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BIOLOGICAL STUDIES ON *Earias insulana* (BOISD.) AND *Earias biplaga* (WLK.) (LEPIDOPTERA: NOCTUIDAE) AS PESTS OF OKRO (*Abelmoschus esculentus* L.) IN NSUKKA, NIGERIA

BY

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ABSTRACT

Earias species are serious pests of cotton and other malvaceous plants in the tropics. The biology of *E. insulana* and *E. biplaga* specifically as pests of okro in Nigeria, was investigated in the field and the laboratory from September 1984 - July 1985 at the University of Nigeria, Nsukka.

From the laboratory studies, fecundity, incubation period, pre-oviposition period, mean durations of larval and pupal stages, adult longevity as well as the duration of life cycles of the moths were established.

Based on frequency distribution of head capsule widths of field-collected and laboratory-reared larvae, and direct count of shed head capsules of these internal feeding larvae, 5 imaginal stages were confirmed for the species. Okro proved to be a suitable alternative host plant for these moths, their life cycles at near natural atmospheric conditions in the laboratory being 21.75 $\pm$ 1.37 days and 26.18 $\pm$ 2.09 days for *E. insulana* and *E. biplaga* respectively. Besides, larvae fed solely on okro fruits (seeds) produced viable progeny. Fecundity of these moths (whose larvae were raised on okro seeds) was very low (8 $\pm$ 3.77 and 9.3 $\pm$ 3.51 eggs for *E. insulana* and *E. biplaga* respectively).

In nature E. insulana was most common during the dry season while E. biplaga occurred mostly during the rainy season.

Pest incidence in the field, evidenced by larval puncturing of and entry into okro fruitlets, commenced at fruiting and lasted virtually till death of the host plants. Overall damage to unaborted okro fruits was 23.06% while abortion of fruitlets resulting from larval attacks amounted to 10.83%. Consequently it is concluded that these two moth species are normally no serious pests of okro as they are of cotton. The heaviest larval damage of okro fruits during this study occurred about the month of January which coincided with the dry season, while the least damage occurred about May during the rainy season. The latter situation fortuitously fits into the cultural practices of okro farmers of Southern Nigeria.

CHAPTER ONE

INTRODUCTION

Vegetables are grown world-wide and are important sources of proteins, minerals and vitamins (Oke,1965; Tindall,1965; Sai,1965; Oyenuga,1968; Oyenuga and Fetuga,1975). In Nigeria okro as well as other vegetable crops are grown mainly as minor backyard garden crops, consequently, many pioneer agricultural research workers here devoted their attention to major food and cash crops of the country (Akinlosotu,1977).

Okro, Abelmoschus esculentus (L.) (Synonym Hibiscus esculentus L.) is an annual species of the Malvaceae or Mallow family. It is known as gumbo, gombo or lady's finger in English-speaking countries; bhindi in India and bamyah or bamiat in Arabic-speaking countries (Franklin and Ruth Ruberte,1978). The exact origin of okro is unknown but it is thought to be of African origin and to occur naturally in the tropics but was introduced into the United States and West Indies under the Spanish name gumbo (Pavlos and Spiros, 1975).

Okro is of significant nutritional value and merits more extensive use in the tropics in home garden and subsistence farms where it is cultivated for its young fruits (pods) and leaves which are rich in proteins, minerals and vitamins (Franklin and

Ruth Ruberte, 1978). In many tropical countries, the uses and varieties cultivated vary from country to country. In Nigeria, Ghana, Liberia and Sierra-Leone, it is widely grown for its young tender fruits which are consumed fresh or dried as a main vegetable dish or made into soups or stews with other condiments. In United States, it is of great economic importance only in some southern states, where it is grown for market processing for preparing stew and "gumbo" soups or it is eaten boiled or fried as a vegetable. The fruit is also frozen, canned as a mixture with other vegetables or preserved in brine for future use. Dried okro is also popular and the dried products are imported and used in diets as flavouring in soups and other food products in United States (Thompson, 1957).

In Nigeria, several cultivars or varieties of the crop are grown all of which are attacked by a wide range of insect pests, especially Lepidopterans, the most important among them being Sylepta derogata (Fallen) (Pyralidae), Anomis leona (Schaua), Heliothis armigera (Hubner), Spodoptera littoralis (Fallen) (Noctuidae), Earias insulana (Boisduval) and E. biplaga (Walker) (Noctuidae). Other serious pests are the flea beetles Podagrica sjostedti (Jacoby), P. uniforma (Jacoby), Aphis gossypii Glov., Bemisia tabacci (Genn.) (Taylor, 1974). Although experience at Nsukka, Nigeria, has shown that the most destructive species on

okra are the flea beetles, Podagrica species, the adults of which eat numerous small holes on the leaves thus reducing their photo-synthetic surface (Egwuatu, 1982), the larvae of the Noctuid moth, Earias species, have also been found to attack okro fruits. They destroy the seeds and render the fruits unsightly, unmarketable and thus unfit for consumption. Although there seem to be a wealth of literature on the control and bionomics of the genus Earias as a serious pest of cotton (Walker and Haidari, 1955; Planes Garcia, 1957; Srinivasan and Bettai Growder, 1962; Haidari, 1967; Murtuza and Waheed, 1969; Assem, Doss and Saddik, 1974; Gupta and Agarwal, 1983; Srivastava, Gajbhiye, Jain, Agnihortri and Munshi Singh, 1983), available literature on the biology of this genus as a pest of okro in Nigeria, especially here in Nsukka, seems to be scanty if not non-existent.

This project therefore has been undertaken with a view to studying the biology and certain aspects of the ecology of Earias species as pests of okro. The studies have been based on field and laboratory observations of the moth on the Awgu early cultivar of okro in and around the University of Nigeria, Nsukka.

It is hoped that such a life history study will not only relate the occurrence of the various biological events in development of Earias such as oviposition, hatching and developmental

transformations to seasons, but will also provide information that can be used to assess the pest status of this species on okro as well as the possibility and practicability, if necessary, of a control measure.

CHAPTER TWO

REVIEW OF LITERATURE

The genus Earias occurs in Africa as two species: Earias insulana (Boisd.) and Earias biplaga commonly known as the spiny bollworm - a name derived from the characteristic bristles or spines which are found on the larvae (Ripper and Lloyd George, 1965).

Bollworms, notably Heliothis armigera (Hb.) and Earias species, are among the important pests that attack cottom (McKinlay and Gerring, 1957). Several species of the genus Earias are pests of considerable importance in many cotton growing countries of the world. Among these are Earias biplaga in Nigeria (Pomeroy, 1925); the Egyptian bollworm E. insulana and E. huegeli (Stoll) in Australia and China (Akinlosotu, 1969).

The Egyptian bollworm E. insulana is widely distributed in Africa and adjacent islands, Southern Europe, Pakistan, India, South East Asia, Japan, Taiwan, Phillipines and Australia (Jurgen Kranz, Heinz Schmutteren, and Werner Koch, 1978). In Africa, E. insulana is often found in mixed populations with E. biplaga and both are pests of okro and cotton but have different climatic requirements and are seldom present at the same time of

the year even in sympatric regions (Croizier, Amargier, Jacquemard, Couilloud and Croizier, 1981). E. biplaga was first recorded as a major pest of Kenaf Hibiscus cannabinus in Nigeria in 1966 (Donnely, 1966) and is more common in Southern Nigeria than E. insulana (Ezueh, 1979). The bollworms present in Western Nigeria are Cryptophebia (Argyroploce) Leucotreta (Meyr), Pectinophora gossypiella, Diparopsis watersi, E. biplaga, E. insulana, Heliothis armigera and Pyroderces simplex (Hayward, 1967). Although collectively the bollworms are very serious pests, their importance individually varies considerably between seasons and localities and is almost entirely linked to the availability of alternative food plants.

Spiny bollworm is not so specific in its host nor so wide ranging as the American bollworm but concentrates largely on weeds of the Malvaceae which are wide-spread in Africa (Prentice, 1972). Its attack on cotton has been reported in several cotton growing countries of the world: Egypt (Abul-Nasr, Megahed and Mabrouk, 1972; El-Saadany and Abd-El-Fattai, 1976), Punjab (Haroon Khan, 1946; Haroon Khan, Ladha Ram Mohindra, Ghanda Ram Sharma and Abul Ghanim, 1948), Nigeria (Gerring, 1948; 1949; Pomeroy, 1925), Coimbatore, South India, (Cherian and Kylasam, 1950), Madras State, India, (Srinivasan and Bettai Grewder, 1962), Tanzania (East Africa),

(Reed,1974) and Bombay (Mihra,1936). In addition to cotton, Earias species is known to feed on the flower buds and fruits of Abutilon indicum, Hibiscus (Abelmoschus) esculentus (okro), H. cannabinus (Kenaf), hollylock,(Althae rosea),Cauliflower,(Urena lobata),M. sylvestris, Malva parviflora, Malvastrum tricuspidatum and Sida cordifolia (Raham,1940; Haroon Khan et al,1948).

Attacks by Earias biplaga on cocoa have been reported from Ivory Coast to the Congo (Kinshasha) and in San Thome (Mallamaire 1936; Alibert, 1951) and is the only species of Earias to do so in Africa (Entwistle, 1969). Similar attacks on cocoa have been reported in Ghana (Patterson, 1923), Togo (Alibert, 1951), Nigeria (Golding, 1946; Entwistle 1963, 1964, 1965; Youdeowei, 1972).

Although E. insulana occurs within the same geographical region as E. biplaga (Pearson, 1958), it has not been observed to attack cocoa (Entwistle, 1969).

Attack of maize ears by E. insulana has also been reported in Egypt (Honsy and El-Sadany,1969; Abul-Nasr and Megahed,1971; Abul-Nasr and Megahed,1974).

The damage caused by this pest is quite substantial and ranges from destruction and shedding of bolls and buds in cotton, to destruction by feeding on okro fruits and seeds and premature shedding or abortion of fruitlets. El-Shaaraway, El-Sadany and

El-Refaei (1975) have estimated the economic threshold of damage of E. insulana on cotton as 10 larvae (8% infestation)/100 green bolls. Estimates of loss or damage caused by this pest on cotton have been variously put at 9% in Giza region of Egypt (Nasr and Azab,1969), 22.52% of the total shedding of buds, flowers and bolls occurring in the growing season (September - February) in Madhya Pradesh,India (Kaushik and Singh,1968); 34 - 51% of fallen bolls in Bombay (Mihra,1936); 80% loss in yield in cotton seed in Iraq (Walker and Haidari,1955); and 88% in Spain (Planes Garcia,1957). A study of the host plants of the spiny bollworm (E. insulana) by Abul-Nasr et al (1972) has shown that infestation rate on okro could be as high as 55.5% and that attack is normally confined to the fruiting bodies. They also found that the rate of attack in terminal shoots, blossoming buds (squares) and flowers is more or less low whereas the fruits (capsules or pods) are most favoured.

The influence of weather conditions (temperature, rainfall and humidity) on the seasonal abundance and distribution of E. insulana and E. biplaga has been investigated (Haidari, 1967); Broodryk 1971; Taher, Metwally, Badawi and Al-Saadany,1978; Balasubramanian, Kulandaivelu and Balasubramanian,1981; Croizier et al.,1981; Katiyar,1982; Nasr, Badr, Hamed and Ahmed,1982; Couilloud,1983). From field experiments carried out in New Delhi, India, Katiyar (1982) reported that the most favourable climatic conditions for

development of E. insulana, E. vitella and P. gossypiella were warm but not excessively hot weather; cloudiness and frequent light rainfall. Haidari, (1967) reported that althougn the geographical distribution of E. insulana appearsto be affected by average temperature and duration of optimum temperature in a given locality, the population density depended not only on temperature but also on other climatic factors, length of growing season and the activity of predators and parasites. Nasr et al (1982) noted that population fluctuations of E. insulana in the Kafr-Shekh region of Egypt were not apparently related to the prevailing temperature, as adult numbers were high in autumn(the largest generation occurring in October), moderate in summer and low in winter and spring. Broodryk (1971) also reported that although E. biplaga was predominant in Gatooma Southern Rhodesia (Zimbabwe)during the winter months, the noctuids are not greatly affected by temperature.

However, Balasubramanian et al (1981) in their report noted that an increase in maximum temperature of $1^{o}C$ could result in an increase of 4.17% in bollworm incidence while an increase in rainfall time of 1 day could decrease the amount of damage by 4.05%. Also Couilloud (1983) observed that high temperature restricted the spread of E. biplaga and that while E. insulana appeared to be a hardier species tolerating a wider range of climatic conditions

and did not adapt well to damp conditions, E. biplaga was predominant and invaded cotton first during the rainy season (period of plant growth, flowering and fruiting), while E. insulana predominated during the dry season. The work of Haroon Khan (1946) on the relative abundance of E. insulana and E. fabia has shown that whereas E. insulana is widely distributed and found under severe and diverse climatic conditions, E. fabia is rare in places where there are extremes of temperature and are common only when there is good rainfall and a sudden drop in summer temperature.

In Tamil Nadu, India, Balasubramanian et al (1981), observed a significant negative correlation between the incidence of E. insulana and E. vitella and morning relative humidity, evening relative humidity, intensity of rainfall and number of rainy days. Taher et al (1978) also observed that humidity did not significantly affect the rate of adult emergence in Cairo, Egypt but a maximum rate of adult emergence resulted at 26°C and 60% relative humidity compared with the other combinations tested involving higher or low temperatures and humidities (22°C and 30°C and 40% and 80% R.H.).

The peak periods of occurrence/incidence of Earias species varies from place to place. In Coimbatore, South India (within the tropics) where cotton is sown in September or October, the first attack became visible in November (dry season) and high larval

populations occurred from the middle of May to July (early rainy season) accompanied by heavy shedding of buds and bolls (Cherian and Kylasam,1950). Planes Garcia (1957), in Spain observed that infestation was light until August and early September (Summer season) but rose to 80% on Egyptian cotton by late October. Katiyar (1977) found that in New Delhi India, cotton was most at risk from E. insulana, E. vitella and P. gossypiella between mid-August and mid-September (late rainy season) when the bolls were in a suitable stage for attack.

In Samaru, Northern Nigeria, Gerring (1948 , 1949) noted that Earias species began to oviposit on cotton in late August and continued on a considerable scale throughout the dry season. Oviposition was considerable until mid-March (larval population being limited by the number of bolls), slight and sporadic in April and May (early rainy season), and ceased in June but the larvae which were absent during this period reappeared in early July. He also observed that on cotton that was allowed to remain from one season to the next without cutting, Earias species was active from February to the end of May. McKinstry (1947) noted that in Gatooma, Southern Rhodesia (Zimbabwe), spiny bollworm (Earias) was present throughout the seasons and was particularly numerous in April (Spring). Peyrelongue and Bournier (1974) reported that in Madagascar

E. insulana survives throughout the year on alternative malvaceous food-plants and that Abutilon asiaticum is a permanent reservoir of E. insulana since throughout the year it provides green bolls necessary for larval survival. Bedford (1941) on the other hand reported that in Anglo-Egyptian Sudan, infestations by Earias insulana on cotton was highest in December irrespective of the sowing date of the cotton.

Studies on the bionomics of these pests (E. insulana and E. biplaga) include that of Yathom (1958) on cotton in Iran; Cherian and Kylasam (1950) in Coimbatore South India; Assem, Doss and Saddik (1974) on okro in the laboratory in Egypt; and Anwar, Ashraf and Arif (1973) on cotton in Kenya in the laboratory. Entwistle (1969) reported that the duration of the larval and pupal stages of E. biplaga are inversely related to the mean maximum temperature and are shortest in the dry season and longest in the wet season.

A pre-oviposition period ranging from 2.8 $\pm$ 0.3 days to 11.4 $\pm$ 1.7 days (Megahed et al, 1972) and 3 - 7 days (Assem et al, 1974) have been reported at varied temperatures and humidities. At temperatures ranging from 15°C to 31.9°C and relative humidities between 50% and 70%, the larval duration of Earias species reported varied from 11 days at 16°C (Pruthi, 1942) 10 - 12 days (Cherian

and Kylasam, 1950) 8 - 10 days (Murtuza and Waheed, 1969), to a maximum mean of 40.8 ± 0.8 days at 17.6°C (Megahed et al, 1972). The pupal duration varied from 7 - 10 days (Cherian and Kylasam, 1950), 9 - 15 days (Assem et al, 1974, to 26.5 days (Poitout et al, 1972).

Several generations of E. insulana have been reported to occur per year in Iran (Haidari, 1967); Egypt Megahed, Tawfik and El-Khateeb, 1972) while 4 - 5 larval instars have been generally established for the species (Pomeroy, 1925; Murtuza and Waheed, 1969; Megahed et al, 1972; and Assem et al, 1974).

CHAPTER THREE

MATERIALS AND METHODS

The biological studies on the two moth pests, *E. insulana* and *E. biplaga*, were carried out under near natural conditions at the Zoological Garden of the University of Nigeria, Nsukka. A plot of the host plant, okro, *Abelmoschus esculentus*, Awgu early cultivar measuring (16.2m x 4.5m) was established and the crops tended under normal horticultural practices until fruiting and death. The plot during each planting period was divided into 3 blocks (5.4m x 1.5m) each containing 60 okro stands in 5 rows spaced 45cm by 30cm apart. The exercises involved 3 plantings in September 1984 - January 1985, January 1985 - May 1985, and March 1985 - July 1985 which were designed to relate pest incidence and damage with the two main seasons of the year (dry and wet). For each planting, host plants were inspected regularly three times weekly especially from flowering to end of fruiting for various life stages of the moth and records kept.

3.1 LIFE HISTORY

3.1.1 INITIAL SOURCE OF LARVAE

Moth larvae, detected on okro flowers and fruits in the experimental plot and okro farms around, were collected for initial

rearing experiments. The larvae were lifted singly with fine camel hair brush and placed on a piece of fresh okro leaf inside a covered Petri dish in which they were conveyed to the laboratory. In the laboratory and within thirty minutes of collection, a small slit was made on freshly harvested young okro fruit and a larva transferred into it. Each fruit with its larval content, was put into a lided cylinderical plastic "cage" (6cm tall, 11.5cm diameter) placed on a laboratory bench for possible development of larva at fluctuating temperatures of 28°C - 31°C and relative humidity of 65% - 80%. For aeration, the cage had three circular holes (5cm diameter) on the sides covered with nylon mesh. The fruit which served both as food and substrate was changed every other day and the larva was transferred into a fresh one as already described while observations were continued until adult emergence.

