INSECT PESTS OF SWEET BERRY (*Richardella dulcifica*) (Schumach and Thonn) Baehni IN GHANA

BY

FRANCIS ATUAHENE-MENSAH

NOVEMBER, 2013.

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI, GHANA

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF CROP AND SOIL SCIENCES

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M. SC. CROP PROTECTION (ENTOMOLOGY)

NOVEMBER, 2013.

DECLARATION

I, hereby declare that this thesis "Insect pests of sweet berry (*Richardella dulcifica*) (Schumach and Thonn) Baehni in Ghana" herein presented for a degree of Master of Science Crop Protection (Entomology) is the result of my own investigations. References to other authors have been duly acknowledged.

Francis Atuahene-Mensah …… ……..

(Student: PG4239310) Signature Date

Dr. E. A. Osekre …….. …….

(Supervisor) Signature Date

Dr. Charles Kwoseh …….. …...……

(Head of Department) Signature Date

ABSTRACT

A study on sweet berries was conducted in three towns representing three regions in Ghana; Nsawam (Eastern region), Kpando (Volta region) and Agona-Wiamoase (Ashanti region) from November, 2010 to June 2012 to (i) determine sweet berry farmers' perspectives about sweet berry production in Ghana; (ii) identify important insect pests of sweet berry, *Richardella dulcifica* (Schumach and Thonn) Baehni and the damage they cause and (iii) identify their management strategies. A majority (67 %) of sweet berry farmers aged over 40 years and 70 % were males. Similarly, majority of them have had at least basic education. All the farmers relied on cultural practices to manage the insect pests of the crop. Seventeen insects' species belonging to five orders were recorded in all the regions with 15 being pests. Diptera, Lepidoptera, Orthoptera, Hymenoptera and Blattodea were collected. Ten insect pests belonging to the order, Lepidoptera, caused different types of damage to the berries with *Catopsilia frorella* Fab. (Lepidoptera: Pieridae) being the most common pest. About 55 % of the damage on berries was caused by *Ceratitis punctata* Wiedemann (Diptera: Tephritidae) which makes it the most important insect pest of the crop in Ghana. All the pests species recorded occurred during all the phenological stages of the plant except *C. punctata* which occurred during only the ripening stage of the berries. Most of the pests attacked the plant in the morning and late afternoon with the berries and leaves being the parts mostly attacked. Six types of damage were recorded with ovipositional punctures being the most common. Cultural and chemical control strategies can be integrated to manage the insect pests.

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CHAPTER ONE

1.0 INTRODUCTION

It is common knowledge that fruits are man's oldest food and provide other potential benefits (Kochhar, 1986). Fruits are very important in the tropics due to their carbohydrates and vitamins contribution to diets. Most fruits contain large quantities of sugar and are high in vitamins A, C and B-complex, which are not abundant in foods of most areas of Africa (Rice *et al.*, 1993).

Sweet berry, *Richardella dulcifica* (Schumach and Thonn) Baehni was first brought to the attention of Europeans in 1725 by a French adventurer, Des Marchais (Holloway *et al.*, 1996). Traditionally, the fruits (berries) have been used in local cultures for centuries to improve the palatability of sour foods and drinks such as fermented palm wine, pito, kenkey, etc.

Scientific and commercial interest in miracle fruits was re-awakened in the nineteen seventies as a result of a study released by the US Department of Agriculture on tropical plants with unusual taste properties and the survey drew attention to a number of sweet-tasting plants including miracle fruits (Holloway *et al.*, 1996).

There are no artificial sweeteners proven absolutely safe, although, they are approved by the Food and Drug Administration (FDA) and sweet berry which is a natural sweetener is hardly to be considered as food with ill effects.

It can be stated that miracle fruit is a promising economically important plant, which is attracting interest on both the domestic and international markets.

