INTRODUCTION

Characoma stictigrapta Hmps. has in recent years become an important pest of cocoa in Ghana (Akotoye & Kumar 1976) but little information is available on its biology and population dynamics. Mayne (1917), Ghesquiere (1922), Cotterell (1927, 1928) and Alibert (1951) referred to its pest potential while later workers included it in general surveys, e.g. Smith (1965) List of Lepidoptera on Cocoa in West Africa. C. stictigrapta is widely distributed in the tropics and in West Africa is found from Sierra Leone to Zaire, including the island of Fernando Po (Cotterell 1928, 1930). In Ghana it has been found in the cocoa growing areas from the coast to the Brong-Ahafo Region. It has also been observed by the present authors to occur at sea level (Legon, Accra) and at 667 m (Amedzofe, Volta Region). It is able to colonize isolated cocoa stands for its larvae and cocoons were found in December 1973 on cocoa in the botanical gardens of the University of Ghana, Legon. Much of the cocoa growing area of the Volta Region consists of patches in isolated secondary forest in Guinea Savanna. It is probable that this moth is an active flyer, and can traverse intervening vegetational zones to reach cocoa patches. However, it can utilize other host-plants such as Cola (Forsyth 1966) and other Sterculiaceae.

The present investigation was undertaken to determine the seasonality and distribution of the caterpillars of this moth and to attempt to relate the findings to difference in localities, physical and biotic factors such as cocoa flushing and cropping.

Characoma stictigrapta is a greyish cryptic moth, sometimes with a conspicuous discoid black spot (1.0 x 1.5 mm large) situated dorsally and centrally on the forewings of both sexes. When fed on 5% sucrose solution, the female lives for about eleven days and the male for about thirty-three days. Adults mate two to four days after emergence with a preoviposition period of five to six days. The green eggs, 0.50-0.55 mm wide and 0.35-0.40 mm tall are laid singly at the rate of fifteen to eighteen per female in a five-to-six day oviposition period. They hatch five or six days later. Egg to adult takes thirty to thirty-one days (larvae, eleven to twelve days; pupae, twelve to fourteen days). A generation lasts thirty-five days and there are about ten generations per year.

The caterpillar is pinkish throughout its five instars and the instars can only be distinguished by the width of the head capsule using Dyar’s law (1890). In the laboratory, the larvae fed on cocoa leaves and pods but the adults would not lay eggs on cocoa seedlings, preferring green pods, and larvae were subsequently raised on the pods.
Characoma stictigrapta on cocoa in Ghana

SAMPLING SITES

Tutu (Akwamim)

This site lies at the outskirts of Tutu, Eastern Region, Ghana, 05°52N and 00°12W, at an altitude of 500 m. It is bounded by a trunk road on one side and by farm bush in a secondary forest on the others. This forest was originally Cletis-Triplochiton climax vegetation that Taylor (1952) called ‘the moist semi-deciduous’ high forest zone. The farm measures about 200 × 50 m and consists of the local amelonado cocoa variety planted haphazardly. The trees were six to nine years old. Shade trees provided an average light intensity beneath the canopy of 41·00 lumens/m², 30–150 lumens/m² in October.

Tafo (Akim)

The town, 06°12N and 00°22W, lies 220 m above sea level and is in the same vegetational zone as Tutu but further into its interior. The farm at the Cocoa Research Institute is surrounded by bush and cocoa-forests. Sampling was carried out in three plots: Plot R.5 with hybrid cocoa planted diagonally at intervals of 2·6 × 2·6 m. The cocoa, as in G.7 and H.13, was about 2–3 m tall and the plot was shaded to give an average light intensity of 100·0 lumens/m², 30–350 lumens/m² in October. Plot G.7, also of hybrid cocoa, was planted in 1970, squarely 2·5 × 2·5 m apart (Fig. 1). Glyricidia trees provide shade to give an average light intensity of 113·0 lumens/m², 30–283 lumens/m² in October. Plot H.13, with hybrid cocoa planted as in Plot R.5 (Fig. 1) but with a light intensity and shade trees as in Plot G.7.

