# SOME ASPECTS OF THE BIOLOGY OF *SESAMIA NONAGRIOIDES BOTANEPHAGA* AND *CHILO ALENIELLUS* IN SOUTHERN GHANA.

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# DECLARATION

I, the undersigned, declare that this thesis is my own original work, which has not been submitted for any degree in any university. All sources of material and help have been duly acknowledged.

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# ABSTRACT

Studies were conducted on some aspects of the biology of *Chilo aleniellus* (Strand) and *Sesamia nonagrioides botanephaga* Tams and Bowden in Southern Ghana. The life cycle of *S. n. botanephaga* revealed 8 developmental stages;the egg, 5 larval instars, a prepupa and a pupa. Female *S. n. botanephaga* was found to lay 330 ± 17.7 eggs within a period of 5 days. She required three surfaces to lay her eggs, which were mainly deposited, on the inner side of the leaf sheath fitting tightly on to the maize stem. The mated females laid more eggs per female (330 ± 17.7 eggs) than the virgin female (268 ± 9.2 eggs). The incubation period of the eggs of *S. n. botanephaga* was found to be 5.23 ± o.o3 (5-7) days in the laboratory. The mean larval duration was 29 days and the prepupal period lasted for 2.00 ± 0.01(1 - 3) days. The first instar larvae dispersed in 1-3 days after hatching. The third, fourth, fifth, and sixth instar larvae fed actively producing large quantities of frass. Pupae frequently occurred close to the exit hole (less than 6 cm). The pupal period varied from 6 to 10 days. The life cycle of *S. n. botanephaga* was completed in 38.2 ± 0.28(29 - 50) days. Adults of *S. n. botanephaga* lived for four to ten

days. The adults reared in the laboratory showed a sex ratio of 2:3 (male: female) which was significantly different from the expected ratio (1:1) (male: female). Female *C. aleniellus* laid no egg in the laboratory when paired or single. No mating was observed in the adults of *C. aleniellus*. The larva of *C. aleniellus* went into diapause in the minor cropping season in December 1998 and came out of diapause in the beginning of the major cropping season in April 1999. Adults from the field collected larvae showed a sex ratio of 1:1 (male: female) with no significant difference between the number of males and females.

# DEDICATION

To the Almighty God, my husband, Mr. Tchoffo Benjamain and to my children, especially to my daughter Miss Tezempa Daliane Naomie.

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# CHAPTER ONE

## GENERAL INTRODUCTION

Cereals are the most important sources of food to man, usually providing his staple diet (Purseglove, (1972). Maize is one of the world's most important cereal crops. Its wide genetic diversity and multiple uses account for its cultivation in a large range of environment (IITA, 1991). The demand for maize as food and feed is expected to increase at 4.1% per annum in the developing countries with an increase in demand, projected at 3.2% per annum, in the Sub-Saharan Africa (Byerlee and Saad, 1993). More than 700 million people in the developing world do not have access to sufficient food to meet their need for healthy and productive life. Access to food by an individual is conditioned by the level of poverty (World Bank, 1992).

According to Pinstrup (1994), the availability of enough food at global, regional, national, district and household levels does not mean it is evenly distributed and that every one is well fed. Despite the production of enough food to feed the world, about 1/5 of the total population of developing countries still lack food. Increase in maize production especially in the rural areas can help reduce the hungry population in the developing countries in the absence of wars and tribal conflicts. However, the net income of the subsistence farmer has remained an issue of great concern to both the national and international policy makers for several years. Nevertheless, the vision that emerged in the early 1960s as a guide to the sources of growth in agricultural production included a more positive view of the role of peasant producers in the process of agricultural development (Ruttan, 1994).

Maize is a tall grass with a large stalk and long leaves. Botanically, it belongs to the family Gramineae in the tribe maydeae. Its genus is *Zea* with only one species *Zea mays* including all cultivated varieties of maize. No wild or uncultivated variety or form is known (Miracle, 1966).

According to Bosque-Perez and Schulthess (1994), maize originated in the central America, probably within the area equivalent to modern day Mexico. Palazek (1992) pointed out that by the 17th century, maize was being cultivated in virtually all areas of Africa where it could thrive. The tripatite theory on the origin of maize is based on archaeological evidence, hybridisation experiments and genetical analysis. It suggested that the ancestral maize was a positive form of pod corn. As a result of hybridisation of the ancestral species with its relative teosonite (*Euchlaena mesucana*) and Tripsacum, maize became highly heterozygous. As a result of natural selection acting on man-made environment, maize evolved into a number of domestic forms, each highly adapted to a specific ecological environment. Balfour (1981) asserted that maize was believed to have been brought to West Africa by the Portuguese. Maize was a major cash crop on the West African Coast at the height of the slave trade and it is thought to have got into Ghana through this means (Miracle, 1966).

Maize is currently one of the most important crops in Africa and it is generally cultivated by small holder farmers who save open pollinated seed from one season to the next (FAO, 1992). Kwapong (1990) reported that maize is a warm weather crop requiring considerable warmth from the time of planting until flowering. A large proportion of maize in West Africa is grown in the forest zone. The rainy season in this zone lasts for about six to nine months (March to November). In this season, the rains are interrupted by a short unreliable "August break". The August break divides the rainy season into the "first" (major) and "second" (minor) seasons. Thus rainfall is bimodal. Maize planted at the beginning of the rains usually in March is called the first season maize while that planted after the "August break" is referred to as the second season maize.

The low productivity of maize in Africa result from the interaction of factors which include: climatic factors such as the volume and distribution of rainfall, soil fertility, inefficiency of prevailing crop management practices and biotic factors comprising diseases and insect pests which are specific to the regions.

Maize is an important source of food and feed in many parts of the world. It is the primary staple and a major source of calories for half the population of sub-saharan Africa (IITA, 1991). Although several commodities are obtained from the stalk, cobs and husks of maize plant, only the seeds are important in human nutrition (Kwapong, 1990). Chemically, the maize is primarily carbohydrate but contain some proportion of protein, oil, and minerals (Miracle, 1966).

Anon (1975), reported that the maize kernel consists of 60% starch, 10% protein and 4% oil and it is an excellent high-energy animal feed. Maize is used as a basis for high-energy ratios for broiler production and for feeding cattle and lambs (Anon, 1975).

As food for humans, maize is prepared in a multitude of ways varying from one area to another. In Ghana, about 24 food items have been identified (Food Research Institute, 1986). While in Cameroon about 10 food items can be identified in the Bamelike area alone. The stalk, leaves and immature ear of maize are used for fodder for livestock, notably in part of the corn belt of the United States and Western Europe (Food Research Institute, 1986). In northern Nigeria, maize stalk is used as firewood for cooking food (Abu, 1986). Maize is also used in the industries for the production of adhesives, explosives, textiles sizing, plastics, chemicals and paintstries (Anon, 1975).

Maize is a cereal which is highly consumed in Ghana. It is cultivated throughout all the ecological zones. Between 1986 and 1989 about 49% or 620,000 ha of land allocated to cereals was planted with maize (CIMMYT, 1991) that yields an average of 700 kg/ha. Maize yield in Ghana is below the average of 1000 kg/ha; likewise in other parts of West

Africa (CIMMYT, 1991). The reasons for these low yields are poor soil fertility and the use of varieties of maize, which are highly susceptible to pests and diseases.

In Ghana maize production is influenced by the agro-climatic factors. A large proportion of the maize in Ghana is produced in the guinea savannah zone (Brong Ahafo and Northern Regions) (Gounou *et al.*, 1993). In this agro-ecological zone, maize production is intensive but numerous diseases and insect pests, low rainfall and high temperatures limit yields. In areas with bimodal rainfall, stemborer population generally tends to reach climax during the minor cropping season (September to March) where the crop is sometime a complete loss to pests (Adeyimi *et al.*, 1966; Girling, 1980). In the Cameroon's, most farmers start planting with the first rains in the major season (March) and planting can continue as late as the end of the month of September (minor season).

Both local and improved varieties of maize are cultivated in Ghana. Because of the ever-increasing population, which also requires increase in food production, cultivation of improved varieties, which are high yielding, is very necessary. The plant breeders do not take into consideration the breeding of varieties of maize which are resistant to insect pests, instead they breed for high yielding varieties with high protein content which are also very susceptible to stemborers. This might be because the breeders know that insecticides can take care of the pest problems (Gounou *et al.*, 1993).

Several species of maize stemborers have been reported in Ghana but the most notorious ones are *Sesamia calamistis* Hampson (Lep. Noctuidae) and *Eldana saccharina* Walker (Lep.Pyralidae). High yield reduction caused by both pests have been reported from the forest zone (Bowden, 1956,1976; Girling, 1980). In the coastal savannah, yield reduction of the maize crop is mainly caused by *E. saccharina* (Endrody Younga,1968). Both species are more abundant in the minor season than in the major cropping season.

*E. Saccharina*, *Busseola fusca* Full [Lep: Noctuidae] and *S. calamistis* are among the most notorious stemborers of economic importance in Africa (IITA, 1991).
The larvae of these insects usually cause the damage. Their feeding lead to death of the growing points, early senescence, reduced translocation, lodging and direct damage of the ears (Appert, 1970, Breniere, 1971).

Estimated yield losses caused by stemborers in Nigeria range from 10% to 100% (Usua, 1968). The story is not different from other part of Africa where the peasant farmers do not plant the minor season maize due to complete loss caused by stemborers.

**JUSTIFICATION**

The present study was necessitated because of the havoc caused by the complex of stemborers present in the crop system. Despite man's struggle to reduce the already existing insect pests below economic injury level,new ones continue to feature. Any Organism that is a threat to food production has to be managed and controlled in order to meet the food requirements of the ever-increasing human population. Thus, all information required for its control should be obtained. According to Sampson and Kumar(1984), for any effective control of an insect pest, knowledge of the life history, biology and the ecology of the insect are very important. *S.n.botanephaga* was discovered by Tams and Bowden (1956), since then, there has been no information on its life cycle. Leyenaar and Hunter (1977), reported that *S.n.botanephaga* can cause 63% of loss in yield of maize in the Coastal savannah of Ghana. The location of the eggs of *S.n.botanephaga* is not known, the result of this study will show the position of the egg and hence, the position of the first instar larvae for easy control before they dispersed. Therefore, there is the need for more research to be carried out on this insect for its management.

*Chilo aleniellus*(strand)(Lepidoptera:Crambidae) has been known on wild grasses in West Africa since 1913 (Tsou, 1914). It was also recorded on wild grasses in Ghana in 1970 (Bleszynski, 1970). This insect was later found on maize in Ghana by Kwapong (1990).

Since *C. aleniellus* has extended its food range from the wild grasses to maize crop and it is now known to cause tassel and stem breakage, all necessary information for its control need to be put in place to prevent it from becoming a major pest of maize in Ghana.

Although the biology of many stemborers such as *S. calamistis*, *c. partellus* and *B. fusca* have been studied, no information exits on the biology and ecology of *C. aleniellus* except its classification that has been reported in Cote d,Ivoire. It is now of great concern to researchers. The purpose of this project is to study the behaviour and some aspects of the biology of *C. aleniellus* and *S. n. botanephaga.*

**BENEFIT OF THE STUDY**

Information generated from this study will be made available for agriculturist and farmers for the management of these species. This work will also reveal the most vulnerable stage of the insect for control.

**MAIN OBJECTIVE**

To study the life history of *S.n.botanephaga* and some aspects of the biology of *C.aleniellus.*

**SPECIFIC OBJECTIVES**

1. To identify the oviposition site of *S.n.botanephaga* in the field and in the laboratory.
2. To evaluate the fecundity and egg fertility of *S.n.botanephaga.*
3. To study the development and duration of the various stages in the life cycle of *S.n.botanephaga*
4. To identify the location of *C. aleniellus* and *S.n.botanephaga* on the maize plant.
5. To compare the feeding behaviour of *C.aleniellus* and *S.n.botanephaga* in the field and laboratory.

To study the mating behaviour of *S.n.botanephaga* in the laboratory.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 INTRODUCTION

As the world population grows geometrically, food production increases arithmetically (FAO, 1971). In mans struggle to increase food production for an ever-increasing human population, he encountered other organisms competing for his crops.

Insect pests are destructive or noxious insects, which compete with man over his crops etc. Because of the complexities of human society, it is impossible to eliminate pest problem by ceasing the activities that encourage them (Metcalf and Luckman, 1975).

Attempts have been made to protect the agroecosystems from insect pest which are the greatest human competitors since beginning of age. More is still required of man due to new insect pests entering the crop system.

Estimate of the pest problem on the world scale suggests that without insect pests, world food production could be increased by about a third. As this represents the loss despite current control measures, it therefore implies that it would be catastrophic for mankind if their control were not attempted or should fail (Van Emden, 1974).

Maize crop which is highly consumed almost everywhere in the world suffers serious yield reduction especially in Africa due to the attack of lepidopterous stemborers. Literature on maize stemborers in Africa dates back to over a century, when *Eldana saccharina* was described as a pest of graminaceous crops in Sierra Leone (Appert,1970). Most of the early studies were concentrated on the biology of the dominant species in the various areas (Tams and Bowden, 1956).

Work on the control of stemborers in Africa has been mainly on chemical control which the small-scale farmers cannot afford. Most of the insecticides banned in U.S.A. and Europe , are still in use in Africa ( Bosque- Perez and Schulthess, 1994, Jotwani,1983.). However, the chemical approach of stemborer control has not been very successful. This is because the insects live inside the stem of the maize and spend most of their life cycle within the plant, making it difficult for the chemical to get in contact with them. The adverse effects of chemicals, their inefficiency for the control of stemborers and high cost makes it imperative that other control measures should be practiced. Examples of such control methods are biological control, cultural control, host plant resistance and integrated pest management. According to Litsinger and Moody (1976), it is important to develop a technology whereby there will be increase in yield without creating conditions that will favour increase in pest population.

## 2.2 THE LEPIDOPTEROUS STEMBORERS OF CEREALS

Lepidopterans are of the class insecta and their importance as insect pests on crops can not be over-emphasised. Lepidopterous stemborers have been known to limit both yield and stability of cereal production in Africa especially for small-scale resource poor farmers (IITA,1998). The borers are known to attack maize, rice, millet, sorghum and Guinea corn. They also attack grasses such as *Pennisetum purpereum* and *Sorghum arundinaceum*. The only criterion for the acceptability being that the stem should be big enough to accommodate a mature larva (Bowden, 1976).

The maize crop industry is under serious problem due to preharvest insect pests particularly the lepidopterous stemborers. Four species of stemborers are known to cause

Significant damage on the maize crop in Africa. These are: *Busseola fusca* Fuller (Lepidoptera:Noctuidae), *Sesamia calamistis* Hampson (Lepidoptera:Noctuidae), Eldana saccharina Walker (Lepidoptera:Pyralidae) and the spotted stalk borer *Chilo partellus* Swinhoe (Lepidoptera:Pyralidae) (Bowden,1954; Harris, 1962; Appert, 1970). The borers attack various parts of the maize plant at different time of plant growth. The larvae cause the damage with well-developed mouthparts adapted for chewing while the adults do not feed on the crop. The eggs are laid on the plant or in the soil near the plant; they hatch from the egg, move on to the crop for a while and tunnel into the stem. Once inside the stem, they begin to feed on the stem tissues. The stem serves as food and shelter for the borers. The stem also provides protection for these insects from their natural enemies and contact chemicals. Their feeding causes the meristem of the plant to die resulting in the formation of "dead heart" when the plant is at its vegetative stage. They also cause tassel breakage or stem tunnelling on the mature plant leading to yield reduction.

