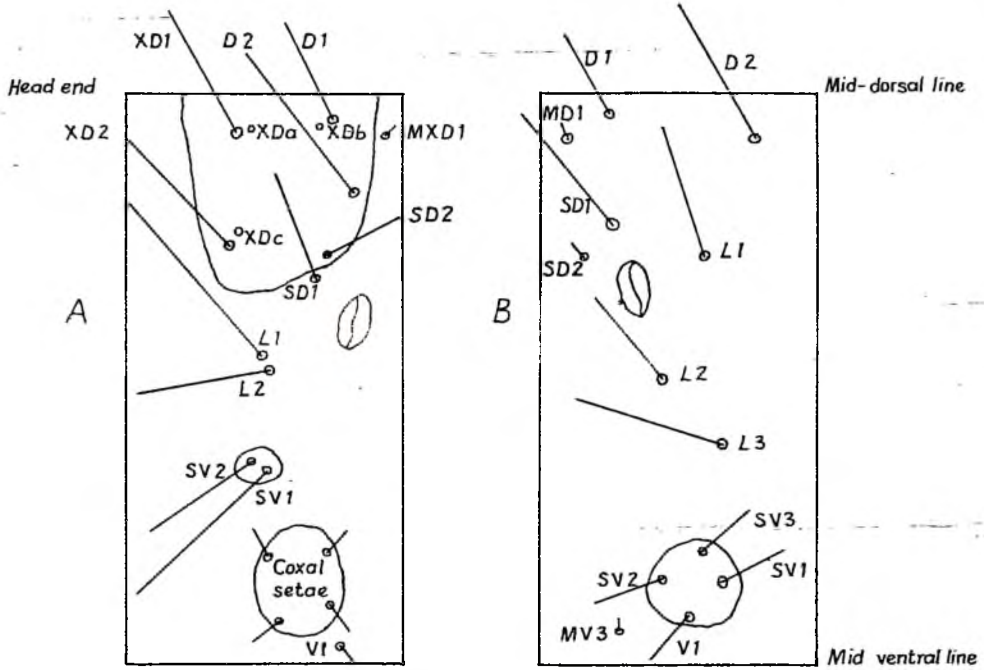


Fig.5.1 : Diagrams of the chaetotaxy of the prothorax (left) and abdominal segments (right) of a glabrous caterpillar.

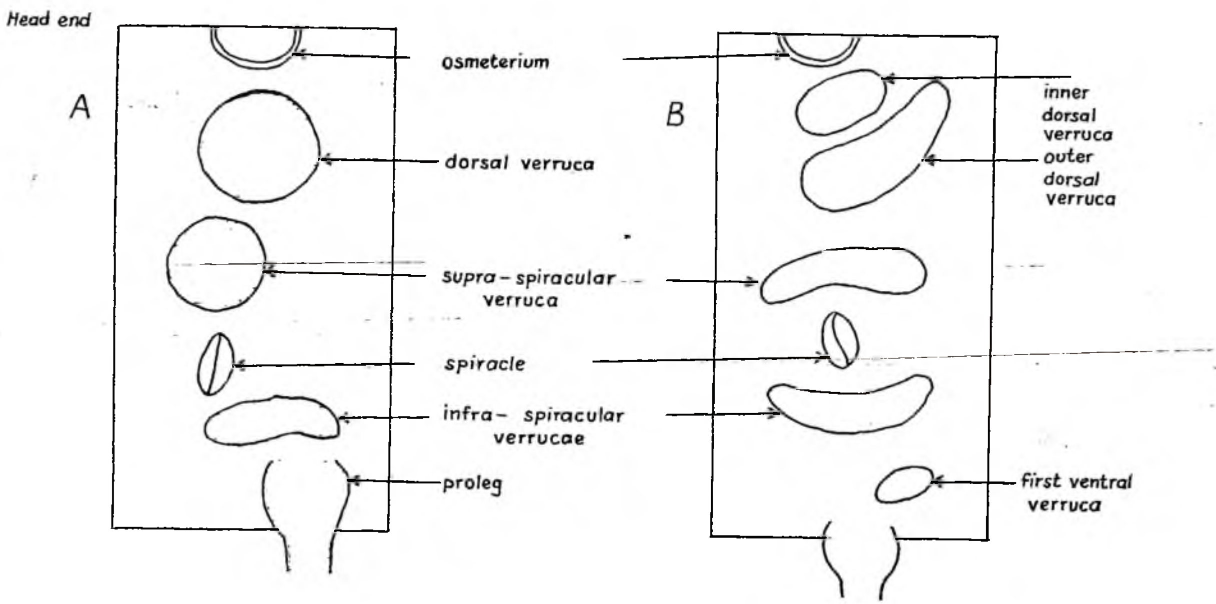


Fig.5.2: Diagrams showing different patterns of arrangement of verrucae on the sixth abdominal segment of some Lymantriid caterpillars.

Table 5.1

The names of the setae of the prothorax and abdomen of a lepidopterous larva according to Hinton (1946), and other abbreviations used in the text.

	Symbol	Name	Function
Prothorax	XD1*	XD group*	Tactile
	XD2*		
	MXD1	microscopic XD seta	Proprioceptor
	Th.	Thoracic	-
Prothorax & Abdomen	D1, D2	dorsal	Tactile
	SD1, SD2	subdorsal	do
	L1, L2, L3	lateral	do
	SV1, SV2	subventral	do
	V1	ventral	do
Abdomen	SV3	subventral	do
	MD1	microscopic dorsal	Proprioceptor
	MV3	microscopic ventral	do
	Ab.	abdominal	-

*No special name in relation to position is given to this group of setae, but both are always on or near the anterior margin of the sclerotized prothoracic dorsal plate.

by Hinton (1957): a slit is first cut along one side from the anus to the anterior margin of the prothorax leaving the head attached. The thorax and abdomen are then opened and the gut and other internal organs scraped away. The larva is then immersed in 10% potassium hydroxide for 2-3 days to facilitate the removal of any other tissues that may still be adhering to the inner wall of the skin. Following this the specimen is washed vigorously in water and afterwards in dilute acetic acid. It is then stained in weak carbol fuschin for one or two days. The thorax and abdomen are spread out in cedar-weed oil and later mounted in Canada balsam or DPX mountant. A binocular dissecting microscope fitted with a camera lucida was used in describing the chaetotaxy and in making setal maps of the various segments. Details of setae found on the mandibles, the labrum, the spinneret and antennae have not been used. In almost all cases descriptions are of larvae as caught in the field, as it was seldom that unhatched eggs from which larvae could be reared, or freshly emerged caterpillars, were encountered. Where earlier instar larvae were found, however, descriptions were made so as to bring out contrasting characteristics, if any, between earlier and maturer larvae, especially where the earlier instar larva has a different appearance from later instars. More than five specimens of each species at about the same developmental stage were examined.

NOCTUIDAE

Anomis leona (Schaus)

Earlier larvae: Head capsule light yellow to yellowish green with six dark brown fairly conspicuous ocelli present on either side of head; body yellowish green, but may be pale green or light orange with number of black round spots on each segment bearing fine setae; integument smooth and tender, at times translucent in newly-hatched larvae making it difficult to spot young caterpillar when resting on green leaf. Prothorax with more dark spots than meso- and metathorax; white narrow line from Th.1 to Ab.10 present mid-dorsally, two closely applied dorso-lateral lines one yellow and another white present from protherax to last abdominal segment; thoracic legs generally colourless and translucent but may have feint greenish tinge; prolegs light green with yellow crochets.

Last instar larva: Head capsule usually yellowish green to deep green, or ground colour green with tinge of pink or orange at vertex, wholly orange with only genae and frons retaining green colour in pre-pupation stages; body dark green with dorsal and dorso-lateral lines prominent; two cream dorsal patches present on Ab.8, absent or very indistinct in early instar larvae; thoracic legs yellow with light brown tarsi; prolegs similarly coloured; prepupation larvae with enlarged segments having pink colour in between them.

Chaetotaxy: Prothorax (Fig.5.1a) with XD1 and XD2 setae, XDb and XDc punctures and microscopic seta MXD1 not distinguishable; D1 and D2 more or less vertically in line along posterior margin of prothorax; SD1 and SD2 present, SD1 shorter than SD2, both setae from same sclerotized plate separate from main dorsal shield, SD1 above and slightly anterior to spiracle; L1 and L2 from small sclerotized plate antero-lateral from spiracle; SV1 and SV2 near base of prothoracic leg; coxal setae usually four; V1 small but distinct especially in last instar larvae. Almost all long setae from round dark staining discs.

On sixth abdominal segment (Fig.5.1b) D1 and D2 more or less parallel to mid-dorsal line, SD1 and SD2 present; SD1 far above and posterior to spiracle and in vertical line with D2 above, SD2 above and slightly anterior to spiracle; L1, L2 and L3 in triangular pattern below and posterior to spiracle, L1 not noticed in early instar larvae; SV1, SV2 and SV3 present on bases of prolegs, SV3 not observed in earlier stages; V1 present on proleg.

On eighth abdominal segment D1 and D2 as on Ab.6; SD1 anterior to, and slightly above level of the upper extremity of spiracle, SD2 not distinguishable in both early and late instar larvae; L1, L3 below and posterior to spiracle and more or less vertically in line, L2 more anterior and below lower tip of spiracle in same horizontal line with L1; SV1 present below L3, SV2 and SV3 absent; V1 present mid-ventrally.

Descriptions of the caterpillar of this species are also given by Alibert (1951) and Smith (1965). The adult has been described by the same authors, and also by Burle (1961).

<u>Characoma</u> <u>stictigrapta</u> (Hampson)

<u>Earlier larvae</u>: Head capsule dark brown; body light pink generally but may also be light green; dark brown sclerotized dorsal plate

present on prothorax with numerous fine setae; two light streaks on either side of middorsal line from Th.2 to Ab.9, number of dark brown spots present on all segments except on Th.1 and Ab.10 dark brown sclerotized plate present dorsally on Ab.10 as on Th.1 with fine backward directed setae; thoracic legs with dark brown coxae and femora but tibiae light brown; ventrum generally light throughout.

Last instar larva: Head capsule light brown with small dark patches; body light to deep pink in larvae feeding on flush or tunnelling in pods, green in larvae feeding on green tender leaves, earlier and last instar larvae with similar body colour; dark brown sclerotized prothoracic dorsal plate with small dark patches on its lighter lateral margin with setae arising from these dark patches as in early larvae several dark brown spots bearing setae present on each segment except Th.1 and Ab.10 and on uniformly coloured ventrum; dorsally four parallel lighter streaks running antero-posteriorly from Th.2 to Ab.10 present, similarly coloured streak present laterally and concurrent with spiracles; coxae and femora dark brown, tarsi light brown.

Chaetotaxy: Prothoracic setae and punctures on dorsal plate (Fig.5.1a) as in Anomis, but MXD1 and XDb not distinguishable in early larvae; SD1 and SD2 not on sclerotized dorsal plate in last instar larvae, SD2 only seta on plate at this stage, SD1 small, much higher than and anterior to spiracle; L1 only seta of lateral group present in earlier larvae, not arising from sclerotized plate, horizontally in line with and anterior to spiracle; in last instar larvae, L2 present in addition to L1 and both from same sclerotized plate just below extended lower tip of sclerotized dorsal shield, L2 very short, immediately below and slightly posterior to L1; SV1 and SV2 from sclerotized plate above coxa of prothoracic leg; four coxal setae present; V1 very minute but prominent.

On sixth abdominal segment (Fig.5.1b) D1 and D2 obliquely in line with each other, D2 longer than, far below and posterior to D1; SD1 and SD2 present, SD2 very short, above and anterior to spiracle; SD1 longer, vertically above spiracle; L1 postero-lateral from spiracle, L2 below and more or less in vertical line with spiracle, L3 inferior and more posterior to both L1 and L2; SV1, SV2 and SV3 present and also V1 on bases of prolegs in both early and last instar larvae.

On eighth abdominal segment dorsal and subdorsal setae as on sixth abdominal segment; SD1 directly above upper tip of spiracle, SD2 minute; lateral setae in form of triangle, all below lower extremity of spiracle, L1 and L3 more or less in vertical line, L2 anterior to L1 and L3; SV1 present and in line with V1 below, SV2 and SV3 absent.

The caterpillar of this species as well as the adult are described by Alibert (1951), Burle (1961), Nicol (1947), Smith (1965), and Urquhart (1961).

Earias biplaga (Walker)

Earlier and last instar larvae with similar colour patterns generally; head capsule dark-brown or black with forked white stripe on frons, head partially retractable into prothoracic collar when larva disturbed; body rather stout and spindle-shaped particularly in larvae nearing pupation; ground colour of body light brown with certain areas of darker shades; number of pointed fleshy projections present on all segments except on prothorax and with colour of particular segment on which present, each process with fine seta at apex on each segment at least one dorsal and another lateral process present.

Chaetotaxy: On prothorax (Fig.5.1a) XD setae present, in earlier larvae not issuing directly from dorsal plate as in last instar larvae but slightly in front of it,XDa, XDb and XDc not distinguishable in early larvae, MXD1 absent in both early and late instar larvae; dorsal setae present towards posterior margin of dorsal shield; subdorsal setae of unequal length, SD1 longer and posterior to SD2, directly above spiracle, in later instar larvae surrounded by darkly staining sclerotized circular plate; SD2 minute but prominent and horizontally in line with SD1; L1 and L2 also unequal in length, L1 longer and directly above L2, both setae anterior to spiracle and not from sclerotized plate; SV1 and SV2 from sclerotized plate above coxa of first thoracic leg; V1 below coxa, minute but easy to distinguish.

On sixth abdominal segment (Fig.5.3a) D2 arising from apex of fleshy dorsal process, D1 slightly above point of origin of D2 process;

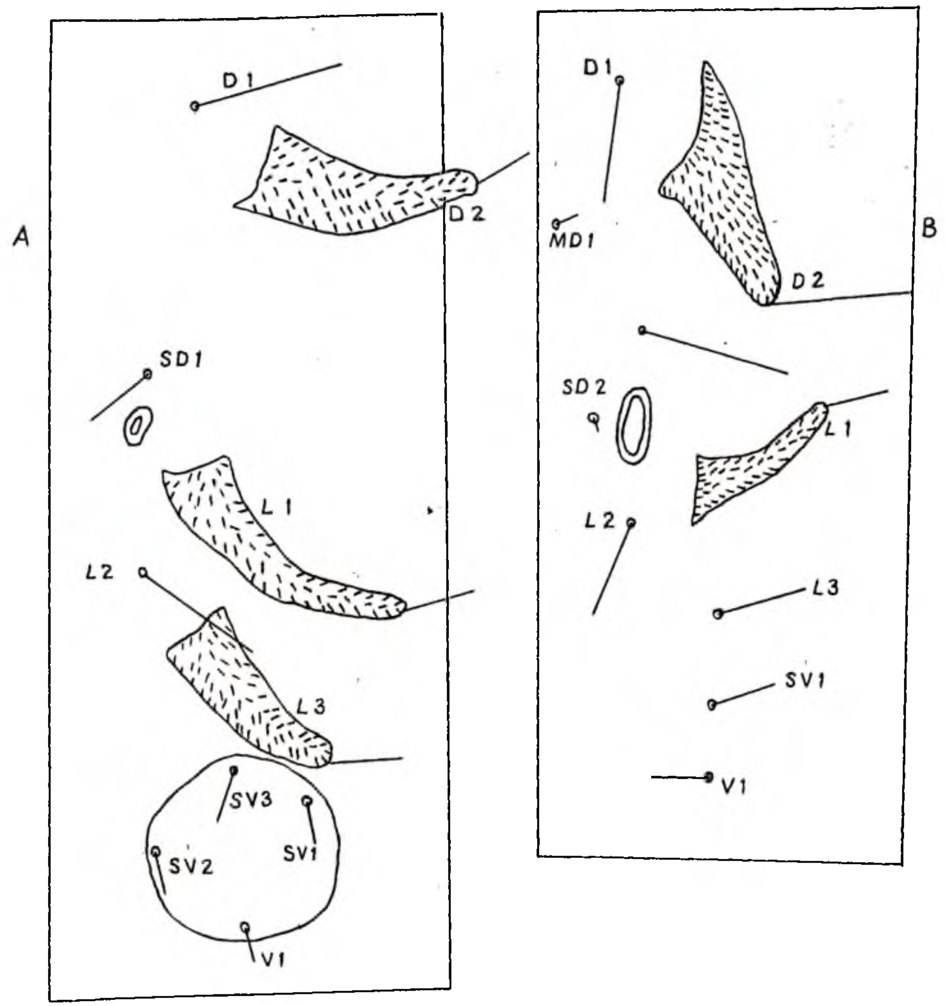


Fig.5.3: Chaetotaxy of the sixth (left) and the eighth (right) abdominal segments of <u>Earias biplaga</u>.

SD1 directly above spiracle, SD2 not present; L1, L2 and L3 on apices of soft projections with exception of L2; L1, L3 and D2 in vertical row; subventral setae present on prolegs including V1.

On eighth abdominal segment (Fig.5.3b) dorsal setae as in sixth segment, MD1 present below and anterior to D1, minute but easy to distinguish and absent in last instar larvae; SD1 much longer than SD2, directly above upper extremity of spiracle, SD2 minute and antero-laterad from spiracle, not distinguishable in early larvae; L1 from apex of freshy projection, below lower tip of spiracle and posterior to it, L2 directly below spiracle, L3 below L1 and in vertical row with SV1 and V1.

The descriptions of the caterpillar and the adult of Earias biplaga have also been given by Alibert (1951), Entwistle (1962, 1969), Pearson (1958) and Smith (1965).

Spodoptera littoralis (Boisduval)

Earlier and last instar larvae generally light to dark grey in colour, with longitudinal fairly broad streaks from Ab.1 to Ab.7, thoracic and remaining abdominal segments not striped; setae on all segments whitish except on Ab.10 where they are brown; head capsule yellow or orange with prominent dark brown cranial setae and brown ocelli; prothorax with yellow or orange sclerotized dorsal plate with long setae, rest of prothorax dark grey to black; meso- and metathorax with dark grey anterior half and lighter posterior half, all three thoracic segments black ventrally; thoracic legs dark grey or black;

Ab1-Ab7, with round black spots from which setae arise; Ab.8 with large dorsal light grey patch on either side of mid-dorsal line, in some larvae these patches may coalesce mid-dorsally, each patch with setae arising from small round bright yellow nipple-like tubercles, lateral and ventral surfaces of segment black; Ab.9 black with white setae from black nipples; Ab.10 with yellow sclerotized dorsal plate bearing setae arising from small dark-topped nipples.

Chaetotaxy: On prothoracic dorsal shield (Fig.5.1a) XD and dorsal setae present on anterior and posterior margins of plate respectively, punctures not distinguishable; SD1 and SD2 of almost equal length, both on same sclerotized plate immediately below dorsal shield, SD2 above and slightly posterior to SD1, both setae above spiracle, SD1 anterior to spiracle, SD2 directly above it, L1 and L2 on same sclerotized plate anterior to spiracle, L2 shorter, slightly inferior and posterior to L1; SV1 and SV2 arranged as lateral setae both from same sclerotized plate above coxa of prothoracic leg, SV1 shorter than SV2, below and posterior to SV2; V1 very small but prominent.

On sixth abdominal segment (Fig.5.1b) dorsal setae from dark staining circular discs, obliquely in line to each other with D2 lower and more posterior to D1; subdorsal setae of unequal length, SD1 long and with darkly staining round base almost directly above spiracle, SD2 very minute but prominent and almost in line with upper end of spiracle anteriorly; lateral setae arranged in form of triangle, L1 just about in line with lower tip of spiracle, with deep staining round basal disk, similarly with L2 and L3; L2 directly below spiracle, L3 much lower down and nearer posterior margin of segment; subventral and ventral setae present on bases of prolegs.

On eighth abdominal segment dorsal, subdorsal and lateral setae as on sixth segment, SD1 and L1 without dark-staining roundish areas at their bases; SV1 and SV2 on same sclerotized plate, SV2 shorter and anterior to SV1, usually not present on eighth abdominal segment; V1 present, well developed.

Descriptions of the caterpillar and adult of S. litteralis are given also by Alibert (1951), Pearson (1958) and Smith (1965).

Lophocrama phoenicochlora (Hampson)

Earlier and last instar larvae with generally similar colour pattern; head capsule light brown to brown with number of dark brown mottles bearing setae; prothorax light brown with four dark brown spots in transverse row at anterior margin of dorsal shield and four similar ones on posterior margin; meso- and metathorax dark brown dorsolaterally and laterally, bright cream ventrally, conspicuous dark brown circular spots bearing setae present dorsally, dorsolaterally and laterally; thoracic legs cream to light brown; abdominal segments mainly light brown to brown with numerous dark brown markings or round spots in various patterns, lighter areas present dorsally from Ab.3 - 8 giving saddle-like impression and tapering posteriorly up to Ab.8, posterior half of Ab.8 darker with feint tinge of military green, two brown to dark-brown dorsal nipple like tubercles closely applied to each other present dorsally and with setae at their apices, small dark brown spots present anterior to nipples; Ab.10 with small sclerotized dorsal plate with several dark brown spots bearing setae; prolegs light-brown with dark brown sclerotized plates on outer surfaces; ventrally larva bright cream.

__Chaetotaxy:__ Dorsal and XD setae present on prothoracic shield (Fig.5.4a), puncture XDc only distinguishable; subdorsal setae unequal and from same sclerotized plate below dorsal shield; SD1 longer than SD2, above and slightly anterior to upper tip of spiracle; L1 and L2 below and far anterior to spiracle, situated on same sclerotized plate, L1 small and above L2; SV1 and SV2 on separate plates immediately below L1 and L2 and slightly above coxa of prothoracic leg; V1 present below coxa, minute but prominent.

On sixth abdominal segment (Fig.5.4b) dorsal setae short and not in line with D2 lower than and posterior to D1; SD1 above but slightly posterior to spiracle, SD2 not seen on Ab.6; L1 postero-laterad from spiracle, L2 below spiracle, L3 slightly below and posterior to L2 and above proleg; subventral and ventral setae present on bases of prolegs.