Kade (Akim)

Kade, 06°06N and 00°49W, lies at an altitude of 100 km towards the centre of the same vegetational and climatic zones as Tutu and Tafo. The sampling site contained well-shaded fifteen year-old cocoa.

METHODS

Two methods involving the technique of sight counting were compared in determining the population trends of Characoma stictigrapta. Throughout the sampling period from October 1973 to October 1974, ten different cocoa trees were sampled on each occasion for caterpillars at Tuto farm and on three plots at Tafo.

Population on flush and shoots

This was studied by the following methods.

Method 1

Sampling at Tutu

Ten trees were selected at random. To do this a cocoa tree was chosen as the starting point and between five to forty steps, selected from a table of random numbers (Campbell 1967), were taken along a straight line in a particular direction; the nearest tree reached was marked ‘number one’ and a change of direction made by making a 90° turn to the left or right, and then another series of steps, indicated by the next random number from the table, were taken and the nearest tree was marked ‘number two’. The routine was continued until ten trees had been selected. Alternate left and right quarter-turns were
Fig. 1. Population of the *Characoma stictigrapta* caterpillars in relation to cocoa flushing at Tutu, 1973–74.
made when selecting the trees. The plot was sampled once or twice a week depending on the abundance of the caterpillars.

**Sampling at Tafo**

The cocoa at the Research Institute was planted in plots of ten rows and ten columns, each numbered 0 to 9. A corner tree of each plot was taken as the reference tree and the rest numbered accordingly. By using random numbers, ten trees were selected for sampling which was done weekly when the population of caterpillars was high, and twice weekly when it was low.

Both at Tutu and Tafo about 5 min were spent at each tree while searching for caterpillars.

**Method 2**

The time-searching method (Basinger 1938) was used at Tutu and Tafo and involved searching for caterpillars in the sampling site for 1 h. A 1 ha area was sampled at each locality.

**Populations in cherelles and pods**

Changes in the caterpillar population in cherelles and pods at Tafo and Kade were monitored by recording caterpillar frass and damage in the sampling areas. This indirect method is as good as one in which the animals are counted providing the relative estimates can be converted into absolute populations by using regression analysis (Southwood 1966).

A sub-plot of 20 × 20 cocoa trees was sampled once monthly from December 1973 to October 1974. All 400 trees were examined on each sampling day and the numbers of damaged or frassed pods and cherelles and total numbers of pods on each tree was recorded. Each cherelle and pod showing damage or frass was assumed to contain one caterpillar.

**Population distribution in time**

All instars of *Characoma stictigrapta* were sampled throughout the study period and their abundance on flushing shoots, leaves, meristems and terminal buds was recorded.

**Intensity of the caterpillar infestation**

The number of caterpillars living on flush leaves, buds and meristems was recorded in the field while those on pods were recorded after bringing the pods to the laboratory and excavating the tunnels in each pod. Frequency histograms of intensity of infestation were made for the population groups living on flush/shoot and in pods.

**RESULTS**

**Population distribution in time**

(i) *Distribution on flush leaves, buds and meristems*

The numbers of caterpillars observed at each site showed a succession of peaks throughout the sampling period and on many occasions no caterpillars were discovered. The distribution of caterpillars between each site was also found to be irregular.

*Tutu (Akwapim)* (Fig. 1). No caterpillars were found on ten randomly selected trees between late October and the third week of November but then the numbers reached a
Fig. 2. Population of Characoma stictigrapta caterpillars in relation to flushing leaves at Tafo for 1973-74: (a) Plot R.5; (b) Plot G.7; (c) Plot H.13.
peak of eleven in mid-December and there were two other lower peaks in late January
and February. Subsequently there were only two minor peaks in early and late April;
during the rest of this period few caterpillars were found on the selected trees. Using the
hourly-search method, the fluctuations of caterpillar numbers was broadly similar but
there were nine peaks instead of the six and the highest in February reached nearly
thirty-five caterpillars per hour per plot. Again no caterpillars were found in mid March
or between late June and late August. Mkhize (1971), at Aburi, found only one major
peak in April which built up from early December with flushing, and reached a maximum
in March.