Most of the stemborers have extended their range of feeding from their main host to other plants. Their original hosts might have been wild plants, but with time they moved to other plants especially the cultivated crops, which are susceptible to them due to their high nutrient content. Because of increase in the range of feeding a number of crops now serve as host for these borers.

*Busseola fusca* Fuller (Lepidoptera:Noctuidae) is a major pest of maize and sorghum but it is now found on many species of grasses and other cereals (Hill, 1975). Forsyth(1966)reported *Sesamia calamistis* Hampson as a pest of rice but it has increased its host range to maize, sugarcane and other plants.

*Eldana saccharina* Walker is a serious pest of sugarcane as it attacks both the young shoot causing dead heart and the mature plant causing hardening of the plant tissue as they bore and tunnel through the stem (Sampson, 1982). Apart from being a serious pest of sugarcane, it is also a serious pest of maize in Ghana (Abu, 1986). According to Lefevre (1944), *Eldana saccharina* attacks cassava, *Manihot utilissima* (Pohl). It also attacks millet, *Elensire coracana* (Gertn) and rice, Oryza sativa (L) (Harris, 1962). Wild grasses such as bush millet; *Pennisetum typhoidis* (Rich) is also attacked by *Eldana saccharina* (CIBC, 1971).

*Chilo* species apart from being pests of rice in Ghana as reported by Quartey (1975),are also found on maize (Kwapong,1990).

Most of the wild host plants of stemborers usually serve as reservoir for reinfestation of the cultivated crops (Kwapong, 1990).

The choice of host plants of stemborers vary with the geographic location. For instance, on the south coast of Malawi, *Eldana saccharina* Walker may be abundant on the wild host plant but absent from the sugarcane which is growing in it immediate vicinity (South African Sugar Journal, 1980).

## 2.3 SEASONAL DISTRIBUTION AND ABUNDANCE OF LEPIDOPTEROUS STEMBORERS OF MAIZE

A lot of researchers have worked on maize stemborer and many people are still researching on these insect pests in Africa. Recent reports still show the seriousness of these pests. A survey carried out in Ghana between 1990 and 1991 showed that *Sesamia calamistis* Hampson and *Eldana saccharina* Walker are the most damaging pests of maize (Gounou *et al.* 1993). In late 1990, *S. calamistis* was the predominant species in all the ecological zones. In late

1991, *E saccharina* followed and infested fields were found in all the areas with a bimodal rainfall pattern (Gounou *et al.*1993). The story is not so different in other parts of Africa. For example, a survey conducted in Cameroon in 1993 revealed that *Busseola fusca* Fuller was a serious pest of maize and the most predominant species in all the ecological zones (Cardwell *et al*, 1997).

Scheibelreiter (1980), reported that the long dry season from November to March which coincide with the harvesting of sugarcane significantly reduces the pest population on sugarcane. The story is different with maize where there is increase population during the minor season. *S. calamistis* reaches its peak in the minor cropping season while *E. saccharina* reaches its peak at the onset of the long dry season. Apart from these overall population fluctuations, there appear to be distinct peaks depending on the species involved, the age and the physical condition of the plant.

## 2.4 DAMAGE CAUSED BY STEMBORERS

### 2.4.1 DEADHEART:

The adult insect lays its eggs on the plant or in the soil near the plant and they hatch to larvae, which infest the maize plant. The larvae on infesting the maize plant eat into the growing regions from the top of the plant causing the damage of the new shoot in the interior part of the vegetative plant. A condition known as "deadheart" results from the death of the meristematic tissues bwhich eventually kills the plant. In other plants, there is the formation of perforations (windowpanes) on the leaves which do not usually result to death of the plant if the meristem is not damaged. Usua (1968) reported that in terms of increase in height and number of leaves, the rate of plant growth during the first two weeks following infestation decreases as the number of stemborers per plant increases. Poor growth is also seen in the number of leaves added on the infested plant. No leaf is added to the plant infested by four to five larvae. Usua,(1968), also observed that the percentage of the plants with "deadheart" increased as the number of borers per plant increase.

## 2.4.2 TUNNELLING AND LODGING

As the larvae bore into the plant, they cause stem tunnelling through their feeding. The stem tunnelling by the larvae weakens the stem, interferes with the translocation of nutrients and metabolites of the plant resulting in malformation of the grains. This can also lead to the breakage of the stem or stunted stem.

Tunnelling of the stem by borers cause most grasses to tiller, thus compensating for the attack of the borers, this is not the case with maize. This explains why the attack of maize by borers is generally more severe because the maize plant does not tiller after the attack (Bowden,1976). Tillering is however,only one aspect of the general adaptive tolerance of native grasses to stemborers. It is not surprising that the native cultivated sorghum shows little response to borer attack whereas the introduced varieties are frequently affected by the borers (Bowden,1976). Kumar (1988), reported that there was greater tunnelling in the susceptible maize varieties by *Chilo partellus* artificially infested. Also he noted that the tunnelling significantly influenced plant growth in all the cultivars tested.

## 2.5 YIELD LOSSES CAUSED BY STEMBORERS

Infestation by maize stemborers has been found to influence significantly maize stalk-rot (Bosque- Prerez and Mareck, 1991). Yield losses reported in Africa as a result of attack by lepidopterous stemborers vary greatly (0-100%) between the ecological zones, regions and seasons (Bosque-Perez and Schulthess,1994). The severity and nature of stemborer damage depend upon the borer species, the growth stage of the plant and the reaction of the plant to stemborer feeding. Feeding by the larvae on maize plant usually results in yield losses as a consequence of death of the growing points, early leaf senescene, reduction in translocation, lodging and direct damage to the ear ( Appert, 1970; Breniere,1971; Bosque-perez and Mareck, 1991).

In Ghana the most notorious field pest of maize are *Sesamia calamistis* and *Eldana succhariana*. High yield losses due to both pests have been reported from the forest zone (Bowden, 1954, 1976; Girling 1986) and losses due to *Eldana saccharina* mainly from the coastal savannah (Endrody-Yanga, 1968).

In Benin, borer population densities on maize are usually below economic injury level (Shanower *et al*,. 1991). However, localised severe outbreaks do occur.

It is possible to measure the relationship between infestation rate and crop loss by using natural or artificial infestation, pesticides or other methods of control. Harris (1962), working in northern Nigeria reported that when maize plants were protected from the attack of the stemborers by the application of pesticides such as endrin, there was increase in yield of the sprayed plants. The low yield of the unsprayed plant was attributed to loss of stands as a result of lodging caused by burrowing larvae.

The degree of borer attack that cause yield loss might be assessed by determining the percentage of the plant attacked, the extent of stalk damage, the levels of leaf damage, percentage of the stem tunnelled, percentage of node bored, number of stalk breakage, extent of ear damage and the number of larvae or pupae per plant (Walker,1980) . Gounou *et al*,.(1993) working in Ghana, calculated ear weight losses caused by stemborers in the various ecological zones. The ear weight in the various ecological zones were as follows: Rainforest zone, 32.5g/plant;

Derived Savannah,19.4g/plant; Coastal Savannah, 13.8g/plant and Guinea Savannah 17.9g/plant with equivalent of 27%, 17.5%, 14.7% , and 15.1% yield loss respectively.

According to Arbuthnot *et al*,.(1958), the southwestern corn borer *Diatraea grandiosella* (Dayar) is responsible for substantial yield losses of maize in southern United States of America.

**2.6 INTERCROPPING AND STEMBORER INTERACTION.**

Intercropping is a major feature of agriculture in tropical countries especially among the traditional farmers. In the industrialised countries, intercroping is rarely used since it is usually inappropriate for modern highly commercialised farming (Dent,1991).

The practice of intercropping is one of the oldest methods for increasing crop diversity and reducing the levels of pest infestation by peasant farmers. The intercropping of plant species which have different pests associated with them generally reduce the level of infestation relative to pure stand (Barrett,1983). Small-scale farmers usually practice intercropping in various forms. The various crop may be planted randomly, or arranged in rows. The different crops may also be mixed in rows or alternate rows may have different crops. This helps to reduce the stemborers and other pest population.

According to Gyawaili (1986), intercropping maize with soyabeans gave almost 13% reduction in *Chilo partellus* and *Sesamia spp.* infestation on maize. Consequently, there was 9.2 % increase in grain weight per plant in the intercrop maize as compared to monocrop.

## 2.7 SOME ASPECTS OF THE BIOLOGY OF *E.saccharina*

A lot of work has been done on *Eldana saccharina* in Africa. The life history has been extensively researched into (Endrody Younga, 1968; Girling, 1968; Girling, 1978, Sampson and Kumar, 1985; Kwapong, 1990). *Eldana saccharina* (Lep:Pyralidae) is a moth which lays pale yellow eggs measuring 0.8mm by 5 mm. The eggs are laid in batches just beneath the soil or in the maize stubbles on the ground during the dry season (Kaufmann, 1983) and in the inner surface of the leaf sheath in the wet season (Sampson and Kumar, 1983). *E. saccharina* female is also reported to oviposite on leaf sheath and between the stem and the soil (Girling, 1978), on the dead plant material (Atkinson, 1980), or on the hairy margins of maize leaf sheaths

(Cochreau,1985).

The adult female ensures survival of the species by depositing a large number of eggs (327 $\pm$ 17) within 4 days (Samson, 1982). Kaufmann,(1983) noted that *E.saccharina* can produce up to 1000 eggs per female. For *E.saccharina* reared on artificial diet, Bosque-Perez and Dabrowski (1989) reported mean fecundity of 380 eggs. Sampson (1982), observed that the oviposition behaviour of *Eldana saccharina* indicates, that there is a tendency in the adult female to conceal the eggs. That the female needs three surfaces in order to lay her eggs. Mating stimulates oviposition and affects the longevity of the female (Davey, 1965).

There are six larval instars, a prepual and a pupal stage before the adult emerges (Sampson and Kumar,1985).The mandibles of the first instar larvae are not well developed and they do not feed much. The older instars are much more active feeders giving off large quantities of frass mixed with silken material and causing great damage to the host plant. The larvae of *E. saccharina* are cannibalistic and aggressive (Girling,1978 and Kwapong 1990). The larvae become prepupae when they stop feeding and spin tough silken cocoon around themselves, then enter into an inactive stage. They pupate and the cocoon become impermeable material which protect the pupae till they become adult (Sampson and Kumar 1985).

The larvae of *E. saccharina* first appear in the stem shortly before flowering of the host plant and reach at peak after harvest (Kaufmann, 1983). She also reported that in Nigeria *E.saccharina* builds up during the dry season reaching it maximum in April. As the rain begins, it gradually declines with the minimum population occurring in December.

In Ghana,Endrody-Younga (1968) observed that the population peaks of *E.saccharina* around Kumasi were in June and October and lowest in February to march.

## 2.8 SOME ASPECTS OF THE BIOLOGY OF S.CALAMISTIS.

Studies have been conducted on some aspects of the biology of *Sesiamia* species in Africa (Bowden, 1951; Endrody - Younga, 1968; Kaufman, 1983). The studies showed that *S. calamistis* (Lepidoptera:Noctridae) lays eggs with flat top and bottom measuring 0.7 x 0.3mm. The eggs are laid along the inner surface of the leaf sheaths of young maize plant in batches of a few to over 500 with an average of 71,arranged in 2-5 neat rows (Kaufmann, 1983). She noted that the eggs change colour from yellowish white to pale orange and the colour deepens as they approach hatching.

The young larva, which emerges after hatching, has a characteristic pale pink body and a dark head. It is sluggish and gregarious throughout the period. Six larval instars,prepupal and pupal stages have been reported by kaufmann (1983). She also observed that males of *S.calamistis* emerge first and fly about actively then mate with females that have just emerged and were still at rest. Oviposition starts in the second night after copulation. A "craw flying" behaviour enhance the laying of eggs. The young larvae attack the maize plant. The feeding sides are the terminal leaves.

An observed characteristic of *S. calamistis* is the keeping of excretory pellets within the feeding tunnels. This behaviour is believed by Kaufmann (1983), to keep its environment very moist.

Kwapong (1990), reported that infestation of *Sesamia* species start very early when plants are about 15 to 30 cm tall with the number of larvae increasing through the pre flowering period

Kaufmann (1983) , working in Ibadan Nigeria noticed that the population of *S. calamistis* build up during the raining season reaching its peak in October. She observed that whithin 3 to 7 days of hatching larvae migrate to adjacent plants by crawling through overlapping leaves. This movement lasts for four to five days.

## 2.9 SOME CONTROL MEASURES OF STEMBORERS.

The control of lepidopterous stemborers include chemical methods, biological, as well as the use of cultural methods (Bosque- Perez and Schulthess, 1994)

### 2.9.1 Chemical Control.

This method involves the use of pesticides against insect pest. Many researchers have reported the effectiveness of chemicals for the control of stemborers. Ahmad and Sharma (1986) reported the use of synthetic Pyrethroids for the control of the maize stemborer *Chilo partellus* (Swinhoe) in India with effective results. There was a reduction in the incidence of "dead heart" (2.4-5 %) on the treated area compared with the untreated area (51.2%). Studies in South Africa showed that application of carbofuran granules to the planting farrows of maize resulted in a significant reduction of infestation by *B. fusca* (Walters and Drinkwater, 1975). A single application of endosulfan against *Chilo partellus* is beneficial when applied shortly before tasselling in maize and before panicle emergence in grain sorghum (Van den berg and Van Rensberg, 1991).

Despite the recorded effectiveness of chemicals, there are associated problems. One of the reasons being that the destructive stage of the pest is inside the stem and the chemical does not reach it easily. However, Duerden (1953) pointed out that to control *Busseola fusca* and *Chilo zenollus*, it is desirable to deposit the chemical into the funnel of the developing plant because most larvae move through this region into the stem. This also makes the work difficult and laborious because hand application is almost a necessity and is very difficult on a large piece of land.

In West Malaysia, chemical control used for the control of stemborer of rice tended to aggravate the situation leading to more serious damage (Lim, 1970). According to Smith ( 1972) spraying large area with Phosphamidon to control rice stemborers resulted in secondary outbreak of the rice galmidge( Orseolia, Oryzea). Chemical control of stemborers is often not adopted by farmers as it involves repeated applications (Sekhom and Sajjan, 1987). In Africa many farmers do not use chemical for the control of stemborers because of their high cost. The use of chemicals for pest control has also discouraged many farmers because of its side effects and persistence in the environment. Luckman (1960), also pointed out that, there was an increase in European corn borer after the use of Dieldrin.

**2.9.2 Biological Control**

Wilson and Huffaker (1976) considered biological control as a science of natural enemies in regulating the number of their hosts. In fact biological control is the use or encouragement of beneficial organisms for the reduction of another living organism which is regarded as pest (Debach, 1964).

In china in 1974, *Trichogramma* spp.were released at the rate of 159,000 parasitoids per hectare of maize to control the first brood of stemborers. Parasitism rate Of 68.2 % was achieved, reducing the damage from 63% to 10%. Two more releases of parasitoids at the second brood caused 78.0% parasitism reducing damage from 31% to 11% (NAS, 1977).

Carlson and Chiang (1973) reported that sprays of sucrose and maltose solution on maize plant can alter the normal pattern of distribution of some predatory insects. The sprays of this solution increase the density of chrysopid predators, which reduce European corn borer in the field. The use of some natural enemies formulated into microbial insecticides (biopesticides) agaist stemborers has been reported. According to Bottrel (1979), *Bacillus thuringiensis*(Bt) is the most common microbial insecticide in use. In China, farmers produce the fungi *Beauveria* species. When this fungus is applied on piled infested maize stalks, it kills overwintering larvae of European corn borer, especially when they begin to move in spring and this practise reduces the field moth population by 75% (NAS, 1977).