On eighth abdominal segment (Fig.5.4c) D2 above and posterior to D1, and arising centrally from stubby dark setiferous nipple; SD1 from slightly raised dark spot and directly above upper end of spiracle, SD2 very minute but clearly visible and antero-laterad of spiracle; L1 just below lower part of spiracle and posterior to it, L2 inferior but slightly anterior to L1 and directly below spiracle, L3 in horizontal line with L2 and more towards posterior margin of segment; SV1 below and

5.4

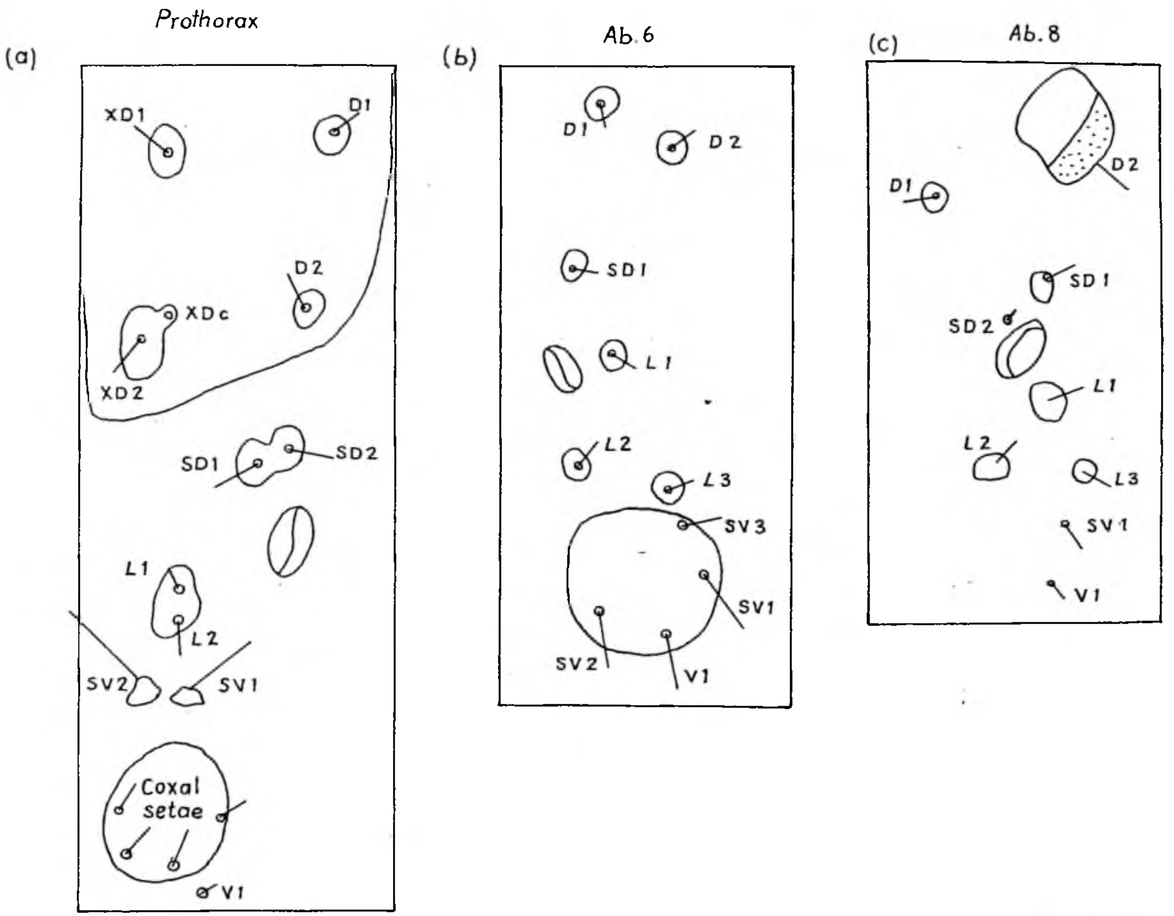


Fig.5.4: **Chaetotaxy of the prothorax, sixth and eighth abdominal segments of <u>Lophocrama phoenicochlora</u>.**

a little anterior to L3; V1 present small but clearly visible.

Descriptions of the cateppillar and adult of this species are also given by Smith (1965).

Plusia chalcites

Both early and late instar larvae pale green; head capsule light green with small brown markings on vertex and many tiny but prominent whitish spots on rest of capsule; prothorax with numerous pimply swellings some bearing short fine setae; thoracic legs light green; from Ab.1 to Ab.8 whitish broad lateral streaks present, also numerous wavy yellowish green longitudinal lines present, oblique whitish markings present dorsolaterally and continuous towards the ventrum, orange colour between abdominal segments, abdominal setae fine and short generally; prolegs absent on Ab.3 and Ab.4, present only on Ab.5, Ab.6 and Ab.10 all light green.

Chaetotaxy: On prothorax (Fig.5.1a) XD and dorsal setae short, fine and issuing from dorsal plate, associated punctures not distinguishable; SD1 and SD2 small and below prothoracic shield, both above spiracle, not arising from common sclerotized plate nor with individual sclerotized plates basally, SD1 anterior to spiracle, SD2 above; L1 and L2 fine and small, below and anterior to spiracle; subventral setae also very small above coxa of prothoracic leg; V1 very minute, rather difficult to distinguish.

On sixth abdominal segment (Fig.5.1b) setae on same general plan as in noctuid species described above; D1 from larger dark staining basal disc than D2; SD1 minute, above but slightly posterior to spiracle, SD2 not distinguishable; lateral setae present, equally minute and short; subventral and ventral setae small, on bases of prolegs.

On eighth abdominal segment dorsal setae as on Ab.6; both subdorsal setae present; SD1 minute and directly above upper end of spiracle, SD2 antero-lateral from spiracle; lateral setae small, in triangular array below spiracle; subventral and ventral setae also small and difficult to distinguish.

Descriptions of the larva and adult of this species are also given by Smith (1965).

<u>Selepa</u> <u>leucograpta</u> (Hampson)

<u>Last instar larva</u>: Head capsule light brown; thorax light brown prothorax, meso- and metathorax with long, clubbed setae mainly dark brown to black, metathorax with prominent dorsolateral banded black-and-white setae, transverse white line present between metathorax and first abdominal segment; abdomen conspicuously light brown bordered with white dorsally from Ab.2 to about Ab.6, laterally abdomen dark brown, all abdominal segments with clubbed setae some dark brown others whitish, setae very long on last two abdominal segments, setae on whole body flicker gently when larva in motion; osmeteria absent.

<u>Chaetotaxy</u>: On prothorax (Fig.5.1a) XD and dorsal setae together with associated punctures present, XDb not distinguishable; subdorsal setae above and slightly anterior to spiracle and from sclerotized feintly staining plate immediately below shield; lateral setae from sclerotized plate partially constricted between the two setae, L1

antero-lateral, and L2 antero-ventral from spiracle; subdorsals above coxa of prothoracic leg; V1 present below coxa unclubbed.

On sixth ~~abdominal~~ segment (Fig.5.1b) setae arranged as in other noctuids studied; SD1 directly above spiracle; subventrals on prolegs.

On eighth abdominal segment SD1 above and a little anterior to spiracle.

Descriptions of the caterpillar and the adult are also given by Alibert (1951) and Smith (1965).

LYMANTRIIDAE

Euproctis xanthomelana (Holland)

Earlier larvae: Head capsule dark brown; prothorax with large light orange setal tubercles or lobes dorsolaterally bearing grey setae at angle of about 45 degrees with long axis of body; dorsal setae grey, short, forward-directed and somewhat over-lapping head capsule; meso- and metathorax with dorsal off-white or light-grey setae; Ab.1 and Ab.2 with black setal tufts dorsally; Ab.3-Ab.7 with either off white or greyish setal tufts smaller than on Ab.1 and Ab.2, sparse, revealing light brown integument with dorsal yellow markings, Ab.8 with rather thick grey tuft of setae, Ab.9 with bright orange integument, setae long, light-brown and directed backwards; lateral setae on all segments straight, whitish and from off-white tubercles; thoracic legs dark brown; prolegs light-brown osmeteria small, orange.

<u>Last instar larva:</u> Head capsule dark brown with fine brown cranial setae; prothorax with dorsal setae grey and directed forwards slightly over head capsule, dorsolateral setae from large orange tubercles, forward directed at 45 degrees with long axis of body; meso- and metathorax with bright white dorsal setae; thoracic legs with greyish coxae and femora, black distally; Ab.1 and Ab.2 with black dorsal setal tufts, Ab.3 to Ab.8 with small white dorsal setal tufts, lateral setae from small orange tubercles, Ab.9 and Ab.10 with fairly long backward directed grey setae; prolegs grey near body but much lighter near crochets; osmeteria orange.

<u>Chaetotaxy:</u> On sixth abdominal segment (Fig.5.2a) single enlarged round dorsal setal tubercle or verruca present directly below osmeterium; supra-spiracular verruca partly antero-ventral from dorsal verruca; infra-spiracular verruca sausage-shaped, postero-ventral from spiracle and above proleg.

On eighth abdominal segment dorsal verruca bean-shaped above and partially posterior to supra-spiracular verruca; supra-spiracular tubercle directly above spiracle; infra-spiracular verruca also slightly bean-shaped and directly below spiracle.

Descriptions of the caterpillar and adult of this species are also given by Smith (1965).

<u>Euproctis</u> <u>melanopholis</u> (Hampson)

<u>Earlier and last instar larvae:</u> Similarly coloured; head capsule dark brown with numerous cranial setae; prothorax with short dark brown dorsal setae, dorsolateral setae long, dark brown; integument black; ventrolateral and lateral setae also white, brown patch between

meso- and metathorax present dorsally, small brightly white setae present at bases of dorsal setae; thoracic legs light brown; integument of thorax black; Ab.1 and Ab.2 with dark brown dorsal tuft of setae each and smaller dark brown lateral tufts present, but generally lateral setae from Th.2 to Ab.10 all off white, on Ab.3-Ab.7 dorsal tufts with long white peripheral setae encircling dark brown shorter setae, small groups of very short white setae present both anterior and posterior to main setal tufts giving impression of spottedness, these short white setae present also at bases of lateral setae; intersegmentally colour light brown; dorsal tufts present on Ab.8, dorsolateral setal tufts smaller than dorsal tufts, lateral tufts off white with short white setae at bases; Ab.9 with backward directed long brown setae with very short, white basal setae; abdominal prolegs orange near body, with dark patches on outer surface and yellowish at ends.

Chaetotaxy: On sixth abdominal segment (Fig.5.2a) dorsal verruca below osmeterium, slightly smaller than, and in vertical line with supra-spiracular verruca and spiracle; infra-spiracular verruca directly below spiracle and superior and a little anterior to proleg.

On eighth abdominal segment dorsal verruca about twice as large as, and directly above supra-spiracular verruca, the latter above and very slightly anterior to upper extremity of spiracle; infra-spiracular verruca below and with about two-thirds its length posterior to spiracle.

The larva and adult stages of this species have been described by Smith (1965).

<u>Orgyia</u> <u>basalis</u> (Walker)

<u>Earlier instar larva</u>: Head capsule dark brown; prothorax light-brown with black or dark brown sclerotized dorsal plate with fine off-white or light grey forward-directed setae arising from anterior margin of plate; large orange dorsolateral setal lobes or tubercles with grey setae at angle of about 45 degrees with body axis; lateral setae light grey and from small black tubercles immediately below large dorsolateral lobes; mesothorax with two yellow semi-triangular marks on either side of mid-dorsal line and bearing off-white to light grey setal tufts, orange tubercles with light grey setae present laterally; metathorax as mesothorax but yellow marks larger with setae off-white; thoracic legs dark brown. Ab.1 and Ab.2 with two dorsal black setal tufts each, small tuft of black setae from small black verrucae present dorsolaterally; lateral setae black and from black orange-capped verrucae; Ab.3 with dorsal tufts of black and grey setae; small dorsolateral black tubercles carrying dark grey or black setae present, lateral setal tubercles orange with small black central part bearing setae; Ab.4 with grey, sparse dorsal setae from small black tubercles, dorsolateral setae off-white, lateral tubercles yellow, setae grey, yellow markings present at posterior margin of segment; Ab.5 with broad dorsal saddle-like yellow marking, grey setae from deep yellow verrucae dorsally and sparsely distributed, dorsolateral setae also from yellow tubercles; Ab.6 with small yellow marks anterior to dorsal setal tubercles; grey setae from black tubercles present,

dorsolateral setae also from black tubercles; Ab.7 as A6, but with small fairly inconspicuous yellow markings anterior to dorsal setal tubercles, dorsal setae grey, lateral setae from orange tubercles; osmeteria orange; Ab.8 with black dorsal setal tuft, dorsolateral setae grey and from black tubercles; Ab.9 with greyish backward-directed setae from orange verrucae; prolegs light brown with dark brown markings on outer surfaces.

Last instar larva: Head capsule dark brown; prothorax with reddish-brown sclerotized dorsal plate bearing short white setae, dorsolateral setae long, grey and at angle of about 45 degrees with long axis of body, setae from large orange lobes; meso- and metathorax with fine sparse white setae from tiny orange tubercles, lateral setae white on all thoracic segments, thorax dark brown ventrally; Ab.1 with thick white dorsal tufts of setae, lateral tuft of setae also thick and white and arising from orange tubercles, dorsolateral setae small, off-white, sparse; Ab.2 with same thick white setal tuft dorsally but lateral tuft black and fanned out like native hand-broom; Ab.3 with white dorsal tuft as on Ab.2, lateral tuft white, fanned out, but not very thick, dorsolateral setae white, sparse and from orange tubercles; Ab.4 with yellow longitudinal streak between prolegs 3 to 6 and running up to Ab.8, white spots present on Ab.5-Ab.7, osmeteria on Ab.6 and Ab.7 orange; dorsal setae on Ab.8 light-brown and fairly erect, dorsolateral setae fanned out, brown and from large orange verrucae, lateral setae fine sparse, off-white and from medium sized orange tubercles; Ab.9 with closely associated white spots antero-dorsally, brown setal tufts backward-directed and from orange verrucae present; prolegs light brown with dark brown sclerotized outer plates.

Chaetotaxy: Distribution of verrucae on sixth and eigth segments follows the same pattern as in O. mixta (Fig.5.2b).

Orgyia mixta (Snellen)

Earlier larvae: Head capsule brown; body black with pairs of white spots and orange markings on posterior abdominal segments from Ab.5-Ab.9; long forward-directed dark setae present on prothorax and anterior abdominal segments; intermediate instar larvae with black dorsal setal tufts on first two abdominal segments and off-white or grey setae on second two abdominal segments; thoracic legs brown; osmeteria deep yellow or gold.

Last instar larva: Head capsule dark brown; prothorax with group of long black or grey setae on each side directed forward at an angle of about 45 degrees; first four abdominal segments each with pair of closely apposed dense yellow or cream tufts of setae; lateral setae on Ab.2 dark, the remaining setae whitish; dark setae present dorsally on Ab.8; integument pale green except for greyish yellow or black mid-dorsal line posterior to dorsal tufts on Ab.1-Ab.4; osmeteria gold; thoracic legs brown; prolegs light brown.

Chaetotaxy: On sixth abdominal segment (Fig.5.2b) inner dorsal verruca small and antero-ventral from osmeterium; upper end of outer dorsal verruca below osmeterium but lower portion in vertical line with osmeterium; supra-spiracular verruca like slender ellipse below spiracle; first ventral verruca immediately above proleg with anterior end projected very close to proleg.

On eighth abdominal segment inner dorsal verruca larger than sixth segment, antero-dorsal from, and closely apposed to large outer dorsal verruca; supra-spiracular verruca horizontally arranged above spiracle; infra-spiracular verruca with anterior half directly below spiracle, and a third of its length slightly anterior to spiracle.

Descriptions of caterpillar are given by Smith (1965) and of the adult by the same author as well as by Collenette (1955).

Argyrostagma niobe (Weymer)

Earlier larva: Head capsule brown; prothorax with light and dark longitudinal stripes, dorsal setae short and light brown, dorso-lateral tuft arising from orange lobes, lateral setae light brown, black spot present just behind dorsolateral orange lobe; meso- and metathorax with long dorsal setae from light tubercles, lateral setae forward directed, from orange verrucae; Ab.1-Ab.4 dark brown with dense tufts of dark brown dorsal setae; Ab.5 with two conspicuous white patches dorsolaterally starting from base of dark-brown dorsolateral setae; Ab.6 with same but smaller white patches than on Ab.5; orange osmeteria present on Ab.6 and Ab.7; prolegs with dark bands outwards.

Last instar larva: Head capsule reddish-brown with dark-brown frons; prothorax with pink or maroon sclerotized dorsal plate, dorsolateral setae long, black and projecting forward at angle of about 45 degrees; mesoand metathorax with transverse row of light brown setae from tubercles with light blue rings, lateral setae with pink tinge and arising from pinkish brown tubercles, posterior part of Th.2 with dark brown saddle and cream stripes on either side; Ab.1-Ab.4 each with dense tufts of brown dorsal setae; Ab.5 with crescentic transverse band dorsally and just posterior to it another light blue one bearing setae, dorsolateral pale brown setae from blue tubercles present; Ab.6 and Ab.7 with pale yellow osmeteria, dorsal setae light and arising from blue-tinged dark tubercles, dorsolateral setae from larger blue tubercles; Ab.8 with conspicuous grey dorsal setae and arising from blue-tinged dark tubercles, dorso-lateral tuft of setae from blue verrucae, dorso-lateral setae also from blue tubercles, large orange markings between dorsal and dorsolateral verrucae; intersegmental membrane between Ab.8 and Ab.9 cream; prolegs with orange and dark brown colour pattern; thoracic legs dark brown.

Chaetotaxy: On sixth abdominal segment (Fig.5.2b) dorsal verruca split into inner and outer dorsal verrucae, the latter sausage-like, below and longer than inner dorsal verruca; both supra and infra-spiracular verrucae sausage-shaped with about one third their length antero-dorsal and antero-ventral from spiracle respectively; first ventral verruca small, about one third thelength of infra-spiracular verruca and postero-dorsal from proleg.

On eighth abdominal segment outer dorsal verruca shorter and more rounded than on Ab.6 and about same length as inner dorsal; similarly infra-spiracular reduced.

Descriptions of the caterpillar of this species also have been given by Bullock & Smith (1968), Collenette & Carpenter (1933) and Smith (1965), and those of the adult by the same authors.

ARCTIIDAE

Diacrisia auriantiaca

Early instar larva: Head capsule light brown; body covered with light brown and white setae; thoracic legs light brown; prolegs similarly coloured.

Last instar larva: Head capsule orange or brown; prothorax deep orange or brown with similarly coloured verrucae bearing black setae; meso- and metathorax with black and white dorsal setae; body basically orange with mid-dorsal white streak running antero-posteriorly from Th.2 to Ab.9; setae from mesothorax to Ab.10 arising from black tapped orangee verrucae; prolegs on Ab.3 - Ab.6 pale yellow with broad dark band on outer surface, Ab.10 prolegs generally black.

Chaetotaxy: Not studied.

Descriptions of the caterpillar and adult of this species have also been given by Smith (1965).

GEOMETRIDAE

Neocleora sp.

Early and late instar larvae with similar colour pattern, early larvae much lighter in shade; head capsule light pink with dark green specks, colour varying from dark green to brown with dark mettles;

body integument military green, also light brown occasionally; Ab.2 with black spot dorsally at anterior margin of segment; on Ab.3 and Ab.4 extended into stripe running posteriorly; abdomen generally with small dark dorsolateral spot above each spiracle; thorax black ventrally, but light-coloured streak present from behind metathoracic legs up to prolegs on Ab.6.

Chaetotaxy: On prothorax (Fig.5.1a) XD and dorsal setae present on prothoracic shield, D1 slightly towards XD1 and antero-dorsal from D2, only XDa puncture discernible; SD1 anterior to and a little below upper end of spiracle, SD2 absent; L1 antero-ventral from spiracle, L2 absent; SV1 and SV2 on feintly staining sclerotized plate below L1, SV1 shorter than SV2; V1 minute but prominent and immediately below coxa of prothoracic leg.

On sixth abdominal segment (Fig.5.1b) dorsal setae present, D2 being postero-ventral from D1, both setae from dark staining bases; SD1 above and anterior to spiracle and more or less in line with upper extremity of spiracle and also from dark staining disc; L1 postero-lateral from spiracle; L2 directly below spiracle; L3 slightly antero-ventral from L3; subventral and ventral setae on bases of prolegs.

On eighth abdominal segment dorsal setae as in sixth segment; SD1 more or less directly above spiracle, SD2 absent; L1 postero-lateral of spiracle, L2 antero-ventral of spiracle, L3 postero-ventral of L2; SV1 in vertical line with minute but prominent V1.

Descriptions of the caterpillar and the adult are also given by Alibert (1951) and Smith (1965).

<u>Colecleora</u> <u>divisaria</u> (Walker)

<u>Early instar larva:</u> Head capsule brown with lighter frons; body brown and smooth with fine setae; prothorax forming cellar behind head capsule, anterior margin of segment white; meso- and metathorax brown; Ab.1-Ab.5 brown with transverse white markings in form of rows of clustered white spots on each segment; Ab.6-Ab.8 brown with no such transverse markings; Ab.9 with two white dots anteriorly separate from each other, two other white dots at posterior margin have coalesced and each individual dot a little larger than each one of the anterior two; Ab.10 with pink tinge; thoracic legs brown; prolegs reddish brown.

<u>Last instar larva:</u> Head capsule cream with brown markings; body light brown, striped longitudinally with fine brown lines; prothorax with cream anterior margin bearing large dark brown patches on membrane between head and prothorax and usually concealed when head retracted; meso- and metathorax with fine longitudinal brown and cream stripes, small dark-brown spots bearing setae present; ventrally thorax with military green colour; thoracic legs reddish-brown with black patches; Ab.1 with dark brown or black semi-triangular mark on either side of mid-dorsal line; laterally spiracle conspicuous with dark brown area around it; Ab.5 with two nipple-like dark swellings dorsally bearing fine setae; Ab.6 with prolegs, not present on Ab.3-Ab.5 prolegs reddish brown; Ab.8 with two short dark stripes from anterior margin of segment to about midway its length, two dark brown nipple-like swelling present dorsally bearing setae; Ab.9 and Ab.10 with uniform cream colour and small brown spots, Ab.10 prolegs maroon; ventrally

abdomen with light mid-ventral streak from Ab.2-Ab.5, broader and brighter on Ab.5.