3.2 OVIPOSITION AND LONGEVITY OF ADULT MOTHS

For studies on oviposition, adult moths resulting from the foregoing field - collected but laboratory reared larvae, were used. Freshly emerged males and females of each species were paired in separate empty jam bottles (6cm diameter, and 11cm deep) covered with nylon mesh, kept at the usual laboratory atmosphere. A small pad of cotton wool, saturated with 10% honey solution and suspended from the mesh lid of the jam bottle, served as a source

of food for the adults during the period of observation. Food was replaced three times weekly.

Since preliminary observations had revealed that female moths seldom oviposit on smooth surfaces, the internal surfaces of the jam bottles were lined with tissue paper to provide fairly rough substratum for oviposition. The cages were examined daily for eggs and the eggs so laid removed with camel hair brush for experiments. Inspections and collection of eggs were continued until death of the females. Male moths that died before the females were replaced. The dates of egg deposition and number of eggs laid were recorded. From these records, individual pre-oviposition and oviposition periods were computed.

The life span (from adult emergence till death) of adult males and females of both species was also recorded. The data on longevity and mean adult longevity was based on laboratory reared adults and experiments conducted under room temperature and humidity. Age-specific survivorship and fecundity tables were constructed and the survival rate (l_x), LT50 (when the population was reduced to 50%), fecundity rate (m_x) and peak periods of oviposition for both moth species were determined using the methods described by Slobodkin (1962), and the modification of Laughlin, (1965). While column (x) represented the pivotal age in days , age (0) was taken as the day of adult

emergence, while (l_x) represented the number surviving at the beginning of age class x expressed as a fraction of an initial population of 1 (i.e. 100% survival), and (m_x) represented the number of living females born per female in each age interval using a sex ratio of 1:1.

3.2.1 INCUBATION PERIOD

Incubation period was determined only for moth eggs laid in the laboratory. To this end, eggs laid on tissue paper lining the experimental bottles were removed with camel hair brush and placed on a filter paper underlaid by a moist pad of cotton wool inside Petri dishes for possible development. With the dishes covered, 10 - 20 eggs were thus incubated in each Petri dish and in contact with water. The eggs were inspected daily until they hatched. The incubation period (from the date the eggs were laid to the time they hatched), as well as the percent hatchability of the eggs were calculated.

3.3 DEVELOPMENT OF THE IMMATURE STAGES

For the determination of larval and pupal developmental periods, first instar larvae of known dates of eclosion were reared singly on host fruits as described earlier until adults

emerged. Daily observations were maintained on larval and pupal developments until adult emergence.

3.4 DETERMINATION OF NUMBER OF LARVAL INSTARS

3.4.1 BY DIRECT REARING AND COUNTING OF SHED HEAD CAPSULES

To obtain the number of larval instars, limited quantities of moth eggs laid in the laboratory were incubated in Petri dishes as already described and the resulting larvae reared singly on fresh okro fruits for the purpose of collecting shed larval head capsules. Each okro fruit was slit longitudinally, the larva placed in the fruit and the two halves of the fruit gently closed up and held together with a rubber band. The fruit was examined daily under the dissecting microscope for shed head capsules. On discovering a shed head capsule, the larva was removed and transferred to another okro fruit and the date of moulting noted. The observation was continued until pupation. The number of shed head capsules found was recorded and the duration in days of each larval instar was computed from the intervals between which shed head capsules were recovered.

3.4.2 BY HEAD CAPSULE MEASUREMENT

Both field collected and laboratory reared larvae of E. insulana and E. biplaga were used. The head capsules were cut off and boiled briefly in 10% NaOH solution to clear them. They were washed, air dried quickly on filter papers and then put on slide for examination and measurement under the dissecting microscope. Head capsule widths for all larvae were read off from an ocular micrometer scale fitted to a binocular microscope at a magnification of 40X. The head capsule width measurements obtained were used for the frequency distribution graph.

For the determination of mean and range of head capsule widths for various larval instars of the moth species, first instar larvae of known dates of eclosion were kept separately in batches of 10 - 15 and the larvae examined daily for shed head capsules. In all there were four such sets of larvae, one for each instar since laboratory observations during this study revealed that the moth undergo four larval moults. For any one batch of larvae, the appearance of moulted head capsules for the first time, second, third and fourth times indicated transformations from 1st to 2nd, 2nd to 3rd, 3rd to 4th and 4th to 5th instars respectively. Since from experience members of any one age group or batch normally completed moulting within two or three days of commencement, members

of each batch were examined and killed as soon as the desired instar was clearly attained. The resulting head capsules were processed in the usual way and their widths read off as usual. Since this study was based on a limited number of larvae, the head capsule width measurement of other field-collected and laboratory reared larvae were fitted into the ranges obtained and used for the determination of the mean and range of head capsule widths for the various larval instars.

3.5 ESTIMATION OF FRUIT DAMAGE AND LARVAL NUMBERS ON FRUITS, ABORTED FRUITS AND FLOWERS

During each of the 3 planting periods, 45 stands from 3 blocks of the experimental plot (15 stands/block) were randomly selected and tagged for the purpose of monitoring the build up of moth larval population as well as their level of damage of the okro fruits. Fruits from the tagged plants were plucked thrice weekly until death of the plants. The fruits were examined for the presence or absence of larvae. They were also assessed for damage through presence of either larval entry holes or emergence holes.

For determination of larval build up on fruits with time, the harvests were carefully examined visually in the laboratory and any larvae found were removed with camel hair brush, counted and then reared for use in other experiments. Similarly since the

entry holes made by the tiny 1st instar larvae were difficult to distinguish from other types of damage, as the former soon healed up and got reduced to small brown spots that resembled feeding punctures, damage was confirmed through actual dissection of all the fruits harvested. The data obtained were used to compute the results.

The shrivelled or fallen flowers and aborted fruits from the tagged plants were also collected, taken to the laboratory, counted and their numbers recorded. They were then opened up singly and searched for larvae. All larvae found were removed and transferred to insect cages for rearing. The number of aborted fruits actually containing larvae were noted and used to estimate the extent of damage to okro fruits.

3.6 RELATIVE ABUNDANCE OF EGGS ON PLANT PARTS

For the distribution of eggs on okro plants, during each of the 3 planting periods, 15 stands located in 3 blocks of the experimental plot were chosen, tagged and examined for eggs throughout the harvest period. The locations of eggs so encountered were noted and the eggs then removed counted and recorded. They were later used for experiments.

CHAPTER FOUR

RESULTS

4.1 BIOLOGY OF *E. insulana* AND *E. biplaga*

4.1.2 INCUBATION PERIOD OF EGGS

The results on incubation period of eggs of *E. insulana* and *E. biplaga* are summarized in Table 1. At fluctuating laboratory temperatures of 28°C - 31°C and humidity 65% - 80%, and with contact water provided, newly laid fertile eggs of *E. insulana* hatched in a mean ± S.D. of 3.3 ± 0.45 days (range 3 - 4 days) giving a percentage hatch of 81.7%. Those of *E. biplaga* hatched in a mean ± S.D. of 3.8 ± 0.79 days (range 3 - 5 days) with a percent hatch of 92.16%.

TABLE 1

Incubation Periods of *E. insulana* And *E. biplaga* At Room Temperature And Humidity

Species	*E. insulana*	*E. biplaga*
No. of eggs incubated	169	279
$\bar{X}$ incubation period (days)	3.3 ± 0.45	3.8 ± 0.79
No. that hatched	138	257
% hatchability	81.65%	93.77

4.1.3 LARVAL DURATION

The larval duration for both species is shown in Table 2. The successful records are numerically low because despite the high percent hatch recorded for eggs of both moth species in the previous section, larval mortality especially of the 1st instar was very high. Consequently the larval duration was based only on larvae that successfully completed their development from 1st instar till pupation. The mean larval duration $\pm$ S.D. for E. insulana was 9.55 $\pm$ 0.66 days (range 9 - 11 days) and 11.68 $\pm$ 0.58 days (range 10 - 12 days) for E. biplaga (mean for 20 and 16 larvae respectively).

From the direct count of shed head capsules of singly-reared larvae, 5 larval instars were established for both moths. However from the frequency distribution graph of pooled head capsules, the 5 larval instars were not depicted by clear cut peaks (Figs. 2A and 2B). Each larval instar lasted 2 - 3 days for E. biplaga and 2 days for E. insulana (Tables 3A and 3B). The mean head capsule growth ratio between successive instars of E. insulana and E. biplaga is shown in Tables 4A and 4B. The mean head capsule growth ratio $\pm$ S.D. for E. insulana larvae was 1.62 $\pm$ 0.17 (range 1.38 - 1.85 mm) and 1.55 $\pm$ 0.05 (range 1.45 - 1.59 mm) for E. biplaga. Figs. 1A and 1B show the linear relationship obtained

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from the plot of log head capsule widths against successive larval instars. This shows that the head capsule widths of the larval instars of both moth species progressively increased at each moult thus agreeing reasonably with Dyar's law that the head capsule of caterpillars grow in geometrical progression, increasing in width at each moult by a ratio (usually about 1.4) which is constant for a given species (Wigglesworth,1965).

TABLE 2

LARVAL DURATION OF E. insulana AND E. biplaga

Species	E. insulana	E. biplaga
No. of observations	20	16
Mean larval duration in days ± SD	9.55 ± 0.66	11.68 ± 0.58
Range in days	9 - 11 days	10 - 12 days

TABLE 3A

DURATION OF LARVAL INSTARS OF *E. insulana*

No. of larvae observed	Stage of Development	Mean duration of larval instar (days)	Range in Days
(20)	Instar I	2 days	2 days
	Instar II	2 "	2 "
	Instar III	2 "	2 "
	Instar IV	2 "	2 "
	Instar V	2 "	2 "

Mean duration of each larval instar = 2 days.

TABLE 3B

DURATION OF LARVAL INSTARS OF *E. biplaga*

No. of Larvae observed	Stage of Development	Mean Duration of Larval Instar (Days)	Range in Days
16	Instar I	2.25 days	2 - 3
	Instar II	2.18 "	2 - 3
	Instar III	2.56 "	2 - 3
	Instar IV	2.56 "	2 - 3
	Instar V	2.38 "	2 - 3

Mean duration of each larval instar = 2.38 days (range 2 - 3 days).

TABLE 4A

MEAN AND RANGE OF HEAD CAPSULE WIDTHS FOR E. insulana LARVAE

Larval Instar	No. of Larvae examined	Mean head capsule width (mm)	Observed range of head capsule width (mm)	Growth Ratio	Predicted/ Expected Range of Head Capsule Width (mm)
I	19	0.246	0.210 - .263	-	-
II	32	0.412	0.264 - .526	1.67	0.351 - 0.439
III	34	0.762	0.527 - .894	1.85	0.488 - 0.973
IV	65	1.195	0.895 - 1.42	1.57	0.827 - 1.403
V	15	1.65	1.43 - 1.68	1.38	1.235 - 1.96

Mean growth ratio. $\pm$ S.D. = 1.62 $\pm$ 0.17.

TABLE 4B

MEAN AND RANGE OF HEAD CAPSULE WIDTHS FOR E. biplaga LARVAE

Larval Instar	No. of Larvae examined	Mean head Capsule width (mm)	Observed Range of Head Capsule Width (mm)	Growth Ratio	Predicted/ Expected Range of Head Capsule Width
I	20	0.27	0.21 - 0.32	-	-
II	8	0.43	0.33 - 0.51	1.59	0.318 - 0.509
III	18	0.63	0.52 - 0.87	1.58	0.521 - 0.806
IV	23	1.08	0.88 - 1.46	1.59	0.827 - 1.383
V	14	1.57	1.47 - 1.63	1.45	1.276 - 2.117

Mean growth ratio $\pm$ S.D. = 1.55 $\pm$ 0.05.

Fig. 1A: Head capsule growth rate of *E. insulana* larvae

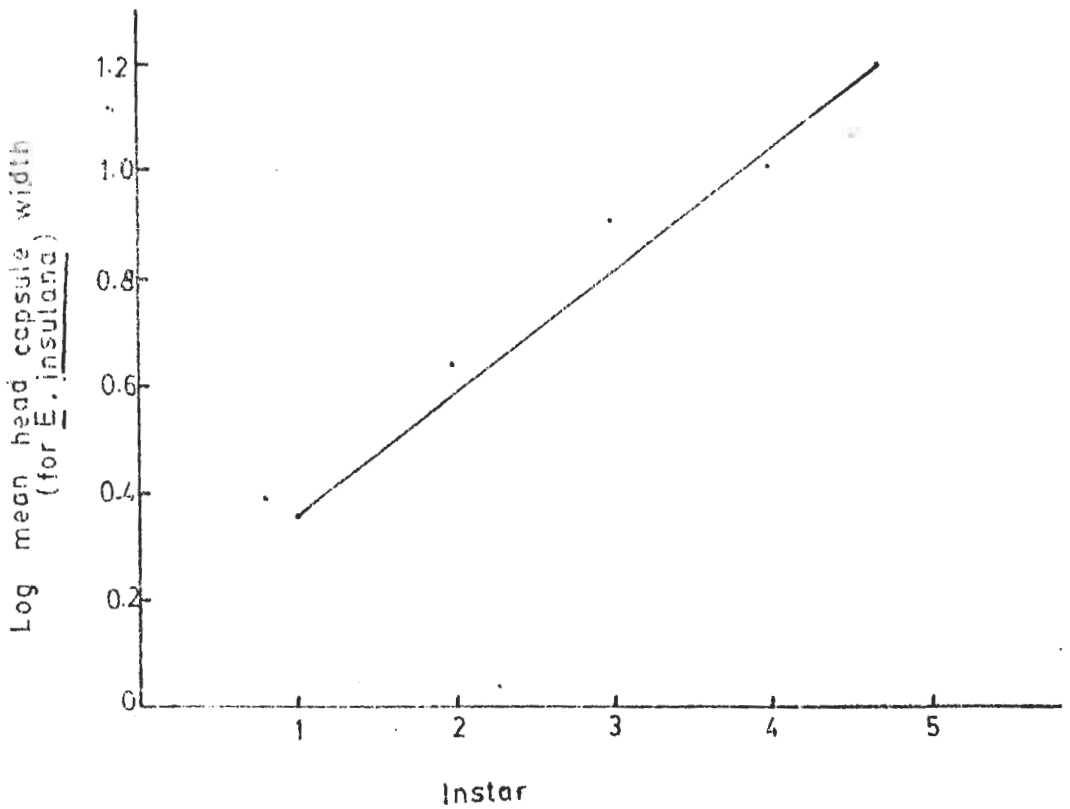
Log mean head capsule width
(for E. insulana)
1.2
1.0
0.8
0.6
0.4
0.2
0
1
2
3
4
5
Instar

Fig. 1 A

Fig. 1B: Head capsule growth rate of E. biplaga larvae

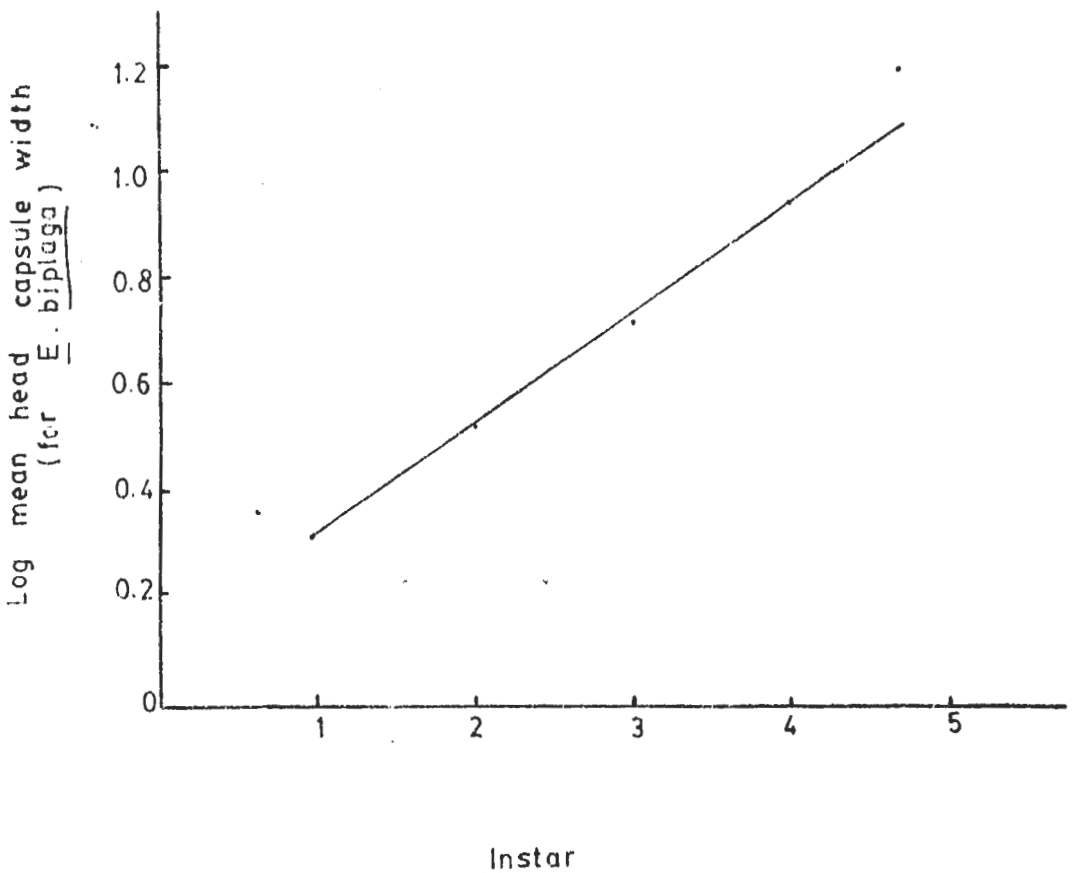
Log mean head capsule width
(for E. biplaga)
1.2
1.0
0.8
0.6
0.4
0.2
0
1
2
3
4
5
Instar

Fig. 1B

Fig. 2A: Frequency distribution of head capsule width of *E. insulana* larvae.