2.9.3 **Cultural control**

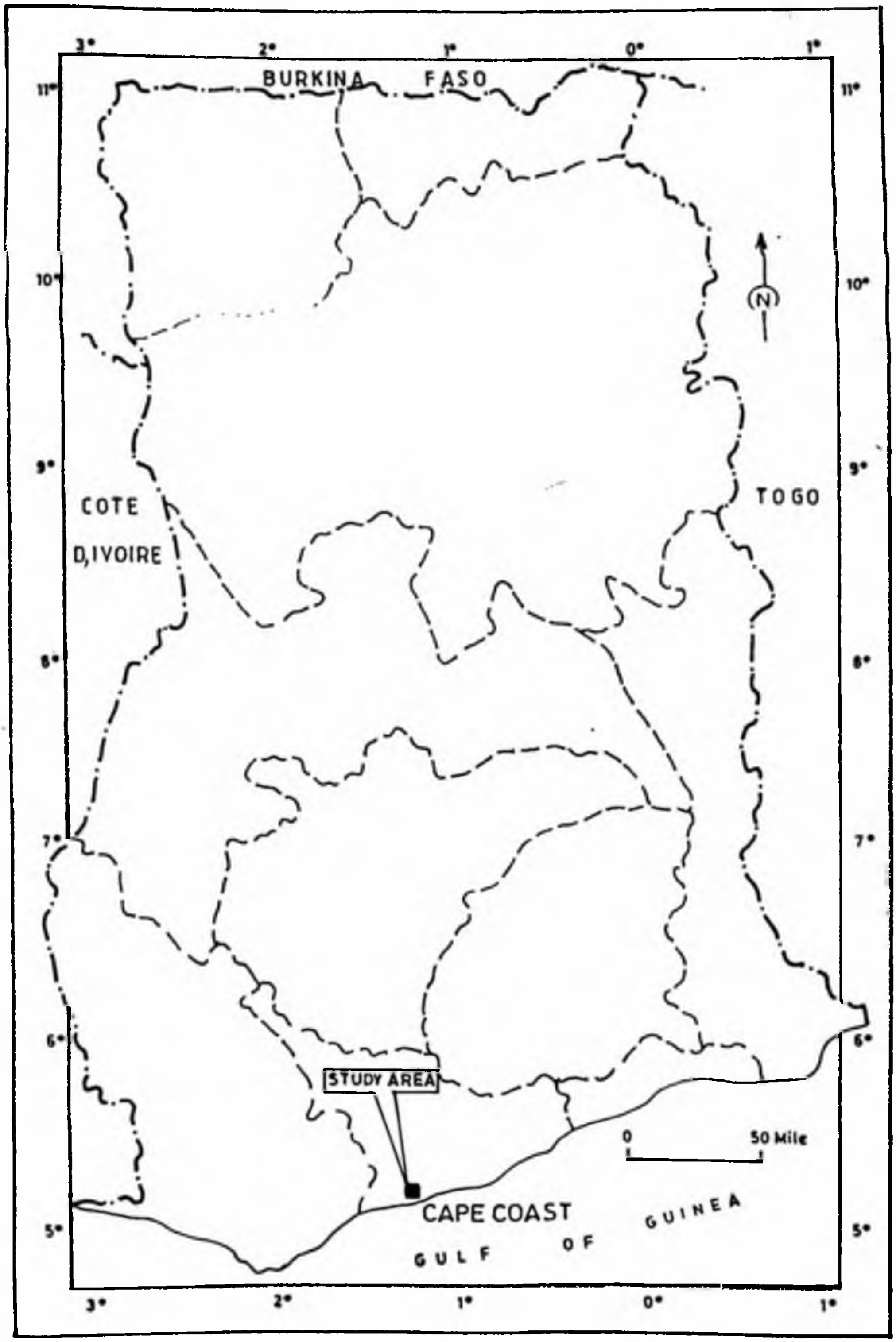
Cultural control of insect pests is effected by the manipulation of the environment in such a way as to render it unfavourable for the growth and survival of the pest. This is achieved through the use of several techniques many of which are considered old and traditional but which help to reduce the chances of insect colonisation. These include: intercropping, manipulating of planting date, use of resistant varieties, management of weed and field margin (Dent, 1991).

Many authors have reported greater infestation of stemborers in late planted maize than early planting,in Ghana and Benin (Aikins, 1957; Girling,1980; Shanower *et al.*, 1991). Farmer practices may have an effect on carry-over population of stemborers especially during the dry season. Such crop residues left after harvest in the field or used as building material or packed behind houses for use as firewood, provide good sites for daupausing species.

The destruction of volunteer sorghum is a cultural method practised by farmers in Northern Ghana (Aikins, 1957). The stubbles left in the soil give rise to what is called ratoon or volunteer sorghum. This enables the pest to build up in sufficient number ready to attack the crop. However,Aikins (1957), observed that the volunteer sorghum if properly utilised , might serve as a trap crop.

Cultural control on its own is unlikely to reduce pest infestation to a desirable level, but with the framework of an integrated pest management (IPM) it can be used to reduce levels of infestation below economic injury level.

Fig. 1 MAP OF GHANA SHOWING THE POSITION OF CAPE COAST



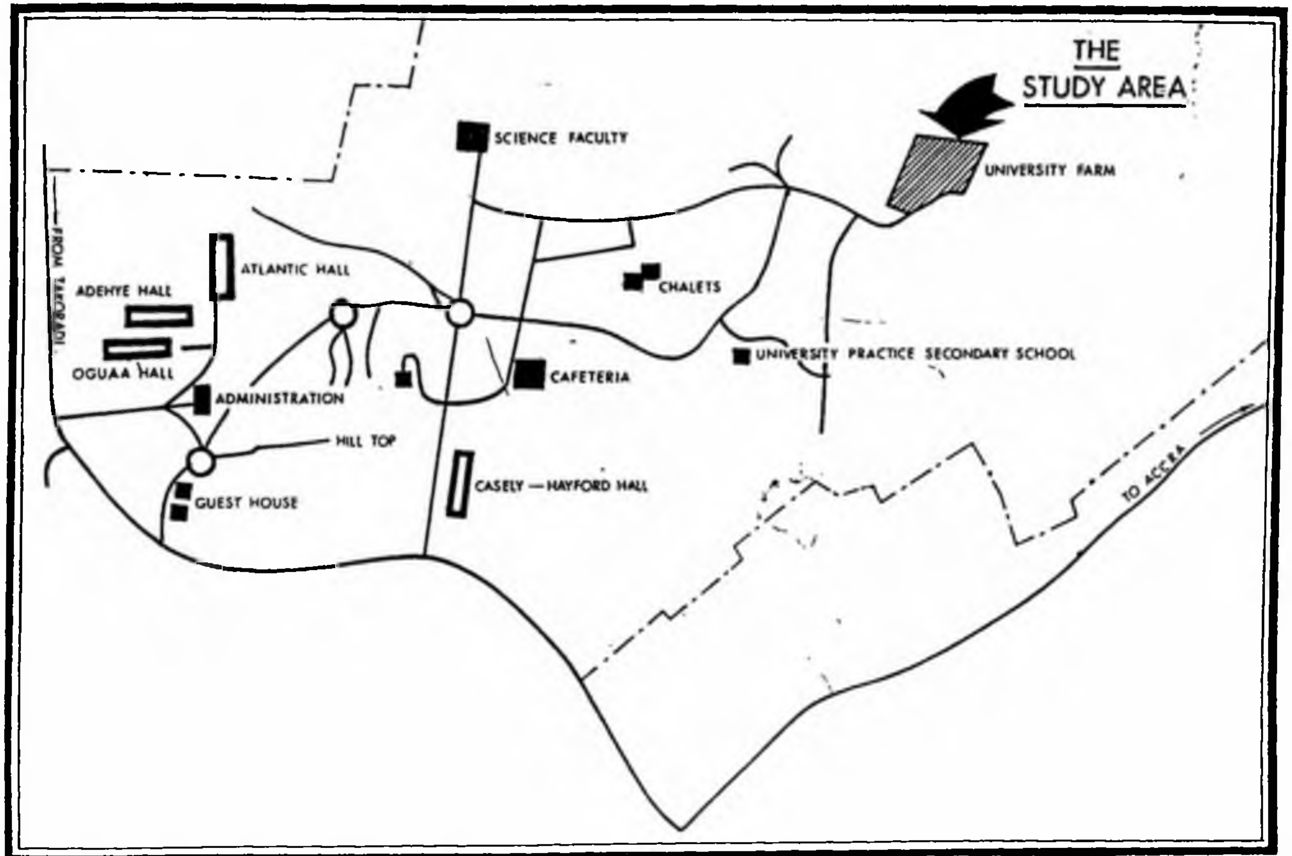



FIG. 1. MAP OF UNIVERSITY OF CAPE COAST CAMPUS, SHOWING THE STUDY AREA.

# CHAPTER THREE

## 3.0 MATERIALS AND METHODS

### 3.1 EXPERIMENTAL SITE:

The project was carried out on the field and in the laboratory. The laboratory studies were carried out in the Zoology Department in the University of Cape Coast (UCC). The project work was undertaken at the University of Cape Coast Teaching and Research Farm located 5km away from the Science Faculty. The farm has a total acreage of 387 acres of cropping land consisting of varieties of crops such as, maize, cassava, sweet potatoes, okro, egg-plant, pineapple, oranges and coconut trees. Cropping is done in the farm through out the year. In the minor season when there is little or no rain, crops are irrigated.

The experiment was undertaken in both the minor and the major seasons. The maize farm during the minor season (dry season) was sited near the rabbit hut at the north and the east, west and south by students plots comprising of sweet potatoes, egg-plant and cassava respectively. The experimental site for the maize crop in the major cropping season (rainy season) was located near a citrus plantation at the north, on the east by okro, on the

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The entire University farm is made up of four main types of soils; Edina, Benya, Atabadzi and Udu series (Kqapong, 1990).

### 3.2 FIELD PREPARATION AND PLANTING

The fields were prepared mechanically by ploughing and harrowing. Each of the two fields measured 30m by 20m. The minor season maize was planted on 26th November 1998 and the major season one 29th of March 1999. The maize was planted in rows with a planting distance of 90cm between rows and 30cm between hills on the rows. This was thinned on emergence to 2 plants per hill. Stems of the uprooted maize plants were used for feeding the insects in the laboratory. The variety of maize planted was the high yielding variety called "Obatampa" for both seasons (Fig 3). Weed control was done by hoeing 3 weeks after planting and also 8 weeks after planting. There was no chemical application.

### 3.3 FIELD SURVEYS AND COLLECTION OF STEMBORERS.

In addition to the study site at the University of Cape Coast,a number of maize fields were surveyed for the presence and

Fig. 3 Maize Field (8 weeks after emergence)

collection of *S.n.botanephaga* and *C. aleniellus* larvae and pupae for laboratory studies. Some of the areas visited include Kakum, Praso, Holy Child school, Mankessim and University environs. The minor cropping season's survey was carried out from November 1998 to March 1999 while that of the major season was from April to June 1999. The maize plants in the field were examined for stemborer damage. The maize plants were inspected and infested plants were recognized by the frass and borer holes on the stem or wilting of young plants. The damaged plants were cut and split for the immature stages of the stemborers.

## 3.4 THE BIOLOGY AND LIFE HISTORY STUDIES OF *CHILO ALENIELLUS* AND *SESAMIA NONAGRIOIDES BOTANEPHAGA*.

Larvae (at various instar stages) and pupae of *C. aleniellus* and *S.n.botanephaga* were collected from the field and brought to the laboratory for further studies. The studies involved rearing the larvae through to adult, sexing at the pupal stage, and Oviposition behaviour.

### 3.4.1 REARING OF LARVAE OF CHILO ALENIELLUS AND *SESAMIA NONAGRIOIDES BOTANEPHAGA* IN THE LABORATORY

Each larva was reared singly in a rearing bottle (200mls) whose top was covered with nylon mesh. The larvae were fed with pieces of cuttings of maize every other day. Newly hatched first instar neonate larvae were isolated singly into petridishes containing moistened filter paper and fresh young leaves with part of the sheaths attached to it. The petridishes were covered so as to prevent the young larvae from escaping. Older instars (from 3rd instars) were fed with fresh maize stems. Each larva was weighed every other day at time of feed change with a sensitive chemical balance. The moulting stages were recognized by the presence of the head capsule or cast skin through careful examination of the frass. Width of head capsule was taken after each moult using a graduated microscope (2X). Other behaviour observed during this period was noted. The temperature of the room was recorded daily by the use of a thermometer and the relative humidity by the use of a hygrometer.

### 3.4.2 SEXING

Sexing was done at the pupal stage. The pupae were sexed and the males were separated from the females. The pupa shows a very distinct sexual dimorphism, which makes sexing quite simple at this stage of the insect. Sexing was done with the aid of a binocular microscope. It is difficult to distinguish the male from the female at the larva stage of both *C. aleniellus* and *S.n.botanephaga*. The male shows through the cuticle a hump at the genital position but the female does not have. However, the adult of both species can be distinguished easily in that the adult male of *S.n.botanephaga* has bipectinate antennae making it easy to separate it from the female, which has filiform antennae. The male *C. aleniellus* is darker than the female making separation easy.

### 3.4.3 MATING

On emergence from the pupal case, the adult male and female were paired in the kilner jars (452.5mls) covered with a nylon mesh to prevent the moth from escaping. Unpaired females were also put in separate jars.

### 3.4.4 OVIPOSITION OF *S.N.BOTANEPHAGA* IN THE LABORATORY.

In the laboratory eggs were collected from the kilner jars in which the male and female insects were paired and singled. Part of the leafsheath as well as folded filter papers were provided inside the kilner jars on which the females laid their eggs. The kilner jars were changed daily for collection and counting of eggs laid by each female a day. The eggs were counted using a binocular microscope and hand lens. The total number of eggs laid per mated and unmated female per day was recorded. This was done till laying was completed just before the death of the insect. The number of days of oviposition was also noted.

### 3.4.5. OVIPOSITION ON POTTED MAIZE PLANTS IN CAGES

Maize variety "Obatanpa" was planted singly in 24 plastic buckets and put into cages measuring (0.9 X 0.9 X 1.8m) (fIG 4). Maize was planted at 3 weeks interval for each set. These buckets containing 3 growth stages of maize plants (pre-tassellinG, tasselling and silking stages) in each cage were replicated 5 times. In each cage five pairs of newly emerged males and females were released. After 2 days, all the plants were removed and searched for the sites where the females laid the eggs. Each plant was divided into 3 parts (the Upper, Middle, and Lower). The number of eggs deposited on each plant for the various plant parts and stages were recorded.

Fig. 4 Cages with Potted Maize Planted

### 3.4.6 EGG SIZE AND INCUBATION OF *S.N.BOTANEPHAGA*

The eggs laid in the laboratory were randomly sampled and their length and widths measured using a graduated slide and a binocular microscope. Measurements were taken a day after laying before shrivelling of the eggs. More than 97 eggs were measured. Infertile eggs were discarded. The fertilised eggs after counting were placed in petridishes containing moistened filter paper. Daily observations were made to record any visible change on the eggs. The incubation period was noted. The number of eggs that hatched was recorded.