<u>Chaetotaxy:</u> On prothorax (Fig.5.1a) XD and dorsal setae present at anterior and posterior margins of prothoracic sclerotized plate, XD punctures not distinguishable; subdorsal setae anterior to and adjacent to upper end of spiracle, SD1 shorter than SD2, immediately anterior to spiracle and postero-dorsal from SD2; L1 antero-dorsal from L2, both setae below and far anterior to spiracle and not arising from sclerotized plates; SV1 shorter than and postero-ventral from SV2, both above coxa of prothoracic leg; V1 present below coxa.

On sixth abdominal segment (Fig.5.1b) dorsal setae present D2 postero-ventral from D1 and much shorter, both setae without sclerotized basal discs; SD1 antero-dorsal from spiracle, L2 directly below spiracle, L3 antero-ventral from L2 and spiracle, sub-ventral and ventral setae present on proleg.

On eighth abdominal segment D2 issuing from large round dark staining basal disc, D1 not clearly distinguishable; SD1 long and antero-dorsal from upper extremity of spiracle; L1 slightly posterior-ventral from spiracle, L2 below spiracle, L3 far below spiracle and antero-dorsal from SV1; V1 about half length of SD1.

Descriptions of the caterpillar of this species have also been given by Alibert (1951) and Smith (1965) and those of the adult by the same authors.

THORTRICIDAE

__Tortrix__ __dinota__ (Meyrick)

Both early and late instar larvae with similar colour patterns; head capsule deep yellow or brown; body reddish brown throughout with dark spots from which setae arise, two dorsal white lines and lateral ones present from Th.2 to Ab.9; prothorax with colourless dorsal plate; Ab.10 with smaller but similarly sclerotized dorsal plate bearing fine silvery setae; thoracic legs dark brown or black; prolegs light brown or colourless in some cases.

__Chaetotaxy:__ On prothorax (Fig.5.1a) XD and dorsal setae very long, XD2 longer than XD1 and D2 much longer than D1, XDa and XDc present, XDb not distinguishable, D2 more or less in horizontal line with XD1, D1 far superior to both XD1 and D2; sub-dorsal setae situated on prothoracic plate, SD1 slightly shorter than SD2 and antero-dorsal from spiracle; three lateral setae present: L1, L2, L3 more or less horizontally in line with each other and on same sclerotized plate adjoining dorsal shield, L1 longest seta and situated between L2 and L3, all antero-ventral from spiracle with L3 nearest to spiracle; SV1 postero-dorsal from and shorter than SV2, both setae from same sclerotized plate above coxa of prothoracic leg; V1 present below coxa.

On sixth abdominal segment (Fig.5.1b) dorsal setae long and partially in horizontal line with each other, D2 being very slightly postero-ventral from D1; SD1 very long about twice length of SD2, directly above spiracle, SD2 on same sclerotized dark staining plate as L2, antero-ventral from spiracle and/above and slightly anterior to L2, arising from sclerotized plate, L3 in vertical line with D2 far above and postero-ventrad from L2; subventral setae closely arranged on base of proleg; V1 present also on proleg.

On eighth abdominal segment D2 postero-ventrad from and shorter than D1; SD1 long anterior to and more or less in line with upper extremity of spiracle; L1 and L2 close together below spiracle, L1 postero-ventrad from spiracle, L3 lower down and posterior to L1; SV1 and SV2 present, SV1 a little longer than SV2 and postero-dorsad from SV2; V1 and antero-ventrad from SV1.

Descriptions of the caterpillar of this species and adult have. also been given by Alibert (1951) and Smith (1965).

<u>Archips</u> <u>occidentalis</u> (Walker)

Early and late instar larvae with same colour pattern; head capsule black; body light green with minute black spots on thorax and abdomen, but relatively few on abdomen; prothorax black, meso- and metathorax light green; thoracic legs black; prolegs pale green.
<u>Chaetotaxy</u>: Not fully studied, but on same basic plan as in <u>T. dinota</u> but setae shorter, SD1 on eighth abdominal segment a little farther anterior to upper end of spiracle than on the same segment in <u>T. dinota</u>.

The larva of this species and the adult have also been described by Smith (1965).

SYNTOMIDAE

Euchromia lethe (F.)

Early instar larva: Head capsule orange or light brown; body deep yellow to orange; prothorax with short sparse dark grey setae; meso- and metathorax with ~~dorsal~~ long, black dorsal setae mixed with the short ones; thoracic legs light brown; ventrally thorax greenish; dorsal setal tufts on Ab.1 to Ab.10 uniformly black but may be inter-mingled with few white setae; dorsolateral setae in same kind of tufts as dorsal setae; prolegs on Ab.3-Ab.6 and Ab.10 orange; osmeteria absent.

Last instar larva: Head capsule deep yellow to orange; body light orange or yellow; prothorax about same colour as head capsule, dorsal setae grey, but short and inconspicuous; meso- and metathorax with black and anteriorly projected dorsal setae; thoracic legs orange or light brown; Ab.1 with dorsal and dorso-lateral setae in thick black tufts intermingled with yellow setae; Ab.2 to Ab.7 with dorsal setae bright yellow with very few black ones here and there, dorsolateral setae black; Ab.8-Ab.10 with sparsely distributed black setae; ventrum of thorax orange, of abdomen greenish; prolegs orange.

Description of caterpillar and adult of this species is also given by Alibert (1951).

5.2: Keys for the identification of the larvae

The characters used in the identification keys that follow are mainly those of last instar larvae, but separate keys have been prepared to facilitate identification of some early instar larvae of hairy caterpillars where these have a different appearance from final instar larvae. For clarity the identification key for hairy caterpillars has been prepared separately from that of unhairy larvae.

5.2.1. Identification key for unhairy last instar larvae

1. Larva green with conspicuous black spots, prolegs present on third, fourth, fifth, sixth and tenth abdominal segments 2

- Larva pale green, not with spots; prolegs present only on fifth, sixth and tenth abdominal segments 3

2. Mediodorsal white line and two dorsolateral yellow and white lines present; large cream patches present dorsally on eighth abdominal segment 4

- Mediodorsal white line absent, but two broad dorso-lateral white lines present; eighth abdominal segment without any patches 5

3. Oblique white markings present dorsolaterally; setae short, SD1 on eighth abdominal segment directly above spiracle .... *Plusia chalcites* (Es.)

- Not with above features 6

4. Seta SD1 on eighth abdominal segment anterior and slightly above upper extremity of spiracle ... *Anomis leona* (Schaus)

- Seta SD1 on eighth abdominal segment vertically above spiracle 7

5. Seta L3 always present in addition to L2 and L3 on prothorax .... *Tortrix dinota* (Meyrick)

- If L3 present on prothorax, then head capsule, prothoracic dorsal plate and thoracic legs always black .... *Archips occidentalis* (Walsingham)

6. Body always grey to black with conspicuous orange prothoracic plate 8

- Body always light brown with areas of darker shades; prothoracic plate not as above 9

7. Larva with dark brown sclerotized dorsal plates on prothorax and on tenth abdominal segment; usually tunnels in pod pericarp or may eat flushes binding them together with silk .... *Characoma stictigrapta* (Hampson)

- Not with above characters 10

8. Light grey streaks present from first to seventh abdominal segments; setae on all segments white; setiferous nipples on eighth abdominal segment always bright yellow, those on ninth abdominal segment always white .... *Spodoptera littoralis* (Boisduval)

- Not as above 11

9. Prothoracic plate always collar-like with whitish anterior rim; body spindle-shaped and with fleshy projections on all segments, each process with fine seta at apex; SD1 on eighth abdominal segment not from such process.. *Earias biplaga* (Walker)

- Not with above characters 12

10. Body military green; second, third and fourth abdominal segments always with dark rectangular spots dorsally, dark spot on fourth segment extended into stripe; prolegs present on sixth and tenth abdominal segments... .... Neocleora sp.

- Body brown, with dark lateral longitudinal stripe on thorax; second, third and fourth abdominal segments not with dark spots; fifth abdominal segment with small setiferous nipples dorsally; prolegs present on sixth and tenth abdominal segments ....Colocleora divisaria (Walker)*

11. Body with various shades of brown, light brown areas always giving saddle-like impression dorsally...............13

- If body light brown, then broad white streak present dorsally from second to sixth abdominal segment.............12

12. Setae on all segments clubbed and particularly well developed on thoracic and posterior abdominal segments .... Selepa leucograpta (Hampson)

- Not as above 13

13. Body tapering posteriorly; dark brown setiferous nipples present dorsally on eighth abdominal segment .... Lophocrama phoenicochlora (Hampson)

*Early instar larvae of C. divisaria are dark brown with conspicuous white transverse markings consisting of rows of white spots.

5.2.2: Identification key for hairy last instar larvae

1. Prothoracic lobes present; dorsal setae on prothorax grey 2

\- Prothoracic lobes absent; dorsal setae on prothorax black 3

2. Dorsal setae on meso- and metathorax white, on first and second abdominal segments black 4

\- If dorsal setae on meso- and metathorax white then additional small white setae present as tiny spots at their bases; dorsal setae on first and second abdominal segments dark brown 5

3. All body setae black, but may be mixed with white setae on meso- and metathorax, and with yellow setae on first and second abdominal segments; osmeteria absent ....Diacrisia auriantiaca (Hampson)

\- If osmeteria absent and setae on meso- and metathorax, and on first and second abdominal segments black, then dorsal setae on third to seventh abdominal segments bright yellow ....Euchromia lethe (F

4. Conspicuous pair of lateral orange streaks always present on third to seventh abdominal segments; lateral setae on all segments white; osmeteria orange .... Euproctis xanthomelana (Holland)

\- Not with above characters 6

5. Dorsal setae on third to seventh abdominal segments sparse and surrounding short dark brown tufts; osmeteria light brown and inconspicuous .. .. Euproctis melanopholis (Hampson)

- Not with above features 7

6. Dorsal setae on first to fourth abdominal segments brown; blue, white and orange markings present above supra-spiracular verruca on all segments; meso- and metathorax with black dorsal setae; osmeteria pale yellow........ Argyrostagma niobe (Weymer)

- Not as above 8

7. If osmeteria orange, then lateral setae on first abdominal segment white and on second abdominal segment black; prothorax with white dorsal setae.......... Orgyia basalis (Walker)

- Not as above 8

8. Dorsal setae on first to fourth abdominal segments bright yellow; prothoracic dorsolateral setae long and black; osmeteria gold ....Orgyia mixta (Snellen)

5.2.3: Identification key for hairy early instar larvae

1. Dorsal setae on first and second abdominal segments black, on third and fourth segments grey 2

- If dorsal setae on first and second abdominal segments black, then dorsal setae on third and fourth segments white....3

2. Fifth abdominal segment with saddle-like yellow dorsal marking; osmeteria orange ....Orgyia basalis (Walker)

- Not as above 4

3. White and orange spots present on fifth to ninth abdominal segments; osmeteria yellow............... Orgyia mixta (Snellen)

- Not with above features 5

4. Dorsal setal tufts on first to fourth abdominal segments dark brown; fifth and sixth segments with two large white patches dorsolaterally....................... Argyrostagma niobe (Weymer)

- Not with above characters.....................................6

5. Body covered with mixture of light brown and white setae; setae not in distinct tufts; mediodorsal line feintly distinguishable; osmeteria absent.................. Diacrisia auriantiaca (Hampson)

- If osmeteria absent, then body setae not as above...............6

6. Body setae uniformly black and in thick distinct tufts; mediodorsal line absent.......................Euchromia lethe (F)

Chapter 6: Biological observations.

6. BIOLOGICAL OBSERVATIONS

Feeding is discussed in the next chapter, in relation to damage.

6.1: Oviposition and larval period

Methods: Chupon tips, axillary buds, flush leaves and chupon stems were inspected for eggs of Lepidoptera. It was seldom that unhatched eggs were discovered in the field, let alone a female moth encountered ovipositing. If found, unhatched eggs were brought back to the laboratory to see whether they would hatch. Larvae hatching out of these eggs were ensleeved singly onto separate cocoa seedlings and checked for their activities.

Results: In October eggs of *Earias biplaga* were found at Tafo on the green part of a chupon stem not very far below the growing tip. The eggs were in small groups of two, three and four, and the total number counted on the one seedling was twelve. Out of these, nine hatched out successfully on the very day that they were brought back from the field. The remaining three did not hatch even after having been kept for over a week in the laboratory although there were no signs of parasitism. Each egg is spherical but rather slightly flattened where it is cemented to the substratum. It is deep yellow in colour and has a number of longitudinal ridges. The average diameter of twelve eggs was 0.44mm, with a range of 0.41 - 0.46mm. The egg groups were very scantily covered with pale yellow scales probably from the terminal abdominal segments of the female moth.

The newly hatched larvae were light brown generally, but had darker areas on the integument. Five of these first instar larvae were placed on small flush leaves near the tip of five separate seedlings. The other four were kept in marmalade jars wherein flush leaves had been placed. On the following day it was observed that three of the larvae placed on flushes near the chupon tips had migrated to the terminal buds of the respective seedlings where they had partially bored into them. The other two had remained on the flush leaves on which they had been left the previous day and there were no signs either that the leaves on which they were had been eaten. The larvae in marmalade jars did not feed on the leaves provided. After another day the two larvae on the flush leaves had not moved to the tip of the chupon still. At first it was thought that they were about to moult, but later in the day the two were found curled up and motionless at the lower part of the muslin, looking sick and apparently dying. Similarly the caterpillars in the jars did not eat any part of the leaves provided and had also dropped to the bottom of the jars. When transferred to terminal buds they did not take to them because, although they still showed some signs of life, they were already very weak and unable to start eating. It seems as if early instar larvae of Earias prefer buds to flush leaves which they may attack only after having first bored into and eaten part of the buds, particularly terminal buds. The three surviving Earias caterpillars had bored down to about a centimetre and half into the tip of the chupons. Further, in their burrows were found cast head-capsules and frass pellets, which showed that moulting and excretion took place inside the burrows. Cast skins were not found inside the burrows but near the entry point, which would suggest that the head capsule is shed a little later on. Head width measurements, in millimetres, of the newly hatched larvae as well as of subsequent stages were recorded. Table 6.1 shows the head widths of the three surviving Earias larvae together with the means; the Roman numerals represent the various instars, and the capital letters represent the three larvae.

From these measurements it can be concluded that Earias biplaga has five larval instars. The average pupal period was 13 days, with a range of 11-15 days.

With regard to Anomis leona, Spodoptera littoralis, Euproctis xanthomelana, E. melanopholis and Argyrostagma niobe no eggs were found in the field, only empty egg-shells from which larvae had already emerged. It was possible to conclude in each case that the egg-shells were of the species in question because the newly emerged caterpillars were frequently found on the same chupons as the shells. It was, however, difficult to come to a definite conclusion if on the same chupon there was more than one species of newly hatched caterpillars. From the positions in which the various empty husks were found on the seedlings, it would appear that Anomis leona females oviposit on the under surface of green tender leaves, Spodoptera littoralis on the under surface of expanded flush leaves and the three lymantriids on the stem and on the upper surface of hardened leaves.

Table 6.1

Head capsule widths, in millimetres, of various instar larvae of three *Earias biplaga* caterpillars reared on terminal buds and flush leaves of cocoa seedlings at Legon.

Instar larva	I	II	III	IV	V
A	0.18	0.31	0.52	1.09	1.38
B	0.21	0.29	0.49	0.96	1.32
C	0.19	0.34	0.57	1.11	1.41
Mean width	0.19	0.31	0.53	1.04	1.37

There were two instances when adult female moths were seen laying eggs; these were with newly emerged E. melanopholis and A. niobe females in the laboratory. E. melanopholis laid on the wall of the emergence cage several batches of yellowish white eggs that were thickly covered with light brown scales. The eggs of A. niobe are similarly coloured and are covered with brown scales. The eggs did not hatch into larvae probably because they had not been fertilized.

In February a larval case of the psychid, Eumeta rougeoti was brought from the field and opened to find out whether the larva inside was alive or not. A large legless, wingless and larviform adult female of this species dropped out. It was motionless and apparently dead, and was preserved in alcohol. In the case there was in addition a barrel-like reddish-brown pupal exuvium from which the adult female moth had emerged. One end of the exuvium tapered to a point and the other was open with yellow fluff showing out. The tiny larvae with greyish-brown bodies and black head-capsules and thoracic tergites started coming out of the exuvium. They were active and moved about briskly with their abdomens tipped at about 90 degrees to the horizontal. As they moved along these early instar larvae laid a network of silk threads on their way. For instance, in one petri-dish in which some of them had been kept so much silk was laid that the two halves of the dish were held together.

To find out what materials were used in the construction of cases, some of the newly-hatched larvae were placed on seedlings kept outside, some on indoor seedlings and others in petri-dishes containing small soil particles and wood shavings and large pieces of filter paper. It was soon noticed that the larvae placed on seedlings had constructed small silk cases in which small shavings from the chupon stems, pieces of twigs and leaves were incorporated. Similarly also the larvae placed in petri dishes with soil particles and other debris constructed cases with some of these substances added to the outer fabric. Not many of those placed on filter paper built cases, but those that did, however, used paper fibres for the purpose. At a later stage short pieces of sticks, arranged longitudinally were added. The process by which the sticks are obtained and incorporated in the case has been described by Entwistle (1963). As late as July some of these larvae could still be found on the cocoa seedlings onto which they had been distributed in February, which shows that psychids have a long larval cycle.

6.2: Moulting

It has been observed that before moulting starts caterpillars always stop feeding and remain motionless at one spot on the leaf or rest, in the case of laboratory reared larvae, on the wall, lid or base of the rearing cage. If disturbed, however, the larvae may either move away to another part of the leaf or cage, or remain where they are and simply curve the disturbed part slightly away from the disturbing agent, such as in lymantriids. The geometrids retain their stick-like stance. *Anomis leona* usually wriggles off the leaf, while *Tortrix dinota* and *Characoma stictigrapta* retreat deeper into their leafy lairs. In three noctuid caterpillars that were observed namely *Anomis leona*, *Characoma stictigrapta* and *Spodoptera littoralis* and also in the geometriids, *Neocleora* and *Colocleora* as well as in the tortricid, *Tortrix dinota*, moulting took place in the following manner; the larvae become gradually enlarged and remain so until the old skin is split all around the neck, that is, between the head and the prothorax. The larva gradually withdraws from this old cuticle by steady, continuous rhythmic movements of the body, such that the old skin passes to the posterior end of the body. Once the thoracic legs have been withdrawn the larva begins to crawl out of its cast skin which remains attached to the substratum. The freshly moulted caterpillar is smooth and remains motionless at one spot some distance from the grey cast-skin which later shrivels into a shapeless lump, or remains flattened out on the surface of a leaf. The head capsule is not shed at the same time as the body cuticle, but remains attached for about a day. Usually, before the onset of moulting the new head capsule is seen to be partially withdrawn from the one to be cast such that its new ocelli are exposed just behind the occipital margin of the head capsule about to be shed. The mouth parts of the next head capsule can be seen through the translucent old one. When a greater part of the new head capsule has been exposed the larva then drops the old one by vigorously shaking its head and thorax together from side to side. A few minutes after, feeding begins.

In the psychids moulting takes place by a midventral split of the old cuticle. All this takes place within the larval case which is first securely attached to a hardened leaf. The freshly moulted larva withdraws from the cast skin which eventually is pushed to the outside in small fragments through the lower hole of the larval case. Pieces of cast skin can often be seen dangling from the lower end of the case. The freshly moulted caterpillar is off-white or cream in colour with a few dark markings on the head capsule and thoracic tergites. Darkening of the body to the natural dark brown shade of the sclerotized parts generally takes a little over six hours.

In E. xanthomelana, E. melanopholis and other lymantriids that were observed, moulting takes place by a mid-dorsal longitudinal split of the cuticle to be cast. The split starts from the region of the metathorax and ends on the second abdominal segment. Before moulting, however, the caterpillar loses a large amount of its hairs and becomes shaggy as a result of some of the hairs remaining loosely attached to the body. The various coloured markings of the cuticle stand out more prominently. The open dorsal slit enables the moulting larva to push its anterior abdominal segments out of the old skin. Gradually, the thorax and the head capsule are pulled out by the larva making heaving and other rhythmic movements. The posterior parts are withdrawn next as the larva slowly crawls forward thus pulling itself free from the cast skin that remains attached to the substratum by the prolegs. In contrast to the position in noctuids, the head capsule in lymantriids is completely withdrawn at the same time as the rest of the body is pulled out of the old cuticle. In some lymantriids, such as Argyrostagma niobe for instance, the subsequent instar larvae may be differently coloured from the preceding ones. The moulting process in the syntomid, Euchromia lethe takes place in the same way as in the lymantriids.

6.3: Pupation

When Anomis leona is ready for pupation, feeding stops. The body segments begin to thicken and become more markedly distinguishable from each other. The green colour of the body darkens and the thoracic segments in particular take on an additional pink coloured hue. The head capsule becomes deep pink or light orange on the vertex, and this same pink tinge occurs also between the segments. The large creamy white spots on the dorsolateral aspect of the eighth abdominal segment lose their brightness, gradually become dull and unnoticeable. Slime is produced profusely all over the body of the larva and silk is spun, with the result that thoracic legs and prolegs become held together mid-ventrally in the silk strands. Silk spinning is done with the aid of the spinneret, a modified labium, which is in turn assisted by the labial palps on either side. The silk serves to secure the larva against the substratum on which the pupal cocoon will be constructed. At this stage the larva is very sensitive to touch; it twitches violently on being prodded, so much so that at times it extricates itself from the binding silk though not completely. It moves about unsteadily because the prolegs to a great extent retain much of the entangling strands of silk. After some time the larva settles again and the preliminaries of cocoon-making are resumed.