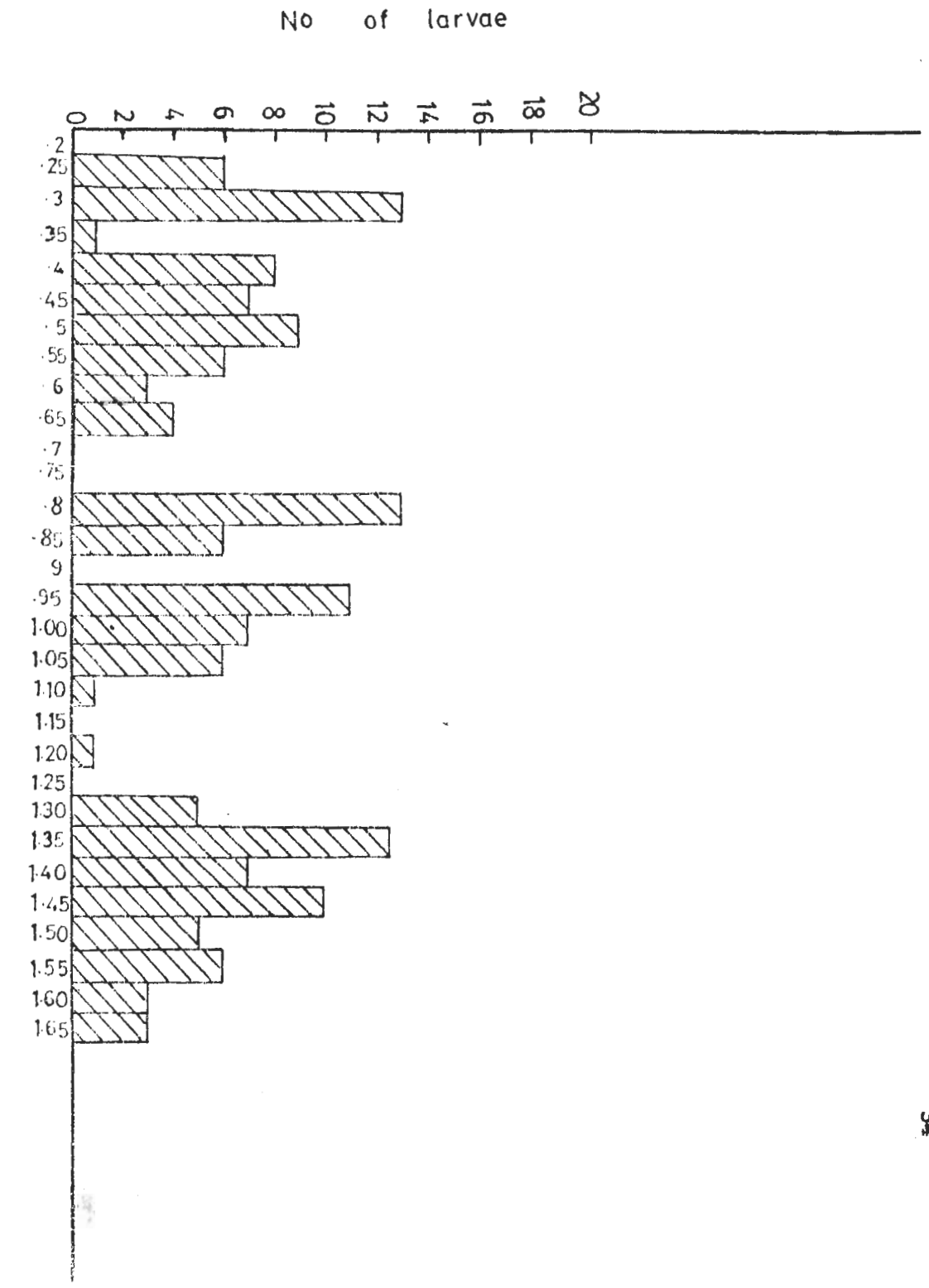
No of larvae
0
2
4
6
8
10
12
14
16
18
20
·2
·25
·3
·35
·4
·45
·5
·55
·6
·65
·7
·75
·8
·85
9
·95
1·00
1·05
1·10
1·15
1·20
1·25
1·30
1·35
1·40
1·45
1·50
1·55
1·60
1·65
Head capsule width (mm)

Fig. 2A

Fig. 2B: Frequency distribution of head capsule width of *E. biplaga* larvae.

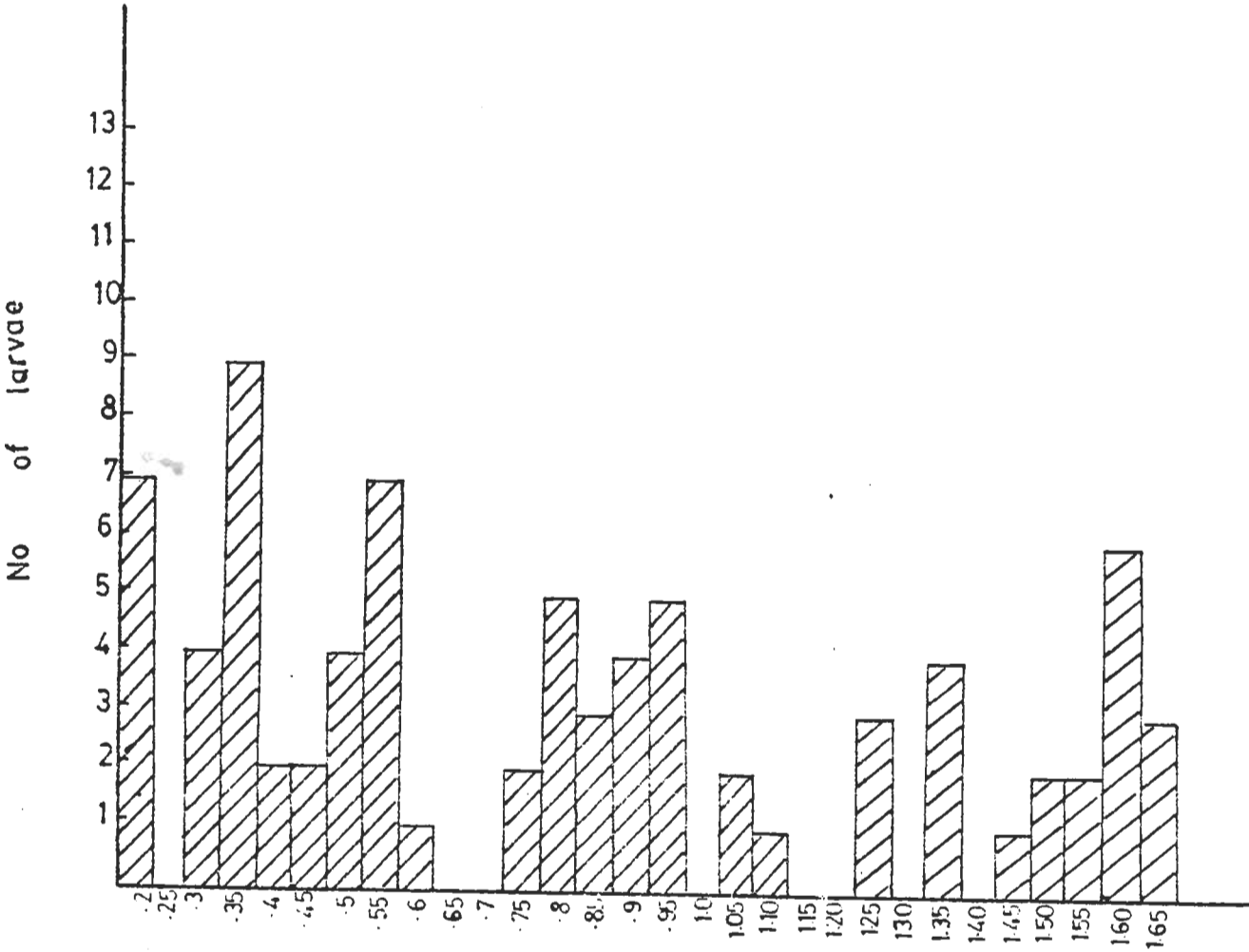
No of larvae
13
12
11
10
9
8
7
6
5
4
3
2
1
.2
.25
.3
.35
.4
.45
.5
.55
.6
.65
.7
.75
.8
.85
.9
.95
1.0
1.05
1.10
1.15
1.20
1.25
1.30
1.35
1.40
1.45
1.50
1.55
1.60
1.65
Head capsule width (mm)

Fig. 2 B

4.1.4 PUPAL DURATION

The duration of pupal period for both species is shown in Tables 8A and 8B. The pupal period of E. insulana lasted 9.2 ± 1.42 days (range 7 - 12 days) while that of E. biplaga lasted 11.5 ± 1.62 days (range 8 - 13 days). The differences was found to be statistically significant (P = .05). The pupal duration of E. biplaga was thus longer (11.5±1.62days) than that of E. insulana (9.2 ±1.42 days).

TABLE 5

OBSERVATIONS ON COCOON COLOUR, SPECIES AND SEX OF ADULTS AT EMERGENCE

Cocoon Colour	No. Examined	No./Species of Adult At Emergence	SEX	
			Female	Male
White	42	E. biplaga (9)	5	4
		E. insulana (33)	18	15
Dirty White	12	E. biplaga (7)	4	3
		E. insulana (5)	1	4
Brown	28	E. biplaga (16)	6	10
		E. insulana (12)	3	9

4.1.5 ADULT LONGEVITY

Under laboratory conditions and with food (honey solution) continuously provided, adults of E. insulana lived relatively longer

7.9 ± 1.95 days (mean for 20 adults) range 4 - 11 days) than those of E. biplaga 7.37 ± 2.02 days (mean for 16 adults) (range 2 - 11 days) (Tables 8A and 8B). The LT50 for E. insulana females was 6.5 days (range 4 - 10 days) as against 5.7 days for males (range 3 - 9 days): for females of E. biplaga, it was 6.2 days (range 2 - 10 days) but 6 days (range 1 - 10 days) for males (Table 6A and 6B and Figs. 3A and 3B). Thus for both species females lived a little longer than males. Differences in longevity of adults as well as those between males and females of both species were statistically significant (P = .05).

TABLE 6A

AGE SPECIFIC SURVIVORSHIP OF ADULTS OF E. insulana (22) FEMALES AND (25) MALES UNDER ROOM TEMPERATURE

FEMALE		MALE	
Age in Days (x)	Survivorship for females (L_x)	Age in Days (x)	Survivorship for Males (L_x)
0	1	0	1
1	1	1	1
2	1	2	1
3	1	3	0.92
4	0.90	4	0.84
5	0.81	5	0.60
6	0.63	6	0.44
7	0.36	7	0.2
8	0.18	8	0.04
9	0.04	9	0
10	0		

TABLE 6B

AGE SPECIFIC SURVIVORSHIP OF ADULTS OF E. biplaga (23) FEMALES AND 20) MALES UNDER ROOM TEMPERATURE

FEMALE		MALE	
Age in Days (x)	Survivorship of Females (l_x)	Age in Days (x)	Survivorship of Males (l_x)
0	1	0	1
1	1	1	0.9
2	0.95	2	0.75
3	0.86	3	0.75
4	0.78	4	0.65
5	0.52	5	0.55
6	0.52	6	0.5
7	0.34	7	0.45
8	0.26	8	0.25
9	0.21	9	0.05
10	0	10	0

Fig. 3A: Age specific survival rate of (25) males (o——o——o) and (22) females (*——*——*) of E. insulana under room temperature.

LT 50 Female = 6.5 days

LT 50 Male = 5.7 days

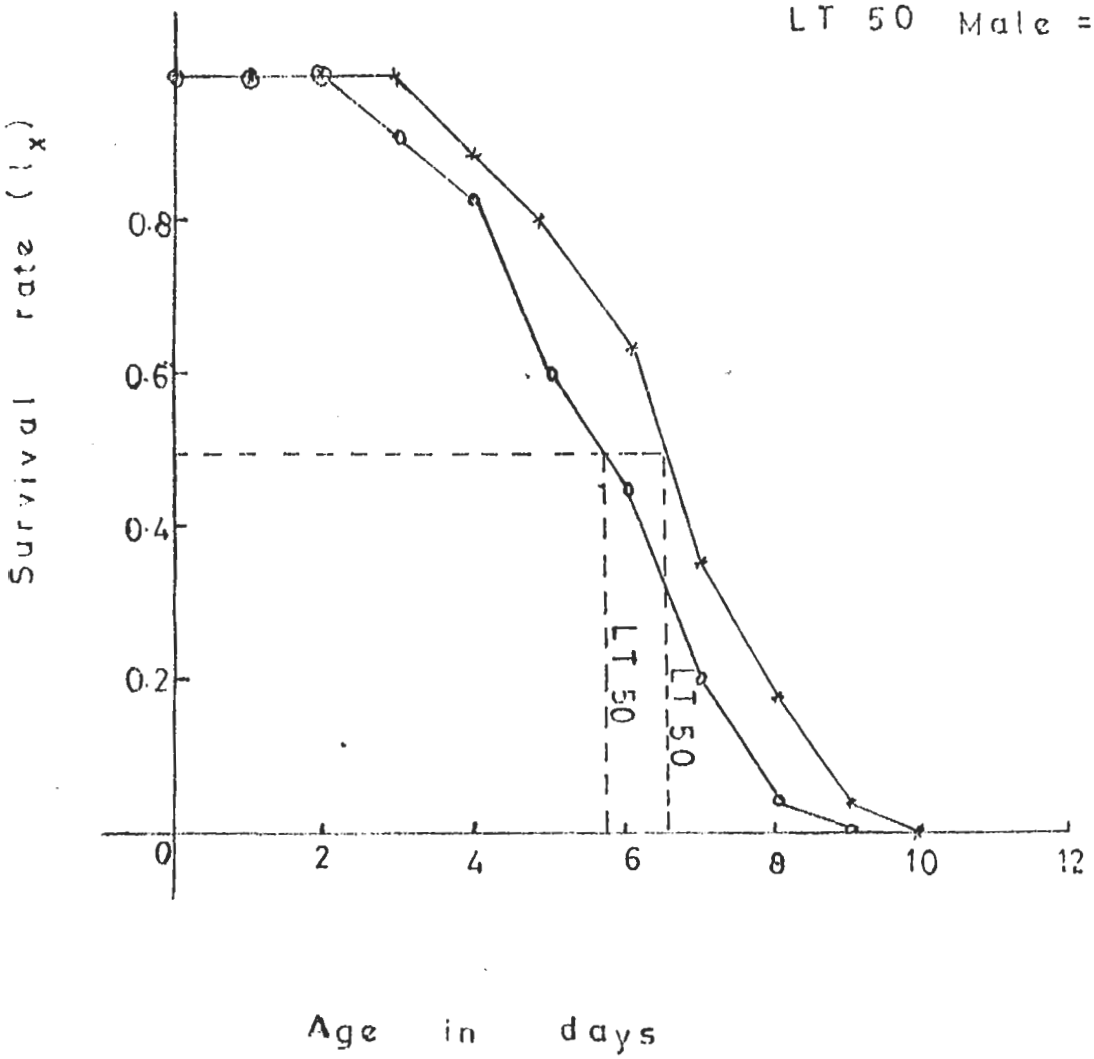

Fig 3A

Fig. 3B: Age specific survival rate of (20) males (—— ——) and (23) females (*^^—*——*) of E. biplaga under room temperature.

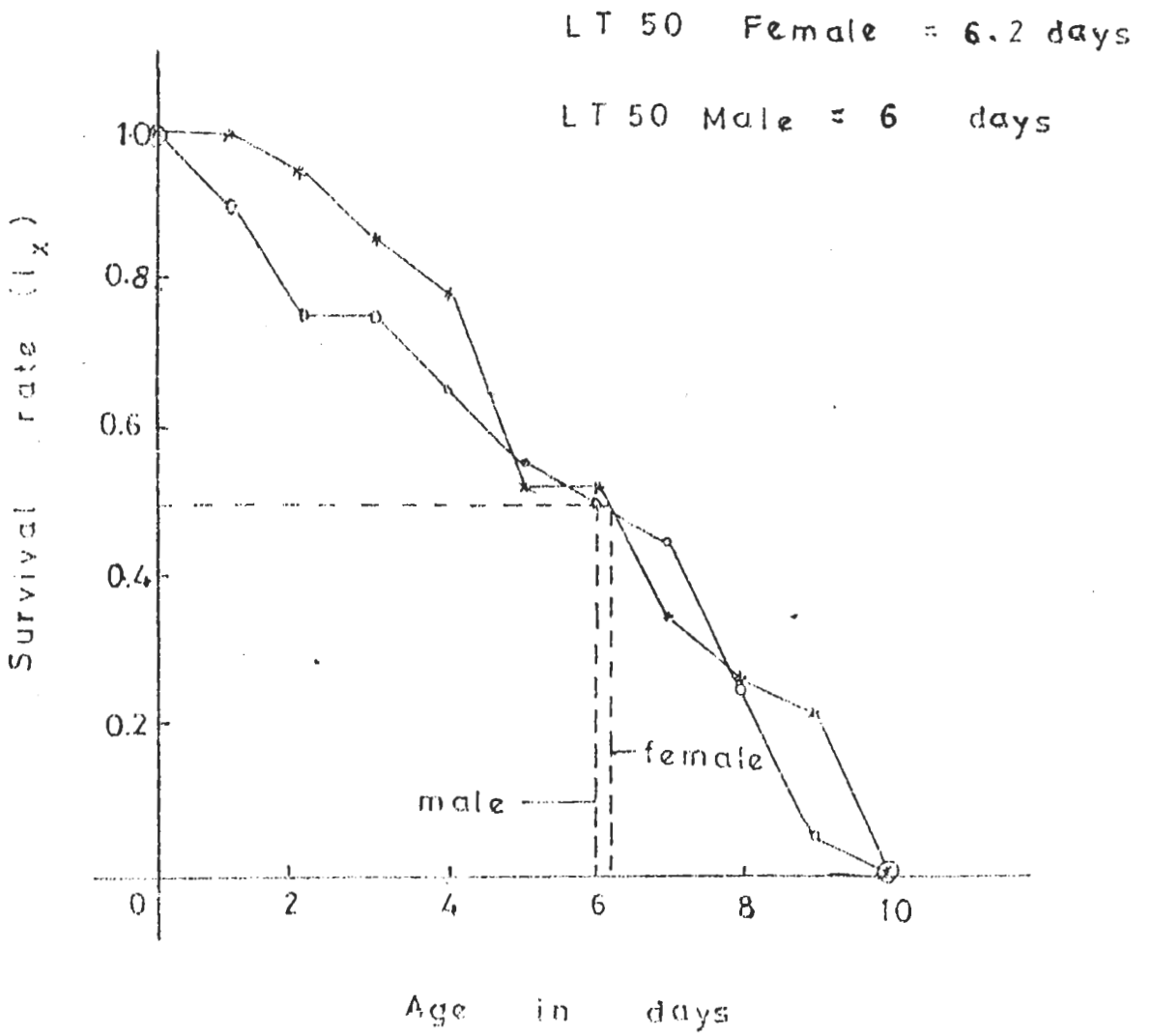
LT 50 Female = 6.2 days
LT 50 Male = 6 days
Survival rate (l_x)
1.0
0.8
0.6
0.4
0.2
0
2
4
6
8
10
female
male
Age in days

Fig 3 B

4.1.6 FECUNDITY/OVIPOSITION

In the laboratory, there was a pre-oviposition period of at least 2 days for E. insulana but 3 days for E. biplaga (Tables 7A, 7B and Figs. 4A and 4B). The mean oviposition period in E. insulana was 3.8 ± 1.39 days (range 1 - 9 days) and 1.5 ± 0.22 days (range 1 - 2 days) for E. biplaga (Table 7).