### 3.4.7 THE IMMATURE STAGES.OF *S.N.BOTANEPHAGA* AND *C.ALENIELLUS*

Fresh pieces of stems cut from the maize plants obtained from the field were used to feed the larvae. Feed was changed every other day by carefully dissecting to remove the larvae from the previous stem pieces. Moulting was indicated by the presence of cast skin and/or head capsule measurement. The behaviour of the larvae in the course of rearing was recorded. The total number of moults as a measure of the number of instars was recorded. Each larva was weighed every other day during feed change. Widths of head capsule found in the frass were taken.

Three different diets were given to *S.n.botanephaga* larvae of the same cohort and their weights were recorded during feed change. The larvae were observed till pupation. Each pupa was weighed and the length and width noted. The prepupae and pupae were kept in the rearing bottles without food until they emerged into adults. The larval and pupal mortalities were also recorded.

### 3.4.8. ADULT STAGE OF *S.N.BOTANEPHAGA* AND *C.ALENIELLUS*

The adults were kept in pairs or singly in the kilner jars to study longevity, fecundity and mating behaviour. They were observed in darkness using red light from the torch. The eggs laid by the female were isolated, counted and used for further studies.

## 3.5 OBSERVATION OF *SESAMIA* SPECIES

Species of *Sesamia* found in the Central Region of Southern Ghana were identified using the key prepared by Tams and Bowden (1953).

The taxonomic character used was the adult genitalia.

### 3.5.1 SOURCES OF MATERIAL.

Larvae and pupae were collected in the field at various areas of the Central Region of Southern Ghana in the minor and major cropping seasons. They were brought to the laboratory and reared to adults. These adults were then used for genitalia preparation.

### 3.5.2 PREPARATION OF THE ADULT GENITALIA

The abdomen was detached from the thorax by applying upward pressure using a pin. The abdomen was placed in a tube containing 5ml of 70% alcohol and boiled for five minutes. The abdomen was transferred into a test-tube containing 5ml of 10% KOH and boiled for 30 minutes to macerate the tissues. It was then transferred into a watchglass containing 50% alcohol to descale the abdomen using camel hairbrush. Using the blind end of the pin, the abdomen was held down and the body contents teased out by pressing with a pin and camel hairbrush. In the female the membrane between the 7th and 8th abdominal segments was carefully separated without damaging the ductus bursae. In the male, the intersegmental membrane between the 8th and 9th abdominal segments was separated. The penis was pulled out from the valves at the posterior end. They were placed in 1% Mercurochrome then in 20% ethanol for 5mins,and dehydrated in 90% alcohol and then absolute alcohol. The dehydrated parts were finally put in euparal essence for five minutes and mounted in euparal.

### 3.6 PREPARATION OF 100ml OF ARTIFICIAL DIET.

The artificial diet used in rearing the stemborers was prepared by addition of the following ingredients.

| | |
|---|---|
| Water | 4.0ml |
| Agar | 3.5g |
| Soya flour | 6.25g |
| Maize stem powder | 3.0g |
| Sodium Chloride | 1.0g |
| Glucose | 1.15g |
| Water for agar | 40ml |
| Formaldehyde | 0.1ml |
| Acetic acid | 1.0g |
| Ascorbic acid | 2.0g |

Agar was dissolved in distilled water. It was added to 30ml of segments was separated. The penis was pulled out from the valves at the posterior end. They were placed in 1% Mercurochrome then in 20% ethanol for 5mins,and dehydrated in 90% alcohol and then absolute alcohol. The dehydrated parts were finally put in euparal essence for five minutes and mounted in euparal.

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| Glucose | 1.15g |
| Water for agar | 40ml |
| Formaldehyde | 0.1ml |
| Acetic acid | 1.0g |
| Ascorbic acid | 2.0g |

Agar was dissolved in distilled water. It was added to 30ml of boiling water and boiled for two minutes. All the other ingredients were dissolved in 50ml of water. The hot agar was added to the ingredients and stirred vigorously. It was then dispensed into plastic vials and put into the incubator for seven days at the temperature of 30 degrees. Feed was changed every week and each larva weighed with a sensitive chemical balance (Chyo MG 500).

# CHAPTER FOUR

## 4. RESULTS

### 4.1 STEMBORER SPECIES COMPOSITION AND POPULATION STRUCTURE

The species of stemborer found on maize during the period of study were; *Eldana saccharina* Walker, *Sesamia calamistis* Hampson, *Sesamia nonagrioides botanephaga* Tams and Bowden and *Chilo aleniellus* (Strand).

During the minor and major cropping seasons, the stemborers were present and their population varied with the species and the stage of the plant growth. *E saccharina* and the two *Sesamia* species were more abundant in the minor cropping season than in the major season. On the contrary *C aleniellus* was more abundant in the major cropping season than in the minor season (Figs. 5 and 6). *Sesamia* species were found infesting younger plants (pre-tasselling ) than the older plants (mature plants) while *E saccharina* and *C aleniellus* were found more on the matured plants than the younger ones (Table 1). Larvae and pupae of *C. aleniellus* and *S.n. botanephaga* species were collected from the field. The number of larvae or pupae collected per plant was dependent on the stage of the plant involved.

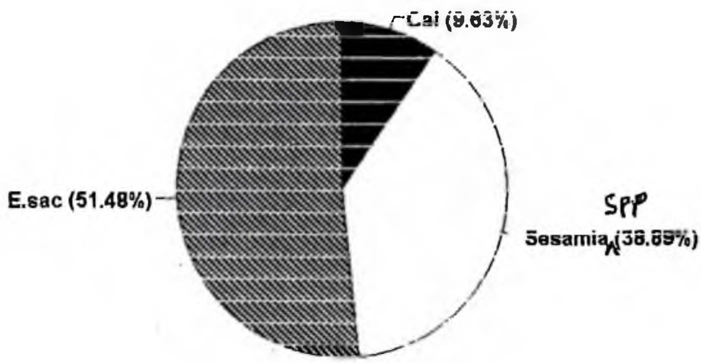


Fig 5: Relative abundance of stemborer species in the minor season

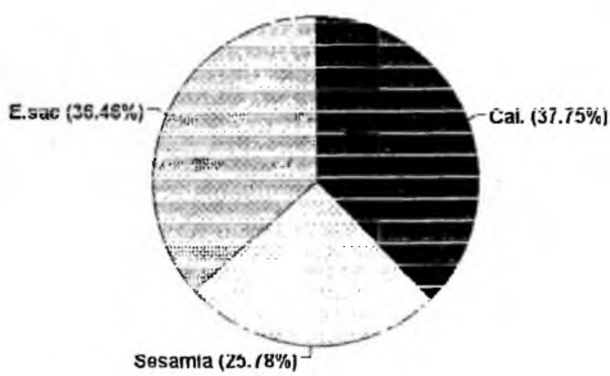


Fig 6: Relative abundance of stemborer species in the major season

**Table 1.** The relative abundance of stemborers at different stages of plant growth.

| | Mean number of larvae and pupae per plant. | | |
|---|---|---|---|
| Minor season | E.saccharina | Sesamia sp. | C.aleniellus |
| Pretasselling to stage 7 | 8.45+1.23 | 10.24+1.94 | 1.90+0.48 |
| Stage 8 and above | 11.35+2.13 | 5.14+1.74 | 2.20+0.39 |
| Major season pretasselling to stage7 | 3.93+2.31 | 8.41+2.86 | 4.35+1.98 |
| Stage8 and above | 5.03+2.6 | 3.65+0.43 | 10.73+2.64 |

## 4.2 THE LIFE CYCLE OF *SESAMIA NONAGROIDES BOTANEPHAGA*

The total developmental period of *S.n. botanephaga* from egg to adult has a mean duration of 35.2±0.28 (29-48) days (Table 2).

### 4.2.1 THE EGG STAGE

#### 4.2.1.1 Description

Eggs of *S.n. botanephaga* had a flat top and bottom measuring 0.85±0.02mm in length and 0.36±0.01mm in width. They were white when first laid but changed to pale orange as they approached hatching.

#### 4.2.1.2 Choice of Oviposition Site by *S.n. botanephaga*

In the laboratory, when adult moths were placed in the kilner jars, eggs were laid on the lid, rim and inner surface of the jars. When the jars were provided with filter paper and pieces of fresh stalks, eggs were deposited in the folds of the filter paper and leaf sheath. Those laid on the leaf sheath were neatly arranged into a long row on the inner side closer to the edge.

**Table 2.** Mean duration of the developmental stages in the life cycle of *S.n.botanephaga* at mean maximum and minimum temperatures of 32.1 + 0.2 and 22.95 + 0.6 C respectively with 78.0% mean R.H.

| Developmental stage | Duration+S.E.(days) | Range (days) |
|---|---|---|
| Egg | 4.23+0.03 | 5-10 |
| 1st instar | 2.63+0.17 | 2-4 |
| 2nd instar | 3.00+0.16 | 2-4 |
| 3rd instar | 5.20+0.21 | 3-7 |
| 4th instar | 5.36+0.21 | 4-7 |
| 5th instar | 4.00+0.34 | 2-6 |
| 6th instar | 1.70+0.13 | 1-4 |
| Prepupal stage | 2.00+0.01 | 1-3 |

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| 3rd instar | 5.20+0.21 | 3-7 |
| 4th instar | 5.36+0.21 | 4-7 |
| 5th instar | 4.00+0.34 | 2-6 |
| 6th instar | 1.70+0.13 | 1-4 |
| Prepupal stage | 2.00+0.01 | 1-3 |

In the caged potted plants, eggs were laid on the inner side of the leaf sheath of the maize plants. It was observed that more eggs (with a mean number 39.52) were laid on the pre-tasselling maize plants than on the tasselled (with number of egg 31.18) and the plants with silk (with mean number 26.29). The part of the plant most preferred by the moths for egg laying was the middle portion with a mean number of 71.0 eggs as compared to the upper and lower portions of the plant with mean numbers of 18.3 and 14.4 eggs respectively.

An analysis of variance (ANOVA) carried on the square root tranformation of the choice of oviposition site in the cage potted plants indicated no significant difference (p.>0.05)(Appendix 1). Using the Duncans Multiple Range Test (DMRT) at 0.05 and 0.01 levels, there was no significant difference between the upper and lower portions of the plant. There were significant differences between the middle portion compared with the upper and lower portions of the plant for oviposition. Therefore in the field the adult Female of S. n. botanephaga preferred laying her eggs on the middle portion of the maze plant than the upper and the lower portions.

4.2.1.3 **Fecundity and Egg Fertility**

The mean number of eggs laid per mated female was found to be 330.2±17.7 eggs and that of unmated female 268.2±9.2 eggs. This indicated that the mated females laid more eggs than the unmated females (Fig 7). The calculated t-value with 14 degree of freedom was found to be 2.011 while the tabulated t-value was 2.625. Even though the mated females laid more eggs than the unmated females, there was no significant difference in the number of egg laid by both mated and unmated females. The females (mated and unmated) began laying their eggs on the second night after emergence and laid throughout for a maximum of 5 days. Number of eggs laid per female increased from the first day reaching it peak on the third day and decreasing to the last day.

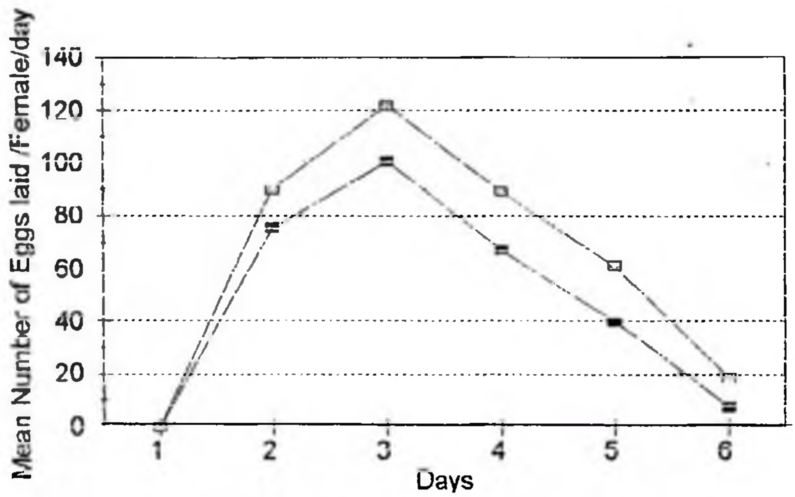



Fig 7 Variation in the mean Number of eggs laid per female per day of *S.n. botanephaga*

#### 4.2.1.4 **Incubation Period**

The numbers of eggs (laid in the laboratory and those collected from the field) observed in the laboratory was 9,872 and out of these 5,213 hatched. The mean incubation period was 5.23±0.02(5-7)days at a mean maximum and minimum temperatures of 32.3±o.5C and 27.6±o.3C respectively and a mean relative humidity of 78.4%.

### 4.2.2 **LARVAL STAGES**

#### 4.2.2.1 **Description and Development**

The larva of *S.n.botanephaga* is buff or pinkish caterpillar with more or less distinct black spots along the body representing the position of the spiracles. It has a pale ventral part. A fully-grown larva is 35.63±0.50mm long. The length and widths of different larval stages are shown in Table 3.

There were 6 larval stages. First neonate larva was very small with brown and sclerotized head. The mandibles were not well developed and the head was retracted into the pro-thorax. It had a mean length and width of 3.2±o.12mm and 1.28±o.12mm respectively.

The second instar larva is longer and larger than the first with a mean length and width of 6.09±0.05 and 1.8±0.13mm

**Table 3.** Lengths and widths of *S.n.botanephaga* at different stages reared in the laboratory.

| Stage | Length (mm) | | | | Width (mm) | | |
|---|---|---|---|---|---|---|---|
| | No. | Min. | Max. | Mean (+S.E.) | Min. | Max | Mean±SE |
| Egg | 20 | 0.75 | 1.0 | 0.85±0.02 | 0.30 | 0.4 | 0.36±0.01 |
| 1st instar | 20 | 2.1 | 4.0 | 3.26±0.12 | 0.45 | 2.1 | 1.28±0.12 |
| 2nd instar | 20 | 5.6 | 6.5 | 6.09±0.13 | 0.75 | 3.0 | 1.84±0.13 |
| 3rd instar | 20 | 12.0 | 20.0 | 16.34±0.50 | 1.60 | 5.2 | 3.21±0.22 |
| 4th instar | 20 | 20.0 | 27.0 | 23.98±0.43 | 2.80 | 7.1 | 5.03±0.27 |
| 5th instar | 20 | 30.5 | 40.8 | 35.63±0.50 | 3.90 | 7.3 | 5.63±0.25 |
| 6th instar | 20 | 23.5 | 32.8 | 27.94±0.64 | 4.20 | 8.2 | 6.19±0.24 |
| Pupa | 20 | 14.6 | 20.3 | 17.45±0.94 | 3.5 | 3.9 | 3.70±0.02 |

respectively. It had a head capsule width of 0.94±0.02mm. The head of the third instar larva is highly sclerotized and appears deep violet. It has a mean length and width of 16.37±+0.5mm and 3.2±0.2mm respectively with a mean head capsule width of 1.33±0.02mm. The marking segments are more distinct in the thirth instar than the second. The mean larval duration is 5.2±0.21(3-7) days.

The fourth instar larva is pigmented with well developed heavily scleriotized mandibles. It has an average head capsule width of 1.55±0.03mm with a mean length and width of23.9±0.4mm and 5.01±0.3mm respectively with a mean larval duration of 5.36±0.2(4-7) days.

The fifth instar is longer and larger than the fourth. It had a mean length and width of 35.6++±1.1 and 5.6±0.2mm respectively. The mean head capsule was 1.8+0.o3mm and the mean larval duration was 4.0±0.3(2-6) days.