The cocoon may be made from silk alone, in which case it is merely a makeshift see-through structure of loosely interwoven silken threads occasionally mingled with pieces of frass. Pupae found on cocoa trees are almost always attached to leaf blades in this way. When the larva pupates in the ground the cocoon is made from silk-bound soil and dust particles, tiny twigs, rotten leaves and some such debris, and it looks very coarse. In the laboratory pieces of paper, wood-shavings and sawdust, and green leaf fragments from the feeding leaves provided can also be neatly held together and lined with silk to construct a cocoon. In both these types of cocoons the anterior ends are thinly woven with silk and often exhibit a hole through which the adult would emerge. Specimens pupating in tubes on the way back from the field usually make thin silken partitions above themselves such that the space encompassed by the septum and the base of the tube served as a pupation chamber. Where pupation occurs between two leaves, these are drawn together and held with silk such that the resulting enclosure is used for pupation with no further laying down of a silken fabric. Some _Anomis_ larvae may pupate in the rolled leaf shelters of _Tortrix dinota_ and _Characoma stictigrapta_. On two occasions some pupae of _Anomis_ were found attached to the fairly large pieces of cocoa leaf fixed on to the cases of psychid caterpillars.

At Kade several Anomis larvae were found preparing to pupate in the velvety and cushion-like mosses at the base of cocoa trees and also occasionally on stems.

The pupa is not formed until about a day after the completion of the cocoon. When it is ultimately fully formed the larval skin splits along the mid-dorsal line including the vertical suture of the head capsule. The newly formed green-coloured, soft pupa gradually emerges as the larval skin is slowly passed backwards by rhythmic abdominal movements of the pupa. At the posterior end, where it remains loosely fixed to the tip or cremastral spines of the abdomen of the pupa, the cast larval skin shrivels and dries up into an amorphous husk. The process of pupal emergence from the larval body was observed to take between 9 and 13 minutes in Anomis. The darkening of the newly emerged pupa sets in a few minutes afterwards and takes up to about four to six hours, at the end of which the pupa is either dark or reddish-brown. When clamped between tweezers, the pupa twirls the abdomen incessantly round and round.

Moths of Anomis were observed during emergence from the pupa. Before emergence of the adult the pupa becomes a little more active than usual, twirling and rotating the abdomen fairly continuously. At emergence the pupal case splits across the head end or occiput and also on either side of the eye and antennal encasement such that the plate covering these organs sags making emergence easy. The cremastral spines retain the pupal case in the cocoon as the moth pulls itself out. In instances where pupal cases were not attached to cocoons by terminal spines, moths were still able to emerge unhindered by pupal cases dragging behind them. The emerging Anomis moths are almost invariably active, but pause for a few minutes to get their wings stretched and hardened before beginning to flutter about in the emergence cages. All newly emerged moths were seen to excrete a light brown liquid a short distance from the pupal cases.

Characoma stictrigrapta, Lophocrama phoenicoclora and Earias biplaga constructed tough felt-like cocoons from silk strands only, rarely including other materials. Their cocoons are always cemented to some part or other of the cocoa tree. The cocoon of Characoma closely resembles that of Earias in shape. The cocoon of the latter caterpillar is shaped like an inverted boat and is of a dierty-white or pale brown colour, and that of Characoma is bright off-white and straw-coloured, blunt anteriorly and rather rounded and semi-conical generally. The cocoon of Lophocrama is partially domed anteriorly and gradually tapers to a point posteriorly. It is shaped more or less like the larva itself. It is a dull off-white colour like that of Earias. Freshly woven cocoons of all the three species are greyish, and take up their respective shades of colour as they gradually dry up.

Characoma cocoons have been found on cocoa stems, pods, pod peduncles and inside tunnels made by the larva in the pod pericarp. Occasionally some cocoons were found under the blotched epiderm of Marmara infested pods. Lophocrama fixed its cocoons mainly on cocoa stems but also on petioles of mature leaves, rarely on flush leaves. Ensleeved Lophocrama larvae pupated on the fabric of the muslin sleeve.

Earias' cocoons were found on stems, petioles, branches and at times also on hardened leaves. At the anterior end of the cocoons of the three species is a vertical slit with the apposed lips loosely sealed with silk so that the emerging adult can easily pass through it to the outside. The texture of the cocoon of Selepa leucograpta is the same as in that of the above species except that in Selepa faecal pellets and also its clubbed setae may be incorporated into the silken mesh. Furthermore it is differently shaped, resembling a light brown limpet.

The lymantriids, E. xanthomelana. E. melanopholis. A. niobe. O. basalis and others, including also the syntomid Euchromia lethe and the arctiid, Diacrisia auriantiaca. make their cocoons by plucking most of their hairs which are then included in the wall of the cocoon. The hairs are held together with silk. That part of the cocoon through which the adult will emerge is less thickly interlaced with silk and hairs than the other parts of the cocoon.

The average pupal periods of the species discussed appear in Table 6.2.

6.4: Protective mechanisms

The green colour of such caterpillars as Anomis leona. Plusia chalcites and Neocleora makes it difficult at times to spot these larvae on the green leaves on which they usually rest when not feeding on flush. They become very conspicuous, however, on flush leaves. It has often been observed that early larval stages of Anomis seem to take up the colour of the leaves that they eat, thus becoming fairly

Table 6.2

Average pupal periods and range of duration of the pupal stages of some laboratory-reared Lepidopteras (in days).

Pupal period	Lophocrama	Earias	E. melanopholis	E. xanthomelana	E. lethe	D. auriantiaca	A. niobe	Neocleora	Tortrix	Characoma	Spodoptera	Anomis	Selepa	Colocleora	O. basalis
Mean	11.3	11	10.4	10.3	10.3	9.8	9.6	9.5	9.5	8.8	8.6	8.4	8	7.9	7.5
Range	10-12	10-13	11-15	8-14	9-11	8-12	8-11	7-11	8-11	9-13	7-10	7-12	7-9	9-11	6-9

blended with the leaf. This may possibly be due to the fact that the gut which is filled with pieces of flush, stands out boldly through the semi-transparent cuticle. It has been observed also that larvae of *Characoma* appear pink when feeding on flush leaves or burrowing in pods, but greenish when eating green tender leaves. *Earias* and *Lophocrama* have certain parts of their bodies darker than others, and this may serve to break up the body outline of these caterpillars so that some parts of their bodies fade into the background thus making it difficult to spot them readily. There was, however, no instance when it was difficult to locate these caterpillars on flush leaves. The notodontid, *Graphidura* sp. has a large reddish-brown saddle-like patch extending from the first abdominal segment to the eighth. The rest of the body including the head capsule is pale green. This caterpillar, which feeds on senescent leaves with parts of the lamina dried up, brownish and curled, can easily pass unnoticed because the dry parts of the leaf blade blend well with the reddish brown saddle of the caterpillar, while the pale green body matches with the greyish-green undried area of the leaf. There are two bright yellow eyespots immediately behind two dorsal reddish brown horns on the eighth segment. When disturbed the posterior part arches sharply revealing these eyespots, the thorax is raised and the head is cocked inwards against the prothoracic legs. If the caterpillar is held by tweezers it violently swings its head round towards the tweezers, biting them repeatedly with its powerful mandibles. *Anomis*, *Characoma* and several other caterpillars behave this way also when pinched by tweezers.

The lymantriids, E. xanthomelana, O. basalis, A. niobe and others, possess osmeteria, one each on the sixth and seventh abdominal segments. These are repugnatorial glands. They are small eversible fleshy structures, often conspicuously coloured (Smith, 1965) and contain an oily substance that glistens when light falls on it. It has, however, not been observed that these osmeteria are used by the above caterpillars in protection as is said to be the case in some caterpillars of papilionid butterflies (Wigglesworth, 1966). The Limacodids, which are generally very brightly coloured, have urticating hairs which produce chemical substances that cause intense itching and inflammation of the pricked or scratched area of the skin.

Neocleora, Colocleora and to a certain extent also Plusia chalcites can be mistaken for dry twigs or petioles and passed over because they are capable or remaining motionless and as straight as twigs. The thoracic legs are folded under the thorax, and the head is partially withdrawn into the prothoracic collar. When disturbed they either drop off the leaf and dangle in the air on their silk threads or remain where they are without moving. If held, however, they wriggle and writhe by way of trying to free themselves.

Anomis, Characoma, Selepa, Diacrisia and Tortrix react to mechanical stimulation, which may be an additional protective endowment. If Anomis is lightly prodded with a pin or bristle it reacts by first curving the affected part of the body away from the disturbing agent. If prodding is continued it quickly drops from the leaf and continues to writhe and twist for some time on the ground.

Characoma and Tortrix quickly retreat into their leaf shelters. Selepa and Diacrisia skip and twist about for some time until they are 'satisfied' that the disturbance has ceased. Spodoptera, Neocleora, Colocleora and some lymantriids are generally unmoved by prinking, but if squeezed they writhe vigorously. It was observed in Anomis and others that the reaction to prodding was evoked more readily from areas immediately around the long tactile hairs than from those between the hairs.

6.5: Myrmecophilous caterpillars

When old pods left hanging on trees or fallen to the ground were cracked open a large number of green dorso-ventrally flattened lycaenid caterpillars tended by the ant Crematogaster striatula were found. The lycaenids either clustered on the inner wall of the pod or inside beans whose endosperm had already been eaten away. Though the general colour of the larvae is green, there are some which are light green and others which are cream, especially those that are about to pupate, whose segments are also much thickened. The head capsule is dark brown and is concealed by a large prothoracic collar. The sides are broad and flattened with the result that thoracic legs and abdominal prolegs are hidden from view. There are numerous light-brown, short, clubbed setae on all segments except for the sclerotized prothoracic dorsal plate. It appears as if the Crematogaster associated with these caterpillars derive something that probably exudes from the setae. In some bean husks larvae and pupae of C. striatula were found together with the lycaenids. In another pod there were several light brown lycaenid pupae in addition to the caterpillars. The pupae have deep purple wing buds and dark brown thoracic tergites. Adults have purple wings with white eye-spots along the inner margin as well as small tails at the tornus. Some lycaenids, e.g. Thecla esmeralda, are also associated with Macromischoides aculeatus (Aryeetey, 1971). Several lycaenid pupae were frequently found in the nests of this ant.

6.6: Parasitism

Methods: Parasitized caterpillars were scored and then brought back to the laboratory for rearing the parasites to the adult stage. Sickly larvae were dissected to see whether they had internal parasites. Some of the emerging adult parasites were carded and others preserved in 70% alcohol together with the dried up carcasses of their hosts.

Results: Anomis, Characoma, Euproctis xanthomelana, Argyrostagma niobe, Eumeta rougeoti and several others (Table 6.3) were frequently found parasitized by braconids, chalcidids and ichneumonids in the field. Characoma is also parasitized by a tachinid. In Table 6.3 it can be seen that Anomis was the most frequently parasitized caterpillar followed by Characoma, Eumeta, E. xanthomelana and Spodoptera. Further, it can be noted that parasitism in relation to the total population of Lepidoptera at Aburi (Table 3.5) was low, averaging about 7.8%. From Fig.6.1 it would seem that there was no clear-cut single peaking period in parasitism, the numbers of parasitized larvae being generally high between weeks 5-24 (late October - early March), that is, the period

Table 6.3

Number of caterpillars found parasitized in the field at Aburi, 1970-71

Weeks	Months	Anomis	Characoma	Earias	Lophocrama	Plusia	Spodoptera	Diacrisia	E. xanthomelana	E. melanopholis	O. basalis	O. mixta	A. niobe	E. lepidographa	E. lethe	E. rougeoti	Psychid 1	Psychid 2	Total parasitized	Total individuals	% parasitism
1-4	IX-X	4	-	-	2	-	-	-	2	-	-	-	1	-	1	-	-	-	10	100	10.0
5-8	X-XI	6	2	-	-	-	2	1	1	-	-	-	-	2	-	-	-	-	14	112	12.4
9-12	XI-XII	3	-	2	-	-	2	-	-	2	-	-	-	-	-	2	3	-	16	147	10.9
13-16	XII-I	-	5	-	2	-	-	-	-	-	-	-	-	-	2	3	-	3	15	165	9.5
17-20	I-II	6	4	-	-	2	-	-	1	1	1	-	1	-	-	1	-	-	17	197	8.6
21-24	II-III	5	3	1	-	-	-	3	-	-	1	-	1	-	-	-	-	1	15	317	4.7
25-28	III	4	-	-	1	-	-	-	-	2	-	1	-	1	-	2	-	-	11	356	3.0
29-32	IV	-	2	-	-	-	-	1	1	-	-	-	-	-	-	2	-	1	7	296	2.3
33-36	V	2	3	-	-	-	-	-	2	-	-	-	-	-	-	1	1	-	9	98	9.2
Total		30	19	3	5	2	6	5	7	5	2	1	3	3	3	11	4	5	114	1788	7.8

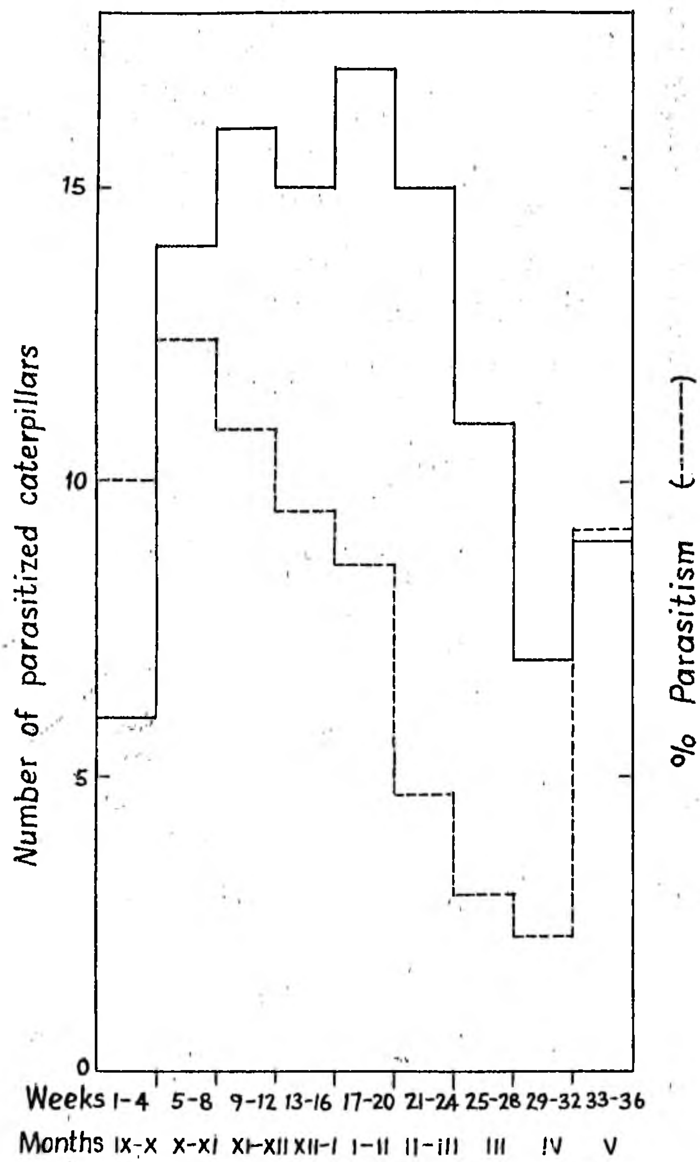


Fig.6.1: Number of parasitized lepidopterous caterpillars at Aburi, 1970-71.

from the short wet sunny season through the dry sunny up to the early part of the long wet sunny season. During this period the numbers of caterpillars were gradually increasing on flushes and more of their individuals were at the same time being affected by parasites. The dry conditions in the December-February period did not seem to have any effect on the parasites, although it could be argued that the sporadic rains that fell at that time probably lessened the severity of the drought (Table 3.12). The results seem to show that there is a close correlation between the incidence of parasitism and availability of lepidopterous hosts.

6.7: Predation

Not many caterpillars were found predated upon in the field. On one occasion two Oecophylla ants were seen pulling an intermediate instar larva of Anomis, one ant at the anterior end and another at the posterior much as in a tug-of-war. The larva which had not yet been killed was continually twitching, but was apparently unable to free itself from the ants' grip. When examined later under a dissecting microscope, it was observed that some haemolymph was oozing out of the wounds made by the ants' mandibles and part of it had formed a dark clot around the wounds. On that same branch one Oecophylla was seen carrying an early instar larva of Anomis towards a nest at the end of the low-hanging branch. Five Oecophylla nests were collected in plastic bags, treated with chloroform to kill the ants and then opened to see whether there were any caterpillar remains in them. In two nests parts of cuticle very closely like that of Anomis were found. There were no remains of hairy caterpillars. On one occasion several <u>Oecophylla</u> were seen carrying a dead acraeid caterpillar up a tree trunk. <u>Pheidole</u> attacked <u>Colocleora</u>, <u>Argyrostagma</u> and <u>Rhodogastria</u> caterpillars that had been placed in sleeves on cocoa seedlings at Legon. These caterpillars were attacked after <u>Pheidole</u> workers had managed to make their way through the netting. Occasionally, these ants would attack the caterpillars from outside the muslin sleeve, that is, when the caterpillars were resting on the fabric rather than on the enclosed leaf. In this case the larva would be torn and pulled bit by bit through the netting until only those parts which could not be forced through the "eyes" of the muslin bag, such as head capsules, would be left behind. In fact, <u>Pheidole</u> was responsible for the high predation of ensleeved larvae. When ostico was smeared on the stems of the seedlings no more <u>Pheidole</u> could reach the sleeves. Although reduviid bugs will feed on chopped up caterpillars in the laboratory (Louis, 1971), these bugs were never found feeding on lepidopterous caterpillars in the field.

Chapter 7: Lepidopteran damage to cocoa.

7. LEPIDOPTERAN DAMAGE TO COCOA

7.1: Mode and patterns of feeding

Methods: To study patterns of feeding damage of the various species leaves which had been eaten were pressed between newspaper pages and left until dry. Diagrams of characteristic feeding patterns of each caterpillar were subsequently traced on translucent paper. It should be noted that the feeding patterns of some species are very similar so that it is difficult to distinguish them unless the caterpillar is actually present on the leaf at the time of inspection.

Results: *Anomis leona* takes up several positions while feeding on cocoa leaves. The early instar larvae sit flush on the leaf on which they are feeding and make small holes in a random fashion on the lamina. *Characoma*, *Earias* and *Spodoptera* larvae feed in a similar way during their very early stages and so also do some eumolpid beetles. Later instar larvae of *Anomis* usually expand the small holes made earlier by eating away more tissue, and when doing this they adapt themselves to the curvature of the partially circular hole. Alternatively, they may migrate to other yet uneaten leaves, position themselves on the margin of the leaf blade and start feeding. *Anomis*, *Neocleora*, *E. xanthomelana* and other caterpillars are fast feeders, eating out large areas of tissue in a short space of time.

In most caterpillars that were observed, continuous feeding at one point was rare. After having eaten a small area the caterpillar moves on to another part of the leaf. Parts that have already been eaten out are rarely eaten again. Before eating, larvae first explore the surface of the leaf with their antennae, keeping their mouth parts very close to the leaf surface or edge. Caterpillars such as Anomis, Neocleora and some lymantriids rest for a few minutes between meals or may move on to other leaves to resume feeding. The tortricids including Characoma feed on the rolled leaves in which they hide. Occasionally they vacate exhausted leaves and start binding new leaves together before feeding is resumed.