Fecundity was generally low and averaged 8 ± 3.77 eggs for E. insulana and 9.3 ± 3.51 eggs for E. biplaga (Table 7). The fecundities recorded in Table 7 are based on eggs laid by only 5 out of 30 E. insulana females and 6 out of 30 females of E. biplaga used respectively for the oviposition studies.

In the laboratory, the largest number of eggs laid by a single female E. insulana throughout life was 82 and that by female E. biplaga was 58. Similarly the largest number of eggs laid by a single female E. insulana in a day was 49 as against 58 eggs for E. biplaga while the lowest stood at 2 and 14 eggs respectively (Table 7). The highest fecundity rate (peak period of oviposition for E. insulana and E. biplaga were obtained on the 2nd and 3rd days of oviposition (5th day after adult emergence) respectively (Tables 7A and 7B figs. 4A and 4B).

Isolated virgin females did not lay eggs throughout their life time thus suggesting that in these moths, copulation is vital for both oviposition and egg fertility.

TABLE 7

FECUNDITY OF FEMALE *E. insulana* AND *E. biplaga* UNDER LABORATORY TEMPERATURE

Species	*E. insulana*	*E. biplaga*
No. of observations	30	30
No. that oviposited	5	6
Total oviposition period in days	19	9
Mean oviposition period in days	3.8 ± 1.39	1.5 ± 0.22
Total No. of eggs laid	240	279
Range of eggs laid	2 - 40	14 - 58
Mean fecundity	8 ± 3.77	9.3 ± 3.51
Largest No. of eggs laid per female	82	58
Largest No. of eggs laid per female/day	40	58

TABLE 7A

AGE SPECIFIC SURVIVAL AND FECUNDITY RATES OF (30) *E. insulana* FEMALES UNDER ROOM TEMPERATURE

Age in Days (x)	Survivorship Rate (l_x)	Total No. of Eggs laid	Mean No. of Eggs Laid	Fecundity Rate (m_x)
0	1	0	0	0
1	1	0	0	0
2	1	0	0	0
3	1	22	0.7	0.35
4	0.90	43	1.4	0.7
5	0.80	60	2	1
6	0.63	6	0.2	0.1
7	0.4	58	1.9	0.95
8	0.26	37	1.2	0.6
9	0.13	00	0	0
10	0.03	0	0	0
11	0.03	14	0.46	0.23
12	0	0	0	0

Sex ratio 1:1 (Anwar, Ashraf and Arif 1973).

m_x = No. of living females born per female in each age interval.

$m_x = N_x/2$, N_x being the total natality per female of age x.

Fig. 4A: Age specific survival rate (*----*----*) and fecundity rate (o---o---o) of (30) E. insulana females under room temperature.

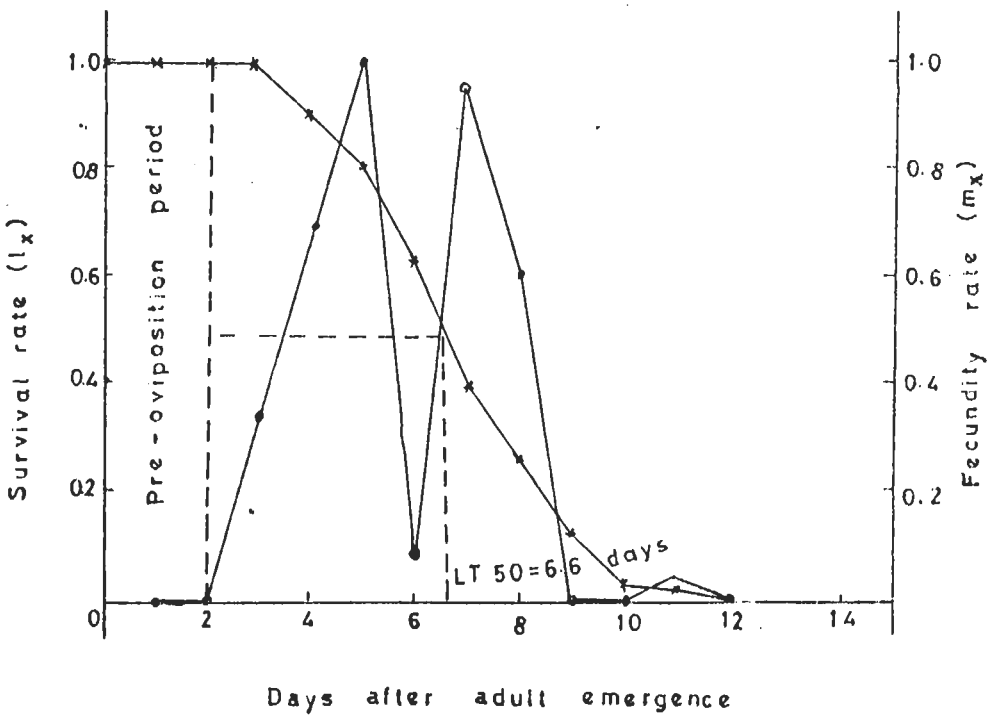
Survival rate (l_x)
Fecundity rate (m_x)
Pre-oviposition period
LT 50 = 6.6 days
Days after adult emergence
1.0
0.8
0.6
0.4
0.2
0
2
4
6
8
10
12
14

Fig 4A

TABLE 7B

AGE SPECIFIC SURVIVAL AND FECUDITY RATES OF (30) E. biplaga FEMALES UNDER ROOM TEMPERATURE

Age in Days (x)	Survivorship Rate (l_x)	Total No. of eggs laid	Mean No. of eggs laid	Fecundity Rate (m_x)
0	1	0	0	0
1	1	0	0	0
2	0.96	0	0	0
3	0.9	0	0	0
4	0.83	63	2.1	1.05
5	0.63	172	5.73	2.86
6	0.63	44	1.46	0.73
7	0.4	0	0	0
8	0.23	0	0	0
9	0.16	0	0	0
10	0	0	0	0

Sex ratio = 1:1 (Anwar, Ashraf and Arif 1973).

m_x = No. of living females born per female in each age interval.

$m_x = N_x/2$, N_x being the total natality per female of age x.

Fig. 4B: Age specific survival rate (*——*——*) and fecundity rate (o——o——o) of (30) E. biplaga females under room temperature.

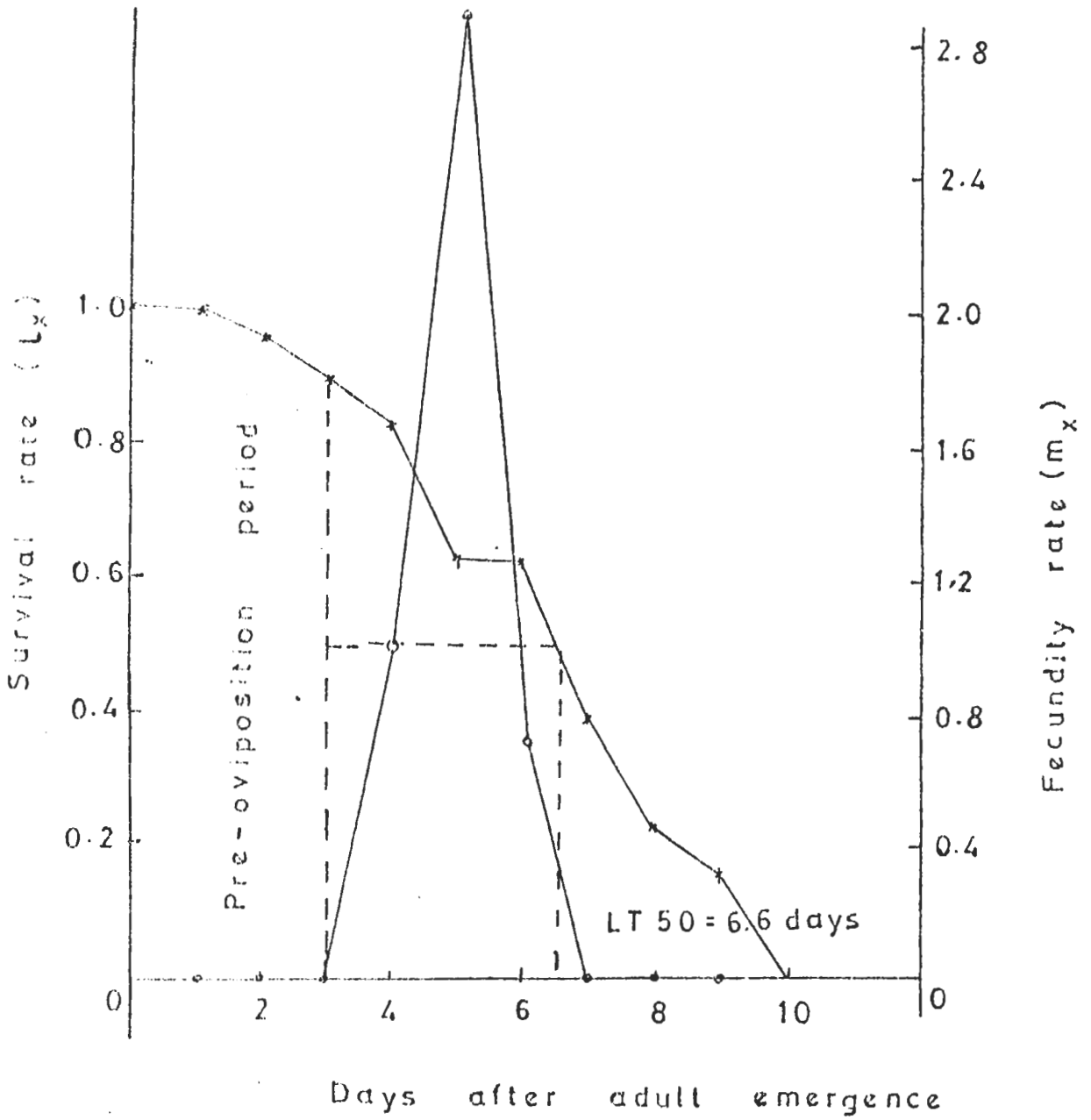
Survival rate (L_x)
1.0
0.8
0.6
0.4
0.2
0
Pre-oviposition period
LT 50 = 6.6 days
2
4
6
8
10
Days after adult emergence
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
Fecundity rate (m_x)

Fig 4B

4.1.7 DURATION OF LIFE CYCLE

Tables 8A and 8B show the duration of life cycle for both species.

The mean duration of life cycle of *E. insulana* was 21.75 ± 1.37 days (range 20 - 25 days) (20 complete records) and 26.18 ± 2.09 days (range 22 - 28 days) for *E. biplaga* (16 complete records).

The differences in duration of life cycles of *E. insulana* and *E. biplaga* was statistically significant (P = .05).

TABLE 8A

LIFE CYCLE DURATION OF E. insulana

No. of Observations	Incubation period in Days	Larval Duration in Days	Pupal duration in Days	Adult Longevity in Days	Duration of Life Cycle (from egg - adult emergence)
20	3 days	10 days	9 days	6 days	22 days
	3 "	9 "	9 "	9 "	21 "
	3 "	9 "	9 "	9 "	21 "
	3 "	9 "	9 "	5 "	21 "
	3 "	10 "	7 "	9 "	20 "
	3 "	10 "	7 "	11 "	20 "
	3 "	10 "	7 "	10 "	20 "
	3 "	9 "	9 "	8 "	21 "
	3 "	9 "	10 "	9 "	22 "
	3 "	9 "	10 "	5 "	22 "
	3 "	9 "	10 "	10 "	22 "
	3 "	11 "	8 "	6 "	22 "
	3 "	9 "	10 "	8 "	22 "
	3 "	10 "	10 "	8 "	23 "
	3 "	9 "	10 "	10 "	22 "
	3 "	9 "	10 "	4 "	22 "
	3 "	9 "	8 "	6 "	20 "
	3 "	11 "	8 "	10 "	22 "
	3 "	10 "	12 "	7 "	25 "
	3 "	10 "	12 "	8 "	25 "
Mean Duration $\pm$ S.D.	3.0	9.55 $\pm$ 0.66	9.2 $\pm$ 1.4	7.9 $\pm$ 1.95	21.75 $\pm$ 1.37

TABLE 8B

LIFE CYCLE DURATION OF E. biplaga

No. of observation	Incubation period in Days	Larval duration in Days	Pupal duration in Days	Adult Longevity in Days	Life Cycle Duration in Days (from egg - adult emergence
(16)	3 days	12 days	12 days	9 days	27 days
	3 "	12 "	12 "	9 "	27 "
	3 "	12 "	12 "	7 "	27 "
	3 "	12 "	12 "	7 "	27 "
	3 "	12 "	12 "	7 "	27 "
	3 "	12 "	12 "	2 "	27 "
	3 "	12 "	11 "	10 "	26 "
	3 "	12 "	13 "	8 "	28 "
	3 "	12 "	13 "	8 "	28 "
	3 "	12 "	13 "	8 "	28 "
	3 "	12 "	13 "	6 "	28 "
	3 "	12 "	13 "	6 "	28 "
	3 "	10 "	10 "	11 "	23 "
	3 "	11 "	8 "	5 "	22 "
	3 "	11 "	8 "	7 "	22 "
	3 "	11 "	10 "	8 "	24 "
Mean Duration $\pm$ S.D.	3 days	11.68 $\pm$ 0.58	11.5 $\pm$ 1.62	737 $\pm$ 2.02	26.18 - $\pm$ 2.098

4.2 BRIEF DESCRIPTION OF IMMATURE STAGES AND ADULTS OF *E. insulana* AND *E. biplaga*

For completeness and avoidance of doubt, the various stages of the two species of *Earias* used in the present study are briefly described hereunder.

4.2.1 EGG: (Fig. 5).

Mean diameter;

E. insulana: 0.52 mm (range 0.42 - 0.57 mm).

E. biplaga: 0.48 mm (range 0.42 - 0.52 mm).

Both spherical, with longitudinal ridges running down the entire surface and pointing upwards to form some sort of crown anteriorly (Fig. 5). Chorion light green, changing from dirty green to brown, with a brown ring at the anterior part prior to eclosion.

MAJOR DISTINCTION BETWEEN THE LARVAE OF *E. insulana* AND *E. biplaga*

The larvae are morphologically similar except that *E. biplaga* is darker brown in colour and has a pair of dorsally located brown tubercles on the 8th abdominal segment, while the larva of *E. insulana* is light brown and has a pair of dorsally located white tubercles on the 8th abdominal segment.

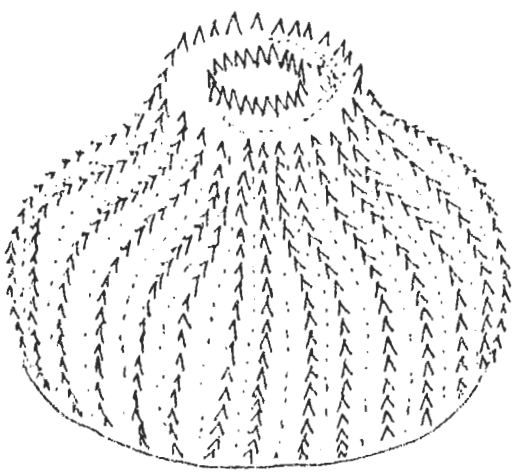

FIG.5. Egg showing shape and longitudinal ridges.

4.2.2 GENERAL DESCRIPTION OF LARVAL STAGES OF BOTH MOTH SPECIES

1ST INSTAR: (Fig. 6).

HEAD

Brown to dark brown.

Mean head capsule width;

E. insulana: 0.24 mm (range 0.21 - 0.26 mm).

E. biplaga: 0.27 mm (range 0.21 - 0.32 mm).

Adfrontal sutures and frons not clearly defined, clypeus not well defined, mouthparts indistinguishable but chocolate brown, ocelli 6, arranged in an arc shape in E. biplaga and S-shape in E. insulana.

THORAX

Prothoracic shield cream; true legs light brown, tubercles on meso- and metathorax not developed, a pair of oval shaped spiracles present on prothorax; peritremes not developed, spiracles absent on meso- and metathorax.

ABDOMEN

Hairy, occluding external segmentation; prolegs cream coloured, located on the 3rd, 4th, 5th and 6th abdominal segments; crochets arc-shaped. Spiracles present on all but last 2 segments, peritremes not developed. Long conspicuous setae present on last abdominal segment. Body colour cream and differs markedly from

those of subsequent instars.

2ND INSTAR

HEAD

Brown with numerous setae.

Mean head capsule width;

E. insulana: 0.41 mm (range 0.26 - 0.52 mm)

E. biplaga: 0.43 mm (range 0.33 - 0.51 mm).

Position, arrangement and number of cephalic appendages are as in 1st instar.

THORAX

Prothoracic shield cream with setae-bearing anteriorly serrated plate running transversely across the centre. Thoracic legs brown; tubercles on meso- and metathorax not well developed but absent on prothorax. A pair of oval shaped spiracles present on prothorax; peritremes not developed; spiracles absent on meso- and metathoracic segments.

ABDOMEN

10 segmented, each bearing 2 pairs of reduced hairy tubercles with long terminal setae, one dorsally and the other laterally. Last segment with a pair of claspers. Prolegs cream. 8 pairs of oval shaped spiracles on 1st 8 segments; peritremes not well developed.

Long conspicuous setae still present on last abdominal segment.

3RD INSTAR: (Fig. 79).

HEAD

Brown with numerous setae.

Mean head capsule width;

E. insulana: 0.76 mm (range 0.52 - 0.89 mm)

E. biplaga: 0.63 mm (range 0.52 - 0.87 mm).

Number, position and arrangement of appendages same as in previous instars.

THORAX

Prothoracic shield cream. Thoracic legs brown; 3 segmented and each terminating in a claw. A pair of spiracles on prothorax; spiracles absent on meso and metathorax, peritremes dark brown and developed. Tubercles on meso and metathorax discernible but absent on prothorax.

ABDOMEN

Segementation, number and location of tubercles same as in 2nd instar. Tubercles hairy and developed. Colour, number and location of prolegs, and shape of spiracles and crochets same as in 1st instar, peritremes dark brown and developed. Larvae of both species basically brown with white, grey and brown markings on body.

A white band runs across the 1st abdominal segment, continues mid-dorsally along abdominal segments till the 8th segment that bears either a white or brown pair of tubercles depending on the moth species. Orange spots on body discernible.