Tafo (Fig. 2). The trend in the numbers found on ten trees on the three plots on this
farm were similar but once again more caterpillars were found when searching lasted an
hour (Figs 1–4). Most caterpillars were found in G.7. However, at Tafo the fluctuations
were out of phase with those found at Tutu. When hourly searches were made at Tafo,
the peaks were generally in early and late November, mid-January, early April and May,
mid-June, August and late October of the following year, 1974; all or most of these
peaks coincided with the troughs of the Tutu population (Fig. 1).

Plot R.5 (Figs 2 and 3(a)). As stated earlier, the method whereby ten random trees
were sampled did not reveal the caterpillar population as well as the hourly sampling
method. Data collected by these two methods showed population peaks on this plot in
late October and November, mid-January and early April, mid-June, late August and
mid-October of the following year. No caterpillars were recorded between late February
to late March, late April to mid-June and from early July till mid-August, and late
September to the end of the first week in September. The highest peak of the hourly-
search method was in January when thirty-two caterpillars were counted in 1 h.

Plot G.7 (Figs 2 and 3(b)). Population trends were similar to those at R.5 except for the

![Graph showing population trends](https://via.placeholder.com/150)

Fig. 3. Population of *Characoma stictigrapta* caterpillars in relation to flushing of cocoa
leaves. (a) Plot R.5; (b) Plot G.7; (c) Plot H.13.
mid-December zero gap and the mid-May peak. Fifty caterpillars per hour were obtained at the highest peak on this plot.

*Plot H.13* (Figs 2 and 3(c)). The population pattern was similar to G.7 although there was a wider gap of zero caterpillars between January and April peaks than in G.7. Also caterpillars were recorded from late July until mid-October.

When random samples of ten trees were examined, caterpillars were found on Plot R.5 only twice between mid-February and mid-October. None were found on other Tafo plots during five weeks from mid-February nor between late June and mid-October, but in the intervening period, up to eight were found in G.7 and 16 in H.13 (Fig. 2). During this period of scarcity only a few more caterpillars were found during hourly searching, although earlier up to fifty were found by this method on G.7.
Population trends based on weekly data (Figs 4 and 5(c)). There was more order in the population trends from all sampling sites of Tutu and Tafo when the data were plotted on a weekly basis compared to the raw data. There appear to be regular seven to nine population peaks in all plots throughout the twelve months of sampling. These peaks might correspond to the generations of the moth as is sometimes the case with lepidopterous populations (Cole, Adkinson & Fye 1973).

(ii) Distribution of population on cherelles and pods

Pods damaged by burrowing or marked by the presence of caterpillar frass were recorded at Tuto, Tafo and Kade with varying plot sizes and the results obtained are as follows.

![Graphs showing population trends](image)

Fig. 5. Weekly population of Characoma stictigrapta on flushing cocoa leaves at Tafo. (a) Plot R.5; (b) Plot G.7; (c) Plot H.13.

Tutu (Fig. 6). Twenty randomly selected cocoa trees were examined twice monthly over the study period and it was found that the numbers of caterpillars and pods attacked fluctuated similarly. There were three peaks of damage, a major one in mid-December and others in May and August for cherelles, green or ripe pods. Though the counts (flush and pod) had a similar major peak in December and a trough in March, the peaks in May
and August for pods tallied with the scarcity of caterpillars on the flush. An explanation for this is that when there are neither flushes, meristems nor terminal buds, the adult has no choice but to lay on pods and cherelles since these are the only oviposition sites.