Anomis usually eats off apices of leaves and larger larvae may devour large areas (Fig.7.1-7.3). The midrib and side veins are almost always eaten near the apex. It is quite common to find a chupon with almost all its leaves badly damaged by Anomis. Leaves that have been eaten by cateppillars retained the scars till maturity, very few were ever found wilted. The psychids begin at the base of the leaf and devour the lamina on either side of the midrib. At times the whole lamina may be devoured before a larva moves to another leaf, only the base of the midrib remaining (Fig.7.4-7.5). Leaves that have been partially consumed by psychids can be recognised by large holes eaten out on either side of the midrib starting from the leaf base towards the middle part of the lamina. In the absence of leaves psychids may eat the bark of chupon stems. Most species of Lymantriids start by eating a hole in the middle part of the lamina after which they move to one side of the leaf blade (Figs.7.7, 7.8). The side to which they migrate first is usually extensively eaten in contrast to the other to which they rarely shift. Leaves eaten by Characoma and Tortrix have numerous

Anomis leona damage

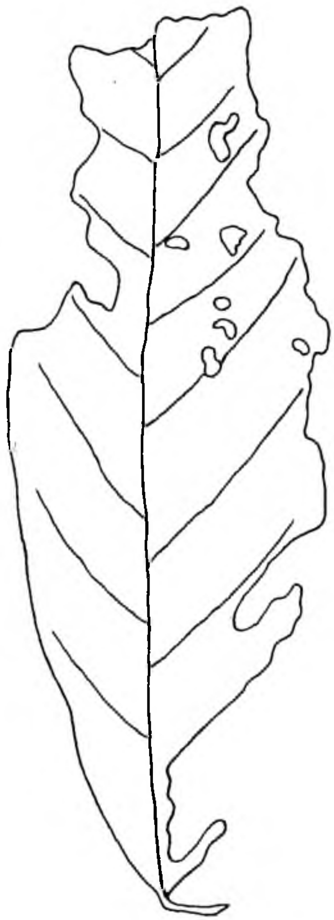


Fig. 7.1

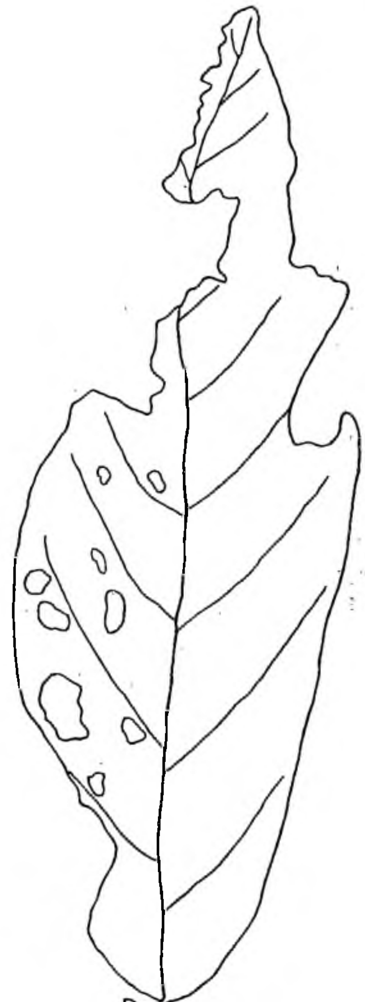


Fig. 7.2

Damage due early instar A. leona

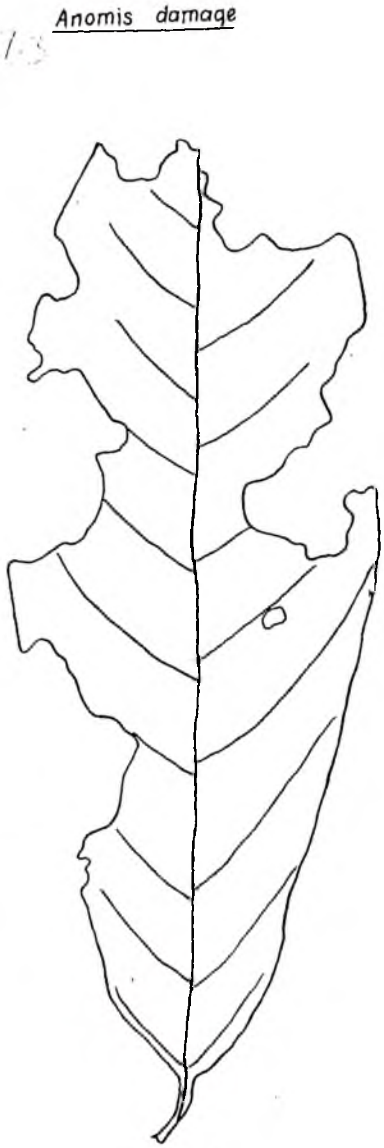


Fig.7.3

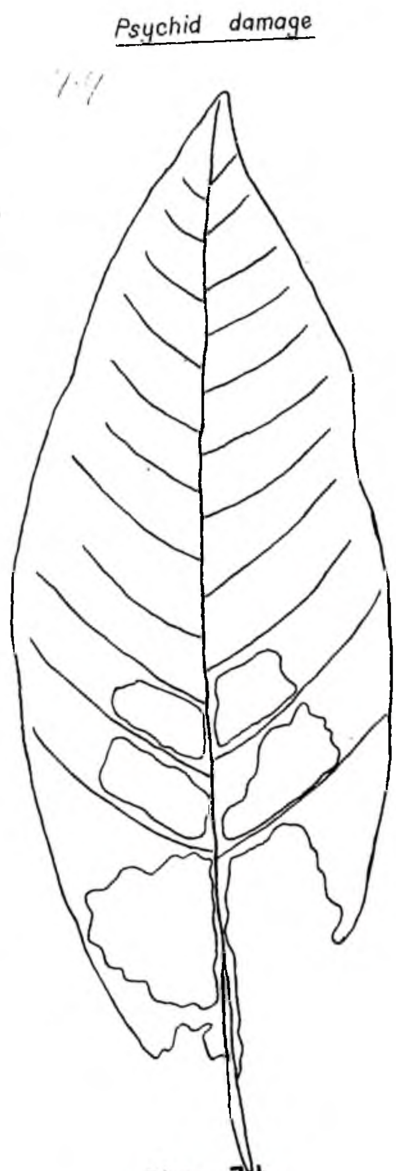


Fig. 7.4

Damage due to later inster A. leone and psychids

Psychid damage

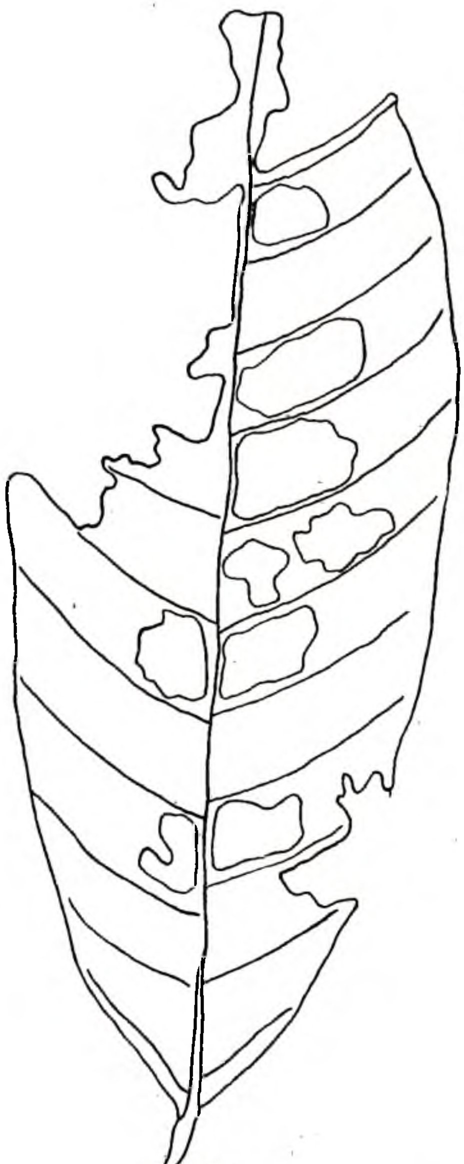


Fig.7.5

Characoma damage

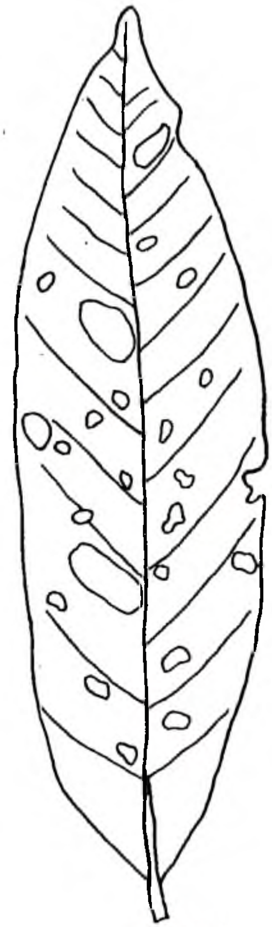


Fig.7.6

Damage due to psychids and <u>Characoma</u>

E.xanthomelana damage

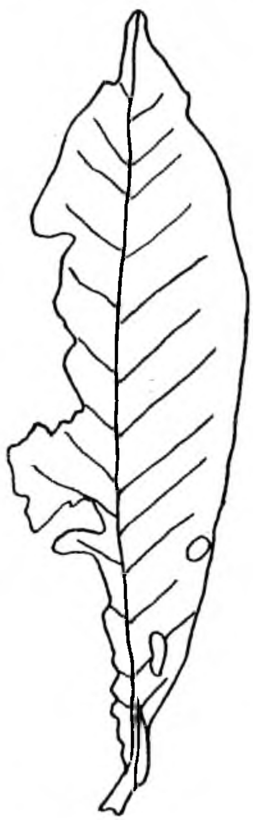


Fig.7.7

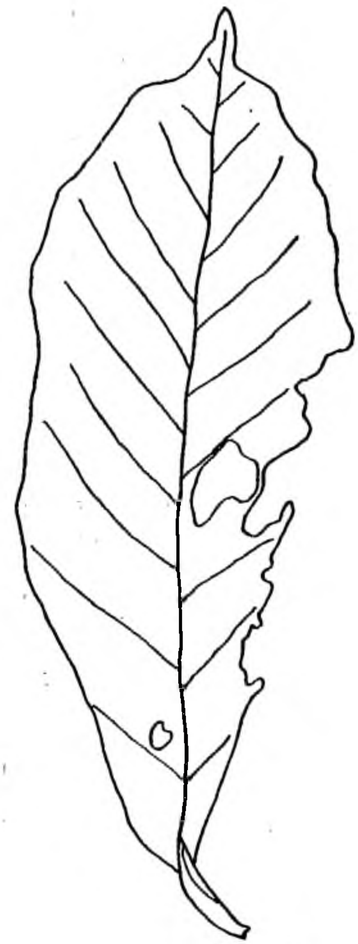


Fig.7.8

Damage due to *Euproctis xanthomelana*

holes (Fig.7.6). Characoma may also bore into chupon tips more or less in the same way as Earias. Tips attacked by this caterpillar can be recognised by the presence of a network of silk strands to which some pellets of frass may be entangled.

Faecal pellets in Anomis, Neocleora, Colocleora, Plusia, Diacrisia and several other caterpillars, are usually ejected forcibly from the anus, which process frequently occurs at the same time as the larva is feeding. In other caterpillars such as lymantriids frass is not discarded in this fashion, but on leaving the anus the pellets either drop to the ground without apparently being 'catapulted' out, or may remain attached to hairs around the anus for some time before eventually falling off. In pod-boring Characoma, frass is bound in silk and mucilage around entrance holes to tunnels in pods. This can be seen at a point where a pod is in contact with the tree trunk or with an adjacent pod.

7.2: Leaf damage in relation to shade

Methods: Eaten and uneaten flush and green tender leaves were counted weekly. This was done from February to May because flush was more plentiful at this time. In a few cases it was possible to conclude from the feeding pattern, which species caterpillar had been feeding on a particular leaf e.g. Anomis, E. xanthomelana and the psychids. When patterns were those characteristic of several species it was necessary to depend upon the presence of a caterpillar on the chupon inspected to identify the species responsible for the damage. Cocoa trees with good and poor canopy were inspected.

Results: More flush leaves were eaten by Anomis than by any other larvae, the greatest damage being on cocoa trees with a poor canopy (Table 7.1). It would appear also that a large number of flush and green tender leaves was consumed in March and April respectively when flushing was at its highest level. Psychids devour flushes, too, particularly in the early stages of their larval life, but their activities become confined to maturer leaves in later instars. It is noteworthy that while flush leaves are relatively more heavily attacked in the open, the tendency is far less marked with mature leaves.

7.3: Damage by other insects

Cocoa leaves and superficial tissue of pods were frequently found damaged by such insects as tettigoniid grasshoppers and eumolpid and elaterid beetles. Pods were also found with parts of the pericarp eaten away with the result that cocoa beans were either exposed or completely dislodged from pods. This kind of damage is probably due to rodents and other mammals.

Table 7.1

Number of flush and mature green tender leaves eaten by some caterpillars at Aburi from February to May, 1971.

February

Species	Shade				No shade			
	Flush		Mature		Flush		Mature	
	No. eaten	% eaten	No. eaten	% eaten	No. eaten	% eaten	No. eaten	% eaten
Anomis	62	30.5	32	9.2	205	54.2	31	9
E. xanthomelana	14	6.9	-	-	30	7.9	-	-
Neocleora	4	1.9	-	-	11	2.9	10	2.9
Psychids 3 spp.	5	2.5	105	30.2	9	0.3	96	27.9
Others	5	2.5	10	2.8	4	0.11	6	1.7
Totals	90	44.3	147	42.2	249	65.9	143	41.7
Total leaves inspected	203		348		378		343	

March

Species	Shade Flush No. eaten	Shade Flush % eaten	Shade Mature No. eaten	Shade Mature % eaten	No shade Flush No. eaten	No shade Flush % eaten	No shade Mature No. eaten	No shade Mature % eaten
Anomis	83	28.6	22	8.7	162	48.6	26	10
E. xanthomelana	21	7.3	-	-	38	11.4	-	-
Neocleora	15	5.2	5	2.0	9	2.7	13	5.0
Psychids 3 spp.	5	1.7	61	24.1	19	5.7	76	29.3
Others	8	2.8	7	2.8	11	3.3	10	3.9
Totals	132	45.7	95	37.5	239	71.7	125	48.3
Total leaves inspected	289		253		333		259	

Table 7.1 (continued)

April

Species	Shade				No shade			
	Flush		Mature		Flush		Mature	
	No. eaten	% eaten	No. eaten	%% eaten	No. eaten	% eaten	No. eaten	% eaten
Anomis	89	39.8	-	-	159	55.2	-	-
E. xanthomelana	6	2.7	-	-	21	7.3	-	-
Neocleora	12	5.4	-	-	15	5.2	33	1.4
Psychids 3 spp.	6	2.7	43	25.6	5	1.7	70	33.3
Others	-	-	9	5.4	4	1.4	4	1.9
Total	113	50.4	70	41.7	204	70.8	109	51.9
Total leaves inspected	224		168		288		210	

May

Anomis	74	34.3	-	-	91	40.8	-	-
E. xanthomelana	16	7.4	-	-	24	10.8	-	-
Neocleora	-	-	-	-	4	1.8	2	1.3
Psychids 3 spp.	-	-	44	29.0	18	8.0	39	25.8
Others	-	-	-	-	-	-	7	4.6
Totals	90	41.7	66	43.4	137	61.4	73	48.3
Total leaves inspected	216		152		223		151	

DISCUSSION

At Aburi flushing was greatest in February-March at the end of the dry sunny season getting into the wet sunny season. This period therefore came earlier than expected. For instance, Greenwood and Posnette (1950) recognised a major flush in March to April and two others in October to December. The small and relatively insignificant flush in November-December may therefore be taken to coincide with the findings of Greenwood and Posnette (1950) as regards the second burst of flush during this period. The high percentage flush in February-March may have been triggered by the February rains. Gibbs and Leston (1970) have suggested that a large flush after the dry season may be due to the decreased leaf complement caused by drought stimulating replacement and because the weather conditions, rain alternating with long hours of bright sunshine in the wet sunny season, are conducive to growth at this time. The cocoa trees at Aburi had however, some degree of flush throughout the sampling period. In December-January, for instance, more than 45% of the trees sampled were in flush in spite of the fact that it was during the dry season. It has been suggested that, because of poor soil conditions or insect attack, some trees may produce flushes at regular intervals (Gibbs and Leston, 1970), and this may possibly have been the case at Aburi. It would appear that while cocoa flushing at Aburi in 1970-71 had a seasonal pattern, this did not exhibit a distinct bimodality; if it does normally occur, it may have been obscured by the moderate but relatively continuous production of flushes throughout the season.

In the course of sampling, a greater number of lepidopterous caterpillars at Aburi were found on flush leaves than on mature hardened or senescent leaves. This preference for flushes may be due to the fact that caterpillars have weak concentrations of such essential enzymes as amylases, sucrases and proteases, and depend on those enzymes already produced in the tissues of the plant (Hocking and Depner, 1961). This, however, may still be unlikely in flush leaf-eating caterpillars because the food value of flush per gram of leaf is probably higher than in hardened leaves, as flushes have generally much less cellulose than hardened leaves. It has frequently been observed that fragments of leaves ingested by caterpillars often appear in the faeces, this being more evident in larvae that feed on mature leaves than on flushes. Some indication of the efficiency with which leaves may be utilized for growth is given by figures obtained in the Noctuid caterpillar Prodenia: of 10.8gm of food eaten by 60 larvae, 5.5gm appeared in the excreta, 3.6gm was added to the weight of the larvae (Crowell, 1943, in Wigglesworth, 1965) Apart from deriving organic nutriment from the growing tips and flushes of seedlings, caterpillars may also be gaining essential mineral substances from the flushes. Wessel (1968, 1970) conducted pot trials with cocoa in Nigeria, and showed that the development of a new flush of leaves removes 39% of the phosphorus and 25% of the potassium from the mature leaves of the preceeding flush. It could be concluded from these experiments that leaves of previous flushes contribute most to the development of new leaves and are the main reservoir of mobile leaf phosphorus and potassium, which may be essential constituents in the growth of caterpillars. Nelson and Palmer (1935) for instance, showed that in the larva of Tribolium (Coleoptera) phosphorus composes about 0.19% of the wet weight at all stages, and that growth is delayed if the phosphorus content of the flour is below 0.1%.

Sampling has shown that fluctuations in populations of leaf-eating lepidoptera at Aburi are not only related to the availability of food but to a certain extent also with the changes in seasons of the year. According to Gibbs and Leston (1970) increase of the population of various species occurs in the period from the latter part of the dry season in February through the build-up of the rains to May and June in the wet season. At Aburi rainfall figures for 1970 (Table 3.12) show that less rain fell in September, when sampling was begun, than in October. At that time a number of lepidopteran species were either absent or present in low numbers. During the wet sunny season and getting to the early part of the dry sunny season, that is, from October to December, a steady build-up in numbers of such caterpillars as Anomis, Characoma, E. xanthomelana, E. melanopholis and S. littoralis was noticeable, possibly because flush production stimulated by the October rains was gradually increasing. Anomis and Characoma show this simultaneous increase in their numbers with the gradual availability of flushes rather clearly, but in the dry months of December-January not many larvae were collected (Fig.3.21e-f). In Table 3.5 and Fig.3.21e-f it can be seen that the numbers of Anomis and Characoma were much higher in weeks 17-20 (January-February) than in the previous four weeks, 13-16. At about this time too, there was a high percentage of trees in flush (Fig.3.1). No sooner had the rains come in late February-April than many more caterpillars were seen on flushes. It is likely, as has often been observed, that during the drier parts of the year such as in December-January, Anomis, on the one hand, survives by feeding on green tender or even slightly hardened leaves, while on the other, Characoma, which normally tunnels in pod husks, makes do with a few flushes that may be available especially on basal chupons or else that there is pupal quiescence. During the short dry dull season in August and the early wet dull season in September, 1969, Leston (1971) collected caterpillars at Kade and Asamankese in the Eastern Region. He concluded from the low numbers of individuals present, of thirteen species, that this is a trough period although the lack of collection at other times of the year leaves this conclusion without valid evidence, which may also be true for the December-January and the May periods at Aburi (Fig.3.21).

Spodoptera littoralis, however, peaked in November-December, a period well inside the dry season. This would suggest that at Aburi this insect is more abundant on cocoa during the drier parts of the year, as no caterpillars were found in February-May which was the period in the wet season. Lyon (1968) gives light trap capture data for five years at Samaru in the savanna zone of Nigeria. He shows that S. littoralis builds up through several generations in the wet season, reaching a peak at the end of the rains around late September or early October. It should be noted therefore that Lyon's data does not clearly bring out the dry season peaking which was observed at Aburi. From this information, however, as well as from Benson and Leston's (1971) data it seems likely that this insect not only moves in savanna areas in the course of its dispersal flights, but also flies to clearings in the forest zone where, in the dry season, it is capable of building up substantial populations on cocoa as well as on other forest crops.

At Aburi, the numbers of Earias biplaga were very low throughout the sampling period, even at times when flushing was at its highest. This is in contrast with what was observed at Tafo in the same period (Table 3.11). It is likely that in unsprayed farms such as at Aburi, the increase in numbers is checked by natural enemies, which are probably killed off in regularly sprayed areas (Entwistle, 1960). No larvae of Earias were found in December-February, which seems to suggest that the dry season has adverse effects on the insect. It is possible that at this time Earias may undergo pupal diapause which, though rather infrequent in the tropics as compared with the temperate regions (Wigglesworth, 1966), may still occur where there is a dry season that must be survived, or just quiescence with release by rain. Earias caterpillars reared between November and January in the laboratory changed into pupae in the normal way, but most of them remained in the pupal stage far beyond its normal duration of approximately eleven days. When the pupal cases were cracked open it was found that the imagines had formed all right but did not emerge, and had completely dried up within the puparia. This failure to emerge, due probably to low humidity conditions of the dry season was also observed in other caterpillars such as E. xanthomelana, O. basalis and some psychids. Entwistle (1969) has observed that in the absence of flush leaves, old larvae of Earias may continue to feed by burrowing vertically down the stem below the already destroyed apical bud. Alternatively Earias may leave the damaged bud and feed on the bark of of the upper portion of the stem, especially if this is unhardened, occasionally burrowing into the stem near the petiolar attachment. When the rains came in the February-March period at Aburi, Earias caterpillars were again encountered on flush leaves. The situation at Tafo was different because the young seedlings that were usually sampled flushed more often than did mature trees (Greenwood and Posnette, 1950) with the result that food was available in virtually all the seasons. Entwistle (1963) observed that at Gambari, Nigeria, there were two population peaks of Earias, one between November and December and another in March, the numbers falling to a very low level in between. The last peak was the largest and followed on the first rains of the dry season, while the first appeared to follow on the rains breaking a short drought in the previous wet season. In Entwistle's view the observed population changes were not directly the result of rainfall, but rather were associated with an increase in available feeding sites. Youdeowei (1971) recorded insect damage on the regenerated chupons at Gambari from April, 1968 to April, 1969. The results show that the most important insects were the leaf-eating caterpillars which attacked the young flush leaves, and in most cases whole leaves were completely eaten. The amount of damage by these defoliators e.g. Earias, Anomis, Spodoptera, Lophocrama and others was highest in May to August which is a period in the rainy season in Nigeria. Fewer chupons were attacked in the drier months from December to February.

The peaking of the three psychids is of interest because it was synchronous with the period of greatest flush in late February-March. Generally, psychids feed on hardened or senescent leaves (Entwistle, 1963) but it has been observed that the early instar larvae first feed on young flush leaves before migrating to hardened ones in subsequent instars. While on flush the young larvae attach tiny pieces of leaf matter and small light twigs onto the outer fabric of their cases. On transferring to harden leaves longer twigs, usually petioles of hitherto uneaten leaves, are eventually incorporated. Older leaves are preferred by later instar larvae possibly because they are better suited for supporting the increasing weight of the caterpillars. Because of the extremely long larval period (Entwistle, 1963) the psychids were present in high numbers throughout the sampling period (Fig.3.21n-p).

E. xanthomelana and E. melanopholis had more or less identical peaking periods, and both were usually found co-existing on the same chupon in the field, though rarely on the same leaf. The likelihood is that either their larval stages are of about the same duration or that the female moths of the two species have fairly similar ovipositing habits. Smith (1965) gives the larval life of E. xanthomelana as 36 days and that of E. melanopholis at about 29 days. It would appear likely therefore that larvae of E. melanopholis pupate about a week earlier than those of the other caterpillars. This may explain why higher numbers of E. xanthomelana were scored than those of E. melanopholis. A pattern fairly similar to that of these two caterpillars is exhibited by O. basalis and A. niobe (Figs. 3.11-3.12). All the four caterpillars belong to the same family, Lymantriidae, and it may therefore be expected that they may have related behavioral traits. The geometrids, Neocleora and Colocleora divisaria did not appear in large numbers on cocoa during the period of sampling (Figs.3.15, 3.16). There were higher numbers of Neocleora in March than those of Colocleora at the same time. In the November-December period more Colocleora caterpillars than Neocleora ones were found in the field in spite of the fact that it was in the dry season and flush was low. It should be noted that these caterpillars are capable also of switching on to mature leaves if flush is scarce. It is also likely that these caterpillars are not adversely affected by conditions of low humidity, which usually prevail in the dry season, because they occasionally pupate in the litter on the forest floor where some moisture is usually retained. The seasonal pattern of the rare species such as Plusia chalcites, E. lepidographa and others (Fig.3.22-3.25) did not differ much from that of the commoner species. The infrequent occurrence of some species on cocoa may be due either to competition for feeding sites with the more successful caterpillars such as Anomis and Characoma.

or to the fact that some of them prefer other plants to cocoa.