4TH INSTAR: (Fig. 8').

HEAD

Head chocolate brown with numerous setae.

Mean head capsule width;

E. insulana: 1.19 mm (range 0.89 - 1.46 mm).

E. biplaga: 1.08 mm (range 0.88 - 1.46 mm).

Adfrontal sutures well developed and frons visible, well defined, and brown in colour. Ocelli 6, arranged in an arc-shape for E. biplage and S-shape for E. insulana. Clypeus well developed, mandibles visible, chocolate brown in colour and developed.

THORAX

Prothoracic shield light brown. Thoracic legs brown; 3 segmented and terminating in a claw. A pair of oval shaped spiracles on prothorax; spiracles absent on meso- and metathoracic segments; peritremes dark brown and developed. Tubercles visible and present only on meso- and metathoracic segments.

ABDOMEN

Abdominal appendages same as in previous instars. Body colour brown. Segments with paired orange spots located laterally.

5TH INSTAR

HEAD

Head with numerous setae, chocolate brown.

Mean head capsule width;

E. insulana: 1.65 mm (range 1.43 - 1.68 mm).

E. biplaga: 1.57 mm (range 1.47 - 1.63 mm).

Adfrontal sutures and frons well developed and visible; frons brown. Ocelli 6 and arranged as in previous instars for both species. Clypeus well developed, mouthparts - mandibles stout, dark brown.

THORAX

Prothoracic shield light brown. Spiracles present on prothorax, peritreme dark brown; spiracles absent on meso- and metathorax. True legs 3-segmented ending in claws. A pair of tubercles each present on the meso and metathorax. Prothorax without tubercles.

ABDOMEN

10 segmented; abdominal appendages same as in the 3rd and 4th instars. Body colour and pattern brown and as in 3rd instar. Orange spots on body segments very conspicous; a pair located laterally on each abdominal segment.

FIG.6. First instar larva.

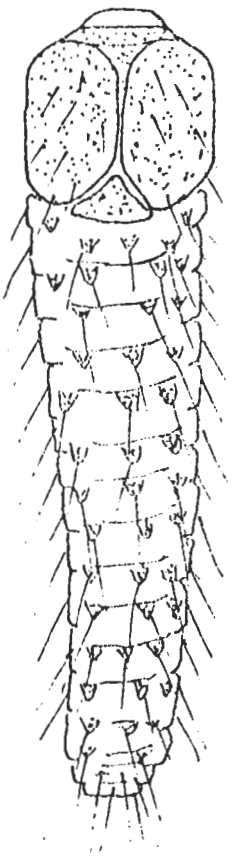

FIG.7. Third instar larva.

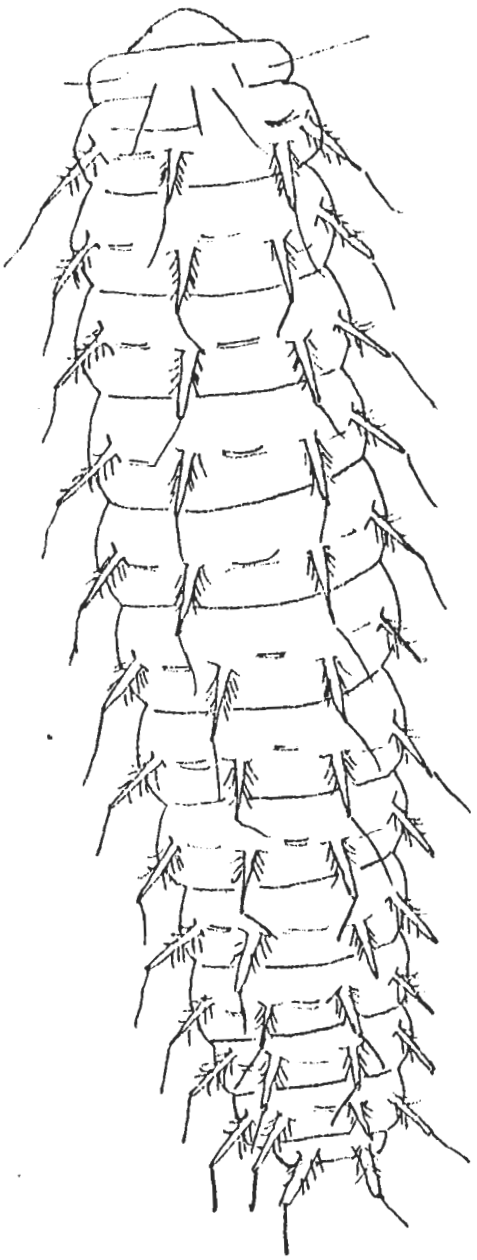

FIG.8. Fourth instar larva.

4.2.3 THE PUPA: (Figs. 9 and 10)..

Body length: 8.5 mm (range 8.15 - 9.9 mm). Body shiny,

light brown or cream ventrally, thoracic segments being relatively darker than abdominal segments dorsally. Metathorax with a pair of spiracles. Eyes, proboscis, antennae and other appendages visible through transparent cuticle and terminate mid-way between the 4th abdominal segment (Fig. 9). Abdomen visible as 5 segments ventrally but as 7 segments dorsally; each segment bears a pair of oval shaped spiracles except the last where the genital organ occurs (Figs. 9 and 10).

4.2.4 ADULTS (Fig 11A)

E. insulana: Small sized moth, wing span about 21.40 mm male; 22.72 mm for females. Males and females very similar generally except that in males the abdomen is narrower; females with a relatively fatter abdomen. Antennae serrated and more hairy in males but rather smooth in females. Forewings uniformly light green, each with a whitish margin which overlap mid-dorsally when the insect is at rest to form a Y-shaped whitish configuration mid dorsally. In addition, 3 posteriorly-located green marks at the edge of each forewing form an inverted V-shaped pattern when the

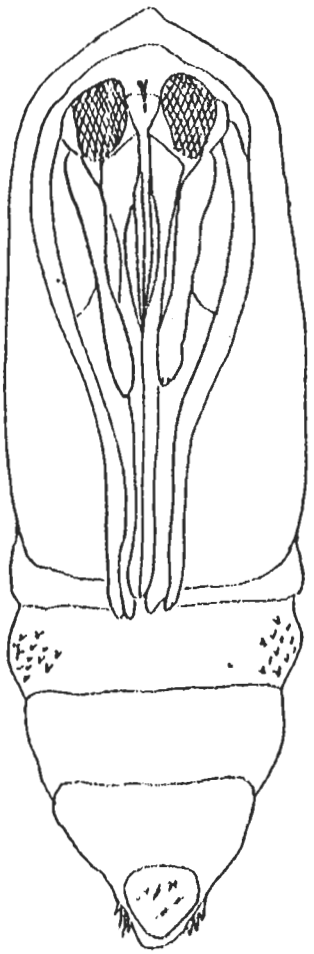

FIG.9. Ventral view of the pupa.

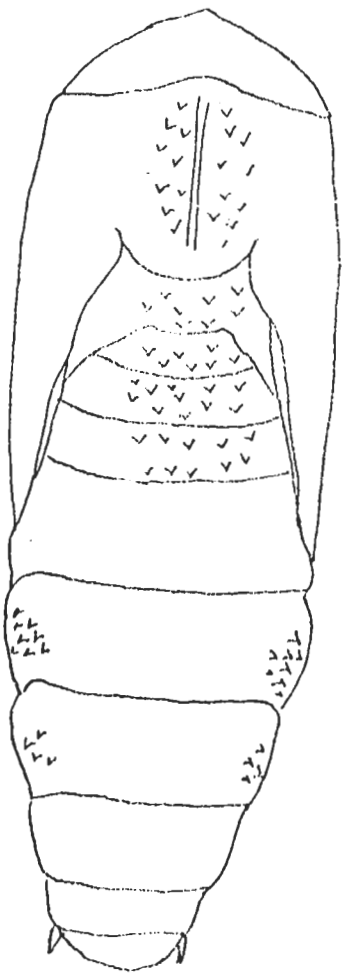

FIG. 10. Dorsal view of the pupa.

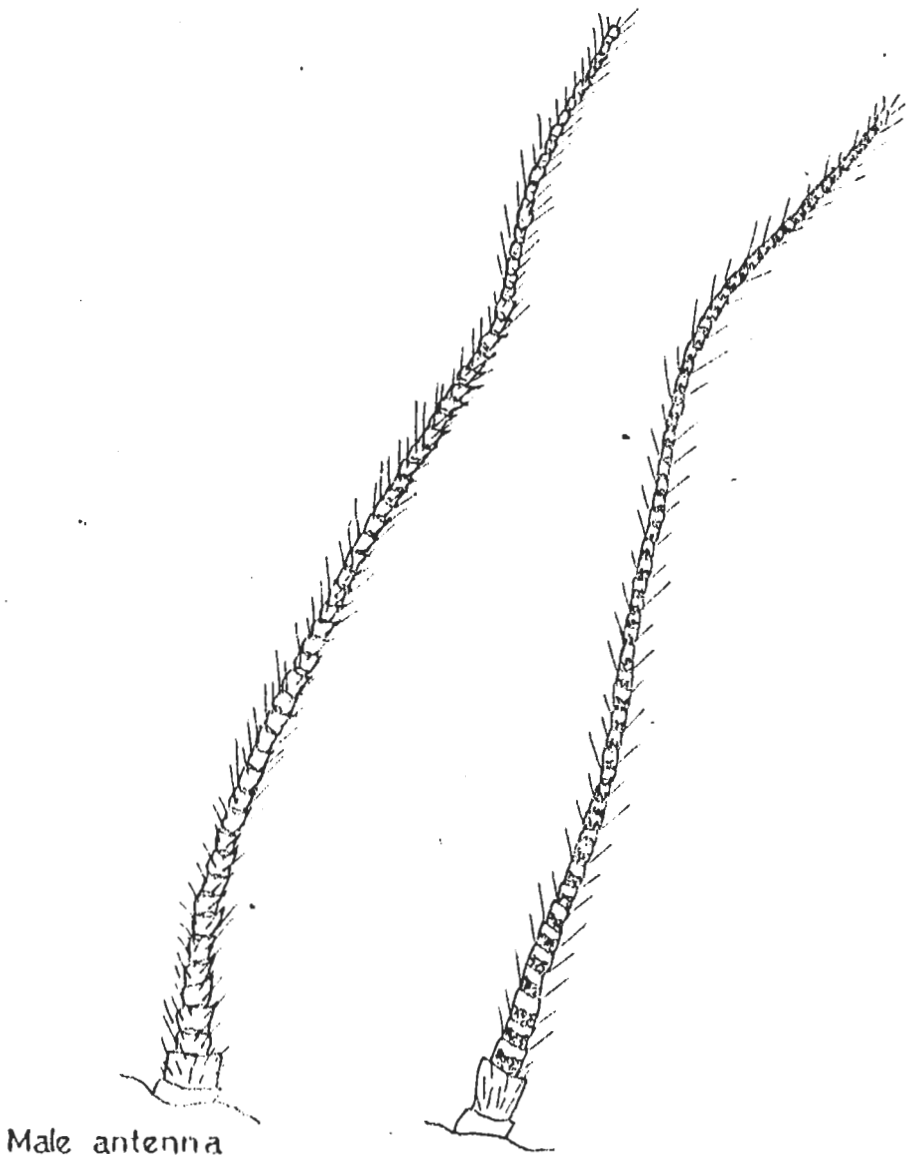

FIG.11. Diagram showing the morphological differences in the male and female antannae.

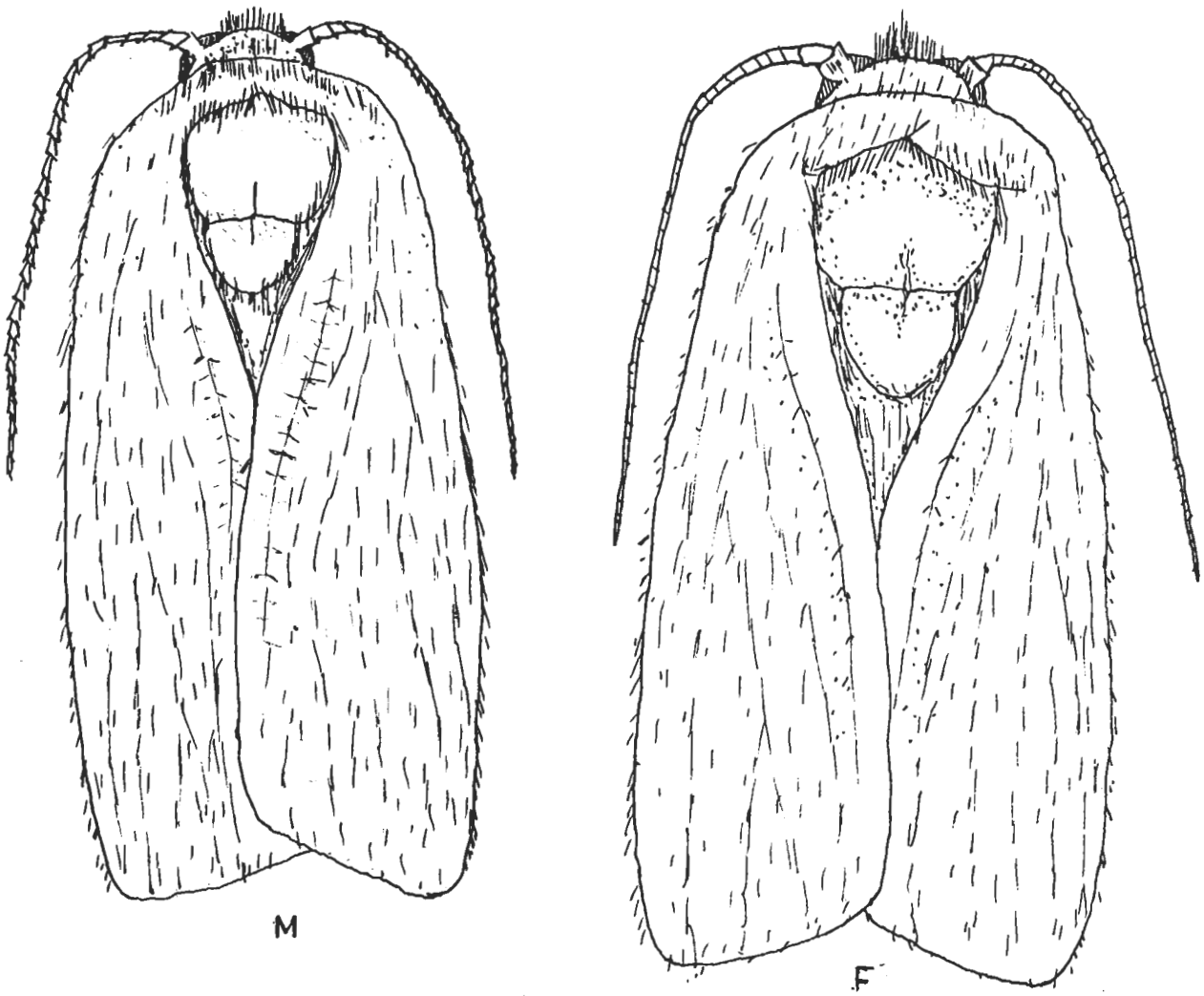

FIG. 11A. Adult male (M) and female (F) E. insulana

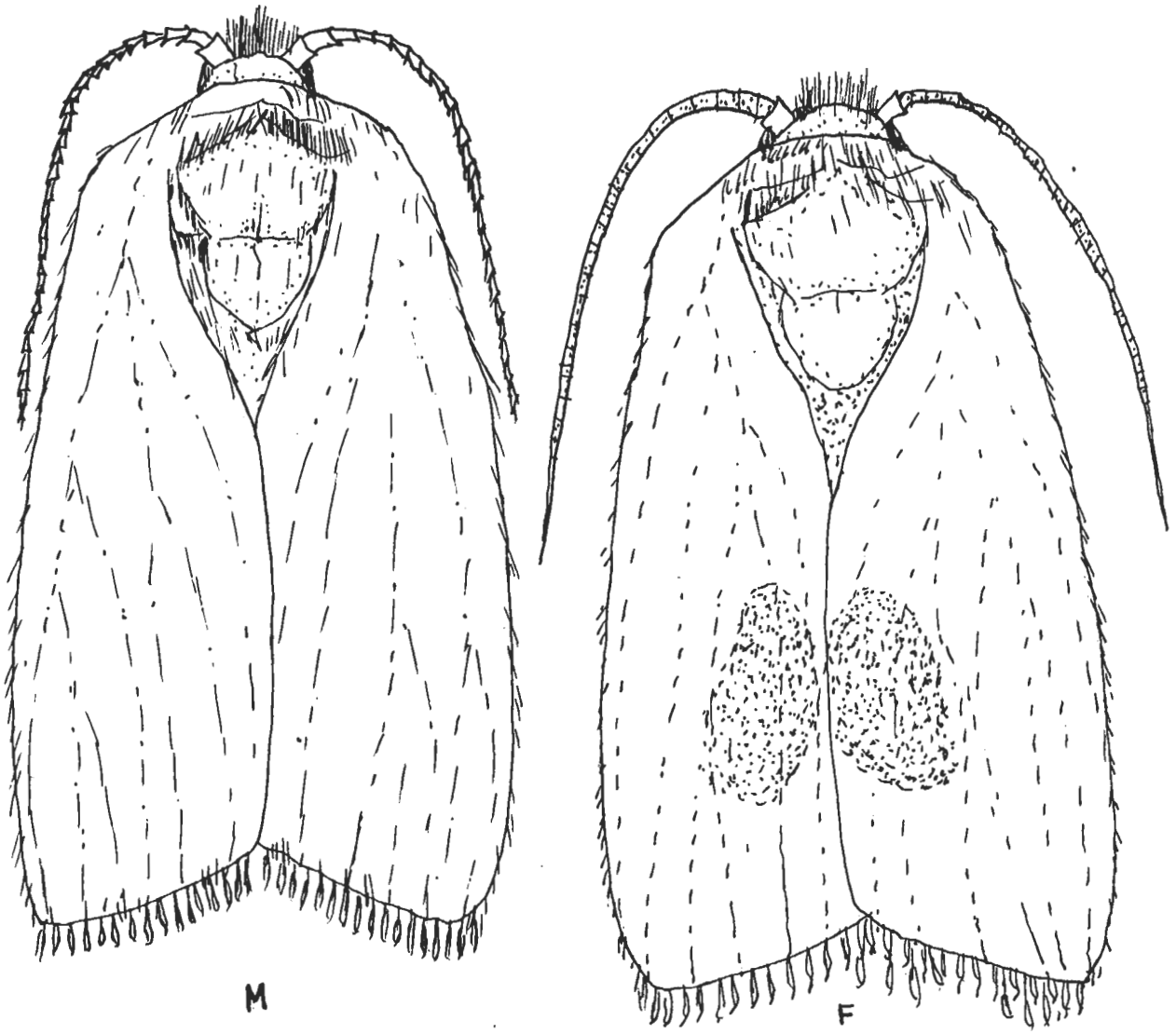

FIG. 11B. Adult male (M) and female (F) E. biplaga

insect is at rest with the wings overlapping. Hindwings creamy white like the rest of the body.