**Tafo** (Fig. 7). A permanent plot of 20 × 20 trees was sampled throughout the period under investigation. The number of damaged pods was closely linked with the total number of pods available. There are two major cropping peaks for this hybrid cocoa, one in February and the other in September with a minimum number of pods on the trees in May. Population trends were similar to that at Tutu although they fluctuated between February and August. The percentage damaged pods changed little from December to September except for dips in March and July. Similar population trends were observed in the flush population on plots H.13 and G.7. The population of *Characoma stictigrapta* was being maintained at these times by pods because flush leaves, meristems and buds were unavailable. The total infestation level of the 400-tree plot for the eleven-month sampling period was 11.1% (1763 out of 15,108 pods).
Kade. On Plot 4B, a mature stand of hybrid cocoa, there was high peak of caterpillars in January. On the 100-tree plot sampled, there were 74·6\% infested ripe pods (746 out of 1000 plucked). Subsequent sampling of all cherelles, mature green and ripe pods in January 1974 showed a 78·8\% infestation (808 out of 1026 second sample pods). By May, following picking, the population had decreased and there were 22·1\% (91 out of 413) infested pods. There was a gradual build up of population in the new pods over the following three months and by August 1974 the infestation had reached about 25\% (435 out of 1733 pods).

Population distribution in space

Caterpillar distribution can be regular (even), contagious (aggregatory) or random. Aggregation has been measured by the constant 'k' of the negative binomial, and Taylor (1961, 1965) showed that each type of distribution could be described by the ‘power law’, \( S^2 = am^b \), where \( S^2 \) and \( m \) are variance and mean respectively, and \( a \) and \( b \) are constants.

Population on pods; distribution between trees

The spatial distribution of some tropical cocoa insects has been described previously.
Characoma stictigraptta on cocoa in Ghana

Fig. 6. Characoma stictigraptta damage on twenty trees at Tutu, 1973–74, as an index of caterpillar populations in pods of cocoa.

Fig. 7. Characoma stictigraptta caterpillar population as measured by the number of pods infested (or damaged) in a 400-tree plot at Tafo, 1973–74.
In Western Nigeria, Youdeowei (1965) showed that the cocoa mirid, *Sahlbergella singularis* Hagl. had an aggregated distribution between cocoa trees. Johnson (1971) showed from data collected in the 1957–60 mirid control trials in Ghana that the mirids have a similar distributional pattern and are also subjected to the ‘power’ law.

When the distribution of *Characoma strictigrapta* caterpillars between trees was subjected to Taylor’s ‘power law’ it appears to be highly aggregated through the eleven-month sampling period. When data on pod damage were analysed, and log $S^2$ plotted against log $m$, the fitted curve had a slope of 1·8 (Fig. 8(a)). A similar analysis of the undamaged crop gave a slope of 1·84 (Fig. 8(b)), showing the non-damaged cocoa pods to be also aggregated in the plot. Cropping of cocoa in the plot had also an aggregated distribution of pods with a slope of 1·52 (Fig. 8(c)). It is possible that aggregation of the pods led to aggregation of caterpillars. When the spatial distribution of caterpillars in this plot over the eleven-month period was compared to that of all available pods (Fig. 9) it was found that although both were bimodal and their major peaks coincided in September, their minor peaks were separated, with that of *C. strictigrapta* occurring in January and that of available pods, in March. This shows that the distribution of

![Fig. 8. Distribution of *Characoma strictigrapta* caterpillar population among (a) damaged cocoa pods, (b) undamaged cocoa pods and (c) the distribution of pods on cocoa trees in a 400-tree plot. Both the caterpillars and the pods have an aggregated distribution with $S^2/m$ values of 1·8 and 1·52, respectively.](image-url)
Characoma stictigrapta on cocoa in Ghana

*C. stictigrapta* in space with respect to time is not strictly associated with the pattern or distribution of available pods. *C. stictigrapta* caterpillars were least aggregated in May as were pods with a value of 1.6 (Table 1). Monthly maps showing intensity of infestation per tree and the clumping of populations as categorized by various classes of infestation magnitudes namely N, 0, 1, 2 and 3, supported the finding that caterpillars form aggregations.