Based on encouraging results obtained from market studies on the commercialization of sweet berries for export, the Ghana Export Promotion Council (GEPC) in collaboration with Agricultural Development Bank (ADB) recently adopted its cultivation and planned to support the establishment of a commercial plant in the country to produce Miraculin (sweet proteins or taste-masking properties of the berries) for export to the US, Japan and other countries. The project is reported to have received considerable interest from a number of major Pacific Rim Companies including Mitsubishi Oil Company and Hasegawa and Kyowa Hakko all of Japan (BRI-Ghana Ltd., 2009). The project will benefit the agriculture, manufacturing and non-traditional export sectors of Ghana's economy and will generate increased earnings of farmers and provide substantial employment opportunities in the rural areas.

Holloway *et al.* (1996) projected that, about 50,000 tonnes of the fruits would be produced in the next two decades to meet the expected export market. These projections indicated that miracle fruit cultivation would increase significantly over the next few years to levels comparable to major export crops such as cocoa and coffee.

However, the delights of these taste-altering berries have been slow to reach the rest of the world for a number of reasons. The most important being insect pests attacks which have been very difficult to manage due to the fact that, very little information is available on these insect pests.

Information gathered on these would go a long way to help formulate appropriate management strategies for these insect pests to enhance the production as well as the export potential of the berries.

It is against this background that this work was undertaken to identify the important insect pests that attack sweet berry, their seasonal occurrence and identification of management options.

The main objective of this study was to identify important insect pests of sweet berry and to identify their management strategies.

The specific objectives were to:

i. determine sweet berry farmers' perspectives about sweet berry production in Ghana,
ii. identify important insect pests of sweet berry,
iii. determine the seasonal occurrence of the insect pests,
iv. determine the injury (damage) they cause, and
v. identify management strategies against the pests.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Description of sweet berry

Sweet berry, *Richardella dulcifica* (Schumach and Thonn) Baehni, also known as miracle fruit, was formally classified as *Synsepalum dulcificum* (Daniell). It belongs to the botanical family of Sapotaceae (Holloway *et al.*, 1996). Miracle fruits are well–known throughout Ghana by various local names including: Asaa or Asawa (Akan); Taami (Ga) and Ledidi (Ewe). Traditionally, the fruits are used to sweeten sour foods and drinks.

The miracle fruit plant is a perennial shrub growing up to 1.5 to 2 m in height. The leaves form dense foliage clustered around the tip of the branches. The plants flower and bear fruits twice a year following the rainy seasons from February to June and September to December. The fruits are borne individually surrounded by a cluster of leaves and develop into a bright-red oblong shaped berry about 2 cm in length. The active ingredient, Miraculin is contained in the thin layer of pulp surrounding the large olive-seed. The entire fruit is encased in a red outer skin (Holloway *et al.*, 1996).

The crop has a gestation period of two years but a longer gestation period lasting three to five years may occur under less favourable conditions of soil, moisture and temperature (Holloway *et al.*, 1996). The fruits begin to ripen within five to eight weeks after pollination. However, the ripe fruits last about four days on the tree (Holloway *et al.*, 1996).

The plant was first brought to the attention of Europeans in 1725 by a French adventurer, Des Marchais and subsequently in 1852, a British naturalist; F. W. Daniell succinctly described the properties of miracle fruits in a report to the British Pharmaceutical Journal as follows:

"Among the remarkable productions furnished by the vegetable kingdom in tropical Africa is one which, from the peculiar properties it possesses, has gained a celebrity now permanently established. European voyagers and traders who first experienced the singular effects of this fruit upon the palate were doubtless greatly astonished at what , to them, must have appeared an extraordinary power whose potency for a certain length of time could change the flavor of the most acids substances into a delicious sweetness, and on this account unanimously conferred upon it the characteristic title of the 'Miraculous Berry', which it has retained and by which it has since been appropriately distinguished'' (Holloway *et al.*, 1996).

Photographs of mature sweet berry plant and berries are shown in Plates 1 and 2 (www.miraclefruitusa.com).

Plate 1: A mature sweet berry plant showing branches with dense clusters of leaves.

Plate 2: A mature sweet berry plant bearing bright red berries.