E. biplaga (Fig. 11B)

Small sized moth, wing span about 20.68 mm male; 22.08 mm for female forewings yellowish green or greenish yellow; hindwings creamy white as the rest of the body.

Sexes easily distinguished; male forewing with a darkened (brownish) margin at the tip; female forewing with a brown patch in the centre. The antennae in both sexes are similar to those of E. insulana and are as shown in Fig. 11.

4.3 FIELD OBSERVATIONS AND NATURE OF DAMAGE CAUSED BY E. insulana AND E. biplaga

The actual process of mating was not observed either in the field or in the laboratory but copulation apparently occurred at night when continuous observation was not very practicable. In the field, moth eggs were usually laid singly on fruit surfaces, and to a lesser extent on the sepals (bracts) of flowers and flower buds (Table 10). The eggs were glued to the tiny hairs of the fruit with secretions from the moth. The number of newly laid eggs found on any one fruit per day ranged between 1 and 10. Although not innately laid in clusters, eggs were at times found in groups of

2 or 3 on okro fruits. On hatching from eggs, first instar larvae of both moth species left the egg cases and tended to disperse. Thereafter they crawled about on the okro fruits and flowers and with time, gained entry into them. Although in the laboratory eggs were mostly found glued singly on the tissue paper lining the oviposition cages, some eggs were also laid in groups of 2 - 4 while some were laid in strings of about 6 - 12 eggs glued together.

Abscessing flowers dropped with their larval content while those that successfully entered the fruits proceeded to develop within. As many as 2 - 3 larvae mostly of the 1st, 2nd and 3rd instars, were at times found feeding within a single shrivelled flower.

Infested immature fruits (fruitlets) shrivelled up and either remained on the plant or aborted. Visual examination and dissection of field collected aborted fruits revealed that some percentage of the aborted fruits (Tables 12A, 12B and 12C) were actually damaged by the larvae as they still contained living individuals. Some of the dissected aborted fruits were found to contain more than one larvae each.

In the case of the fruits, boring action often resulted in production of mucilagenous exudates at the surfaces. On many occasions larvae, especially 1st instars got trapped and died in the

exudates.

Although okro fruits of almost all ages were normally attacked, the tender ones between 2 and 10 days old were the major victims. The larvae are internal feeders and usually bore into the fruit from the tip, the side or through the base of the fruit stalk (calyx) (Plates 1 and 2). In most cases, infested fruits had their entry holes plugged with excreta (frass). As the larvae grew and the contents of each carpel were consumed, they moved into adjacent carpels destroying the seeds as they fed (Plates 3 and 4). Although as many as 10 eggs were occasionally deposited per fruit, and one to six hatchlings could be found crawling on a fruit prior to boring, dissections showed that most infested fruits each contained only one larva. But no cannibalism was observed among the larvae in the laboratory.

When fully grown, the larvae crawled out of the fruit in order to pupate: they never pupated within the fruit. In the laboratory, pupation occurred both in the day and at night but mostly at night. Once out of the fruits, fully grown larvae crawled about in search of places to spin their silken cocoon. In the laboratory, they usually pupated on the nylon mesh covers to the rearing cages while in the field they pupated either on the shoots of okro or on nearby sticks and even on dry leaves on the ground.

The larvae spin silken layer at the base of the substratum, and by gradual side to side movement of the head, the first layer of the cocoon which is initially transparent revealing the larva is constructed. The cocoon hardens up with time and becomes non-transparent. The cocoon is shaped like an inverted boat (Plate 5) and the pupa is obtect (appendages adhered to rest of the body). However, the cocoon colour varied from white, dirty white;to brown but the differences in colour could not be used to distinguish the species nor the sexes (Table 5). Adult emergence occurred mostly at night.

From the field records, it was found that most of the larvae collected during the dry months of the year (September - February) gave rise to E. insulana adults while most of the larvae collected during the rainy months of the year (March - July) when ambient temperatures were generally low and humidities high gave rise to E. biplaga adults. Thus data on E. biplaga life cycle was collected mainly during the rainy months when they were more abundant while those of E. insulana were collected during the dry season months when they were more common.

The adult moths are nocturnal in nature and were found only on very few occasions in the field during the study period. On emergence in the laboratory, adult moths rested for a while before

flying about within the cages. Adult moths did not feed immediately after emergence. Feeding started about the 2nd day after emergence and occurred mostly in the morning and evening hours. There was not much colour variation in the body colour of adults on emergence. The adults of E. insulana had greenish forewings. On the other hand, males of E. biplaga had greenish-yellow forewings, while the females had greenish-yellow forewings with a brown patch at the centre of each forewing (a sexual dimorphic character).

This study was characterised by scarcity of specimens of both moth species. Consequently, based on 30 females of each species, observed fecundity was comparatively low (Table 7) and this in turn accounted for low production of and availability, of eggs for the experiments.

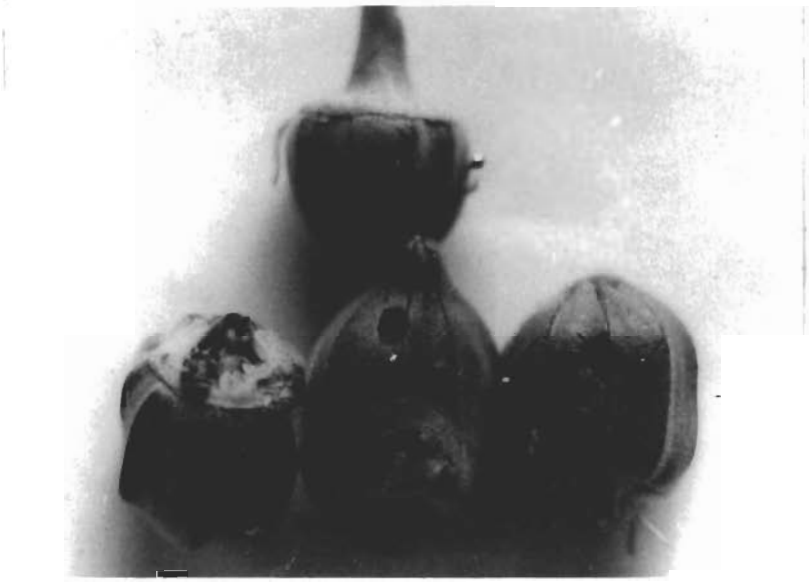

Plate 1

Plate 2

Plates 1 and 2: Showing infested fruits damaged by larvae of E. insulana and E. biplaga.

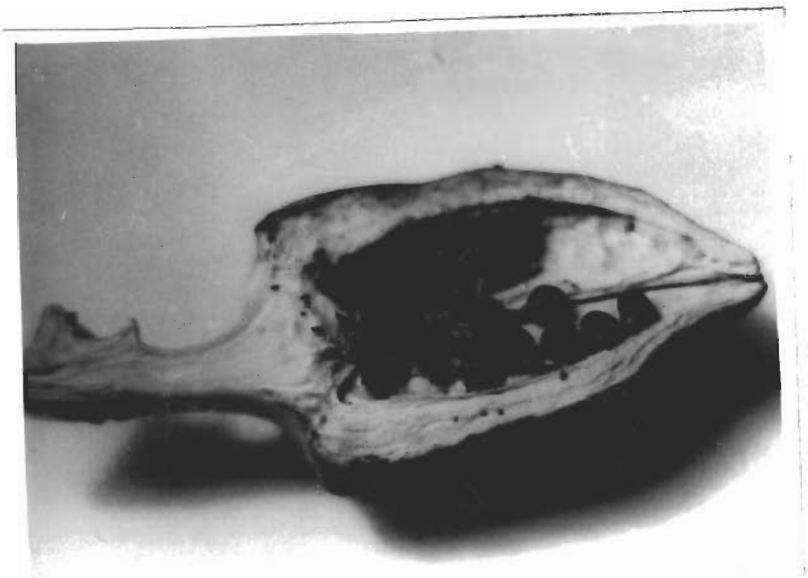

Plate 3

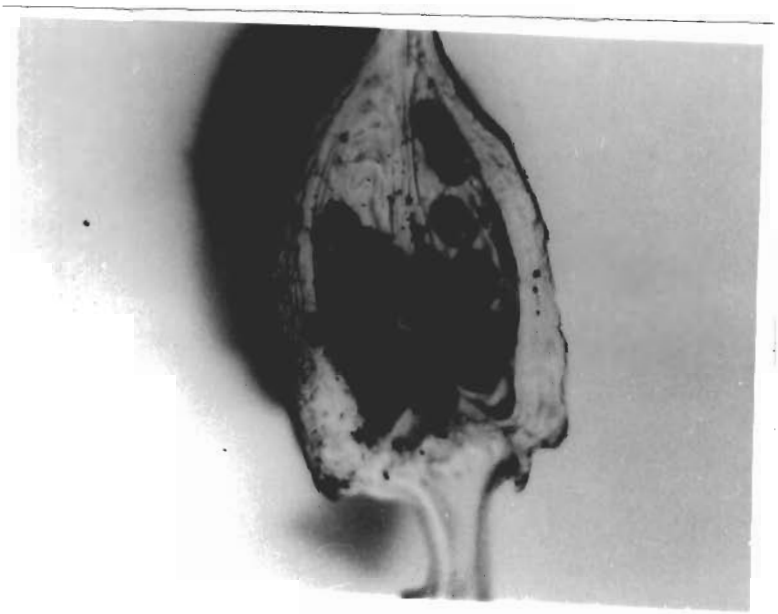

Plate 4

Plates 3 and 4 showing the nature of damage of okro seeds by the larvae of E. insulana and E. biplaga.

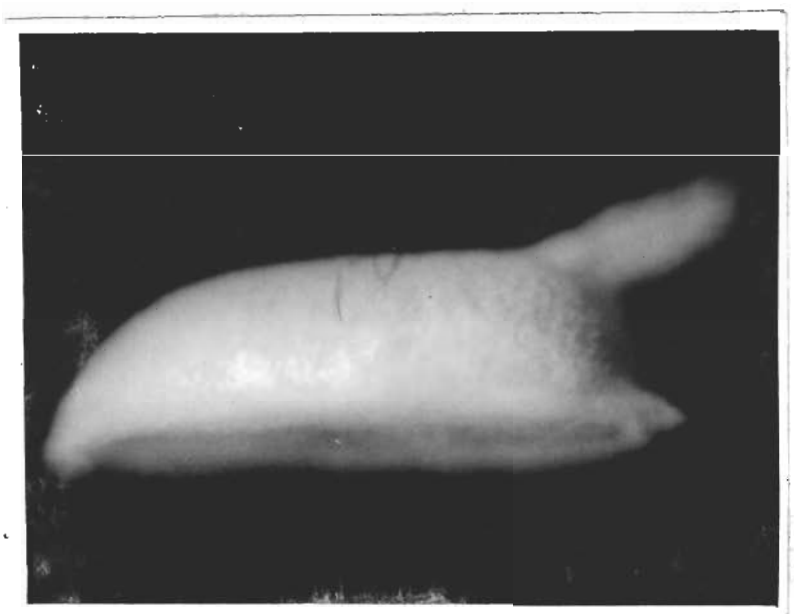

Plate 5: Side view of cocoon illustrating the shape of the cocoon (inverted boat-shape).

4.4 ASSESSMENT OF DAMAGE

4.4.1 DAMAGE AND LARVAL NUMBERS ON FRUITS FROM THE 3 PLANTING PERIODS

For okro sown in the 1st planting period (September 1984), normal fruiting period covered about 7 weeks all in the dry season of the year. In these, moth larval attack became visible first week of December. Of 251 fruit samples plucked and dissected for larvae, 53.79% were infested (Table 9A). Larval populations built up fast within the 1st three weeks, reached a peak about the 5th week and tailed off again in the 6th and 7th weeks.

For okro sown in January 1985, fruiting period lingered for about 8 weeks into the early rains. Moth attack became obvious in 2nd week of March with 26.8% only of the 545 fruits sampled infested (Table 9B). The larval population build up and damage on fruits were low in the 1st, 2nd and 4th weeks. However the build up and damage reached a peak in the 5th and 6th weeks and decreased again in the last two weeks.

For the 3rd planting in March 1985, fruiting and pest attack started last week of May and lasted for 8 weeks, all in the rainy season. The larval build up and damage on fruits was generally low with the peak incidence and greatest damage occurring about the 7th and 3rd weeks of harvest respectively (Table 9c). Only about 7.55% of 635 fruits harvested were infested. The greatest

damage on fruits (65.9%) occurred in the month of January during the 1st planting period (dry season) (Table 13B) while the lowest damage (0%) occurred in May during the 3rd planting period (rainy season). The relationship between monthly temperature, rainfall, humidity and egg and larval build up on fruits, aborted fruits, shrivelled flowers, as well as the percent damage on fruits and aborted fruits are shown in (Tables 13A, 13B & 14) and are graphically represented on figs. 12A, 12B, 12C, 13A, 13B, 13C and 14.

From the graphs, larval build up and damage on fruits decreased with increase in temperature and rainfall. Thus a negative but highly significant correlation ($r = -0.73$ and $r = -0.87$), ($P = .05$) was obtained from the correlation of larval build up, and percent damage on fruits with rainfall respectively while humidity and temperature did not statistically affect the larval build up and damage on fruits.

Fig. 14 shows the relationship between egg build up in the field, larval build up on fruits, flowers, aborted fruits and percent damage on fruits. The monthly larval build up in the field increased with increase in egg deposition. Consequently, the months with heavy deposition of eggs in the field corresponded with those with high larval populations which resulted in high percentage damage on harvested fruits.

4.4.2 DAMAGE ON ABORTED FRUITS

Although abortion of okro fruitlets could be caused by certain physiological and weather conditions, some of the cases recorded during this study, were certainly brought about by boring and feeding action of larvae of Earias species on immature fruits (fruitlets).

During the 1st planting period, 22 (19.13%) out of 115 aborted fruits collected were infested by the moth larvae. Aborted fruitlets collected in the 1st 2 weeks of harvest were not damaged by the larvae. Damage on aborted fruits became evident from about the 3rd week of harvest and continued throughout the harvest period with the greatest damage occurring about the 6th week of harvest (Table 12A).

Of the 155 aborted fruits collected during the 2nd planting period, only 29(18.71%) were infested by larvae. The aborted fruits collected in the 1st two weeks from fruiting were also free from larval attack while the percentage infestation was highest in the 5th week collections (Table 12B).

For the 3rd planting period, 44 (15.49%) of 284 aborted fruits so collected were infested by moth larvae. Again collections from 1st week fruiting were pest free while the largest number of infested fruitlets were recorded about the 3rd week of fruiting period (Table 12C). On the whole, more fruitlets aborted through

larval attack during the 1st planting period (September - January) when fruiting fell within the dry season than during the 2nd and 3rd plantings (March - July) when fruiting period coincided with the rainy season. Indeed for this series, heaviest larval damage was recorded in the month of January (25%) while the least damage (0%) occurred in May.

TABLE 9A

ESTIMATION OF WEEKLY DAMAGE AND LARVAE FOUND ON FRUITS FROM THE 1ST PLANTING PERIOD (19TH SEPTEMBER 1984 - 19TH JANUARY 1985

Week of Harvest (Week after Plantings)	Total No. of Fruits Harvested	Weekly Mean No. of Fruits Harvested	Total No. of Larvae collected	Weekly Mean No. of Larvae Collected	Total No. of Fruits damaged Infested	Weekly Mean No. of Fruits Damaged/Infested	Weekly Mean % Damage	Total % Damage
1st Dec.'84 (12 Wks)	15	5.0	-	-	-	-	0	$\frac{45 \times 100}{83.65}$
2nd (13 Wks)	30	10.0	6	2	3	1	10.0	= 53.79%
3rd (14 Wks)	50	16.66	39	13	24	8	48.19	
4th (15 Wks)	33	11.0	30	10	27	9	81.81	
5th Jan'85 (16 Wks)	79	26.33	96	32	63	21	79.76	
6th (17 Wks)	20	6.66	16	5.33	9	3	45.05	
7th (18 Wks)	24	8.0	24	8.0	9	3	37.53	
Totals	251	83.65	211	70.33	135	45		

TABLE 9A

ESTIMATION OF WEEKLY DAMAGE AND LARVAE FOUND ON FRUITS FROM THE 1ST PLANTING PERIOD (19TH SEPTEMBER 1984 - 19TH JANUARY 1985

Week of Harvest (Week after Plantings)	Total No. of Fruits Harvested	Weekly Mean No. of Fruits Harvested	Total No. of Larvae collected	Weekly Mean No. of Larvae Collected	Total No. of Fruits damaged Infested	Weekly Mean No. of Fruits Damaged/Infested	Weekly Mean % Damage	Total % Damage
1st Dec.'84 (12 Wks)	15	5.0	-	-	-	-	0	$\frac{45 \times 100}{83.65}$
2nd (13 Wks)	30	10.0	6	2	3	1	10.0	= 53.79%
3rd (14 Wks)	50	16.66	39	13	24	8	48.19	
4th (15 Wks)	33	11.0	30	10	27	9	81.81	
5th Jan'85 (16 Wks)	79	26.33	96	32	63	21	79.76	
6th (17 Wks)	20	6.66	16	5.33	9	3	45.05	
7th (18 Wks)	24	8.0	24	8.0	9	3	37.53	
Totals	251	83.65	211	70.33	135	45		

TABLE 9B

ESTIMATION OF WEEKLY DAMAGE AND LARVAE FOUND ON FRUITS FROM THE 2ND PLANTING PERIOD (14TH JAN 1985 - 4TH MAY 1985)

Week of Harvest (Weeks after Planting)	Total No. of fruits harvested	Weekly mean No. of fruits harvested	Total No. of larvae collected	Weekly mean No. of larvae collected	Total No. of fruits damaged/ infested	Weekly mean No. of fruits damaged/ infested	Weekly mean % damage	Total % damage
1st March'85 (9 Wks)	40	13.33	4	1.3	3	1.0	7.52	$\frac{49 \times 100}{181.165}$
2nd (10 Wks)	64	21.33	6	2	6	2.0	9.38	= 26.89%
3rd (11 Wks)	90	30.0	36	12	3	1.0	3.33	
4th (April'85 (12 Wks)	58	19.33	3	1.0	6	2.0	10.35	
5th (13 Weeks)	73	24.33	57	19.33	30	10.0	41.10	
6th (14 Wks)	114	38.0	51	17.0	60	20.0	52.63	
7th (15 Wks)	76	25.33	33	11.0	33	11.0	43.43	
8th (16 May'85 Wks)	30	10.0	21	7.0	6	2.0	20	
Totals	545	181.165	211	70.63	147.0	49.0		