**Degree of infestation on pods and cherelles**

In pods and cherelles, an average of 5.3 caterpillars were found on pods taken from Kade, with a maximum of twelve caterpillars per pod (Fig. 10). From infestation and damage analyses, the Tafo infestation was 60% of that at Kade so that the mean infestation per pod at Tafo was about 3.2 caterpillars per pod.

**Degree of infestation on buds, meristems and flush leaves**

As many as sixteen caterpillars per flushing shoot were found for both Akwapim and Tafo areas with an average infestation of three caterpillars per shoot. As the pods were

![Graph showing spatial pattern of distribution of Characoma stictigrapta caterpillars in a 400-tree plot.](image)

**Fig. 9.** Spatial pattern of distribution of Characoma stictigrapta caterpillars in a 400-tree plot (H.13). — Total pods available; --- damaged pods.

heavily infested compared to the flushing shoots, perhaps the pods provide a better habitat and food source than the shoots whose flushing is transient and unlikely to offer adequate protection and food source for development.

**Physical and biotic factors on caterpillar distribution**

When seasonality graphs for *C. stictigrapta* are examined, caterpillar fluctuations are intrinsically dependent on the availability of flush. The population fluctuated with flushing except occasionally at Tafo and Tutu when there were population peaks with little or no flushings. On such occasions, the caterpillars especially the I–III instars were found living on the quiescent terminal buds and meristems. It is likely that most of them could not develop to pupae during this period without finding alternate food from nearby cherelles or pods, but this is unlikely since *C. stictigrapta* caterpillars are generally dormant and sedentary. The flushing cycle may be determined after six seasons as shown by Gibbs & Leston (1970) and the present authors (Fig. 11).
Table 1. Pod damage by Characoma stictigrapta caterpillars on a 400-tree cocoa plot at Tafo

<table>
<thead>
<tr>
<th>Months</th>
<th>Cocoa pods/400 trees</th>
<th>Variance ($S^2$)</th>
<th>$S^2/\bar{x}$</th>
<th>Cocoa pods/400 trees % Damaged</th>
<th>Variance ($S^2$)</th>
<th>$S^2/\bar{x}$</th>
<th>cocoa pods/400 trees pods damaged</th>
<th>Variance ($S^2$)</th>
<th>$S^2/\bar{x}$</th>
<th>pods undamaged</th>
<th>Variance ($S^2$)</th>
<th>$S^2/\bar{x}$</th>
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<tr>
<td>December 1973</td>
<td>341</td>
<td>3.34</td>
<td>3.6</td>
<td>210</td>
<td>61.6</td>
<td>1.92</td>
<td>3.3</td>
<td>131</td>
<td>0.69</td>
<td>2.09</td>
<td>131</td>
<td>0.69</td>
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<tr>
<td>January 1974</td>
<td>632</td>
<td>5.68</td>
<td>13.3</td>
<td>223</td>
<td>35.3</td>
<td>7.46</td>
<td>3.6</td>
<td>209</td>
<td>2.77</td>
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<td>209</td>
<td>2.77</td>
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<td>34.9</td>
<td>2.52</td>
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<td>641</td>
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<td>9.4</td>
<td>0.17</td>
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<td>222</td>
<td>1.58</td>
<td>2.82</td>
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<td>0.56</td>
<td>1.6</td>
<td>19</td>
<td>21.6</td>
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<td>2.5</td>
<td>69</td>
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<td>July</td>
<td>2030</td>
<td>83.67</td>
<td>2.5</td>
<td>17</td>
<td>0.8(4)</td>
<td>0.10</td>
<td>16.5</td>
<td>2013</td>
<td>83.64</td>
<td>16.63</td>
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<td>August</td>
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<td>176</td>
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<td>15.9</td>
<td>3332</td>
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<td>33.95</td>
<td>26.4</td>
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<td>October</td>
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<td>4.2</td>
<td>150</td>
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<td>1.58</td>
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<td>15108</td>
<td>540.66</td>
<td>86.9</td>
<td>1763</td>
<td>248.42</td>
<td>58.72</td>
<td>86.55</td>
<td>13245</td>
<td>477.58</td>
<td>86.89</td>
<td>13245</td>
<td>477.58</td>
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</table>