The increase in lepidopteran populations at Aburi may therefore be associated with the maximum availability of flushes. Several species were abundant in the wet sunny season from the second half of February to April. Gibbs and Leston (1970) have also shown that non-lepidopterous insects such as, for example, the leaf-feeding eumolpid beetle, Paraivongius viridiaeneus, have two main periods of population increase which correspond with times when leaves produced in the two periods of major flushing approach maturity; that is, from the late wet sunny to the early wet dull season in May-July, and from the wet sunny to early dry season in October to early December. Similarly, the psyllid Tyora tessmanni which attacks leaf-buds wherein it both oviposits and feeds (Leston, 1970) had its main period of increase in numbers in the first wet sunny season in April in 1966, when cocoa shoot tips were plentiful.

Although the number of caterpillars observed on green pods at Aburi is not large, it is clear that certain Lepidoptera which normally confine their feeding activities to flush leaves can direct their attention to green pods when flush is absent or scarce. Cotterell (1930), Navel (1921) and Smith (1965) recorded that Euproctis mediosquamosa caterpillars eat the surface of cocoa pods in Ghana. At Aburi, Anomis leona, Argyrostagma niobe and E. melapholis were found eating superficial tissue of pods. The damage done by A. leona and to a certain extent also by Earias biplaga to the pericarp of pods in Ghana has been reported by Lodos (1967). In Nigeria Gerard (1966) has reported that of the three lymantriid species occasionally found damaging pods,

A. niobe is the most important and was unusually abundant on cocoa trees with a closed canopy at Gambari near Ibadan. Characoma stictigrapta; apart from feeding on flush, also bores into husks of green pods, though rarely reaching the beans in its tunnelling activities. It can be seen that more damage was done by Characoma caterpillars in October when there were many pods available. In March fewer pods were attacked by Characoma probably because new flush leaves were plentiful at the time (Fig.3.1). More pods were infested in May when flush was again at a low ebb. Pod infestation by Characoma appears to be correlated with a good canopy. Lodos (1967) has observed that Characoma frequently causes wilting of cherelles. The actual damage done by the borer is not serious, but there is a danger of fungal attack (Entwistle, 1962; Patterson, 1914). According to Lodos (1969) the eumolpid, Paraivongius semipiceus, is another common cocoa pest which attacks pods and cherelles, eating the exocarp. The damage can be serious. It would appear that when more pods are produced in the period September-November, which is in the wet dull season up to the beginning of the wet sunny season, the numbers of Marmara also increase, probably because of an abundant food supply.

Results show that there is an association between shade and the increase in numbers of Lepidoptera found on cocoa. Cocoa trees with a poor canopy harboured much higher numbers of some lepidopterous caterpillars such as Earias biplaga, Anomis leona, Spodoptera littoralis and others, but where the canopy was good Characoma stictigrapta, Euproctis xanthomelana, Diacrisia anriantiaca, Tortrix dinota and

Orgyia basalis were constantly encountered. Gerard (1970) and Lavabre (1965) have, however, reported Anomis as occurring on shaded cocoa. Cotterell (1928) reported that C. stictigrapta attack on pods was more prevalent in areas of heavy shade and humidity. Similarly, at Aburi, there was a higher percentage of Characoma infested pods where there was good canopy. Data from shade versus no-shade experiments (Johnson, 1962; Smith, 1962) show that de-shaded plots were in an unhealthy condition, as many trees lost terminal buds due to the activities of E. biplaga which was more abundant on deshaded trees.

It is possible that more light results in an increase of Earias, because the adult female moth may prefer lighted to shaded areas for oviposition. At Aburi, Tafo and Kade large numbers of Earias individuals were frequently encountered on seedlings growing on shadeless plots. Shaded seedlings remained healthy, few being damaged apically. In Nigeria, Entwistle (1963, 1964, 1965) and Gerard (1964, 1970) observed that numbers of Earias larvae were much higher on unshaded trees despite the poorer stature and leafiness of the plants. Lavabre (1965) found a similar situation in the Ivory Coast, where Earias was in large numbers on young cocoa seedlings grown in the open. It should be noted that destruction of the apical bud by the early instar larvae of Earias biplaga leads to production of regenerative lateral shoots which in their turn may be attacked (Entwistle, 1964). Formation of a jorquette is also delayed or prevented and in case of heavy attack the canopy never forms fully. Vertical growth is hindered resulting in bushy seedlings.

Marmara surveys at Aburi, Amanokrom and Kade have for the first time brought to light the significant relationship between this pod-husk miner and cocoa grown in the sun, judging from the high chi-squared values obtained.

With regard to the after-effects of insecticides on lepidopteran populations, the results have shown that much larger numbers of caterpillars were found in regularly sprayed areas such as at Kade and Tafo than at the rarely sprayed farms at Aburi. It should be noted that although sampling at Tafo was carried out only once a month, the number of caterpillars counted was in most cases greater than the mean of the lumped four weekly scores from the four farms at Aburi. Populations of *Earias* were reported to have risen immensely on sprayed trial plots at Tafo (Smith, 1962). Similar increases took place in numbers of the lepidopterous stem-borer, *Eulophonotus myrmeleon* and the stem-webber, *Metarbela* sp. after the use of gamma- BHC in routine capsid control in Ghana (Entwistle, et al., 1959; Entwistle, 1961, 1962; Gerard, 1964; Smith in Gerard, 1964). In Nigeria increase in *E. myrmeleon* was attributed to a severe dry season (Entwistle, 1963), but Youdeowei (1971) reported post-treatment increases at Apoje near Ibadan. *E. myrmeleon* bores deeply in living wood, attacking stems from one inch to eight inches in diameter (Entwistle, 1962, 1963). Attack is recognised by the presence of a large exit hole to each burrow from which a dark stream of mucilage normally flows when the larva is active inside. At Aburi, however, similarly attacked chupons were rare. The larva of *Metarbela* sp. on the other hand, excavates a short escape gallery into the heart wood, and devours the bark beneath a protective tent of silk and frass. The larva prefers jorquettes or branch unions (Entwistle, 1962).

A great number of pods were infested with the pod-husk miner Marmara at Kade where most of the cocoa plots had been heavily sprayed with DDT, in contrast to the situation at Aburi and Amanokrom. Marmara infestation is always beneath the epiderm of succulent green pods where hardening has not yet occurred (Johnson & Entwistle, 1959). As the larva matures the initial straggling mine develops into a blotch causing peeling of large pieces of the epiderm. Ripe pods may show traces of earlier attack. The damage has no effect on quality and quantity of beans but it is sometimes difficult to tell if the damaged pods are ripe or not. In 1957 a spectacular increase in Marmara followed six monthly applications of dieldrin at Tafo and at Oyoko (Entwistle et al., 1959; Gerard, 1964), but Marmara decreased when the concentration and frequency of sprays were reduced. It is not yet fully known whether the rise in Marmara is due to a specific chemical or merely to an excessive dosage (Johnson & Entwistle, 1959). It is quite probable that under natural conditions parasitism is the main factor responsible for the death of early instars and also affects a high percentage of the population later, especially in the fruiting season (Gerard, 1964), so that with the application of insecticides the free-flying parasites of Marmara get killed (Entwistle, 1960) thus upsetting the natural biological balance. Under natural conditions Marmara appears to be held in check by at least three species of parasitic Hymenoptera, namely, Bracon sp (Braconidae), Ageniaspis sp (Encyrtidae) and a chalcidoid species (Entwistle, 1960). During peak population periods the rate of parasitism of Marmara is extremely high, about 60%, the greater part of this being due to Ageniaspis which is endo-parasitic. At Kade and Aburi very few cases of parasitized Marmara were recorded. Not much study has been made on the predation of Marmara by ants. Some Oecophylla were frequently seen foraging on trees or assembled in large numbers on pods that were infested with Marmara. On examination of the pods for live larvae, these were usually found, especially on those pods which still had their Marmara blotched epiderm intact. The thin epiderm under which Marmara mines, most probably helps to protect the larvae against the ants. Only larvae migrating from their mines to seek pupation sites are likely to be attacked. Gerard (1963) noticed that ants were absent from areas treated with dieldrin. He started an experiment to find out whether more pupae are obtained from trees when ants are excluded than when ants are allowed full access. The results of this study, when published, could show if ants are predacious on the larvae of Marmara. Gerard (1963, 1964) is, however, strongly of the opinion that under normal conditions parasites are more likely to be responsible for the relatively high larval mortality.

A knowledge of the biology of some of the more important Lepidoptera is considered essential for effective control measures against these pests. Following, therefore, are notes collated from various sources as well as from personal observations on the biology of these Lepidoptera:

Earias biplaga (Walker)

Earias biplaga oviposits usually about three days after emergence and soon after copulation for specimens in captivity (Pomeroy, 1925). Eggs are laid on leaf buds (Chatt, 1953) or near the terminal bud (Johnson, 1962). Entwistle(1963; 1969) has, however, given a much more comprehensive list of possible oviposition sites of *E. biplaga* namely woody stem, green stem, apical bud, leaf scar, leaf bract, petiole, upper and lower leaf surfaces. Eggs are mainly laid on stems, especially on leaf bracts not far from the stem apex (Entwistle, 1969). Pomeroy (1925) recorded an average of 51 and a maximum of 86 eggs laid by *E. biplaga* in captivity on cotton, whereas Entwistle's (1964) records show an average of 93 and a maximum of 108 eggs. The egg which is at first green changes from gold to dark gold during incubation and develops a darker apical annulus on about the second day (Entwistle, 1969). The incubation period in Nigeria varies within ranges of 3-6 days (Pomeroy, 1925), 4-5 days (Entwistle, 1963) and 5-6 days in Ivory Coast (Alibert, 1951; Mallamaire, 1936).

In the field the first part of the larval period is passed feeding within the apical bud, as often shown by shed early instar head capsules commonly found inside destroyed buds (Entwistle, 1963; 1964; Lavabre, 1969; Leston, 1971; Schmidt, 1967; Smith, 1962). Older larvae feed on flush leaves (Chatt, 1953; Entwistle, 1963, 1964, 1969; Gibbs and Leston, 1970; Leston and Gibbs, 1971) occasionally on cherelles (Entwistle, 1969; Lavabre, 1969; Lodos, 1967) resulting in cherelle wilt (Lodos, 1967), and also on the bark of young green stems, or they may even burrow down the stem below an already destroyed terminal bud (Entwistle, 1964, 1969). The larval period in the Ivory Coast is anything from 20 to 22 days (Mallamaire, 1936) and on an average of 15.52 days in Nigeria, being longer in the wet season and shorter in the dry season (Entwistle, 1969). Similarly with the pupal period, which varies inversely with temperature. It is longest in the wet season and shortest in the dry season. On cotton-reared larvae in Nigeria it is 13.3 days and in Ghana 13 days on cocoa-reared larvae (Pomeroy, 1925).

The pupal period varies from 11-13 days in the Ivory Coast (Mallamaire, 1936), 10-12 days in Ghana (Pomeroy, 1925) and 9-12 days in Nigeria (Entwistle, 1963, 1969). In laboratory-reared specimens at Legon it was 10-13 days. Pupation takes place on the plant, generally on the stem and petioles (Entwistle, 1969). On cocoa, the cocoon which is shaped like an inverted boat and made of tough felt-like silk (Alibert, 1951; Pearson, 1958) varies greatly in tone, from straw-yellow to a deep grey-yellow (Entwistle, 1969) while on cotton it is a dirty white or pale brown (Pearson, 1958). It has been observed by Entwistle (1969) that pupation does not occur until about a day after the commencement of cocoon formation.

Adults are nocturnal and their diurnal resting places rarely seem to be cocoa itself (Entwistle, 1969). The life span of laboratory reared adults is longer in individuals placed on a diet of sucrose and water than in those on water alone or nothing (Entwistle, 1963, 1969). Alibert 1951), Entwistle (1969) and Pearson (1958) have shown that there are considerable differences in the shape of the labial palps between the sexes and in wing coloration with the time of the year.

Anomis leona (Schaus)

The eggs are laid singly on the lower surface of a cocoa leaf, rarely on the upper surface (Alibert, 1951; Dagatiguy, 1953; Lavabre, 1954) and incubation takes 4-5 days (Dagatiguy, 1953). The egg is spherical, but much flattened on the part resting on the leaf. It is light blue with a tinge of green and has fine peripheral stripes (Alibert, 1951). When the embryo is fully developed, the egg-case becomes transparent and three to four sided, and the young larva on emerging is green to light yellow (Dagatiguy, 1953). The young caterpillars feed on young flush leaves (Alibert, 1951; Dagatiguy, 1953; Gibbs and Leston, 1970; Lavabre, 1965; Leston, 1970, 1971; Leston and Gibbs, 1971; Schmidt, 1967; Smith, 1965; Youdeowei, 1971), and very rarely on mature hardened leaves, but occasionally on mature tender ones (Alibert, 1951). Lodos (1967) and Smith (1965) have given reports of A. leona feeding on cherelles. The duration of the larval stage is from 20-22 days (Alibert, 1951; Smith, 1965) while the pupal period in the Ivory Coast ranges from 8-12 days (Alibert, 1951) and 7-12 in Ghana. Adults are night fliers and have very rarely been seen during the day (Alibert, 1951).

Characoma stictigrapta (Hampson)

The adult lays its eggs which hatch in four to five days (Alibert, 1951), near the stalk end of the pods, from where the emerging young caterpillars proceed to bore their way through the pod-husk (Alibert, 1951;

Chatt, 1953; Smith, 1965; Urquhart, 1961). Masses of frass left adhering to the pod near the entry hole are frequently seen where two pods are touching (Lodes, 1967; Nicol, 1947). Observations made by Patterson (1922), Entwistle (1962), Lodos (1967), Magnin (1954) and Schmidt (1967) on the activities of the larva of C. stictigrapta show that damage is superficial and confined to the exocarp of the pod. The larva rests near the entry hole to a tunnel amidst the frass-mucilage mass and quickly escapes into the husk when disturbed. In the absence of pods or where they are very few, larvae may also attack young flush leaves tying them together with silk or may enter the stem below the apical bud and burrow downwards for two to three inches (5.0-7.5cm), binding the terminal leaves with silk. Alibert (1951) found the duration of the larval stage in the Ivory Coast to be 25-35 days, but Smith (1965) puts it at 25-30 days in Ghana. Pupation is normally on the pod surface or in the soil (Entwistle, 1962) or in the tunnels made by the larva in the husk. The pupal period lasts from 13-15 days in the Ivory Coast (Alibert, 1951) and 10-13 in Ghana. The adult is nocturnal (Nicol, 1947) and hides beneath leaves during the day (Alibert, 1951).

Lophocrama phoenicochlora (Hampson)

No information is available from the literature about the place where the adult moth lays its eggs, but they are probably deposited on leaves such that when the first instar larvae emerge they find flush leaves on which they feed easily accessible. The caterpillar which bears some resemblance to Earias biplaga is often found co-existing with Earias on chupons. The duration of the larval stage is uncertain but the pupal stage lasts from 9-14 days (Smith, 1965), and 10-12 in laboratory-reared specimens. The adult has not been seen during the day, which means it is probably active at night.

Spodoptera littoralis (Boisduval)

Eggs are laid in batches of several hundreds on the lower surfaces of leaves and are covered with grey scales from the abdomen of the female moth (Alibert, 1951). Incubation takes 3-5 days in Ivory Coast and 3-4 days in Ghana (Smith, 1965). Before eclosion the larva cuts the apical operculum of the egg open and the emerging larvae aggregate on the feeding leaves (Alibert, 1951). Larval life lasts 18-22 days in Ivory Coast (Alibert, 1951) and 22-24 days in Ghana (Smith, 1965). Pupation takes place in the soil; alternatively, the larva constructs a loose cocoon of silk. The pupal stage has been reported by Alibert (1951) to last 10-12 days in the Ivory Coast and 8-11 days in Ghana (Smith, 1965).

Eulophonotus myrmeleon (Felder)

Some aspects of the biology of this moth have been reported on by Alibert (1951), Entwistle (1963), Mallamaire (1955). Entwistle (1963) reports that in laboratory reared specimens mating occurred within 24 hours of emergence and lasted up to six hours, and 500 sticky eggs were laid in strings. Alibert (1951) and Mallamaire (1955) state that eggs are frequently laid in necrotic tissue and cankered wounds, especially above petioles and pod stalks. Eggs laid in the laboratory hatched after 11 days. Smith (1965) reports an incubation period of 12-13 days. Duration of the larval period is estimated at not less than 3 months (Entwistle, 1963). The larva bores into the woody stem and branches of cocoa of about 1" - 8" (2.5 - 20.0 cm) diameter. The gallery has a single entrance hole at its base and lies parallel with the long axis of the stem. Pupation takes place in the wood, the mature larva first isolating itself at the blind end of the gallery by means of a silk septum loosely interwoven with wood particles. Smith (1965) estimates the pupal period at 20 days. Alibert (1951) and Entwistle (1962, 1963) have described the sequence of events that occur before emergence of the adult. When the adult is ready to emerge, the pupa moves towards the exit hole from which the pupal case is often to be seen protruding after the adult has flown. The male and female moths differ greatly from each other, the female being larger and having sooty black wings (Alibert, 1951; Entwistle, 1962).

Marmara sp.

The egg is laid on the pod surface, and on eclosion the larva immediately tunnels beneath the epiderm of a green pod (Alibert, 1951; Entwistle, 1960, 1962; Entwistle et al. 1959) or of chupons and fans (Johnson and Entwistle, 1959). Entwistle (1962) observed that the earlier part of the mine is narrow and sinuous giving rise to distinctive dark brown scribbling marks on pod surfaces. These later take up a blotch formation. Entwistle (1962) has reported six larval instars all passed in the mine. He states that during the first four instars the larva is dorso-ventrally flattened, and on ecdysis to the fifth instar it becomes cylindrical. Entwistle,(1962) has not observed the behaviour of the sixth instar larva in Ghana but in Ivory Coast Alibert (1951) reports that, on maturing to the cylindrical form, the larva leaves the mine to rest in a web in the leaves where it subsequently pupates.

Gerard (in Smith, 1965) states that the duration of the larval stage is about 24 days and of the pupal stage about 11 days.

Neocleora sp.

Not much has been reported on the oviposition sites of this moth, but it is likely that the eggs are laid on leaves so that the emerging larvae find it easy to migrate to flush leaves on which they feed. Duration of the larval stage is from 28-31 days while the pupal stage lasts from 11-12 days (Alibert, 1951). In the laboratory the pupal period was 7-11 days. The adult is a powerful flier and rests beneath cocoa leaves during the day (Alibert, 1951).

Calocleora divisaria (Walker)

Oviposition probably takes place on or near flush leaves such that young larvae that hatch out find food nearby. The larval period is probably more than 23 days and the pupal stage usually 8-11 days (Smith, 1965). In specimens reared in the laboratory, the pupal period was 9-11 days.

Orgyia basalis (Walker)

Eggs are laid in batches of 6 and 15 and are covered with scales from the last abdominal segment of the female moth (Alibert, 1951). Incubation takes 5-6 days and the young larvae that hatch out of the eggs feed on flush leaves (Alibert, 1951; Smith, 1965). Larval life takes 15-25 days and the pupal stage has a duration of 6-7 days (Alibert, 1951; Smith, 1965), and 6-9 days in laboratory reared specimens.

Euproctis xanthomelana (Holland)

The larvae that emerge from the eggs feed on young flush leaves (Smith, 1965). Larval life is about 36 days, and the pupal stage has a duration of 15-22 days (Smith, 1965), but 8-14 days in larvae reared in the laboratory.

Euproctis melanophelis (Hampson)

The larva eats young leaves and has a duration of about 29 days. The pupal stage lasts 7-19 days (Smith, 1965); a duration of 11-15 days was found with larvae reared in the laboratory.

Argyrostagma niobe (Weymer)

Copulation occurs soon after emergence (Bullock and Smith, 1968). The female, whose abdomen is distended with ova, is unable to fly and is actively sought by the male. The ova are usually laid on the trunk of a host plant and very occasionally on the cocoon. During oviposition on the trunk the female faces up the tree and climbs slowly upward, pausing to lay a line of 5-6 eggs by swinging her abdomen to one side. The eggs stick together to form a solid mass and are covered with scales from the abdomen of the female.

The larvae hatch in about 14 days by breaking the chorion near the thickened rim and congregate over the egg mass for about 24 hours, by which time emergence is complete and the empty shells have been eaten. The larvae disperse and move up the tree until they reach young leaves where they commence feeding. Pupation takes place on the tree trunk and the pupal period lasts 8-11 days in specimens reared in the laboratory. In wattle-feeding *A. niobe* the pupal stage has a duration of about 14 days (Bullock & Smith, 1968).

Diacrisia auriantiaca (Holland)

The larva eats young flush leaves. No reports have been given on the life cycle though from personal observations the pupal stage lasts 8-12 days in the laboratory.

Diacrisia rattrayi (Roths.)

The larvae are polyphagous and they also feed on young cocoa leaves. The larval stage lasts 25-30 days and the duration of pupal stage is nine to ten days (Alibert, 1951).

Appendix I

A list of the geographical distribution of Lepidoptera affecting cocoa in West Africa has been prepared and is appended to this dissertation so that it may be available for consultation at all times. West Africa is defined here as in Keay (1954) and Leston (1968), from Nigeria westwards including Fernando Po, but Cameroons and Sao Thome and Principe are excluded. In this list, mention of some important lepidopterous species commonly found in the area under study will be noted and sources cited if they are also found in areas outside but adjacent to West Africa.

The following lepidopterous species have been reported as attacking cocoa in the study area. The names of the caterpillars are those in current use, but it is likely that these are far from being stabilized at present; some popular old names, now replaced by new ones, have been retained in parentheses. The families are arranged after Imms (1965), and the host plants of the various Lepidoptera other than cocoa have been included where they have been reported. The names of all plants listed have been checked with the Second Edition of Hutchinson and Dalziel ed. by Keay (1954-).