TABLE 9C

ESTIMATION OF WEEKLY DAMAGE AND LARVAE FOUND ON FRUITS FROM THE 3RD PLANTING PERIOD (28TH MARCH 1985 - 25TH JULY 1985)

Week of Harvest (Weeks after planting)	Total No. of fruits harvested	Weekly mean No. of fruits harvested	Total No. of larvae collected	Weekly mean No. of larvae collected	Total No. of fruits damaged/ infested	Weekly mean No. of fruits damaged/ infested	Weekly mean % damage	Total % damage
1st May '85 (9 Wks)	71	23.6	3.0	1.0	-	-	0	$\frac{15.98 \times 100}{211.59}$
2nd June '85 (10 Wks)	55	18.33	5.0	1.66	5	1.66	9.09	= 7.55%
3rd (11 Wks)	141	47.0	10	3.33	15	5.0	10.63	
4th (12 Wks)	176	58.66	7	2.33	13	4.33	7.38	
5th (13 Wks)	45	15.0	3	1.0	3	1.0	6.66	
6th (14 Wks) July'85	72	24.0	10	3.33	5	1.66	6.94	
7th (15 Wks)	57	19.0	18	6.0	7	2.33	12.24	
8th (16 Wks)	18	6.0	7	2.33	-	-	0	
Totals	635	211.59	63	20.98	48	15.98		

TABLE 10

RELATIVE ABUNDANCE OF EGGS ON PLANT PARTS

PLANT PARTS

Month	Pedicel	Stem	Leaves	Flower Bud/ Flower Bracts	Fruits
Dec.	-	-	-	22	46
Jan.	-	-	-	30	25
March	-	-	-	0	-
April	-	-	-	6	58
May	-	-	-	0	-
June	-	-	-	0	-
July	-	-	-	0	80
Totals	-	-	-	58	209

Total number of eggs collected from the field = 267

$$\% \text{ found on fruits} = \frac{209 \times 100}{267}$$

$$= 78.27\%$$

$$\% \text{ found on flower bud/flower bract} = \frac{58 \times 100}{267}$$

$$= 21.72\%$$

TABLE 11A

LARVAL CONTENT OF SHRIVELLED/FALLEN FLOWERS: 1ST PLANTING (19TH SEPTEMBER 1984 - 19TH JANUARY 1985)

Week of Collection (Weeks after Planting)	No. of Shrivelled Flowers Collected	No. of Larvae Collected
1st (2nd-8th Dec'84) (12 Wks)	10	-
2nd (13 Wks)	18	-
3rd (14 Wks)	26	11
4th (15 Wks)	15	2
5th Jan' 85 (16 Wks)	35	4
6th (17 Wks)	17	6
7th (18 Wks)	27	17
Totals	148	40

TABLE 11B

LARVAL CONTENT OF SHRIVELLED/FALLEN FLOWERS: 2ND PLANTING
(14TH JANUARY 1985 - 4TH MAY 1985)

Week of Collection (Weeks after Planting)	No. of Shrivelled Flowers Collected	No. of Larvae Collected
1st (10th-15th March'85) (9 Wks)	24	-
2nd (10 Wks)	37	-
3rd (11 Wks)	49	4
4th April '85 (12 Wks)	25	2
5th (13 Wks)	86	7
6th (14 Wks)	100	16
7th (15 Wks)	48	10
8th May '85 (16 Wks)	16	4
Totals	385	43

TABLE 11C

LARVAL CONTENT OF SHRIVELLED/FALLEN FLOWERS: 3RD PLANTING (28TH MARCH 1985 - 25TH JULY 1985)

Week of Collection (Weeks after planting)	No. of Shrivelled Flowers Collected	No. of Larvae Collected
1st (28th-31st May'85) (9Wks)	58	5
2nd June '85 (10 Wks)	57	7
3rd (11 Wks)	114	6
4th (12 Wks)	37	4
5th (13 Wks)	104	7
6th July '85 (14 Wks)	35	2
7th (15 Wks)	37	0
Totals	442	31

TABLE 12A

LARVAL CONTENT OF ABORTED FRUITS: 1ST PLANTING (19TH SEPT. 1984 - 19TH JANUARY 1985)

Week of Collection (Weeks after planting)	No. of Aborted fruits collected	No. infested/ damaged	No. of Aborted fruits containing larvae	Total No. of Larvae collected	% Damage
1st (2nd - 8th Dec. " 1984) (12 Wks)	12	-	-	-	0
2nd (13 Wks)	7	-	-	-	0
3rd (14 Wks)	26	6	6	6	23.07
4th (15 Wks)	10	1	1	1	10
5th (16 Wks)	21	2	1	2	9.52
6th (17 Wks)	33	12	11	14	36.36
7th (18 Wks)	6	1	-	-	16.66
TOTALS	115	22	19	23	

$$\% \text{ damage} = \frac{22 \times 100}{115} = 19.13\%$$

TABLE 12B

LARVAL CONTENT OF ABORTED FRUITS: 2ND PLANTING (14TH JANUARY 1985 - 4TH MAY 1985)

Week of Collection (Weeks after planting)	No. of aborted fruits collected	No. infested/ damaged	No. of aborted fruits containing larvae	Total No. of larvae collected	% Damage
1st (10th - 16th March, 1985) (9 Wks)	8	-	-	-	0
2nd (10 Wks)	3	-	-	-	0
3rd (11 Wks)	12	3	-	5	25
4th (12 Wks)	18	2	-	2	11.11
5th (13 Wks)	23	7	8	8	30.43
6th (14 Wks)	55	9	6	7	16.36
7th (15 Wks)	26	6	7	4	23.07
8th (16 Wks) May' 85	10	2	2	2	20
Totals	155	29	23	28	

$$\% \text{ damage} = \frac{29 \times 100}{155} = 18.71\%$$

TABLE 12C

LARVAL CONTENT OF ABORTED FRUITS: 3RD PLANTING (28TH MARCH 1985 - 25TH JULY 1985)

Week of Collection (Weeks after planting)	No. of aborted fruits collected	No. infested/ damaged	No. of aborted fruits containing larvae	Total No. of larvae collected	% Damaged
1st (28th - 31st May'85) (9 Wks)	34	-	1	1	0
2nd June '85 (10 Wks)	37	8	-	3	21.62
3rd (11 Wks)	70	17	7	9	24.28
4th (12 Wks)	33	6	5	7	18.18
5th (13 Wks)	68	10	6	9	11.70
6th July'85 (14 Wks)	27	3	1	2	11.11
7th (15 Wks)	15	-	-	-	0
TOTALS	284	44	20	31	

$$\% \text{ damage} = \frac{44 \times 100}{284} = 15.49\%$$

TABLE 13A

MONTHLY ESTIMATION OF LARVAL INCIDENCE OF *E. insulana* AND *E. biplaga* IN THE FIELD IN RELATION TO MONTHLY RAINFALL, TEMPERATURE AND HUMIDITY

	MONTHS						
	Dec.	Jan.	March	April	May	June	July
Rainfall (mm)	0	6.9	153.9	61.3	264.5	109.2	167.7
Temperature (^{o}C)	22.75	24.45	25.4	24.15	23.45	25.5	23.2
Humidity (%)	41.5	58.5	59.5	68.5	73	78	86.76
No. of Fruits Harvested	128	123	194	351	71	417	147
Monthly mean No. of Fruits Harvested	42.7	41.0	64.7	117.0	23.0	139.0	49
Total No. of larvae Collected on fruits	75	136	46	165	3	25	35
Monthly mean No. of larvae collected on fruits	25.0	45.33	15.33	55.0	1.0	8.33	11.66
No. of Flowers collected	69	79	110	275	58	312	72
No. of larvae collected on flowers	13	27	4	39	5	26	2
Monthly mean No. of larvae from flowers	4.33	9	1.33	13	1.66	8.66	0.66
No. of aborted fruits collected	55	60	23	132	34	208	42
No. of larvae collected from aborted fruits	7	16	5	23	1	18	1
Monthly mean No. of larvae collected from aborted fruits	2.33	5.33	1.66	7.66	0.33	6.0	0.33
Monthly total of larvae collected	95	179	55	227	9	69	38

Data on rainfall, temperature and humidity were collected from the Meterological Station of University of Nigeria, Nsukka.

TABLE 13B

MONTHLY ESTIMATION OF DAMAGE ON FRUITS AND ABORTED FRUITS BY *E. insulana* AND *E. biplaga* IN RELATION TO MONTHLY RAINFALL, TEMPERATURE AND HUMIDITY

	MONTHS						
	Dec.	Jan.	March	April	May	June	July
Rainfall (mm)	0	6.9	153.9	61.3	264.5	109.2	169.7
Temperature (^{o}C)	22.75	24.45	25.4	24.15	23.45	25.5	23.2
Humidity (%)	41.5	58.5	59.5	68.5	73	78	86.76
No. of fruits harvested	128	123	194	351	71	417	147
Monthly mean No. of fruits harvested	42.7	41.0	64.7	117.0	23.0	139.0	49
No. of fruits infested/ damaged	54	81	12	135	0	36	12
Monthly % of fruits infested	42.18	65.9	6.18	38.5	0	8.63	8.16
No. of aborted fruits collected	55	60	23	132	34	208	42
No. of aborted fruits damaged	7	15	3	26	0	38	3
No. of aborted fruits containing larvae	7	12	0	23	1	16	1
% of aborted fruits damaged	12.72	25.0	13.04	19.69	0	18.26	7.14
% of abortion caused by larval attack	12.72	20.0	0	17.42	2.94	7.6	2.38

Total No. of fruits collected = 1,431

No. of fruits damaged = 330

Total of damage = $\frac{330}{1,431} \times \frac{100}{1}$ = 23.06%

TABLE 14

RELATIONSHIP OF MONTHLY TEMPERATURE, RAINFALL, HUMIDITY WITH EGG BUILD UP ON FRUITS, % DAMAGE AND LARVAL BUILD UP ON FRUITS, ABORTED FRUITS AND SHRIVELLED FLOWERS

Month	Rainfall (mm)	Temperature °C	Humidity	Egg build up on fruits	Larval build up on fruits	% damage on fruits	Larval build up on aborted fruits	% damage on aborted fruits	Larval build up on shrivelled flowers
Dec.	0	22.75	41.5	68	25	42.15	7	12.72	13
Jan.	6.9	24.45	58.5	55	45	65.9	16	25	27
March	153.9	25.4	59.5	0	15.33	6.18	5	13.04	4
April	61.3	24.5	68.5	64	55	38.5	23	19.69	39
May	264.5	23.45	73	0	1	0	1	0	5
June	109.2	25.5	78	0	8.33	8.63	18	18.26	26
July	167.7	23.2	86.76	80	11.66	8.16	1	7.14	2

Data on rainfall, temperature, humidity were collected from the meterological station of University of Nigeria, Nsukka.

Fig. 12A: Relationship between rainfall (_____) and larval numbers (----------) of E. insulana and E. biplaga on okro fruits.

Fig. 12B: Relationship between temperature (_____) and larval numbers (----------) of E. insulana and E. biplaga on okro fruits.

Fig. 12C: Relationship between humidity (_____) and larval numbers (----------) of E. insulana and E. biplaga on okro fruits.

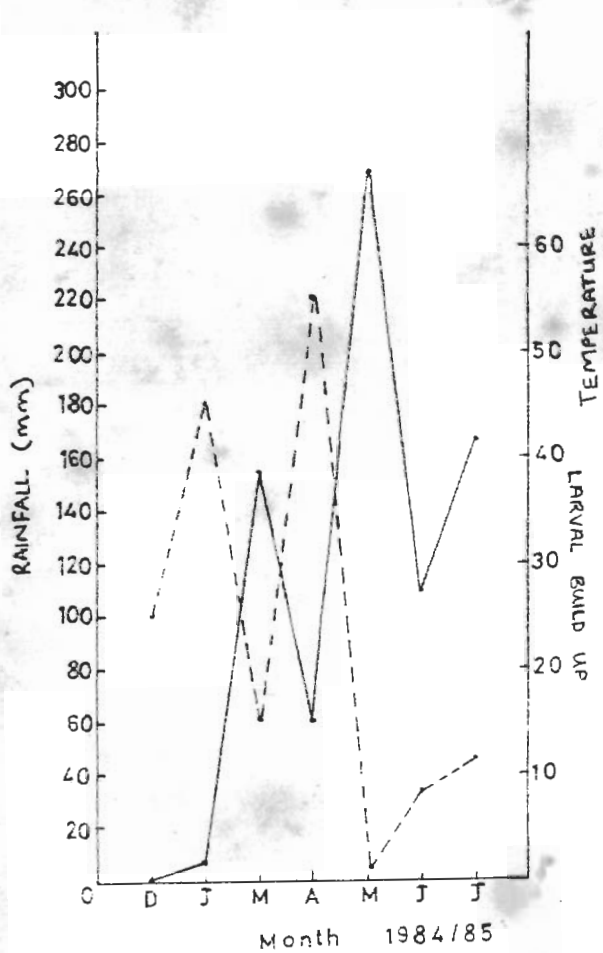

Fig. 12A

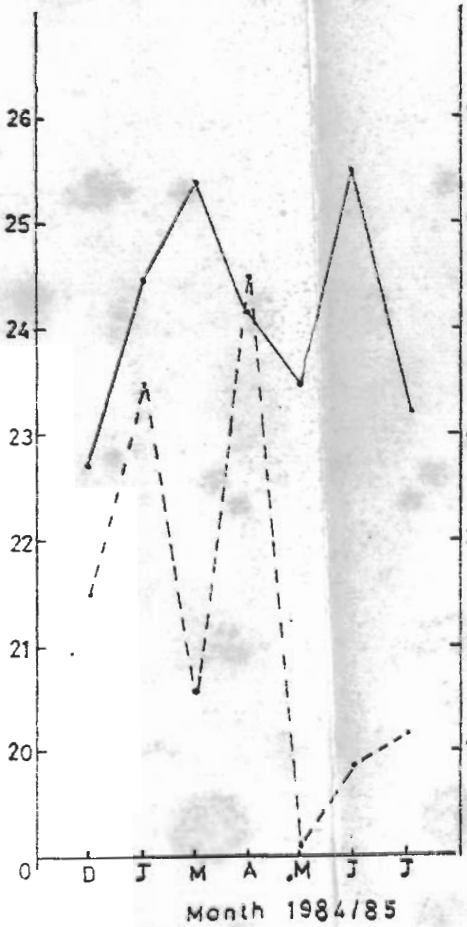

Fig. 12B

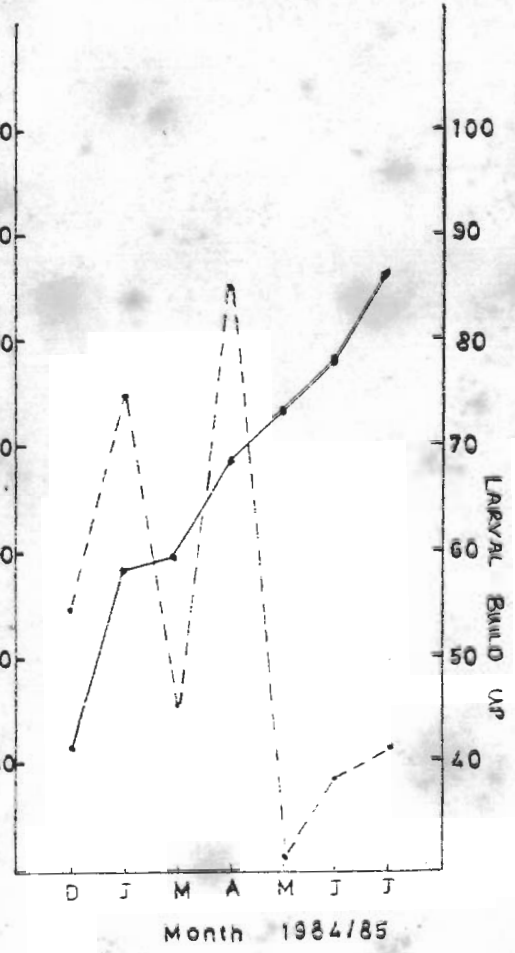

Fig. 12C

Fig.13A: Relationship between rainfall (_____) and % damage (----------) of E. insulana and E. biplaga on okro fruits.

Fig.13B: Relationship between temperature (_____) and % damage (----------) of E. insulana and E. biplaga on okro fruits.

Fig.13C: Relationship between humidity (_____) and % damage (----------) of E. insulana and E. biplaga on okro fruits.