The sixth instar larva is the largest of all the instars with a mean length of 37.3±0.1mm and a mean width of 6.23±0.02mm.The bristles are so distinct and visible to the naked eyes. The larva is very active when disturbed. It has a mean head capsule width of2.06±0.03mm. The head capsules widths of the various larval stages of *S.n. botanephaga* in the laboratory are shown on table4.

The pre-pupa is less active even when touched. It does not feed and is short and tough with a mean length and width of 27.9±0.03 and 6.1±0.2mm respectively. It has a mean duration of 2.0± 0.01 (1 - 3) days.

#### 4.2.2.2 Larval Behaviour

Laboratory observation showed that the first instar larvae of *S. n. botanephaga* do not feed much and produce very little frass. They spent most of their time moving about and exhibited a high tendency of escaping. Their mandibles were not well developed, so they could not bore into the stem. The mandibles of the second instar larvae were more developed and the presence of more frass indicated their feeding more than the first instar larvae.

**Table 4.** Mean head-capsule width of various instar stages of *Sesamia nonagroides botanephaga* in the laboratory.

| Instar Stage | Mean head capsule width ± S.E. (mm) | Growth ratio | Range (mm) |
|---|---|---|---|
| 1 | 0.35+0.009 | | 0.29-0.41 |
| 2 | 0.94+0.024 | 1.45 | 0.15-1.20 |
| 3 | 1.33+0.021 | 1.59 | 1.10-1.50 |
| 4 | 1.55+0.032 | 1.46 | 1.00-1.80 |
| 5 | 1.85+0.033 | 1.35 | 1.65-2.20 |
| 6 | 2.062+0.028 | 1.29 | 1.85-2.30 |

The third, fourth, fifth and sixth instars were usually found in the stem. They are active feeders with well-developed mouthparts feeding and producing large quantities of frass

The larvae fed with three different diets (soft maize stalk, hard maize stalk and artificial feed) showed a significant difference in weight per week (Fig 8). When an ANOVA was carried out, there was a significant difference in change in weight for the three diets with F-calculated being 21.930 and F-tabulated being 9.340 (Appendix 2). The soft and hard stem diets were compared using the t-test. There was a significant difference in weight for every two days of feed change. The calculated t-test was 3.514 and t-tabulated was 2.254 with 29 degree of freedom.

#### 4.2.2.3 **LARVAL MORTALTY**

The larval mortality of *S. n botanephaga* as observed in the laboratory varied with larval development up to the last instar. The differences in mortality at different stages of larval development were statistically significant. The highest and lowest mortalities were found to occur at the early instars (first and second instars) and the last instars (fifth and sixth instars) respectively (Fig 9).

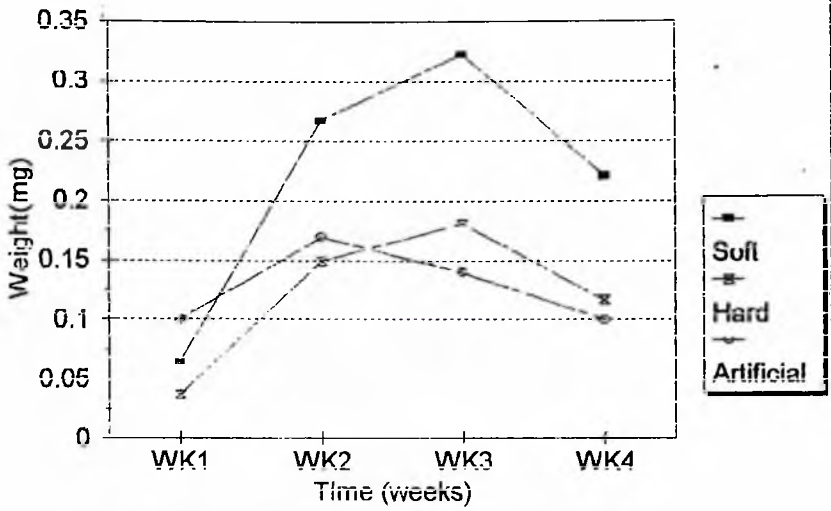



**Fig 8: Mean weight gain *S. n. botanephaga* fed with three different diet.**

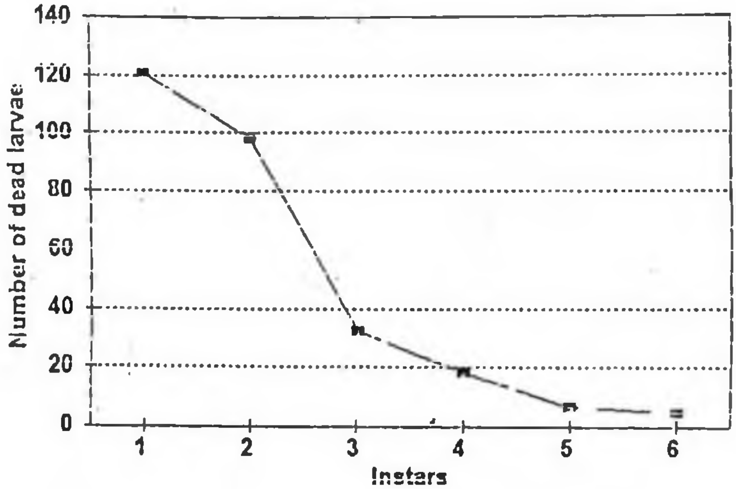



Fig. 9 Larval mortality in the Laboratory of S. n. botanephaga

Before the fifth day after hatching most of the young larvae had moulted to the second instar. They were highly vulnerable during and just after the first instar thus a high degree of mortality was observed during this period. From the twenty-sixth day, the larvae have become adapted to the environment, thus low larval mortality was observed during this period.

### 4.2.3 THE PUPAL STAGE

The newly formed pupa is pale brown and immobile but shows wiggling movement of the abdomen during sexing or when touched. It can roll on its sides as well. Usually pupation takes place in the stem. The pupae of *S.n. botanephaga* had a mean weight of 1.98±1.70g with a mean duration of 8.12±0.08(6-9) days. They had a mean length and width of 17.45±0.94mm and 3.70±0.02mm respectively. Pupal mortality under laboratory conditions was very low (1%).

### 4.2.4 ADULT *SESAMIA NONAGRIOIDES BOTANEPHAGA*

#### 4.2.4.1 Description

The head of *S. n. botanephaga* adult is light to dark brown. The prothoracic shield is light brown and the dorsal surface of the metathorax, mesothorax and the abdominal segments 1-9 is pinkish. The female and male had a mean length of 16.2±0.04 and 15.7±0.02mm respectively. Females had filiform antennae while the males had bipectinate antennae. The females (both mated and unmated) did not lay egg on the first night after emergence. Fig 10 shows the general life cycle of *S. n. botanephaga*.

#### 4.2.4.2 Adult Longevity

It was observed in the laboratory that the females lived longer than the males. The mean survival period for the males and females were 8.7±0.06(6-10)days and 9.1±0.08(7-11)days respectively. The difference between the two was statistically not significant thus both sexes had almost the same life span. It was also noted that the unmated females lived longer by 1-2 days than the mated females.

#### 4.2.4.3 Sex Ratio Of *S.n.Botanephaga*

S.n.botanephaga reared in the laboratory had a sex ratio of approximately 2:3 (176 males: 265 females). The calculated

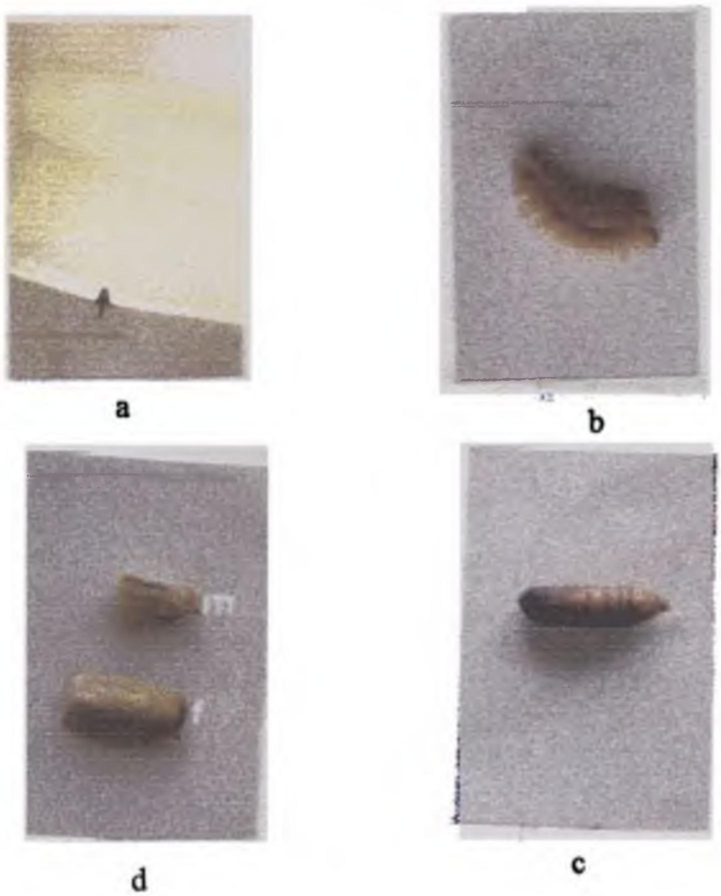



Fig. 10 Various stages in the life cycle of *S. n. botanephaga*
( a = egg [arrowed], b = larva, c = pupa, d [f]= adult female, d [m]= adult male)

chi-square (X) was 2.209 and the tabulated one was 1.847. Therefore, there was a significant difference between the number of males and females reared in the laboratory.

## 4.3 SOME ASPECTS OF THE BIOLOGY OF *CHILO ALENIELLUS*

### 4.3.1 LAVAL STAGE

#### 4.3.1.1 Description

The larva of *C. aleniellus* is slender, cylindrical and tapering at both ends. There are six ocelli surrounding a dark pigmented area on the head. The head is dark brown and the prothoracic shield is light to dark brown. The thoracic legs and the anterior part of the coxae are dark brown. The body pinaculae are numerous with different shapes and sizes, well scleriotized, prominent and dark brown giving the larva a dark spotted appearance. The head capsule widths of *C aleniellus* measured in the laboratory increases from one instar to another (Table 5).

**Table 5.** Mean head-capsule width of various instar stages of *Chilo aleniellus* in the laboratory.

| Instars | Mean head-capsule width +S.E. (mm) | Growth ratio | Range (mm) |
|---|---|---|---|
| 1 | 0.38+0.023 | | 0.20-0.60 |
| 2 | 0.91+0.021 | 1.38 | 0.60-1.20 |
| 3 | 1.13+0.042 | 1.45 | 0.85-1.45 |
| 4 | 1.41+0.031 | 1.29 | 1.10-1.80 |
| 5 | 1.68+0.036 | 1.22 | 1.30-1.90 |

#### 4.3.1.2 Larval Behaviour

The second instar larvae collected from the field during the study fed very little producing small quantities of frass because the mandibles were not well developed. The third, fourth and fifth instar larvae had well-developed mouthparts. Those that were not in diapause fed inside the stem producing large quantities of dry frass. Laboratory observations showed that *C. aleniellus* undergoes diapause in the minor season when condition are unfavourable.

The larvae collected from the field at different stages showed different behavioural pattern in the laboratory. Those that where collected at the early instars (second and third) fed and maintained their normal dark spotted colour for about 14 days before entering into diapause. But those that were already matured (fourth and fifth instars) entered diapause 7days and below after collection or pupated without entering in to diapause. The normal larva was dark spotted while the diapause larva was pale white (Fig 11). During diapause, the larvae moulted several times (up to 8 times). There were fluctuations in the weights of larvae per week with the highest and lowest weights being 121mg and 20mg respectively. The number of larvae collected each month and the number that died are presented

A

B

Fig. 11 A = Normal dark spotted larva
B = Diapausing pale white larva

on Fig 12 and 13 respectively. Larvae collected in major cropping season never entered into diapause.

#### 4.3.1.3 LARVAL MORTALITY

The larval mortality of *C aleniellus* in the laboratory varied with the month, with the highest and lowest mortality in the months of January and June respectively.

### 4.3.2 PREPUPAL AND PUPAL STAGES

The prepupa was short, tough and inactive even when disturbed. It has a mean duration of 2.4±0.06(1-3) days.

The newly formed pupa has pale-creamy colour with a dorsal ridge. It is immobile and is protected in a cocoon. Pupation takes place inside the stem. It has a mean weight of 0.081±0.009 g with a maximum and minimum length of 14.3 and 10.6mm respectively. The mean developmental period of the Pupa was 7.19±0.08 (6-8) days. It was noted that only few diapause larvae reached the pupal stage and many died in that state while few managed to reach the adult stage (Figs 14, 15 and 16).