Xyloryctidae

<u>Odites</u> sp.

Ghana (Smith, 1965)

Alt. host plant: <u>Pseudospondias</u> <u>microcarpa</u>

Lithocolletidae (Gracillaridae)

<u>Marmara</u> sp. (= <u>Spulerina</u> sp.?)

Ivory Coast (Alibert, 1951; Braudeau, 1969; Lavabre, 1954, 1965)

Ghana (Carter, 1961; Entwistle, 1960, 1961, 1962, Entwistle et al., 1959; Gerard, 1962, 1963; Hart, 1911; Johnson, 1962; Johnson and Entwistle, 1959; Laryea, 1955; Nosti, 1961)

Nigeria (Nosti, 1961)

Fernando Po (Nosti, 1961)

Cameroons (Anon, 1965)

Glyphipterygidae

<u>Imma</u> sp.

Ghana (Smith, 1965)

Cossidae

<u>Eulophonotus</u> (<u>Engyophlebus</u>) <u>myrmeleon</u> (Felder)

Sierra Leone (Hargreaves, 1937; Squire, 1949)

Ivory Coast (Alibert, 1951; Braudeau, 1969; Lavabre, 1954; Magnin, 1954).

Ghana (Carter, 1961; Caswell, 1962; Cotterell, 1927, 1928, 1930; Entwistle, 1959, 1962; Entwistle et al. 1959; Gerard, 1963; Laryea, 1955, 1958; Marchart, 1968; Smith, 1965)

Nigeria (Caswell, 1962; Entwistle, 1963; Golding, 1928; Lamborn, 1914; Youdeowei, 1971).

Fernando Po (Cotterell, 1930)

Sao Thome and Principe (Carvalho, 1968; Cotterell, 1930;
Mallamaire, 1955, Navel, 1921; Schmidt, 1967)

Cameroons (Lavabre, 1954)

Engyoplebus obesus (Karsch)

Sierra Leone (Hargreaves, 1937)

Alternative host plant: Cola nitida. Acalypha sp. in
Ghana (Forsyth, 1966)

Limacodidae

Semyrilla lineata (Holland)

Ghana (Smith, 1965)

Stroteroides nigrisignata (Strand)

Ivory Coast (Alibert, 1951)

Ghana (Smith, 1965)

Alternative host plant: Coconut.

Latoia lepida (Cramer)

Ivory Coast (Alibert, 1951; Mallamaire, 1955; Lavabre, 1954)

Ghana

Alternative host plant: Centrosema plumieri. Cocos nucifera,
Mangifera indica.

Latoia (Parasa) viridifascia (Holland)

Ghana (Smith, 1965).

Latoia (Parasa) viridissima (Holland)

Nigeria (Golding, 1931; 1946)

Alternative host plants: Cola sp., Hura crepitans

Latoia (Parasa) vivida (Walker)

Sierra Leone (Hargreaves, 1937)

Ivory Coast (Alibert, 1951)

Alternative Host plants: Ricinus sp. Communis. Coffee

Ghana

Nigeria (Golding, 1928, 1946)

Alternative host plants: Sarcocephalus esculentus, Coffee sp

Sao Thome and Principe (Navel, 1921)

Latoia vitelina (Karsch)

Ghana (Smith, 1965)

Afronarosa (Narosa) hedychroa (Bethune-Baker)

Ghana (Smith, 1965)

Ctenocampa hilda (Druce)

Ghana (Smith, 1965)

Sierra Leone (Hargreaves, 1937)

Parasa microbasis (Hampson)

Sao Thome and Principe (Navel, 1921)

P. euchlora (Karsch)

Nigeria (Golding, 1928)

Teinorrhyncha (Ctenolita) pyrosomoides (Holland)

Ivory Coast (Alibert, 1951)

Ghana (Smith, 1965)

T. auribasalia (Holland)

Ghana (Smith, 1965)

Alternative host plant: Musa sapientium var. paradisiaca

Hyphormia subterminalis (Hampson)

Ghana (Smith, 1965)

Casphalia flavicollis (Walker)

Ghana (Entwistle, 1960; Smith, 1965)

Casphalia picta (Schaus)

Ghana

Cosuma rugosa (Walker)

Ghana (Smith, 1965)

Alternative host plants: Mallotus oppositifolius. Brillantaisia nitens.

Baria elsa (Druce)

Ghana (Smith, 1965)

Phlebodicha cardinalis West and P. secunda (Strand)

Ghana (Smith, 1965)

Zinaria recurvata (Hampson)

Ghana (Smith, 1965)

Thosea sp.

Ghana (Smith, 1965)

Trachyptera nigromaculata (Hering)

Ghana (Smith, 1965)

Alternative host plant: Baphia nitida

Omocena convergens (Hering)

Ghana (Smith, 1965)

Alternative host plant: Terminalia ivorensis

Omocena sp.

Ghana (Smith, 1965)

Niphadolepis seleniphora (Hering)

Ghana (Smith, 1965)

Rhypteira sordida (Holland)

Ghana (Smith, 1965)

Metarbelidae

Metarbela sp.

Ghana (Entwistle, 1960, 1962; Smith, 1965)

Salagena transversa (Walker)

Ghana

Psychidae

Acanthopsyche (*Metisa*) *sierricola* (White)

Nigeria (Bourgogne, 1955; Golding, 1946; Entwistle, 1963; Lamborne, 1914; Youdeowei, 1971)

Alternative host plants: *Combretum* sp; *Herrania* sp; *Hibiscus esculentus*; *Indigophora* sp., *Gliricidia sepium*, *Mucuna pruriens* var. *utilis*, *Citrus*, *Coffea canephora*, *Cuviera nigrescens*, *Crotalaria juncea* and *Cola nitida*.

Eumeta cervina Druce

Ghana (Entwistle, 1963)

Nigeria (Entwistle, 1963; Youdeowei, 1971; Golding, 1946, Bourgogne, 1955).

Alternative host plants: *Mangifera indica*, *Casuarina equisetifolia*, *Citrus* sp. and *Gossypium* sp.

Eumeta rougeoti Bourgogne

Ghana (Entwistle, 1963)

Nigeria (Entwistle, 1963; Youdeowei, 1971)

Alternative host plants: Persea americana, Cola gigantea var. glabrescens, Citrus sp., Coffea canephora and Casuarina equisetifolia.

Kotochalia junodi (Heylaerts)

Ghana (Entwistle, 1963)

Nigeria (Entwistle, 1963; Youdeowei, 1971)

Alternative host plants: Ricinus communis, Cassia siamea, Cajanus indicus, Coffea canephora, Casuarina equisetifolia and Gliricidia sepium.

Manatha aethiops (Hampson)

Ghana (Forsyth, 1966)

Alternative host plant: Pterocarpus erinaceus

Manatha obscurior sp. n. and Acanthopsyche entwistler sp.n.

Nigeria (Bourgegne, 1962; Entwistle, 1963)

Zygaenidae

Staphylinochrous tenellula (Holland)

Ghana

Olethreutidae

Olethreutes sp. nr. praecedens (Walsingham)

Ghana (Forsyth, 1966)

Alternative host plant: Trichilia rubescens

Argyroploce leucotreta (Meyrick)

Ghana (Forsyth, 1966)

Alternative host plant: Gossypium sp. and Ricinus communis.

Laspeyresia sp.

Ivory Coast (Alibert, 1951)

Ghana (Forsyth, 1966)

Alternative host plant: *Coffea* sp

Tortricidae

Archips occidentalis (Walsingham)

Ghana (Smith, 1965)

Tortrix dinota (Meyrick)

Ivory Coast (Alibert, 1951)

Ghana (Smith, 1965)

Alternative host plant: *Baphia nitida* and *Sterculia tragacantha*

Enarmonia sp.

Ghana (Forsyth, 1966)

Pyralidae

Sylepta retractalis (Hampson)

Ghana (Forsyth, 1966)

Nigeria (Golding, 1946)

Alternative host plant: *Sterculia tragacantha*

Ivory Coast (Alibert, 1951)

Senegal (Mallamaire, 1955)

Alternative host plant: *Cola* sp.

Mussidia nigrivenella (Rag.)

Senegal (Mallamaire, 1955)

Ivory Coast (Alibert, 1951; Mallamaire, 1955)

Alternative host plant: *Butryospermun parkii*

Ghana (Nosti, 1961)

Nigeria (Golding, 1946; Nosti, 1961; Patterson, 1922)

Alternative host plant: Phaseolus lunatus, Zea mais and Gossypium sp.

Fernando Po (Nosti, 1961)

M. pecticornella (Hampson)

Ghana

Alternative host plant: Butryospermum parkii

Pilocrocia melastictalis (Hampson)

Ghana (Smith, 1965)

Polygrammodes hirtusalis (Walker)

Ghana (Forsyth, 1966; Smith, 1965)

Lasiocampidae

Leipoxais rufobrunnea (Strand)

Ghana (Smith, 1965)

Nigeria (Golding, 1940; 1946)

Alternative host plant: Ricinus communis

Leipoxais peraffinis (Holland)

Cameroons (Zacher, 1915)

Leipoxais sp. nr. peraffinis (Holland)

Ghana (Smith, 1965)

Leipoxais sp.

Ghana (Smith, 1965)

Nigeria (Golding, 1937)

Bombycopsis indecora (Walker)

Ghana (Smith, 1965)

Gonobombyx angulata (Aurivillius)

Ivory Coast (Alibert, 1951)

Saturniidae

Nudaurelia dione (F.)

Ghana (Smith, 1965)

Ivory Coast (Alibert, 1951)

Alternative host plant: *Jatropha curcas* and *Spondias lutea*

Imbrasia epimithea (Drury)

Ghana (Smith, 1965)

Eupterotidae

Phiala hologramma (Aurivillius)

Nigeria (Golding, 1946)

Nymphalidae

Acraea alcione (Hewitson)

Ghana

Alternative host plant: *Tragia* sp.

A. lycea (Godart)

Ivory Coast (Alibert, 1951)

A. rogersi (Hewitson)

Ghana

A. pharsalus (Ward)

Ghana

A. zetes (L)

Ivory Coast (Alibert, 1951)

Phalanta columbina (Cramer)

Ghana (Smith, 1965)

Euryphura plautilla (Hewitson)

Ghana (Smith, 1965)

Precis pelagra (F.)

Nigeria (Golding, 1946)

Lycaenidae

Hypolycaenia sp.

Ghana

Hypokopelates eleala (Hewitson)

Ghana (Smith, 1965)

Alternative host plant: *Albizia zygia*

Hesperiidae

Coeliades forestan (Stoll)

Ghana (Forsyth, 1966)

Nigeria (Golding, 1946; Peacock, 1913)

Alternative host plant: *Malpighia glabra* and *Brassica* sp.

Geometridae

Scopula sp.

Ivory Coast (Alibert, 1951)

Neocleora sp.

Ghana (Entwistle, 1957, 1962; Smith, 1965)

Ascotis reciprocaria (Walker)

Ghana (Smith, 1965)

Alternative host plant: *Ceiba pentandra*

Ascotis selenaria (Hubner)

Ivory Coast (Alibert, 1951)

Hyposidra smithi (Warren)

Ghana (Smith, 1965)

Colocleora divisaria (Walker)

Ivory Coast (Alibert, 1951)

Ghana (Smith, 1965)

Nigeria (Golding, 1946; Peacock, 1913)

Alternative host plant: *Mallotus oppositifolius*

Boarmia sp. *smithi* (Warren)

Ghana (Smith, 1965)

Buzura johanneria (Gib.)

Ghana (Smith, 1965)

Xenimpia erosa (Warren)

Sierra Leone (Hargreaves, 1937)

Ghana (Smith, 1965)

Sphingidae

Hippotion eson (Cramer)

Ivory Coast (Alibert, 1951)

Ghana

Alternative host plants: *Anchomanes difformis* and *Solanum anomalum*.

Polyptychus carteri (Butler)

Ivory Coast (Alibert, 1951)

Alternative host plant: *Cola* sp.

Arctiidae

Diacrisia auriantiaca (Holland)

Ghana (Smith, 1960)

Alternative host plant: *Datura* sp.

Diacrisia quadrilunata (Hampson)

Ghana (Forsyth, 1966)

Diacrisia curvilinea (Walker)

Ghana (Forsyth, 1966)

Nigeria (Golding, 1946; Peacock, 1913)

D. rattrayi (Rothschild)

Senegal (Mallamaire, 1955)

Ivory Coast (Alibert, 1951)

Ghana (Cotterell, 1928; Entwistle, 1962)

Alternative host plants: *Albizia zygia*, *Averrhoa carambola* and *Amaryllis belladona*

Nigeria (Youdeowei, 1971)

Alternative host plants: *Zephyranthes tubispatha*, *Hippeastrum equestre*, and *Combretum* sp.

Cameroons (Lavabre, 1957)

Diacrisia mundata (Walker)

Ghana (Caswell, 1962; Cotterell, 1927, 1928)

Alternative host plants: *Helianthus annuus*, *Phaseolus* sp., *Zea mays* (Forsyth, 1966).

Diaorisia maculosa (Cramer)

Ghana (Forsyth, 1966, not on cocoa)

Alternative host plants: Arachis hypogaea and Voandzeia subterranea

Nigeria (Caswell, 1962; Golding, 1946; Hergreaves, 1937)

D. chionea (Hampson)

Ghana

Rhodogastria luteibarba (Hampson)

Ghana

Rhodogastria leucoptera (Hampson)

Ghana

Nigeria (Golding, 1940)

Alternative host plant: Combretum mucronatum

Asura atricraspeda (Hampson)

Ivory Coast (Alibert, 1951)

Asura sp.

Ghana

Syntomidae

Syntomis dilateralis (Hampson)

Ghana

Euchromia lethe (F.)

Ghana

Alternative host plant: Ipomoea sp. (Forsyth, 1966)

Nigeria (Golding, 1928)

Alternative host plant: Purgularia extensa

Ivory Coast (Alibert, 1951; Lavabre, 1954)

Alternative host plant: Ipomoea sp.

Cameroons (Zacher, 1915)

Metarotica invarea (Walker)

Ivory Coast (Alibert, 1951)

Balacra ehrmanni (Holland)

Ghana (Smith, 1965)

Balacra pulchra (Aurivillius)

Ghana (Smith, 1965)

Balacra testacea (Aurivillius)

Ivory Coast (Alibert, 1951)

Noctuidae

Achaea catocaloides (Guenee)

Ivory Coast (Alibert, 1951; Braudeau 1969; Lavabre, 1954)

Ghana (Forsyth, 1966; Smith, 1965)

Alternative host plants: Averrhoa carambola. Citrus sp; Eugenia uniflora. Lycopersicon esculentum. Mangifera indica. Milletis sp., Myrianthus libericus and Phyllanthus discoides.

Togo (Mallamaire, 1955)

Cameroons (Lavabre, 1954; 1958)

Achaea lienardi (Boisduval)

Ghana (Forsyth, 1966; Smith, 1965)

Alternative host plants: Averrhoa carambola. Citris paradisi. Psidium guajava. Albizia zygia. Euphorbia hirta and Ficus sp.

Anomis leona (Schaus)

Ivory Coast (Braudeau, 1969; Dagatiguy, 1953; Lavabre, 1954, 1958; 1965; Lavabre et al. 1966)

Ghana (Caswell, 1962, Cotterell, 1943; Leston, 1970; Leston and Gibbs, 1971; Lodos, 1967; Smith, 1965)

Alternative host plants: Averrhoa carambola. Citrus paradisi. Lycopersicon esculentum. Mangifera indica. Cola cordifolia. Grewia carpinifolia. Hibiscus sp., Leptonychia pubescens. Nesogordonia papaverifera and Sterculia tragacanthe.

Nigeria (Booker, 1967; Gerard, 1969; Golding, 1931; Youdeowei, 1971)

Alternative host plant: Cola nitida

Cameroons (Lavabre, 1954)

Sao Thome and Principe (Cotterell, 1930; Schmidt, 1967)

Anomis (Cosmophila) fulvida (Holland)

Cameroons (Lavabre, 1958)

Characoma stictigrapta (Hampson)

Senegal (Mallamaire, 1955)

Sierra Leone (Hargreaves, 1937)

Alternative host plant: Cola nitida

Ivory Coast (Braudeau, 1969; Lavabre, 1954, 1958, 1965; Magnin, 1954)

Ghana (Chatt, 1953; Cotterell, 1928; Entwistle, 1962; Laryea, 1955; Lodos, 1967; Nicol, 1947; Nosti, 1961; Patterson 1914, 1922; Smith, 1965; Urquhart, 1961).

Alternative host plant: Cola sp. (Forsyth, 1966)

Nigeria (Golding, 1946; Lamborn, 1914; Nosti, 1961)

Alternative host plant: Cola sp.

Cameroons (Nosti, 1961)

Sao Thome and Principe (Carvalho, 1968; Cotterell, 1930; Navel, 1921; Schmidt, 1967).

Eudrapa mollis (Walker)

Ghana (Forsyth, 1966; Smith, 1965)

Selepa leucograpta (Hampson)

Ghana (Entwistle, 1962; Leston, 1971; Smith, 1965)

Selepa sp.

Ivory Coast (Alibert, 1951)

Plusia acuta (Walker)

Ghana

Alternative host plant: Pisum sp. (Forsyth, 1966)

Nigeria (Golding, 1946; Peacock, 1913)

Alternative host plant: Musa sp., Nicotiana sp., Rhigiocarya racemifera

Plusia chalcites (Esp.)

Sierra Leone (Hargreaves, 1937)

Alternative host plant: Nicotiana sp.

Ghana (Caswell, 1962; Smith, 1965)

Alternative host plant: Nicotiana sp.

Sao Thome (Seabra, 1919)

Plusia signata (F.)

Sierra Leone (Hargreaves, 1937)

Alternative host plant: Calendula officinale, Cineraria.

Ivory Coast (Alibert, 1951)

Ghana (Forsyth, 1966; Smith, 1965)

Alternative host plant: Brassica oleracea, Nicotiana tabacum

Nigeria (Golding, 1946)

Alternative host plant: Mucuna aterrima

Spodoptera littoralis (Boisduval) (= Prodenia litura auctt nec F.)

Ivory Coast (Alibert, 1951)

Ghana (Smith, 1965)

Alternative host plants: Xanthosoma mafaffa (Benson & Leston, 1971), Vigna unguiculata, Solanum melongena, Lycopersicon esculentum; Gossypium sp., Centrosema sp. Brassica oleracea var. capitata, Allium cepa.

Nigeria (Golding, 1937, 1946; Peacock, 1913)

Alternative host plants: Amaranthus caudatus, V. unguiculata N. tabacum, Mucuna aterrima.

Fernando Po (Nosti, 1961)

Lophorusa semiscripta (Mabille)

Ghana (Smith, 1955)

Earias biplaga (Walker)

Sierra Leone (Hargreaves, 1937)

Alternative host plants: Hibiscus rosa-sinensis, H. sabdariffa and H. steralifolius

Ivory Coast (Alibert, 1951; Braudeau, 1969; Lavabre, 1965; 1966, 1969)

Alternative host plants: _Thespesia_ sp., _Abutilon asiaticum_, _Urena lobata_.

Ghana (Caswell, 1962; Chatt, 1953; Cotterell, 1927; 1928; Entwistle, 1963, 1969; Gerard, 1964, 1967, 1970; Johnson, 1962; Leston, 1970; Lodos, 1967; Pearson, 1958; Smith, 1961)

Alternative host plants: _Gossypium_ sp. (Forsyth, 1966)

Togo (Alibert, 1951; Cotterell, 1928).

Alternative host plants: _Urena lobata_ and _Hibiscus_ sp.

Nigeria (Booker, 1967; Caswell, 1962; Entwistle, 1960, 1962, 1963, 1964; Golding, 1946; Lamborn, 1914-15; Nosti, 1961; Opeke, 1965; Peacock 1913; Pomeroy, 1921, 1925).

Alternative host plants: _Gossypium_ sp., _Sida carpinifolia_, _Hibiscus esculentus_, _Abutilon zanzibaricum_, _Sterculia tragacantha_, _Hibiscus rosasinensis_ and _A. mauritianum_.

Cameroons (Lavabre, 1969; Nosti, 1961)

Sao Thome and Principe (Carvalho, 1968; Schmidt, 1967)

Earias citrina (Saalmuller)

Ivory Coast (Alibert, 1951; Lamborn, 1914-15)

Lophocrama phoenicochlora (Hampson)

Sierra Leone (Hargreaves, 1937)

Alternative host plant: _Cola nitida_

Ghana (Entwistle, 1962; 1965)

Nigeria (Golding, 1937; Youdeowei, 1971)

Cameroons (Lavabre, 1957)

Maurilia albirivula (Hampson)

Ghana (Smith, 1965).

Lymantriidae

Argyrostagma (*Dasychira*) *niobe* (Weymer)

Ghana (Smith, 1965)

Alternative host plants: *Albizia zygia* (Forsyth, 1966)

Nigeria (Gerard, 1966); Golding, 1946).

Alternative host plants: *H. esculentus* L.

Dasychira endophaea (Hampson)

Ghana (Smith, 1965).

Dasychira georgiana (Fawcett)

Ghana (Forsyth, 1966; Smith, 1965)

Alternative host plants: *Baphia pubescens*, *Byrsocarpus coccineus*, *Hymenostegia afzelli* and *Ricinus communis*.

Nigeria (Golding, 1931)

Alternative host plant: *Arachis hypogaea*

Orgyia mixta (Snellen)

Ghana (Leston, 1971; Smith 1965)

Orgyia basalis (Walker)

Sierra Leone (Hargreaves, 1937)

Ivory Coast (Alibert, 1951)

Ghana (Smith, 1965)

Cameroons (Lavabre, 1957)

Alternative host plant: *Arachis* sp.

Euproctis dewitzi (Grunberg)

Ivory Coast (Alibert, 1951)

Ghana (Smith, 1965)

Nigeria (Golding, 1946)

Alternative host plant: Gossypium sp.

Euproctis lepidographa (Hampson)

Ghana (Smith, 1965)

Euproctis lyona (Swinhoe)

Ghana (Smith, 1965)

Nigeria (Peacock, 1913)

Alternative host plant: Gossypium sp.