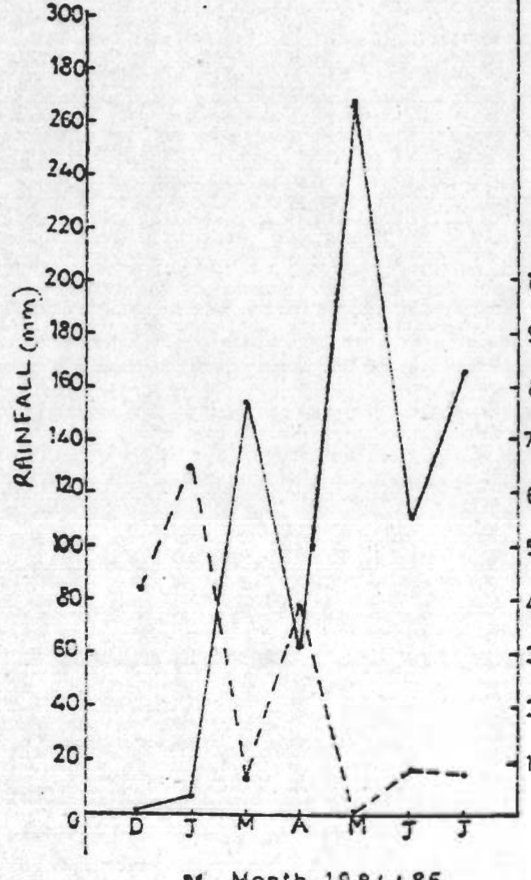

FIG. 13A

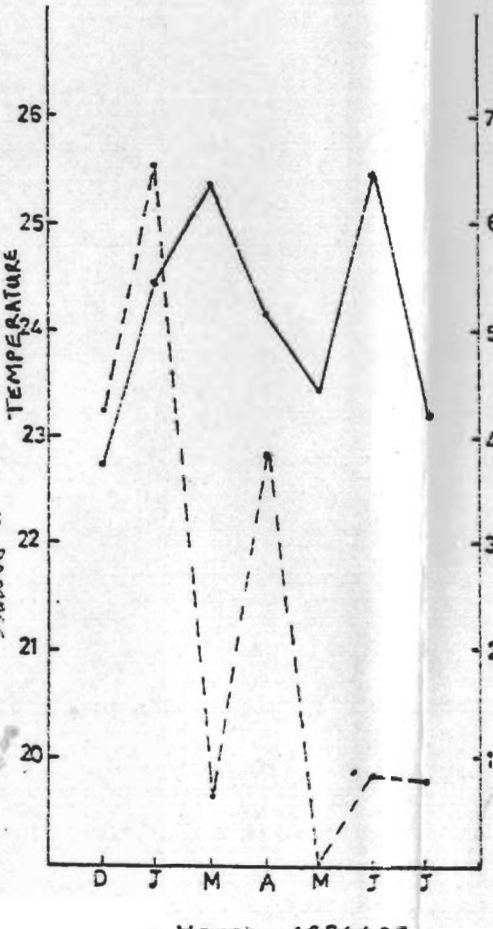

FIG. 13B

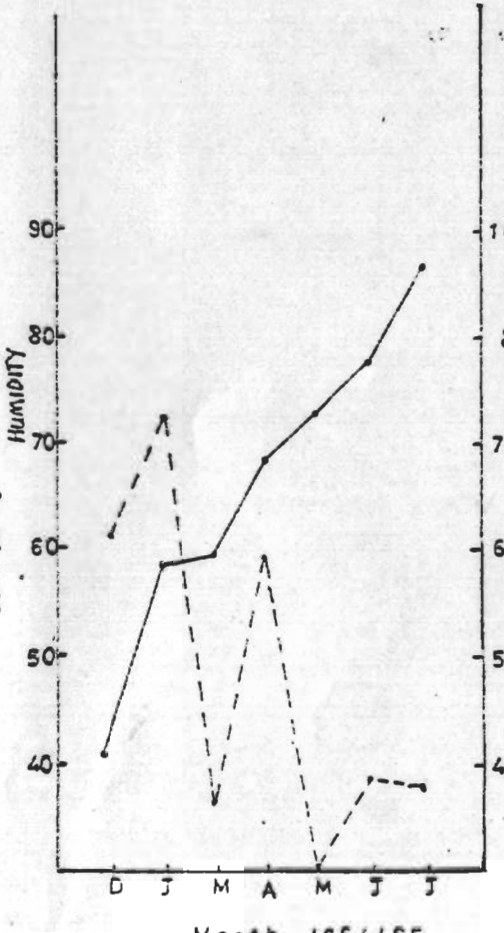

FIG. 13C

Fig. 14: Comparison of the number of eggs (o-o-o-o-o-o-o) and larvae of E. insulana and E. biplaga found on fruits (o----o----o), flowers (----------), and aborted fruits (*------*------*), with damage on fruits (_____).

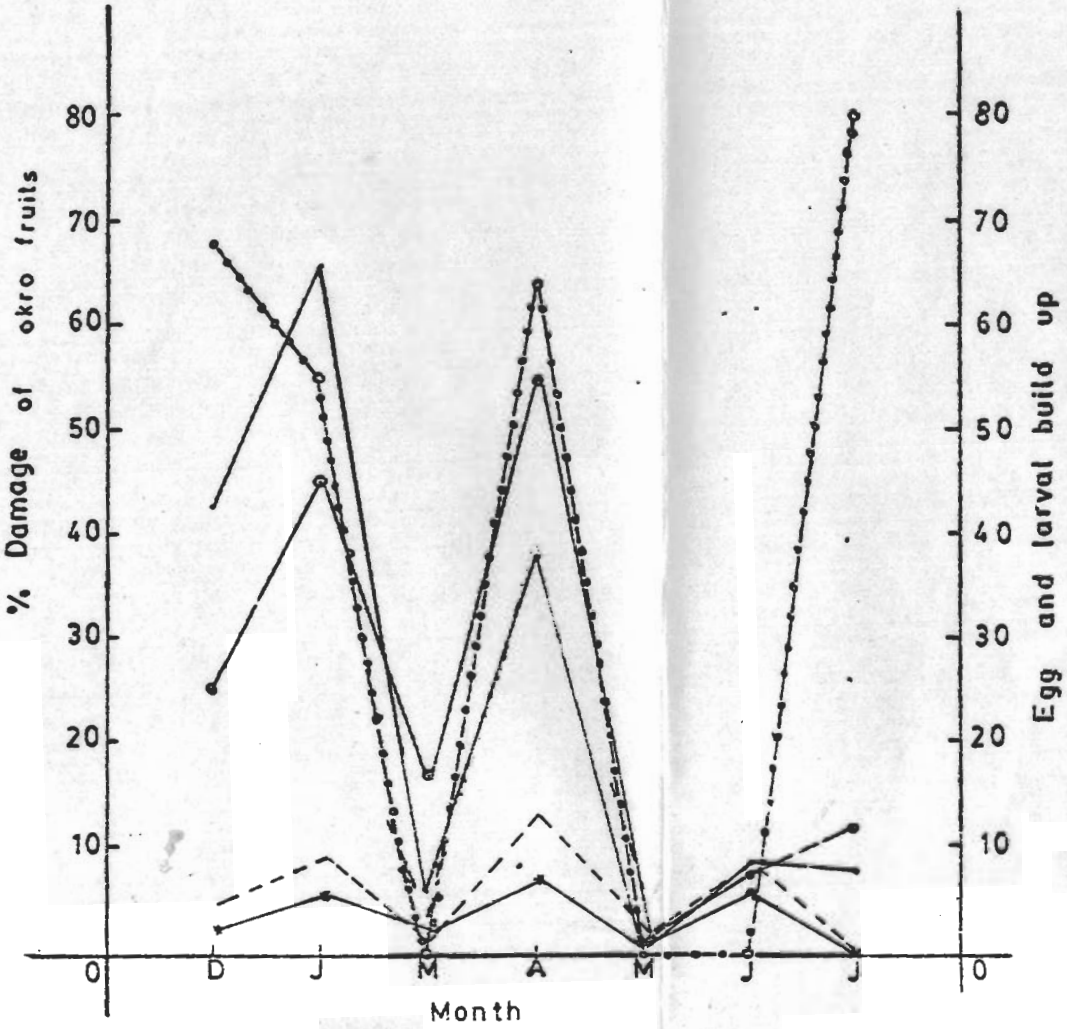
% Damage of okro fruits
Egg and larval build up
80
70
60
50
40
30
20
10
0
D
J
M
A
M
J
J
Month

Fig. 14

CHAPTER FIVE

DISCUSSION

DEVELOPMENT (Life Cycle)

In the present study at temperatures of 28°C - 31°C and humidity 65% - 80% and using okro as host plant, developmental period of E. insulana from egg stage to adult emergence took 21.75 ± 1.37 days and that of E. biplaga 26.18 ± 2.09 days. Resulting progeny laid viable eggs suggesting that indeed okro is a suitable alternative host plant. The results are somewhat similar to those obtained for Earias species at temperatures ranging from 19°C - 29°C and humidity 56.5% - 57% when larvae were fed on cotton fruits. Megahed et al (1972) recorded 10 overlapping generations in the laboratory with a minimum mean duration of 23.6 ± 0.6 days at 28°C and 56.5% RH, and a maximum mean duration of 82.5 ± 1.4 days (at 19°C and 57% RH) while Haidari, (1967) recorded 6 - 8 generations with each generation lasting about 23 days at 25°C - 29°C.

The egg, larval, pupal and life cycle durations of E. biplaga were longer than those of E. insulana and the differences were statistically significant ($P = .05$). This is however possible since the duration of immature stages are inversely related to temperature and are longest during the rainy season and shortest during the

dry season (Entwistle, 1969). Thus the relatively lower temperature during the rainy season when E. biplaga was more abundant might have lowered the rate of development and slightly prolonged the duration of life cycle while E. insulana that occurred mostly during the dry season had a relatively faster rate of development and thus a shorter life cycle duration.

5.1.2 ADULT LONGEVITY

Although from this study adults of E. insulana lived longer (7.9 $\pm$ 1.95 days) than those of E. biplaga (7.3 $\pm$ 2.02 days), the differences in life spans was not statistically significant. However on average, female moths (E. insulana 6.5 days; and E. biplaga 6.2 days) lived longer than males (E. insulana 5.7 days; E. biplaga 6 days).

In literature, adult females of Earias species have similarly been reported to live longer than males. Females lived for 4 - 10 days at 30°C and 70% RH, 2 - 7 days at 5°C and 50% RH (Assem et al, 1974); 10 days or more at 28 - 29°C and 39 days at 14.2°C (Yathom, 1958); 14 $\pm$ 0.9 days at 31.9°C and 51.2% RH and 41.8 $\pm$ 4.3 days at 19°C and 59% RH (Megahed et al, 1972). Male adult longevity was 8, 4.5, 2.5, and 2 days at 25°C, 30°C, 35°C and 40°C respectively (Grewal et al, 1969); 10 days (Yathom, 1958); 17 - 28 days (Entwistle, 1969); 2 - 8 days at 30°C and 70% RH and 1 - 5 days at 15°C and

50% RH and 16 - 35.65 ± 3.6 days (Megahed et al, 1972).

Although the difference in longevity of my male and female moths was statistically significant (P = .05), there appeared to be no relationship between female longevity and number of eggs produced since the correlation analysis of female longevity and number of eggs laid gave a non-significant value. The relatively longer longevity of females over males could have been due to the unknown physiological state of the tested females (Kehat and Gordon, 1975) since according to them the contradictory findings on male and female longevity of the noctuid S. littoralis is due to the above reason. In the said species, longevity of males become greater when mated females and males are compared and that of females become greater when unmated females and males are compared. No difference in longevity is detected when a mixed population of mated and unmated females is compared with males. From this observation it is therefore possible that most of the females used in the present oviposition studies did not mate under the laboratory conditions hence their relatively longer longevity over males.

5.1.3 FECUNDITY

In this study adult E. insulana on a diet of honey laid 8 ± 3.77 eggs throughout life while E. biplaga similarly deposited

9.3 ± 3.51 eggs. Assem et al (1974) observed that at 30°C and 70% RH and 15°C and 50% RH, the average number of eggs laid per female of E. insulana was 10 - 50 and 50 - 70 respectively. Yathom, (1958) reported that at moderate temperatures of 25 - 28°C, which prevailed in Israel, the average number of eggs laid per female E. insulana was 136 eggs as against 54 eggs per female at 29°C. In the same sp species, Megahed et al (1972) reported a minimum of 164 ± 20.4 eggs at 31.5°C and 56% RH and a maximum of 422 ± 29.7 eggs at 26.6°C and 56.5% RH. From the foregoing records, the fecundity levels reported in the present work are thus decidedly very low.

In Lepidoptera, dietary variations in the rearing media (quality and quantity of food, and nutrients of larval and adult diet) are known to affect the total number of eggs laid (fecundity) (Wigglesworth, 1965; Vishwapremi and Krisha, 1975; Megahed et al 1972). Vishwapremi and Krishna (1974) observed that feeding of the larvae of E. fabia on different components of okro (whole fruit, mesocarp, epicarp and seeds), produced variations in the number of eggs laid per female (fecundity) and that seed-reared females laid the maximum number of eggs 675.1 while the lowest fecundity of 119.4 eggs was recorded in epicarp-reared moths. Krishna et al (1977) also observed that differences in both concentrations and adult diet affected the fecundity of E. fabia females and that females fed on

15% raffinose solution laid more eggs while concentrations below 1% level severely reduced egg yield.

It seems likely therefore that the low fecundities recorded in this study as against higher values reported in literature is due to differences in the larval and adult diets (nutritional composition of the host/food plants (cotton, okro and honey) used for the studies. Moreover analysis of both cotton and okro fruits have revealed variations in their nutritional composition. While Church, (1971) has shown that the average composition of whole cotton seed by percentage is carbohydrate 23, oil 22, protein 20, moisture 10, crude fibre 20 and ash 5, it has been reported by Franklin and Ruth Ruberte (1978), that the caloric contribution of okro is low reflecting the presence of little carbohydrate and little fat. The nutritional content of fresh okro pod expressed in percentage is moisture 87.05 - 88.05, protein 2.01 - 2.93, fat 0.29 - 0.40, ash 0.92 - 1.10, carbohydrate 6.59 - 6.83, fibre 1.21 - 2.13 (El-Nahry, El-Ghorab, and Younes, 1978).

5.1.4 DETERMINATION OF LARVAL INSTARS BASED ON DIRECT COUNT AND FREQUENCY DISTRIBUTION OF LARVAL HEAD CAPSULES

From direct count of shed head capsules, it was established that during development under the reported near natural conditions, E. insulana and E. biplaga pass through 5 larval instars. This

agreed reasonably with the 4 - 5 larval instars reported for the same species(Pomeroy,1925; Murtuza and Waheed,1969; and Megahed et al,1972)when reared on cotton. In the present investigation, however, the frequency distribution of widths of pooled larval head capsules (representing wider spread of materials than the limited numbers reared in the laboratory alone) did not give 5 clear cut peaks as should be expected (Schmidt, Campbell and Trotter,1971).

Apparent complexities arising from frequency distributions of larval head capsules have been explained by Schmidt et al 1971 and Schmidt and Lauer 1977: and they may reflect possible postembryonic developmental polymorphism. According to them, such graphs become easier to interpret only when head capsule widths are broken into both sex and instar groupings and that this method is unsuitable for determining the number of larval instars in Lepidopterous species with post-embryonic polymorphism. The inconclusive peaks to the frequency distribution graph of larval head capsule widths obtained in this study could therefore be due to the non-separation of the larval specimens into both sex and instar groupings. It also suggests a possibility of developmental polymorphism in the moth species studied, which though not observed on this occasion has been reported in E. biplaga in Western Nigeria (Entwistle,1969);

E. insulana and E. biplaga in Ivory Coast (Couilloud, 1983). In Ivory Coast for instance, besides the typical green form, E. insulana had a yellow winter form that predominated in December - February, an intermediate bordered form in Spring and Autumn, and a rare spotted form in September - December while E. biplaga had wet season, dry season and intermediate forms and sexual dimorphism within each. He also reported that while relative humidity was the most important factor determining colour form, temperature played a secondary role.

5.2 FIELD OBSERVATIONS AND ASSESSMENT OF DAMAGE

5.2.1 RELATIVE ABUNDANCE OF E. insulana AND E. biplaga

Despite similarity in morphology, life cycle, and nature of damage of larval stages of both moth species, E. insulana was more abundant during the dry season (September - February) though found only in small numbers, particularly at the beginning and end of the rainy season, while E. biplaga was more common during the rainy season (March - July). This observation agrees with the findings of Haroon Khan, (1946) in Punjab, India; Broodryk, (1971) in Gatooma, Rhodesia and Couilloud (1983) in Ivory Coast that while E. insulana is more common in the dry season E. biplaga predominates during the rainy season.

Ecologically therefore, it would appear that E. insulana is a hardier species than E. biplaga and thus capable of tolerating a wider range of climatic conditions (Couilloud, 1983).

5.2.2 DAMAGE OF FRUITS

Although damage was not monitored all through the year, attacks by E. insulana and E. biplaga larvae started only when fruiting of okro commenced. It is therefore possible, as Adkisson (1961) pointed out, that the source of larval diet and availability of nectar for adults to feed on are also important factors in determining pest incidence and abundance. Although differences in larval build up during the rainy season and dry season were not statistically significant, the build up during the rainy season was greater than in the dry season. This could probably be due to differences in the length of the growing season which was relatively longer in the rainy season (March - July) and thus supported more larvae than the dry season that lasted from December - February . Moreover it is believed that the population of phytophagous insects decline during the dry season and increase during the wet season when host plants are plentiful (Lyon, 1968).

About 10.83% of the 16.06% cases of abortion recorded was caused by the larvae while only 23.06% of the harvested fruits were damaged.

Based on the total number of fruits sampled, the total damage on okro fruits was low. Since here in Nigeria both healthy and infested okro fruits are easily marketed together, and the infested fruits are still partly useable by people, damage on okro by the Earias species could be said to be relatively negligible thus every infested okro fruit may therefore not be regarded as a total loss. The t-test analysis of the damages caused during the rainy and dry seasons was statistically significant with the greatest damage on both harvested fruits and aborted fruits occurring in January (dry season) and the least damage occurring in May (rainy season). Coincidentally in Nigeria, okro like most food crops, are grown when they would benefit most from the rains. Here the rains not only supported the growth of okro but also make for low incidence of its two subject moth pests in the field during this season. It is therefore advisable to time the planting of okro such that fruiting and harvesting will occur within the rainy months of the year when damage is expected to be minimal - a fact which is reflected in the traditional agricultural practices of the people.

In India, an increase in rainfall time of 1 day decreased bollworm damage by 4.05% (Balasubramanian et al,1981). Similarly Balasubramanian et al (1982) concluded that the incidence of E. insulana, E. vitella, H. armigera and P. gossypiella on cotton in

Tamil Nadu, India in the year 1979 - 80 was low as a result of heavy rainfall and low temperatures.

5.2.3 PEST STATUS ON OKRO

According to Lyon (1971), no diapause has been demonstrated in Heliothis and Earias in Nigeria thus infestations of these pests probably originate on alternative dry season hosts. He also noted that the fact that neither of these bollworms is a major pest may be due to the fact that the numbers on the alternative hosts decline to low level in the dry season and recover slowly on the cotton. This could as well explain the low percent damage and non-seriousness of the moths as pests of okro. Thus it is possible that okro only serves as one of the alternative host plants for the moths when cotton is not in season and which therefore accounts for the low pest incidence and damage recorded on okro.

5.2.4 POSSIBLE CONTROL

Based on the results of this study, it is suggested that E. insulana and E. biplaga of okro could effectively be controlled by application of a systemic insecticide since the larvae are internal feeders. Contact insecticides could also be used and spraying should be timed to coincide with hatching of 1st instar larvae from eggs when only minute amounts of insecticides are

required to kill the very young instars since older or mature larvae become progressively more difficult to kill due to their increasing mass (Mabett, 1983).

In view of the damage caused by the pests and the hazards of environmental pollution by pesticides, the use of the suggested foregoing expensive chemical control measures may not seem justifiable. Instead, for the control of these pests, proper timing of sowing and harvesting dates, timely and regular picking and removal of infested fruits, as well as removal of aborted fruits and flowers are suggested as an effective way of managing the damage-causing larval populations of these moth species.

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