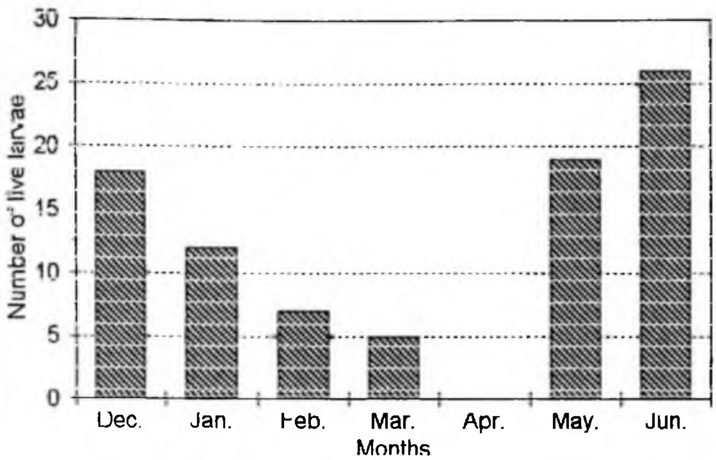



**Fig1.2 Total number of live C.al collected per month**

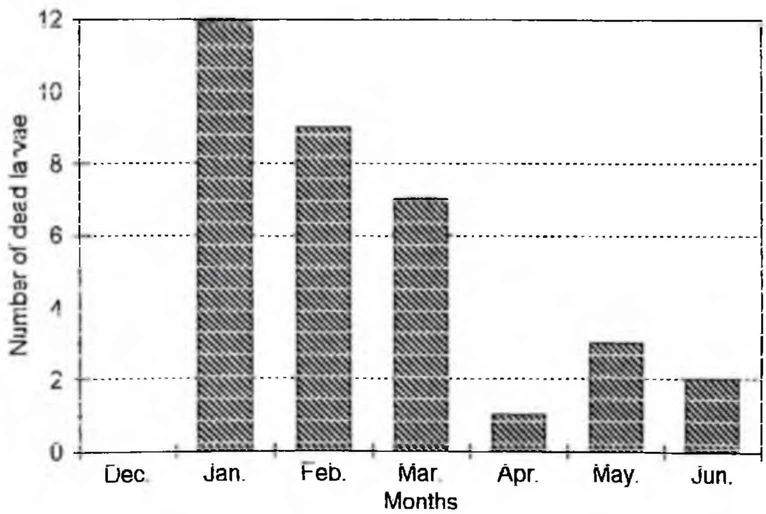



**Fig1.3 Total number of dead larvae per month**

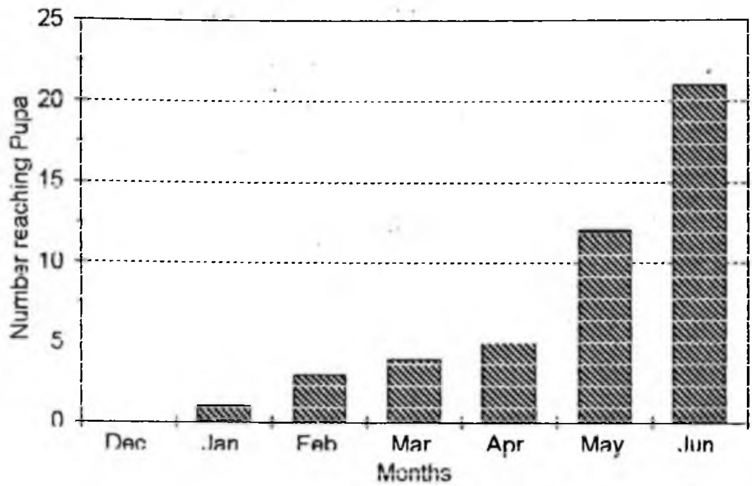



Fig14 Total number of C.al reaching Pupa per month

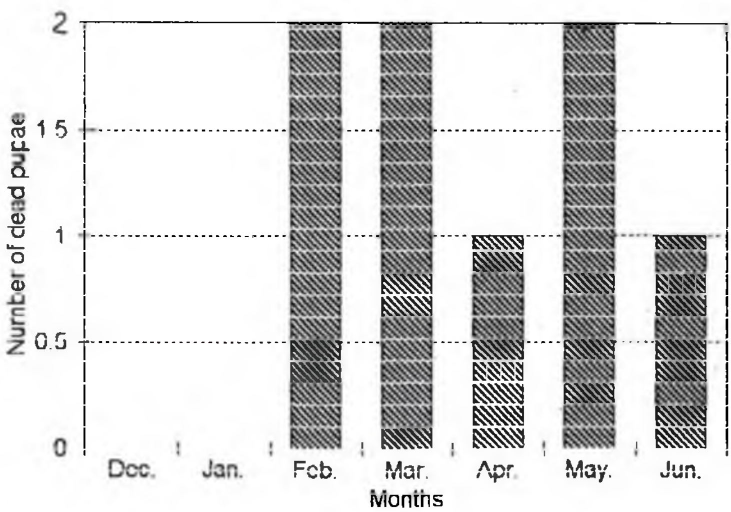



Fig15: Number of dead Pupa per Month

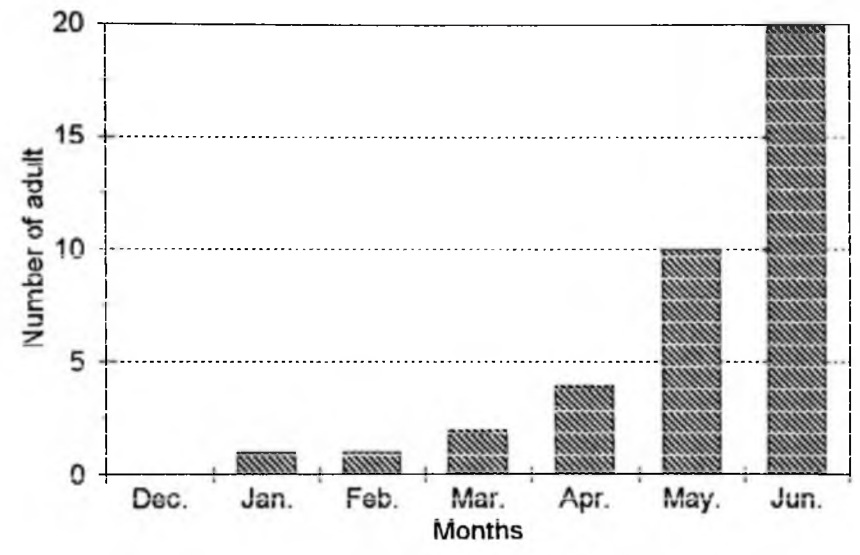



Fig. 16 Number of C. aleniellus reaching adult per month

### 4.3.3. THE ADULT

#### 4.3.3.1 Desciption

The adults of *C. aleniellus* are aggressive with pointed filliform antennae. The male and female have mean lengths from the head to the abdomen of 9.72±0.05mm and11.16±0.32mm respectively. The female appears slightly bigger and longer than the male. It is also lighter than the male. Both the male and female have filliform antennae (Fig 17). The adults in the laboratory (both paired and unpaired) did not lay egg and no mating was observed. Some pupae could not emerge completely because of the unfavourable conditions. Their heads got stocked in the pupal cases (Fig 18).

#### 4.3.3.2 Adult Longevity

A mean survival periods of 7.3±0.03(6-8)days and 7.9±0.06(6-9)days were recorded for adult male and female respectively. The difference between the means was not statistically significant. The t-calculated was 1.856 for females and the t-tabulated was 1.872 for males with 29 degree of freedom.


Fig. 17 Adult *C. aleniellus* (f = female, m = male)

A

B

Fig 18 A = A normal adult of *C. aleniellus*
B = An Abnormal adult *C. aleniellus*

#### 4.3.3.3 SEX RATIO

The sex ratio based on the number of insects reared in the laboratory was approximately 1:1(98 males: 105 females). There was no significant difference between the number of males and females. The calculated chi-square (X) was 0.348 while the tabulated X was 1.847.

## 4.4 SOME COMPARATIVE ASPECTS OF THE BEHAVIOUR OF *SESAMIA NONAGRIOIDES BOTANEPHAGA* AND *CHILO ALENIELLUS* IN THE LABORATORY AND FIELD

### 4.4.1 Laboratory Observations

During the rearing of insects in the laboratory, the feeding habits of *S.n.botanephagnd* C.*aleniellus* were observed. S.n.*botanephaga* was found to feed more and produced large quantities of frass than C.*aleniellus* (Fig 19). S.n. botanephaga was more active than C.aleniellus. Observations were made as to whether both insects undergo diapause or not and C.*aleniellus* was found to undergo diapause while *S. n. botanephaga* did not.

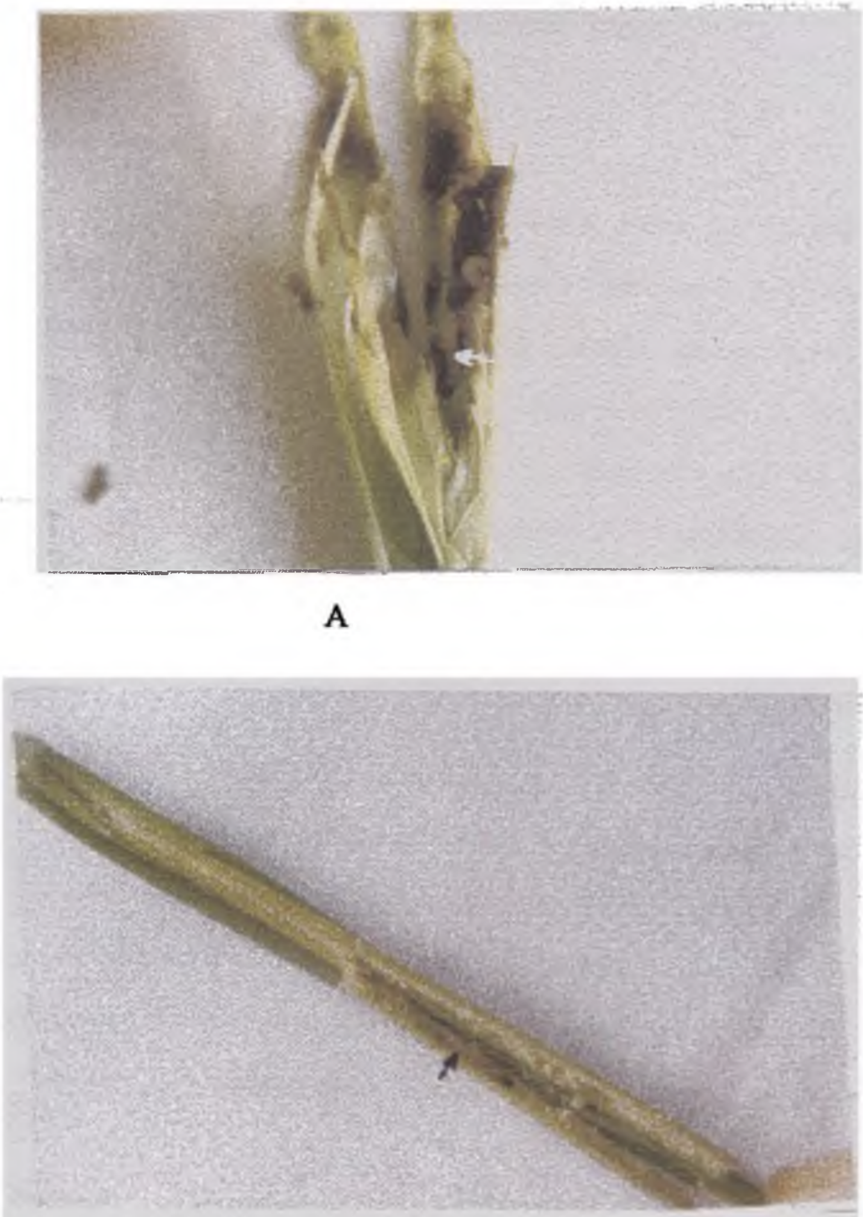
A

B

Fig. 19 The damage caused by larvae (arrowed) in the laboratory
[A = *S.n. botanephaga* larva, B = *C. aleniellus*]

### 4.4.2. **Fiield observations**

In the field, the larvae of S.n. botanephaga were aboundant in young plants while larvae of C. aleniellus were mainly found on the tassels (Fig 20).



A

B

Fig. 20 The damage caused by larvae (arrowed) in the field
[A = *S*.n. *botanephaga* larvae, B = *C. aleniellus* larva]

# CHAPTER FIVE

## 5. 0. Discussion

A lot of the work done in Ghana tend to support the fact that E. *Saccharina and* Ses*amia spp* are serious pests of maize in the Country (Aikins, 1957; Scheilelreiter, 1980; Sampson, 1982; Anon, 1985, Kwapong 1990). This clearly indicates that the presence of these insects is independent of the location. In this study E. *saccharina and* Ses*amia species* were present on the maize plant in all areas where stemborers were collected.

The most important species of stemborers found in the Central Region during the minor seasons were Eld*ana saccharina,* Ses*amia spe*cies and Chi*lo aleniellus.* It was also observed by Borkety-La (1995) that in the major season, Chi*lo aleniellus was* the most predominant stemborer species. Kwapong (1990) made similar observations.

Ses*amia species* reported in Ghana include, *Sesamia n. botanephaga* (Endrody-Younga, 1968; Leyenear and Hunter ( 1977) and S. *calamistis (S*ampson and Kumar, 1982 ). S. *n. botanephaga was* found to cause 90% of "dead heart" in all the areas where stemborers were collected. Leyenear and

Hunter (1977) also reported S. *botanephaga to* cause 63% loss in the yield of maize in the coastal savanna of Ghana.

*C. aleniellus discovered* on maize in Ghana in 1990 was found to be more predominant in the major season than minor season. Contrary to the observations made by Baidoo (1996) that *Chilo aleniellus* is completely absent in the minor season, this work shows that *C. aleniellus* is present on maize in both seasons.

The adult females of *S.n.botanephaga* ensure survival of the species by depositing a large number of eggs (330 ± 14.7) within a short period (5 days). The females do not lay eggs during the night of emergence. On the first night after emergence, mating occurs and eggs are laid from the second night to the sixth night with the third night being the peak of oviposition period. The pre oviposition period is 2 days thus, any control operation aimed at destroying the adults must be carried out within two days after emergence, otherwise it would not be effective.
Investigation on the factors influencing the developmental periods, egg production and longevity in insects have been reviewed by Johansson(1964; Davey (1965) and Engleman

(1964) . Their findings indicate that mating stimulates oviposition and affects longevity of the females. Virgin females of *Sesamia* spp and *B. fusca* laid fewer eggs and live longer than mated females (Beard, 1940; Johansson, 1942; Woodward, 1952; Khalifa, 1950; Roth and Willis, 1956; Odhiambo and Arora 1973). Observation made during this study on *S. n. botanephaga* indicated that the mated females laid more eggs per female (230 ± 14.7) than the virgin female (168 ± 12.3). The effect of mating and egg production is thought to be a mechanical stimulus which is a blood- borne factor released from the spematheca. This factor acts through the neuro secretory cells of the brain (Davey, 1968; Gordon and Loher, 1968). Spermatozoa transfer or mating is not the mating stimulus that influences egg maturation (Quo, 1959; Engelmann, 1964; Gordon and Bandal, 1967).

The eggs produced by mated females are viable while the unmated females produced eggs, which are not viable. Immediately the eggs were laid, they appear whitish. Later the viable eggs became light yellow and turn to orange. The unviable eggs appear deep yellow and shrivel after 5 days.

In the field caged potted plants 68.9% of the total number of eggs laid by *S.n. botanephaga* were deposited on the middle portion of the plants on the inner side of leaf sheath, which fit tightly onto the maize stem close to the edge. The eggs were held together and secured the substrate by a fluid, which is exuded by the female just before the actual oviposition act. In the laboratory eggs were deposited on the lid and rim of the jars. Where leaf sheath were provided, eggs were laid on the inner side of leaf sheath closer to the edge. Where pieces of folded papers on pieces of sticks were put into the jar, the eggs were deposited in the folds of the paper rolled on the stick. When folded filter paper was placed in the jar, eggs were deposited on the folds. When leaf sheath, pieces of folded paper and folded filter paper were provided in same jar, more eggs were deposited on the leaf sheath than pieces of folded paper and folded, filter paper. These observations on the oviposition of *S.n botanephaga* indicate that there is a tendency in the adult female to conceal the eggs. This also indicates that the choice of oviposition site depends on the material used. For example some chemicals emitted by the natural plant (leaf sheath) might have made the insect to deposit more eggs on a leaf sheath than the others.

Waiyaki (1971) believes that the female requires two surfaces to lay eggs. However, this present work shows that the female requires three surfaces to lay its eggs. Before the eggs are laid, the female probes the substratum with ovipositor as pointed out by Waiyaki (1971) and Girling (1978). The opposite side of the ovipositor must be in contact with two opposing sides (inner surface of a leaf sheath and the stalk and inner sides of folded paper), while the top of the ovipositor touches the third side (the surface on which the eggs are laid or deposited) then the eggs are laid touching each other and are glued to the surface. Eggs of *S.n botanephaga* are laid quite close to the edge of the leaf sheath but Kaufman (1983) observed that *S. calamistis* female lays her eggs further away from the edge of the leaf sheath. This can be used to differentiate the two species in the field. The tendency to conceal the eggs is highly adaptive and ensures safety of the eggs. This is possible because the females possess telescopic ovipositors. In the field, the tendency to lay eggs on the inner surface of the tight fitting sheath is very important for egg survival for the following reasons:

a) The chamber between the stalk and a tight fitting sheath where the eggs are located is likely to be more humid and so the eggs are free from dessication. Diurnal fluctuation in humidity in such a micro-environment may be reduced to a minimum.

b) Usua (1968) noted that at lower humidity the incubation periods for *Busseola fusca* and *Sesamia calamistis* was longer. At 40% RH, no egg of *B. Fusca* hatched while at 14.7% RH. *S. Calamistis* eggs hatched in 8 - 10 days. This delay may be due to slowing down of some moisture-depended physiological process in the egg. Wigglesworth (1956) observed that at 20°C the incubation period of the pea leaf weevil (*Sitona lineala* L) is 10.5 days at 100% RH and 21 days at 62% RH. Thus high humidity is necessary for early egg hatching.