Euproctis mediosquamosa (B. Baker)

Ghana (Nosti, 1961)

Nigeria (Nosti, 1961)

Fernando Po (Nosti, 1961)

Sao Thome (Cotterell, 1930; Navel, 1921)

Euproctis melanopholis (Hampson)

Ghana (Smith, 1965)

Alternative host plant: Terminalia ivorensis.

Euproctis pygmaea (Walker)

Ivory Coast (Alibert, 1951; Mallamaire, 1955)

Euproctis xanthomelana (Holland)

Ghana (Forsyth, 1966; Smith, 1966)

Euproctis sp.

Ghana (Forsyth, 1966)

Naroma signifera (Walker)

Ghana

Alternative host plant: Tragia sp. (Forsyth, 1966)

Stracena _fuscivena_ (Swinhoe)

Ghana

Crorema _mentiens_ (Walker)

Ghana (Forsyth, 1966)

Notodontidae

Graphidura sp. nr. _argenteomaculata_ (Aurivillius)

Ghana (Smith, 1965)

Alenophalera _variegata_ (Aurivillius)

Ghana (Smith, 1965)

Scalmicauda sp.

Ghana (Forsyth, 1966)

SUMMARY

1. Seasonality of lepidopterous defoliators of cocoa at Aburi has been studied. Various species could more or less be classfied in the order of the times when each species was at its highest peak e.g. there were some with early single peaks, double peaking periods and also others with relatively none or with minor peaking. Among others Spodoptera littoralis had an early single peak that coincided with the dry season in November-December, while Anomis leona and Characoma stictigrapta had late single peaks in February-March and April respectively, i.e. in the wet season. Earias biplaga showed double peaking. With the exception of the psychids, Anomis and Characoma were by far the commonest caterpillars at Aburi in the course of sampling.

2. Sampling has shown that fluctuations in populations of leaf-eating Lepidoptera are tied up with the availability of food in the form of new flush leaves. Anomis and Characoma showed this simultaneous increase in their numbers with the gradual availability of flushes rather clearly, but in the dry months of December and January not many larvae were encountered probably because cocoa flushing was low.

3. The pod-borer, Characoma stictigrapta, apart from feeding on flush also bores into husks of green pods. More damage was done by this caterpillar in October-November when there were many pods available. In March, fewer pods were attacked probably because of new flush leaves which were also plentiful at the time, but more pods were again infested in May when flush was at a low ebb. Pod infestation by Characoma appears to be correlated with a good canopy.

4. With regard to the after-effects of insecticides on Lepidoptera populations, the results have shown that larger numbers of caterpillars are found in regularly sprayed areas such as at Kade and Tafo than at the rarely sprayed farms at Aburi. A great number of pods were infested with the pod-husk-miner, Marmara, at Kade where most of the cocoa plots had been heavily sprayed with D.D.T. in contrast to the situation at Aburi and Amanokrom.

5. The study has shown that there is an association between shade and the increase in numbers of Lepidoptera found on cocoa. Cocoa trees with a poor canopy harboured much higher numbers of some lepidopterous larvae such as Earias biplaga, Anomis leona, S. littoralis, and Marmara sp. and several other species. Flush leaves are therefore relatively more heavily attacked in the open than in the shade.

6. There were seasonal fluctuations in the diversity of species of Lepidoptera found at Aburi. There was a great variety of species in September-October in spite of the fact that there were few individuals. In February-March individuals were more plentiful yet the species were less diversified. It would appear that species diversity is inversely correlated with abundance of individuals in a tropical environment.

7. The information from experiments on food preferences suggests that caterpillars feed more on flushes than on mature leaves, and that direct contact with the leaf is necessary before feeding actually starts. Smell probably plays a minor role.

8. The various commonly occurring species of lepidopterous larvae have been described and keys furnished to distinguish them. The

chaetotaxy of the various species was also studied.

9. Observations on oviposition, moulting, pupation and protective mechanisms of the more important species have been made.

10. Parasitism and predation of caterpillars was noted. *Anomis*, *Characoma*, *Euproctis xanthomelana*, *Argyrostagma niobe* and several other species were frequently found parasitized by braconids, chalcidids and ichneumonids in the field. Not many caterpillars were found predated upon in the field. *Oecophylla* ants, however, were occasionally seen attacking *Anomis*.

ACKNOWLEDGEMENTS

I am grateful to the Cocoa Research Advisory Committee of the University of Ghana, Legon, for financial assistance in this project. I am thankful to Professor D.W. Ewer for providing working facilities in the Zoology Department, Legon, and for his continued interest and concern in this work. I wish to thank also Mr. Dennis Leston, my immediate project supervisor, for his guidance, criticism and encouragement. I am deeply indebted to Professor D.W. Ewer and Dr. R. Kumar, the members of my supervisory committee, who have made valuable suggestions from time to time. Their edifying criticisms are greatly appreciated, and had time been available further attempts would have been made at finding answers to some interesting problems that have arisen in the course of this project.

I wish to extend my thanks to Mr. D.A. Brown of the Cocoa Research Institute, Tafo, for kindly supplying cocoa seedlings that were used in rearing caterpillars. I also wish to express my gratitude to Dr. A.A. Opoku of the Agricultural Research Station, Kade, for allowing me to work on the various cocoa plots at the station. I am thankful to Mr. T.S.K. Akoto who typed the final copy of this thesis.

I am thankful to the following colleagues for their assistance in various ways: Messrs. E.A. Aryeetey, D. Louis and S. Whyte.

REFERENCES

Alibert, H. (1951). Les insectes vivant sur les cacaoyers en Afrique Occidentale. Mem. Inst. franc. Afr. noire. 15, 1-174.

Aryeetey, E.A. (1971). Unpublished M.Sc. thesis

Benson, G. & Leston, D. (1971) Insect and sun damage to cocoyam in Southern Ghana. PANS. in press.

Booker, R.H. (1967). Entomology: Insect pests of cacao; ecological survey of the cacao fauna. Half yearly Prog. Rep Cocoa Res. Inst. Nigeria. 7, 16-18.

Booker, R.H. (1969). Entomology: Insect pests of cacao; ecological survey of the cacao fauna. Ann. Rep. W. Afr. Cocoa Res. Inst. Nigeria. 1967-68, 30-31.

Bourgogne, J. (1955). Revision de especes Africaines du genre Eumeta Walker (Clania Auctt.) (Lepidoptera:Psychidae). Trans. R. ent. Soc. Lond. 107, 125-138.

Braudeau, J. (1969). Le cacaoyer. G.P. Maisonneuve et Larose, Paris, 1-304.

Bullock, J.A. and Smith, R.G. (1968). The bionomics and control of Argyrostagma niobe (Weymer) and Dasychira georgiana Fawcett (Lepidoptera,Lymantriidae) on black wattle in Kenya. Bull. ent. Res. 58, 191-410.

Burle, L. (1961). Le cacaoyer. G.P. Maisonneuve et Larose, Paris, 1-315.

Campbell, R.C. (1967). Statistics for Biologists. Cambridge University Press, London.

Caswell, G.H. (1962). Agricultural Entomology in the Tropics. Edward Arnold Ltd., London.

Carter, W. (1961). Vector control; cutting out; the use of tolerant and resistant varieties. Rep. to Inten. Co-op. Admin. and USOM. Ghana. Tafo 15th Feb. 1961, 3

Carvalho, J.P. de P. (1968). Notes on the meeting of Entomologists held in Sao Thome and Principe. 8-12 Aug. 1967. Ser. tec. Inst. Invest. agron. Angola. Nova Lisboa. 1, 1-22.

Chatt, E.M. (1953). Cocoa: Cultivation, processing analysis. Interscience Pubs. London.

Collenette, C.L. and Carpenter, G.D.H. (1933). New species and descriptions of larvae, of Lymantriidae from Uganda. Entomologist's mon. Mag. 69, 264-265.

Collenette, C.L. (1955). A key to the African genera of Lymantriidae. Trans. R. ent. Soc. London. 107, 187-197.

Cotterell, G.S. (1927). Pests of cocoa in the Gold Coast. Proc. 1st W. Afr. Agric. Conf. Ibadan, Nigeria 98-112.

Cotterell, G.S. (1928). Minor pests of cocoa. Yearb. Dept. Agric. Gold Coast, 13, 100-106.

Cotterell, G.S. (1930). Report on the occurrence of Sahlbergella sp. and other insect pests of cacao in Fernando Po, San Thome and Belgian Congo. Yearb. Dept. Agric. Gold Coast, 22, 112-130.

Cotterell, G.S. (1943). Entomology: Pests and a disease of cacao in Gold Coast. Rept. Centr. cocoa Res. sta. Tafo, 1938-1942, 46-55.

Crowell, H.H. (1943). Feeding habits of the southern armyworm, Prodenia evidania Cramer and rate of passage of food through its gut. Ann. Ent. Soc. Amer. 36, 243-249.

Dagatiguy, Fanny (1953). Note sur un insect nuisible au cacaoyer Anomis leona Schaus (Noctuidae). Bull. centre Recherches Agron. Bingerville. 7, 39-44.

Dethier, V.G. (1937). Gustation and olfaction in lepidopterous larvae. Biol. Bull. 72, 7-23.

Dethier, V.G. and Chadwick, L.E. (1948). Chemoreception in insects. Physiol. Rev. 28, 220-254.

Entwistle, P.E., Johnson, C.G. and Dunn, E. (1959). New pests of cocoa in Ghana following applications of insecticides. Nature, 184, 2040.

Entwistle, P.F. (1960). Pod husk miner; minor pests. Rep. W. Afr. Cocoa Res. Inst. 1958-1959, 33-34.

Entwistle, P.F. (1962). Entomology. Rep. W. Afr. Cocoa Res. Inst. 1960-61, 81-92.

Entwistle, P.F. (1963). Entomology: Earias biplaga in Nigeria . Rep. W Afr. Cocoa Res. Inst. 1961-62, 100-113.

Entwistle, P.F. (1963). A note on Eulophonotus myrmeleon (Lepidoptera: Cossidae), a stem borer of cocoa in West Africa. Bull. ent. Res. 54, 1-3.

Entwistle, P.F. (1963). Observations on the morphology of some adult females and immature stages of four species of Psychidae (Lepidoptera) on Theobroma cacao L. in Western Nigeria. Proc. R. ent. Soc. Lond. (B), 32, 72-80.

Entwistle, P.F. (1963). Observations on the biology of four species of Psychidae (Lepidoptera) on Theobroma cacao L. in Western Nigeria. Proc. R. ent. Soc. Lond. (A) 38, 145-152.

Entwistle, P.F. (1964). Entomology: Earias biplaga. oviposition sites. Rep. W. Afr. Cocoa Inst. 1962-63, 48-58.

Entwistle, P.F. (1965). Entomology: Earias biplaga. field populations. Rep. W. Afr. Cocoa Res. Inst. 1963-64, 66-72.

Forsyth, J. (1966). Agricultural insects of Ghana. Accra.

Gardner, J.C.M. (1946). On the larvae of the Noctuidae, I. Trans. R. ent. Soc. Lond. 96, 61-72.

Gerard, B.M. (1963). Marmara studies. Rep. W. Afr. Cocoa Inst. 1961-62, 31-32.

Gerard, B.M. (1964). Minor pests: Pod husk miner (Lepidoptera: Lithocolletidae). Rep. W. Afr. Cocoa Res. Inst. 1962-63, 30.

Gerard, B.M. (1964). Side effects from the use of insecticides. II. Effects on insects other than mirids. Proc. Cacao Mirid Control Conf. Tafo, Aug. 1963, 28-32.

Gerard, B.M. (1964). Insects associated with unshaded Theobroma cacao L. in Ghana. Proc. Conf. Mirids other Pests cacao, Ibadan, 1963, 101-111.

Gerard, B.M. (1966). Lymantriid caterpillars eating cacao pods. Nigerian Ent. Mag. 1, 6-7.

Gerard, B.M. (1970). Temporary shade plants and insect pests of young cacao. Rep. Cocoa Res. Inst. Nigeria, 1968-69, 44-45.

Ghesquiere, J. (1923). Quelques ennemis du cacaoyer dans l'Ouest Africain. Revue Bot. appl. Agric. trop. 117-120.

Golding, F.D. (1927-28). Notes on the food plants of Nigerian insects. Bull. ent. Res. 18, 95-99.

Golding, F.D. (1931). Further notes on the food-plants of Nigerian insects. Bull. ent. Res. 22, 221-223.

Golding, F.D. (1935). Further notes on the food plants of Nigerian insects, III. Bull. ent. Res. 26, 263-265.

Golding, F.D. (1937). Further notes on food plants of Nigerian insects, IV. Bull. ent. Res. 28, 5-9.

Golding, F.D. (1940). Further notes on the food plants of Nigerian insects V. Bull. ent. Res. 31, 127-130.

Golding, F.D. (1946). The insect pests of Nigerian crops and stock. Special Bull. Agric. Dept. Nigeria. 4, 1-4.

Greenwood, M. and Posnette, A.T. (1950). The growth flushes of cacao. J. hort. Sci. 25, 164-174.

Hargreaves, E. (1928). Miscellaneous pests of cacao and other crops in Sierra Leone in 1927. Rep. Lands For. Dept. Sierra Leone, 1927, 18-20.

Hargreaves, E. (1937). Some insects and their food plants in Sierra Leone. Bull. ent. Res. 28, 505-520.

Hart, J.H. (1911). Cacao: a manual on the cultivation and curing of cacao. Duckworth and Co. Ltd., Lond.

Hinton, H.E. (1943). The larvae of the Lepidoptera associated with stored products. Bull. ent. Res. 34, 163-212.

Hinton, H.E. (1946). On the homology and nomenclature of the setae of lepidopterous larvae, with some notes on the phylogeny of the Lepidoptera. Trans. R. ent. Soc. Lond. 97, 1-37.

Hinton, H.E. (1957). The larvae of the species of Tineidae of economic importance. Bull. ent. Res. 47, 251-346.

Hocking, B. and Depner, K.R. (1961). Larval nutrition in Agrotis orthogonia (Lepidoptera:Phalaenidae): digestive enzymes. Ann. ent. Soc. Am. 54, 86-89.

Hutchinson, J. and Dalziel, J.M. (1954-). Flora of West Tropical Africa, 2nd edn. (Ed. by R.W.J. Keay and F.N. Hepper) London.

Imms, A.D. (1965). A General Text book of Entomology. 9th edn. (Revised by O.W. Richards and R.G. Davies) Methuen, London.

Johnson, C.G. and Entwistle, P.F. (1959). Marmara incidence. Rep. W. Afr. Cocoa Res. Inst. 1957-58, 38-41.

Johnson, C.G. (1962). The ecological approach to cocoa disease and health. Agriculture and Land Use in Ghana (Ed. by J.B. Wills) London.

Lamborn, W.A. (1914). The agricultural pests of the southern provinces, Nigeria. Bull. ent. Res. 5, 197-214.

Langley, Russell (1968). Practical statistics. Pan Books Ltd., London

Laryea, A.A. (1955). Minor pests and diseases of Cocoa. Lecture notes on capsid control in Ghana: FAO study tour on cocoa statistics. Tafo, Ghana.

Lavabre, E.M. (1954). Insectes dangereux aux cultures du cacaoyer au Cameroun. Agron. Trop. 9, 479-484.

Lavabre, E.M. (1954). Protection des cultures de cafeiers, cacaoyers et autres plantes perennes tropicales. Inst. franc. du cafe et du cacao. Paris. 1-268.

Lavabre, E.M. (1958). Note on insect pests of cocoa in the French Cameroons. Rep. Cocoa Conf. London 1957, 105-108.

Lavabre, E.M. (1966). Maladies et parasites des cacaoyers autres que les Mirides, la pourriture brune et le 'Swollen Shoot' en Afrique. Conf. Intern. sur les Rech. Agon. Cacaoyers Abidjan. 15-20 Nov. 1965.

Lavabre, E.M. et al (1966). Etude preliminaire de la transmission de viroses nucleaires et de bacterioses aux chenilles de cacaoyers. Cafe. Cacao. The. 10, 336-341.

Lavabre, E.M. (1969). Recent progress in breeding certain pests of African cocoa in the laboratory: Distantiella theobroma (Distant), Sahlbergella singularis Hagl., Earias biplaga Walker and Tragocephala sp. Pl. Prot. Bull. F.A.O. 17, 132-135.

Leston, D. (1968). Where are West Africa and Guinea? Entomologist's mon. Mag. 104, 43-45.

Leston, D. (1970). Entomology of the cocoa farm. Ann. Rev. Ent. 15, 273-294.

Leston, D. (1971). Unpublished Ph.D. thesis.

Leston, D. and Gibbs, D.G. (1971). Phenology of cocoa and some associated insects in Ghana. 3rd Intern. Cocoa Conf. Accra. 23-29 Nov. 1969. In press.

Lodos, N. (1968). The role of insects in cherelle wilt of cocoa in Ghana. 2nd Intern. Cocoa Conf. Salvador, Brazil. 19-25 Nov. 1967, 283-286.

Lodos, N. (1969). Minor pests and other insects associated with Theobroma cacao L. in Ghana. Ghana J. Agric. Sci. 2, 61-72.

Louis, D. (1971). Unpublished M.Sc. Thesis.

Lyon, D.J. de B. (1968). Catches of Spodoptera littoralis (Boisduval) in a light trap at Samaru. Nigerian Ent. Mag. 1, 115-117.

Magnin, J. (1954). La lutte contre les insectes nuisibles au cacaoyer dans l'Ouest Africain. Bull. Centre Rech. Agron. Bingerville, 9, 41.

Maliamaire, A. (1955). Catalogue des principaus insectes, nematodes, myriapodes et acariens nuisible aux plantes cultivees en Afrique Occidentale Francais et au Togo. Bull. Prot. Vegetaux. Dakar. 2, 23-60.

Marchart, H. (1968). Radiotracer study of the predators on D. theobroma (Distant) Hemiptera:Miridae). Intern. Atomic Energy Agency. Vienna. 1968, 1-11.

Minnich, D.C. (1925). The reactions of the larvae of Vanessa antiopa L. to sounds. J. exp. Zool. 42, 443-469.

Navel, H.V. (1921). Les principaux ennemis du cacaoyer aux iles de San Thome et de Principe; raport sur mission d'etude agricole et phytopathologique. E. Larose. Paris. 1-135.

Nelson, J.W. & Palmer, L.S. (1935). The phosphorus content and requirements of the flour beetle Tribolium confusum Duval, and a study of its need for vitamin D. J. Agric. Res. 50, 849-852.

Nicol, J. (1947). Insect Pests of cacao Trees. Tafo, Ghana (Mimeographed)

Nosti, J. (1961). Cacao, Cafe The. Salvat Editores, Barcelona.

Opeke, L.K. (1966). The ecological factor of light on cacao, Theobroma cacao L. Conf. Intern. sur les Recherches Agron. cacaoyers. Abidjan, 15-20 Nov. 1965, 121.

Owen, D.F. (1969). Species diversity and seasonal abundance in tropical Sphingidae (Lepidoptera). Proc. R. ent. Soc. Lond. (A), 44, 162-168.

Patterson, W.H. (1914). Pests of cacao, coconut, kola and other plants in the Gold Coast. Rep. Agric. Dept. 1913 18-27.

Patterson, W.H. (1922). Report of the Entomologist: Insect pests in the Gold Coast in 1921. Rep. Agric. Dept. 1921, 27-30.

Patterson, W.H. (1922). Cocoa insect pests. J. Gold Coast Agric. and Commerc. Soc. 1, 60-64.

Peacock, A.D. (1913). Entomological pests and problems of Southern Nigeria. Bull. ent. Res. 4, 191-220.

Pearson, E.O. (1958). The Insect pests of cotton in tropical Africa Emp. Cotton Grow. Corp. and Commonw. Inst. Ent. London.

Pomeroy, A.W.J. (1921). Entomology: Miscellaneous pests in Nigeria in 1920-21. Rep. Agric. Dept. Southern Provinces. 21-23.

Pomeroy, A.W.J. (1925). The cotton ball worms of Southern Nigeria. Ann. Bull. Agric. Dept. Nigeria. 4, 89-108.

Schmidt, C.T. (1967). The biological problems in Sao Thome and Principe. Garcia de Orta 15, 495-500.

Seabra, A.F. de, (1919). Studies on the diseases and parasites of cocoa and other cultivated plants in Sao Thome. Notes on the chief animals and plants relating to Agriculture in Sao Thome, especially as regards the cultivation of cacao. Companhia Agricola ultramarina, Lisbon. 1-13.

Smith, M.R. (1961). Minor pests of cocoa: Lepidoptera. Rep. W. Afr. Cocoa Res. Inst. 1959-60, 43-46.

Smith, M.R. (1962). Minor pests of cocoa: Shade Versus no shade experiments. Rep. W. Afr. Cocoa Res. Inst. 1960-61, 44-51.

Smith, M.R. (1965). A list of Lepidoptera associated with cocoa in West Africa with notes on identification and biology of species in Ghana. Tech. Bull. Cocoa Res. Inst. Tafo. 9, 1-68.

Squire, F.A. (1949). Entomology: Crop pests, Cacao. Ann. Rep. Agric. Dept. Sierra Leone.

Urquhart, D.H. (1961). Cocoa. 2nd edn. Longmans Green, London.

Wessel, M. (1968). Effect of age on morphology and mineral composition of hardened cacao leaves. Ann. Rep. Cocoa Res. Inst. Nigeria. 1966-67, 107-109.

Wessel, M. (1970). Intake and export of nutrients in cacao leaves. Trop. Agric. Trinidad. 47, 167-170.

Wigglesworth, V.B. (1965). The Principles of Insect Physiology. Methuen, London.

Wigglesworth, V.B. (1966). The Life of Insects. Weidenfeld and Nicolson, London.

Williams, C.B. (1930). The Migration of Butterflies. Oliver and Boyd, London.

Williams, C.B. (1958). Insect Migration. Collins, London.

Williams, C.B. (1964). Patterns in the balance of nature. and related problems in quantitative ecology. Academic Press, London.

Youdeowei, A. (1971). Some insect pests associated with cacao rehabilitation in Nigeria. 3rd Intern. Cocoa Res. Conf. Accra. 23-29, Nov. 1969. In press.

Zacher, F. (1915). Beitrage Zur Kenntnis der West-Afrikanischen Pflanzenschadlinge. Tropenpflanzer. Berlin. 17, 504-534 (Summary in Rev. Appl. Ent. (A) 9, 106).