For total study period

Dec. 1973–Oct. 1974 15108 49.15 7.9 16027 11.7 5.33 7.87 13295 43.42 7.90

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Characoma stictigrapta on cocoa in Ghana

Fig. 10. Intensity of infestation of vegetative parts of cocoa leaves, buds and pods by Characoma stictigrapta at Tafo, Tutu and Kade.

Fig. 11. Seasons at: (a) Tafo, after Gibbs & Leston (1970); ——Sunshine (31 yr mean); ——rainfall (36 yr mean); (b) Tutu, diagram based on rainfall (with limit drawn at 10.16 cm and sunshine with limit drawn at 5.5 h of sunshine). Data on rainfall and sunshine obtained from Meteorological Department of Ghana, Legon. ——Sunshine (18 yr mean); ——rainfall (35 yr mean).
Table 2. *Number of Characoma stictigrapta caterpillars, pod damage and parasitization in relation to monthly rainfall at Tutu and Tafo (1973–74)*

<table>
<thead>
<tr>
<th>1973–74 months</th>
<th>Rainfall (cm)</th>
<th>Tafo % damage of pods and cherelles</th>
<th>Caterpillars (av. of three plots)</th>
<th>Tutu % damage of pods and cherelles</th>
<th>Caterpillars on flush</th>
<th>% parasitization by <em>Apanteles</em> spp.</th>
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<td>October</td>
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<td>–</td>
<td>9.8</td>
<td>10.9</td>
<td>–</td>
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<td>23.5</td>
<td>10.2</td>
<td>10.2</td>
<td>30.3</td>
<td>1.2</td>
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<td>36.0</td>
<td>4.2</td>
<td>9.4</td>
<td>34.9</td>
<td>12.8</td>
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<td>22.0</td>
<td>26.3</td>
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<td>12.5</td>
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<td>53.0</td>
<td>8.1</td>
<td>4.1</td>
<td>13.3</td>
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<td>3.9</td>
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<td>11.2</td>
<td>0.7</td>
<td>11.4</td>
<td>25.5</td>
<td>0.8</td>
</tr>
<tr>
<td>September</td>
<td>18.0</td>
<td>16.2</td>
<td>0.5</td>
<td>19.3</td>
<td>21.1</td>
<td>1.8</td>
</tr>
<tr>
<td>October</td>
<td>24.7</td>
<td>10.7</td>
<td>6.4</td>
<td>11.2</td>
<td>26.1</td>
<td>2.0</td>
</tr>
</tbody>
</table>
Insect parasites exert varying influences on the numbers of *C. stictigrapta* caterpillars on pods and flush leaves (Table 2). Percentage parasitization showed peaks in January, which coincided with low numbers of pod caterpillars at Tafo, and in May with a peak of pod caterpillars. However, these peaks coincided with peak of flush caterpillars at Tafo. At Tutu the trends of parasitism are similar to those at Tafo, *Apanteles* spp. peak in March and in July and coincide with low numbers of caterpillars in both pod and flush at Tafo and Tutu, except for the May peak which coincided with the flush caterpillar population at Tafo.

Only rainfall was found to have any influence on caterpillar numbers. On the 400-tree plot at Tafo, rainfall peaks of March, July and October coincided with low caterpillar populations.