Usua (1968) also found that the incubation period of *S. calamistis* eggs decreased with increased temperature and relative humidity. The mean incubation period of *S.n. botanephaga* as observed during this study was 5.7 ± 0.02 (5-7 days) in the laboratory with mean maximum and minimum temperature of 32.3 ± 0.5°C and 27.6 ± 0.3 °C respectively and a mean relative humidity of 78.4%. There are six larval instars, a prepupal and a pupal stage before the adult emerges. Kaufuman (1983) also observe same on *S.*

*calamistis*. This indicates that both species are of the same genus.

The young larva, which emerges after hatching, has a characteristic pale pink body and a dark head. The first instar larvae do not have well developed mouthparts but the heads are salerotized. The presence of very little frass indicates that the first instar larvae do not feed much. They spend most of the time moving about, showing a high tendency to escape. The second instars are less mobile and feed more than the first instars. The third, forth, fifth and sixth instars are very active feeders exuding large quantities of frass intermixed with silken material. In the field, the presence of such frass is an indication of Stemborer infestation. However, the quantity of frass produced is not a correct index of feeding activity because while tunnelling, the larva eats its way through the plant tissue and the plant material chewed into a pulp goes through the gut and is ejected as frass. The amount of nutrients extracted from the material in the gut of the insect depends on the physiological state of the larva. Larva produces more frass when it is boring than when it is inside the stem. Larvae migrated to adjacent plants by crawling through overlapping leaves or using the thread which they produced. This observations confirms Kaufman's (1983) reports, that larvae migrated to adjacent plants by crawling through overlapping leaves three to seven days after eclosion.

The older instar larvae (fourth, fifth and sixth) show active movements only when they are disturbed. Some days (1-3) before the last larval moult, it cuts an exit hole on the side of the tunnel usually leaving a very thin epidermis over it. It stops feeding and enters into an inactive stage (the pre-pupal stage). Then it pupates in a cocoon, which is an impermeable material that protects the pupa.

Girling (1978) noted that the newly hatched larvae spread out from the oviposition site and they can descend to lower leaves by spinning threads or sometimes blown onto neighbouring plants by the wind. Observations made in this study also indicated that, the newly hatched larvae spread out from the oviposition site to upper leaves by active crawling. They descended to the lower leaves by spinning threads or are sometimes blown into neighbouring plants. It was noted that, these newly hatched larvae spread out during the first, second and third day of hatching.

The deposition of more eggs on the middle portion of the plant, help the young first instar larvae to spread easily to other parts of the plant.

The pupa is immobile, thus can easily fall prey to natural enemies. This is however, prevented by the impermeable silken material which covers the pupa (Cocoon). The newly formed pupa is a pale, cream-colour organism. It later darkens to a dark-brown colour before emergence of adult. It can easily be distinguished from the pupa of *E. saccharina* and *C. aleniellus* by the absence of dorsal ridge and its uniform pale cream-colour without a dorsal ridge. In this study emergence of adult occurred in the day and night. According to Girling (1978) emergence of *E. saccharina* adults occurred only in the night. Occasionally it occurred during the day following very rough handling of pupa that was ready for emergence. Such adults usually had deformed wing.

Again, Girling (1978) observed mating on the night of emergence of females. During this study the adults mated on the first night after emergence and on the second night they start laying eggs. They lay continuously for about 5 days. The mated female laid maximum number of eggs on the third night after emergence and there after laid decreasing number of eggs each night up to the sixth night. Very few eggs or no egg are laid on the sixth night.

The survival periods of the adult varied from 5 10 days under different conditions. The adults of the minor lived shorter days than those of the major season. Virgin female of most insects live longer than mated females (Beard, 1940; Johnson, 1942; Woodward, 1952). In this study the unmated females of *S. n. botanephaga* lived longer than the mated females (9.88 ± 0.13 and 8.64 ± 0.17 days respectively. The unmated males also live longer than the mated males (9.5 ± 0.07 and 8.35 ± 0.07) days respectively. The differences were not significant . Therefore, the unmated and mated males and females had the same longevity.

The sex ratio based on *S. n. botanephaga* reared in the laboratory was approximately 2:3 (176 males: 265 females). The observed ratio was significantly different from 1:1. Perhaps this difference is caused by relatively high mortality of males at the larval stage.

The life cycle of *S. n. botanephaga* is completed in 38 .24 ± 0.28 (29 48) days. So long as the host plants are available, the cycle is repeated immediately the adults emerge without a resting stage.

The larva of *C. aleniellus* is slender and dark spotted. The larva of *C. aleniellus* could be distinguished from other stemborer larvae by its large brown pinacula, chaetotaxy and spotted dark colour. The second instar larvae collected from the field fed very little producing small quantities of frass. There are five larval instars. The third to fifth instars are very active feeders. Laboratory observation showed that *C. aleniellus* larva is more sluggish in the laboratory than those in the field. From 10 days or less after collected from the field, many larvae lose their body pigments (especially those in 4 and 5 instars) and became pale-white in colour. It might be due to the onset of harmattan that triggered these larvae into diapause. So *C. aleniellus* larvae enter into diapause when conditions are unfavourable. From December to April, the larvae reared in the laboratory were in diapause and did not feed. Some died with a very reduced weight between 0.021 and 0.018 g. The larvae came out of diapause in April when conditions became favourable and pupated after 5 months in diapauses. Kwapong (1990) also observed that the larvae of *C. aleniellus* could stay in diapause for six months. However all the larvae he collected died without reaching pupal stage. The larvae collected from the month of May and June went through the normal life cycle without any diapause. The larvae maintained their colour body pigment (Dark spotted) till pupation.

The pupa of *C. aleniellus* is light brown immediately it pupates but becomes darken when it is about to emerge. The larvae that pupated between the months of December and March are those that were brought from the field which have not spent up to 10 days in the laboratory and still having their original body colour (have not entered diapause). Those that manage to go through the diapause and pupated, many died without reaching the adult stage. Most of the dead pupae were the males. The diapausing larvae that pupated most of them could not come out successfully. Their body came out but the heads got stucked in the pupal case. Adult *C. aleniellus* was active and aggressive. The females are light brown but the males are darker. Both male and female had filiform antennae. The adults that emerged never mated in the laboratory. The males were inactive and died within 1 3 days. The females stayed for about seven days but laid no eggs. Even when fed with sugar solution no eggs were laid. The adults that emerged during the major season were very active and could live up to about 8 days but no eggs were laid.

In this study it was also noted that most of the diapausing larvae spinned webs and were quiet inside the maize stalk. Those that were removed from the web and placed on new stem fed just a little and formed new webs. After the formation of three webs, no web was formed and they stopped feeding even when put inside the stalk. However, most of them died before the end of March. Some of them died because of rough handling.

According to Harris (1962), the diapause lasted from 6 to 7 months but occasionally a larva will continue in diapause for more than a year. Kaufman (1983) noted that only one out of the three generations of Busseola *fusca* diapaused as full-grown larvae. In October, all the larvae were still feeding. In November 23%, became dormant and in December 100% were diapausing. It was noted that no pupation took place even when larvae were given juicy young cobs. It was also observed that only few diapausing larvae kept in the laboratory became adult, however, no mating occurred and females laid unfertilized eggs. This study also revealed that only few diapausing larvae reached adults in the laboratory and no mating took place and the female did not lay any egg even when fed with sugar solution.

Aikins (1957) pointed out that diapause in *Coniesta species* help them to survive the dry period (December to March) in maize stalks either in the larval or pupal stage and the adult emerges from May onwards. Similar observations were made on *C. aleniellus*. This was also confirmed in this study. The larvae collected in December stayed in diapause till April before they pupated.

Infestation of *Sesamia. n. botanephaga* was high during the minor season especially on the young maize plants leading to "dead heart",formation. The reason being that the minor season crop coincided with the period when S. *n. botanephaga* was at its peak. Also low rainfall and high temperatures leading to outbreaks during this period characterized the high population of sesamia in the minor season. Endrody -Younga (1968) reported that Sesamia infestation in the Ashanti Region of Ghana was negligible in the major season but very high in the minor season causing serious damage to maize crop. As a result farmers feel reluctant to plant the minor season maize. Kwapong (1990) observed that the population of *Sesamia species* decreases as the maize became older. This was also confirmed in the present study. Botchey (1984) reported low pest population during the major season. Furthermore, Sampson and Kumar (1983) suggested rainfall as a mortality factor reducing stemborer population in sugar cane. Thus rainfall is an important mortality factor of stemborers in agroecosystem.

Heavy rains in the major season could reduce the coincidence of stemborers in several ways. These may include; prevention of mating of the male and female by not coming in contact. Because of the rains other insects can hide where the eggs are laid thereby destroying or preying on them, heavy rains can wash eggs away especially in flooded areas; similarly newly hatched first instar larvae could also be washed off the maize plants during heavy rains. Jerath (1968) observed that larval density of *E. saccharina* decreased with the rains and remains at low density throughout the rainy period. Akinson (1981) also noted that the activity of mating and egg laying by adult moths could be depressed or stopped by the rains. It was also observed by Sampson and Kumar (1983) that the washig off of dispersing first instar larvae of stemborers by the rains accounted for the low density in the major season.

Furthermore, Harcourt (1966) also reported that rainfall is an important mortality factor of the first and second instars of Pieris *rape (L)* on Cabbage. Finally, Van Hins (1981) pointed out that rainfall is an important mortality factor of the early instar larvae of *Spodoptera frugiperda* on maize.

The time of planting also determines the population of stemborers. It was observed by Herzog et *al.* (1987), that maize planted between March and May are not heavily infested by stemborers as those planted from June onward. The reason for high infestation in minor season maize is that stemborers have built up their numbers before the crops reach infestation stages. They move into the late crop and cause serious damage. During the minor season, partners can easily come in contact and more eggs are protected to continue the cycle. Thus the rains could no longer perform its function as a mortality factor. Herzog et *al. (1987) also* noted that early planting of maize crop allows the majority of the plants to pass the reproductive stage before the peak pest population occurs.

The feeding activity of stemborers cause "dead heart", the hardening of the meristematic tissues a tassel breakage depending on the species involved. During this study, it was noted that all the "dead heart" was caused by *Sesamia species*. The damage was more severe in the minor season than the major cropping season with rainfall being the major mortality factor. Kwapong (1990) also observed that all the "dead heart" he found was caused by Sesamia species. However, Sampson (1982) noted that "dead heart" in sugar cane was caused by E. *saccharina*.

When the larvae of S.*n. botanephaga* were fed with different type of diet, it was noted that there was a significant difference in weight. The weight of those feed with soft stem was far higher than those that were fed hard with stalk and artificial diet. This actually confirms that S. *n. botanephga* prefered the young maize plants to the mature ones. For those that were fed with hard stalk many pupated a day before those fed with soft stalks. Girling (1978) noted that the number of instars larva depended partly on diet but in this study even though there was a significant difference in weight, there was no significant difference in the period of pupation of the larvae fed with the three different diet. The duration of the instars remained the same for those fed with the three diets.

In this study, it was also noted that 90% of tassel breakage was caused by *C. aleniellus*. Kwapong (1990) also pointed out that *C. aleniellus* was the major cause of tassel breakage in the major season.

The result of this study indicated that stemborers showed succession with the phenology of the maize crop. *Sesamia. n. botanephaga* infested the field at early plant stage (4 - 6 Weeks after emergence (WAE)). *C. aleniellus* attacks the crop when maize has tasselled (from 7 WAE) and *E. saccharina* preferred the older plants when cobs are already formed . This implies that for effective control of the stemborer complex using chemical control methods, the farmer may need a continuous application, which might be laborious or impossible. Other methods of pest control like biological, cultural and integrated pest management will be more suitable for stemborer complex control.

It was also noted during this study that more than one species of stemborer could be present on the same plant occupying different niches. *Sesamia sp.* and *Eldana saccharina* were found on the same plant but occupying different parts of the plant. However, the case was different with *C. aleniellus*. All the plants on which C.

*aleniellus was* collected were destroyed and it was found not to be associated with other species of stemboers as pointed out by Kwapong (1990) and Borketey-la (1995).

Other species of *Chilo have* been reported in different ecological zones in Ghana. Wills (1962) reported the presence of C. *Phaoesema in* Northern Ghana. Shroder, (1970), also recorded *Chilo species* in the Eastern and Volta regions where the humidity is quite low. C. *Zaccanious was* reported on sugarcane at Asutsuare by Sampson (1982). Each species may have special adaptation which enable them inhabit particular environments.

The portion of the plant occupied by stemborers could be used in their control depending on the species involved. For instance, wastage of chemical could be reduced when controlling C. *aleniellus by* applying on the upper portion of the plant because this study showed that after hatching, the first instar larvae migrate to the upper part of the plant. With Ses*amia spp* and El*dana saccharina ch*emical application should be concentrated on the mid and on the lower internodes where majority of the larvae bore into the stem. The area where the eggs are laid on the plant could also be used for control.

In studying the mating behaviour patterns of *S. n. botanephaga in* the laboratory, it was found out that the adult male moth initiated mating display and activity. This confirms the observation made by Atkinson (1980). Khasimuddin, (1978) noted that, in some moths and butterflies it was the female that initiated the courtship behaviour.

For mating to take place, the two partners must come together, as a result, the male has to display certain actions to attract the female, these included flapping of the wings, puffing out special pencil hairs at the tip of the abdomen and releasing the attractant phenomones. Virgin females that were sexually matured responded similarly by flapping their wings with circular movement round the male. Sometimes the female did not respond to the movement made by the male, this probably indicates that not all females become sexually motivated. Thus, not all the females in the environment contribute to the increase in population. Mating may occur but the female still lays infertile eggs probably because mating leading to fertilization did not take place properly or seminal fluid did not contain viable sperms. On the other hand, the male may not also respond to the call of the female for one reason or the other. For example, when the male and female C. *aleniellus* were paired, it was noted that the female made some movements when the two were put together but the male did not respond. However, this might be due to the fact that the conditions were not suitable for mating. No mating took place in the laboratory in both seasons.

With S. *n. botanephaga, it* was observed that mating pairs remained in copula for more than 30 minutes probably to make sure that the spermatophore was successfully transferred into the bursa copulatrix of the female. Girling (1978) noted that this process is very important since, one mating was sufficient to fertilize the whole egg complements in E. *saccharina*. On the basis of the total developmental time of S. *n. botanephaga* observed during this study, two generations of S. *n. botanephaga* are possible on a maturing maize plant with average life cycle of 13 weeks.

Sex ratios of both field-collected and laboratory reared S. *botanephaga* and C. *aleniellus* were approximately 2:3(male:female) and 1:1(male:female) respectively. There was a significant differences from the expected with S. *n. botanephaga*. This shows that more females were present in the system than males. On the other hand the differences were not significant from the expected with C. *alleniellus*. This shows that equal number of males and females were present in the agro ecosystem therefore, the probability of locating mating partners was high. Easy location of mating partner could also lead to rapid outbreaks.

The comparison made in the laboratory between S.n. botanephaga and C. *aleniellus* showed that C. *aleniellus* undergoes diapause during the minor season when conditions were not favourable but S. *n. botanephaga* went through it normal cycle in both minor and major cropping seasons. C. *aleniellus* absorbed the moisture in its frass as it passes through the gut thus producing dry frass. The frass of S. *n. botanephaga* was found to be very wet and according to Kaufman (1983), this is to keep its environment moist. It was also noted that S. *n. botanephaga* larvae were active feeders producing large quantities of frass while C *aleniellus* larvae were slower feeders producing small quantities of frass. The maximum weight of S. *n. botanephaga* was found to be 0.623g while the maximum of C. *aleniellus* was found to be 0.190g. The mean head capsule width of the last instar of S. *n. botanephaga* was found to be 2.062 ± 0.028 mm and that of C. *aleniellus* was 1.683

± 0.036 mm. The larvae of S. *n. botanephaga* were far larger and longer than that of C. *aleniellus.*

*The mean length of S.* n. botanephaga pupa *was 18.063* ± *0.361 mm while that of C.* aleniellus *was 14. 438* ± *0.316 mm. S.n.* botanephaga pupa *has a mean weight of 0.220* ± *0.023 g and C.* aleniellus pupa *has a mean weight of 0.081* ± *0.009 g. It was also noted during this study that the mean duration from pupa to emergence for* S.n. botanephaga and *C.* aleniellus were *9.00* ± *0.37 and 6.93* ± *0.22 days respectively.*

Male and female adult S.n. *botanephaga do* not have the same type of antennae (filiform and bipectinate respectively) while male and female C. *aleniellus have* same type of antennae (filiform). The adult S. *botanephaga light* brown for male and female but for adult of the male is darker than female C. *alleniellus.* Adults of both species do not feed on the crop. From the field observations, it was noted that S. *n. botanephaga is* more abundant on the minor season maize than C. *aleniellus.* The mean collection of larvae for S. *n. botanephaga and* C. *aleniellus on* 30 plants was found to be 10.24 ± 1.94 and 2.20 ± 0.39 respectively.

*S. n. botanephaga was* found to cause serious damage ("dead heart") more on young plants than the mature ones, *C. aleniellus was* mostly collected on maize that had already tasselled causing tassel breakage. Furthermore both species were found feeding on different parts of the plant. S. *n. botanephaga was* usually found on the lower portion of plant and C. *aleniellus on* the upper portion. In the field, S. botanephaga is a pinkish caterpillar and *C.n. aleniellus is* a dark spotted caterpillar.

# CHAPTER SIX

## 6.0 SUMMARY

Stemborers are the most important pest of maize in Ghana. During this study, *Eldana saccharina* was found to infest maize crop from eight weeks after emergence (WAE) causing extensive tunnelling, lodging and tassel breakage. This stemborer was also found to prefer the lowest internodes of the maize plant. Although it attacked the plant during the later stages of its development, the peak population was attained at the time of harvest. However, there were more of this stemborer in the minor cropping season than the major season.

*Sesamia* species was found to attack maize plant at the early stages of the plant development (from four weeks after emergence) causing "dead heart" and ultimately the death of the plant. Some plants with "dead heart" were found to have tillered but they did not tassel thus no cob was formed. *Sesamia* species were found to prefer the middle internodes of the plant. Its population was low at the time of initial infestation but got to its peak at 8 weeks after emergence.

*Sesamia nonagrioides botanephaga* was more abundant in the minor cropping season than the major season. It bred continously in both seasons without any diapause. The eggs of *S. n. botanephaga* are flat at the top and bottom measuring 0.85x0.36mm. They are laid on the inner side of the leaf sheath neatly arranged in a row closer to the edge of the leaf sheath. They were white when laid and became pale orange before hatching. A mated female was found to lay about 330 ± 17.7 egg throughout the oviposition period while the unmated female laid 268 ± 9.20 eggs. A mature *S.n. botanephaga* larva is violet on the dorsal part and light pale on the ventral side. The average weight of an adult *S.n. botanephaga* female was 0.273 ± 0.62g with the heaviest being 0.623g. The length of a mature larva was 34 ± 15mm in lenght. The early instars (first and second instars) were very active and could spread from one part of the plant to another. The older instars (third to sixth instars) were active feeders producing large quantities of frass. The pupa was enclosed in a cocoon (a protective material) and no feeding during this period.

*Chilo aleniellus* was found on maize in both the minor and major cropping seasons at the tasselling stage of the plant causing tassel breakage. *C. aleniellus* was more abundant in the major cropping season than the minor season. The population of this stemborer reached its peak two to three weeks before harvest. It was found to undergo diapause in the minor cropping season and that is probably why its population was low in the minor cropping season. *C. aleniellus* went through a normal life cycle in the major cropping season without any diapause. It entered into diapause in the minor cropping season. The onset of harmattern in the minor cropping is known to trigger the larvae into diapause. These insects stayed in diapause from the month of December to April. The normal larva of *C. aleniellus* is dark and spotted. The diapausing larva is whitish. In the major cropping season (from April to August) it maintained the dark spotted colour. In the minor cropping season (from December to March) when conditions became unfavorable, it entered into diapause, lost its body pigments and became pale white. It stayed in diapause for about 20 weeks. Studies elsewhere have shown that diapausing larvae can remain in that state for a year. The pupa of *C. aleniellus* is enclosed in a cocoon until it emerges. The adult male of *C. aleniellus* is smaller and darker than the female. They feed on juicy and decay substances.

**This work revealed that:**

*Eldana saccharina*, *Sesamia calamistis*, *Sesamia nonagrioides botanephaga* and *Chilo aleniellus* are the common maize stemborers found in the Central Region of Ghana.

The heavy rains in the major cropping season served as a mortality factor that reduced the pest population. *S.n. botanephaga* was found to cause "dead heart"(Fig.20a).

98% of *Chilo aleniellus* were collected on the tassel and were found to cause serious tassel breakage (Fig.20b).

*C. aleniellus* larvae were found not to be associated with other stemborers on the same plant as the case of *E saccharina* and *Sesamia* species.

*C. aleniellus* entered diapause in the month of December and came out of it in April when conditions became favourable

Adult *C. aleniellus* (paired and unpaired) did not lay egg in the laboratory and no mating was observed.

# CHAPTER SEVEN

## 7.0 CONCLUSION

Despite the efforts made by various researchers in Ghana on maize stemborers, a lot remain to be done for their management. More work is still needed in the Central Region where maize is the major crop.

The abundance of a particular species of stemborers at a particular time of the year depends on the climate. During this study, it was observed that *C. aleniellus* was more abundant in the major cropping season than the minor season. This observation was however, different from that of *E. saccharina* and *Sesamia* species, which were more abundant in the minor cropping season.

The low population of *S. n. botanephaga* in the major cropping season is an indication that rainfall was one of the major mortality factors. Therefore, the abundance of *C. aleniellus* in the major cropping season than minor season might be due to the fact that the prevailing conditions during this period were favourable for their growth and survival. Thus rainfall has little effect on them.

To ensure survival, stemborers lay large number of eggs concealed and protected from their natural enemies. This and other behavioural adaptations (such as diapause) make them more successful as crop pest.

Some of the common ways by which local farmers can manage stemborer populations include; cultural method of conrol such as burning of stems and stubbles left on the field after harvest. Farmers should avoid using maize stalk for the building of fence or pile stalk behind houses as a chief source of fuel. Maize should also be planted at the right time. Planting of resistant variety and the manipulation of planting date may also help to reduce stemborers population.

Because of the different infestation times of the stemborer complex noted during this work, it would be difficult for the local farmer to use chemical for their control. This would involve continuous application, which is laborious and expensive. Nevertheless, the best approach for stemborer control is integrated pest management (IPM) where several methods of control are combined to manage the pest population. Effort could also be made to mass-rear natural enemies for innundative releases.

When *S. n. botanephaga* larvae were fed with three diets in the laboratory, it was noted that there was a significant difference in the weight of the larvae with those fed with soft stalk (4-7 WAE) having the highest compared to those fed with hard stalk and artificial feed. However, it was observed that eventhough there was a significance difference in weight; the larvae fed with the three different diets (soft stalk, hard stalk and artificial diet) pupated almost at the same time. Therefore, the diets neither increased nor decreased the life cycle of *S. n. botanephaga*. Hence, these diets cannot be used as a means of quick rearing of *S. n. botanephaga* in the laboratory for experimental purposes.

Today millions of people especially in the developing countries do not have access to sufficient food to lead a healthy and productive life. Thus, there is the need to find ways of managing these stemborers properly since maize forms one of the most important staple for about 50% of the population of the developing countries. Therefore, the transparency and openness of all parties; the government, Non-governmental Organisations (NGO) and donors will be a way to accelerate the process to ensure proper management of maize stemborers keeping their populations below economic injury level. This can be done through funding of research work on stemborer management thereby, attracting many people into research. This will help to find alternative solutions to the food crisis threatening the world especially the developing countries.

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# APPENDIXES

## ANALYSIS OF VARIANCE TABLE

### Appendix 1

Choices of oviposition site in caged potted maize plant (upper-part, middle-part and lower-part of the plants)

| Sources of variation | DF | SS | MS | F-value | P-value |
|---|---|---|---|---|---|
| Treaments | 2 | 12.926 | 6.463 | 1.660 | 0.316 |
| Error | 12 | 73.121 | 6.095 | | |

### Appendix 2

Mean weight gain of *S. n. botanephaga* larvae fed with three different diets.

| Sources of variation | DF | SS | MS | F-value | P-value |
|---|---|---|---|---|---|
| Treatments | 2 | 0.058 | 0.029 | 21.918 | 0.001 |
| Error | 21 | 0.036 | 0.001 | | |

## Appendix 3: WEIGHT OF DIAPAUSING LARVAE FOR EVERY OTHER DAY

| No. of days | Number of Larvae | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 1 | 0.5 | 0.058 | 0.06 | 0.101 | 0.054 | 0.062 | 0.058 | 0.077 | 0.059 | 0.105 | 0.074 | 0.162 | 0.072 | 0.05 | 0.061 | 0.121 | 0.112 | 0.069 | 0.057 | 0.046 |
| 3 | 0.05 | 0.072 | 0.051 | 0.105 | 0.103 | 0.059 | 0.048 | 0.152 | 0.103 | 0.199 | 0.0152 | 0.121 | 0.073 | 0.045 | 0.059 | 0.052 | 0.104 | 0.074 | 0.053 | 0.048 |
| 5 | 0.052 | 0.078 | 0.05 | Pupa | 0.098 | 0.076 | 0.078 | 0.127 | 0.082 | 0.11 | 0.085 | 0.098 | 0.073 | 0.041 | 0.059 | 0.067 | 0.102 | 0.046 | 0.051 | 0.049 |
| 7 | 0.058 | 0.079 | 0.044 | 0.096 | 0.065 | 0.043 | 0.065 | 0.074 | 0.066 | 0.114 | 0.094 | 0.092 | 0.073 | 0.047 | 0.056 | 0.061 | 0.104 | 0.041 | 0.057 | 0.054 |
| 9 | 0.054 | 0.065 | 0.043 | 0.09 | 0.061 | 0.041 | 0.054 | 0.07 | 0.073 | 0.104 | 0.111 | 0.1 | 0.074 | 0.049 | 0.054 | 0.063 | 0.1 | 0.045 | 0.052 | 0.054 |
| 11 | 0.05 | 0.062 | 0.04 | 0.089 | 0.055 | 0.04 | 0.048 | 0.07 | 0.07 | 0.1 | 0.1 | 0.099 | 0.063 | 0.047 | 0.055 | 0.05 | 0.098 | 0.048 | 0.05 | 0.062 |
| 13 | 0.052 | dead | 0.039 | Emergen | 0.051 | dead | 0.05 | 0.06 | 0.071 | 0.089 | 0.098 | 0.095 | 0.063 | 0.047 | 0.054 | 0.049 | 0.095 | 0.051 | dead | 0.062 |
| 15 | 0.044 | | 0.038 | Female | dead | | 0.052 | 0.06 | 0.071 | 0.079 | 0.092 | 0.0191 | 0.05 | 0.045 | 0.052 | dead | 0.083 | 0.047 | | 0.061 |
| 17 | 0.041 | | 0.036 | | | | 0.058 | 0.06 | 0.07 | 0.095 | 0.096 | 0.09 | 0.053 | 0.044 | 0.05 | | 0.085 | 0.045 | | 0.063 |
| 19 | dead | | 0.035 | | | | 0.058 | 0.056 | 0.068 | 0.093 | 0.099 | 0.086 | 0.055 | 0.041 | 0.045 | | 0.092 | 0.043 | | 0.055 |
| 21 | | | 0.033 | | | | 0.06 | 0.055 | 0.069 | 0.087 | 0.099 | 0.084 | 0.043 | 0.043 | 0.045 | | 0.091 | 0.05 | | 0.05 |
| 23 | | | 0.031 | | | | 0.064 | 0.05 | 0.067 | 0.085 | 0.09 | 0.08 | 0.045 | 0.046 | dead | | 0.083 | 0.045 | | 0.049 |
| 25 | | | dead | | | | 0.065 | 0.049 | 0.066 | 0.08 | 0.089 | 0.079 | 0.042 | 0.046 | 0.042 | | 0.081 | 0.043 | | 0.046 |
| 27 | | | | | | | 0.062 | 0.040 | 0.064 | 0.075 | 0.084 | 0.08 | 0.04 | 0.035 | 0.04 | | 0.084 | 0.045 | | 0.041 |
| 29 | | | | | | | 0.058 | 0.046 | 0.065 | 0.085 | 0.09 | 0.082 | 0.033 | 0.034 | 0.039 | | 0.08 | 0.041 | | 0.036 |
| 31 | | | | | | | 0.056 | 0.04 | 0.065 | 0.08 | 0.092 | 0.081 | 0.035 | 0.033 | Emergence | | 0.091 | 0.041 | | 0.032 |
| 33 | | | | | | | 0.045 | 0.04 | 0.07 | 0.08 | 0.094 | 0.069 | 0.035 | 0.031 | | | 0.089 | 0.043 | | 0.043 |
| 35 | | | | | | | 0.068 | 0.04 | 0.073 | Pupa | 0.091 | 0.067 | dead | 0.03 | | | 0.084 | 0.046 | | 0.039 |
| 37 | | | | | | | 0.069 | 0.038 | 0.076 | 0.079 | 0.072 | 0.067 | | 0.026 | | | 0.08 | 0.047 | | 0.037 |
| 39 | | | | | | | 0.06 | 0.037 | Pupa | 0.079 | 0.072 | 0.077 | | 0.024 | | | 0.08 | dead | | 0.036 |
| 41 | | | | | | | 0.069 | 0.037 | 0.068 | 0.078 | 0.064 | 0.065 | | 0.021 | | | 0.076 | | | 0.03 |
| 43 | | | | | | | 0.069 | 0.032 | 0.06 | 0.076 | 0.061 | Pupa | | 0.021 | | | 0.067 | | | 0.034 |
| 45 | | | | | | | 0.069 | 0.03 | 0.06 | Emergen | 0.053 | 0.059 | | dead | | | 0.058 | | | 0.029 |
| 47 | | | | | | | 0.072 | 0.03 | dead | | 0.062 | 0.057 | | | | | 0.071 | | | dead |
| 49 | | | | | | | 0.06 | dead | | Female | 0.035 | 0.056 | | | | | 0.074 | | | |
| 51 | | | | | | | 0.059 | | | | 0.043 | Emergence | | | | | 0.059 | | | |
| 53 | | | | | | | 0.05 | | | | 0.033 | | | | | | 0.058 | | | |
| 55 | | | | | | | 0.048 | | | | 0.0331 | | | | | | 0.035 | | | |
| 57 | | | | | | | 0.047 | | | | | | | | | | 0.055 | | | |
| 59 | | | | | | | Emergence | | | | | | | | | | 0.056 | | | |