Table 3. Characoma stictigrapta caterpillar damage to pods on twenty trees/month (1973–74)

<table>
<thead>
<tr>
<th>Month 1974</th>
<th>Cherelles Total</th>
<th>% damage</th>
<th>Green mature pods Total</th>
<th>% damage</th>
<th>Ripe pods Total</th>
<th>% damage</th>
<th>% overall damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>November</td>
<td>31</td>
<td>27</td>
<td>168</td>
<td>29</td>
<td>40</td>
<td>34</td>
<td>30</td>
</tr>
<tr>
<td>December</td>
<td>45</td>
<td>14</td>
<td>28</td>
<td>39</td>
<td>75</td>
<td>52</td>
<td>35</td>
</tr>
<tr>
<td>January</td>
<td>70</td>
<td>3</td>
<td>41</td>
<td>7</td>
<td>22</td>
<td>27</td>
<td>12</td>
</tr>
<tr>
<td>February</td>
<td>42</td>
<td>0</td>
<td>41</td>
<td>12</td>
<td>21</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>March</td>
<td>75</td>
<td>0</td>
<td>81</td>
<td>2</td>
<td>43</td>
<td>19</td>
<td>4</td>
</tr>
<tr>
<td>April</td>
<td>167</td>
<td>2</td>
<td>89</td>
<td>8</td>
<td>52</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>May</td>
<td>134</td>
<td>16</td>
<td>140</td>
<td>26</td>
<td>52</td>
<td>35</td>
<td>25</td>
</tr>
<tr>
<td>June</td>
<td>142</td>
<td>6</td>
<td>151</td>
<td>14</td>
<td>93</td>
<td>28</td>
<td>16</td>
</tr>
<tr>
<td>July</td>
<td>73</td>
<td>11</td>
<td>171</td>
<td>18</td>
<td>29</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>August</td>
<td>91</td>
<td>17</td>
<td>177</td>
<td>30</td>
<td>67</td>
<td>30</td>
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<tr>
<td>September</td>
<td>40</td>
<td>15</td>
<td>180</td>
<td>22</td>
<td>75</td>
<td>27</td>
<td>21</td>
</tr>
<tr>
<td>October</td>
<td>28</td>
<td>14</td>
<td>132</td>
<td>22</td>
<td>19</td>
<td>42</td>
<td>26</td>
</tr>
</tbody>
</table>

**DISCUSSION**

The important points which emerge from this study are that: the moth occurs wherever cocoa is grown in Ghana; seven to nine population peaks were found per year and probably represent the number of generations, this corresponds with laboratory rearing when ten generations each on average thirty-five days long were obtained; caterpillar populations were kept low by rainfall, natural enemies and scarcity of flush shoots.

When populations were high, caterpillars were abundant on flush leaves, shoots, buds and meristems. This occurred during the dry season of harmattan and when the numbers of parasites were low. The absence of rain washing away young larvae and abundance of food, cocoa trees flushing together with the flush covering each tree, enhanced the increased populations.

When ten trees were examined (Method 1) caterpillars were not detected but they were found when searching was prolonged to an hour (Method 2). Thus in future work the timed method for the assessment of caterpillar populations should be employed. The value of this method was confirmed by Johnson (1971) for mirids. Johnson criticized Gerard’s (1966) method of ten sample trees per plot as being unrepresentative of a whole plot and that the mirid population may be mechanically disturbed. This anomaly could be corrected if permanent sampling trees are avoided and ten new trees are selected for
each sampling occasion (as done in the present work). Johnson concluded that 'whole plot visual counts give results as valid as the more accurate but laborious method of sheet knockdown counts and avoids populations' disturbance as occasioned by the more intensive sampling methods'.

The dispersal and spatial distribution of *Characoma stictigrata* caterpillars in pods and with respect to time were strongly aggregated as found in Nigeria (Youdeowei 1965) and Ghana (Johnson 1971) for mirids. The caterpillar aggregation was partially related to pod aggregation in September but not in January and March. It appears that the female moths were selective in their choice of oviposition sites preferring clustered pod-bearing zones to sparsely cropping areas. This ensures the larvae with a ready and continued supply of food and living space.

Mkhize (1971) showed only single seasonal peaks of many caterpillars, that is, there were no fluctuations in insect populations from September to May in Akwapim area. The noctuids *Anomis, Characoma, Spodoptera, Lophocrama* spp. had only one peak, usually corresponding to the major peak of flushing in April. However, some Lepidoptera such as *Earias, Euprostictis, Orgyia, Argyrostigma, Diaerisia, Torrix, Colodeora* and *Neodeora* spp. usually had two peaks associated with flushing. The present study in the same area provided a different picture. Cocoa flushed regularly with seven to eight cycles within the study period of October 1973–October 1974; there are seven to nine corresponding population peaks for *Characoma stictigrata*. This is similar to that of *Earias bippula* Wlk. in Nigeria and Ghana (Smith 1962; Entwistle, 1962, 1964) although the population peaks were not compared with cocoa flushing.

Flushing of cocoa is the production of new leaves. Cocoa flushing is a cyclical event with a periodicity of about two months and is little understood. While some authors (e.g. Pyke 1933) consider that the rhythm arises because of the periodical differentiation of leaf primordia, others (e.g. Asomaning, Kwakwa & Hutcheon 1971) believe that it may be dependent on the attainment of a certain physiological state. Flushing of cocoa means abundance of food for insect leaf and meristem feeders such as lepidopterous larvae, some Coleoptera, psyllids, aphids and others. The present study shows that *Characoma stictigrata* caterpillars increase and decline in numbers with cocoa flushing. Although previous seasonality studies on cocoa flush-associated insects have shown these insects to have two annual peaks corresponding to the two major annual flushes of March and October (Gibbs & Leston 1970), the present study has shown that *C. stictigrata*, although a flush associated insect, fluctuates regularly with several peaks throughout the year.

Rain can significantly reduce the population of insects such as noctuids, pentatomids, psyllids and aphids (Fye 1973, Owusu-Manu 1974). In the present work, rains washed young caterpillars from flush leaves or drowned them when tunnelling inside cocoa pods. Seasonality of the *C. stictigrata* caterpillars and rainfall at Tutu and Tafo show negative phasing—suggesting that rainfall adversely affected the numbers of caterpillars. In addition natural enemies consisting eleven to thirteen species of hymenopterous parasites, three to four dipteran species of tachinids and syrphidas, nematodes and fungi, e.g. *Aspergillus* sp., were found during the present study and possibly depressed populations of *Characoma stictigrata*.

In Nigeria (Entwistle 1972), the relative abundance of *Earias bippula* in the dry season has been explained on the basis of higher temperatures which accelerate development leading to rapid population build up. Youdeowei (1971) also pointed out that short generations of *Sahlbergella singularis* Haglund lead to rapid increase of its populations.
Characoma stictigrapta on cocoa in Ghana

Similar effects may be operating with Characoma stictigrapta. Thus a more rapid development at higher temperatures, lack of rains, abundance of food and living space may account for its relative abundance together with other meristem and leaf-feeding lepidopterous caterpillars and their frequent outbreaks during the harmattan season.

ACKNOWLEDGMENT

We would like to thank the referee, who evaluated this paper, as well as Dr T. H. Coaker, for valuable criticism.

SUMMARY

(1) Population dynamics of Characoma stictigrapta caterpillars a pod and leaf feeding pest of cocoa in Ghana, was studied.

(2) The caterpillars were found on pods throughout the year and had aggregated distribution. Populations on the flush leaves and other vegetative parts of the cocoa tree did not occur all the year round, being dependent on the availability of the leaves.

(3) The dispersal pattern of the caterpillars among pods determined the pattern and nature of damage on pods, which was also aggregated.

(4) The natural enemies of the caterpillars and heavy rains appeared to keep the population low at certain times of the year.

(5) Populations of natural enemies also fluctuated throughout the year being influenced at least by rain.

REFERENCES


*(Received 26 March 1976)*