2.2 Geographical distribution

Sweet berries are native to West Africa covering wide belts which include, Serria Leone, Ivory Coast, Ghana, Togo, Nigeria, Cameroon, Gabon and Zaire (Holloway *et al.*, 1996). In Ghana, the plant is found throughout the savannah to the fringes of the forest zone. It grows particularly well in river banks, notably along the Volta River and its tributaries. Large populations have been sighted in the Aburi-Akwapim ridge, Nsawam, Bunso, Asamankese, Kibi, Esuasu, Anum,

Mpraeso, Puru River bed, all of Eastern Region; Komenda in the Central Region; Kpando, Nkunya and Worawora in the Volta Region and Afram Mankrong and Ankasa in the Western Region (Holloway *et al.*, 1996).

The plants are known to be grown as a sole crop in these regions. Besides, there are a few plants which grow in the Brong-Ahafo and Ashanti regions in Ghana where they are grown among many other crops (mixed cropping) (BRI-Ghana Ltd., 2009).

2.3 Crop husbandry

Considerable research on the agronomic conditions of growth of sweet berries was conducted at the Plant Genetic Resources Research Institute of the Council for Scientific and Industrial Research (CSIR-PGRRI) at Bunso by Henry Holloway during the sixties and early seventies, providing a large body of knowledge and experience for the current efforts of commercial cultivation (Holloway *et al.*, 1996).

Sweet berries prefer to grow in wet lithosol soils and alluvial deposits found in river basins as well as swamps and marsh lands around lakes and lagoons. The plants are moisture-loving and the roots grow deep in moist, well-aerated soils (Holloway *et al.*, 1996).

Nurseries for seedling development are sited preferably close to streams or dams for adequate water supply. Seeds, obtained from actively growing trees are depulped and dried in air for about three to seven days. The seeds are sown in polyethylene bags filled with good quality top-soil. The seeds germinate in two to three weeks. The plants are allowed to grow under nursery care

for about six months, reaching 0.25 to 0.35 m tall before transplanted into the field. Plantain and cocoyam trees may also be planted to give temporary shading to the seedlings. The seedlings are planted with spacing of about 2 m x 2 m. It is possible to plant 300 to 700 trees per acre (Holloway *et al.*, 1996).

Standing water promotes root rot, which eventually kills the plants. Closer planting improves moisture retention and promote rapid growth of the seedlings which minimize weed control. With closer spacing, the roots grow deep into the soil rather than spread out. The plants can reach 1.5 to 2 m in height when mature. Sweet berry plants do not require pruning. The plant can produce between 800 to 3000 fruits equivalent to 1.0 to 1.5 tons per acre (Holloway *et al.*, 1996).

2.4 Production projections on sweet berry

Sweet berry is basically known as a wild plant with a few plants maintained in home gardens, farm dwellings and even graveyards. However, it is now becoming popular with plans to cultivate it on commercial basis. Recently, a Ghanaian biotechnology company, Bio-Resource Institute Ghana Ltd., (BRI) and many farmers began a concerted effort to commercialize sweet berries for export to international markets because of the economic benefits associated with the crop.

BRI has done extensive studies on similar sweetener products to generate a strategic plan for business development of the market for Miraculin. This strategy involves a three-stage plan for Miraculin production to meet an expanding market development programme spread over a fifteen-year period (Holloway *et al.*, 1996).

Phase I will require about 120 tons of sweet berries per year to produce Miraculin. Demand in Phase II is expected to reach 25,000 tons of sweet berries over a five-year period, building up to Phase III with requirements of 50,000 tons of sweet berries to support full market expansion. Total acreage required for cultivation of sweet berries is expected to reach 50,000 acres (Holloway *et al.,* 1996).

These projections indicate that sweet berry cultivation will grow in scale and significance over the next few years to levels comparable to major export crops such as cocoa and coffee. BRI will establish long-term purchasing agreements with major suppliers of sweet berries to meet Miraculin production targets. Prices are expected to be determined by market forces. However, current prices indicate that, sweet berries will assure far greater returns to farmers than existing cash crops (Holloway *et al.,* 1996).

2.5 Uses of sweet berry

Sweet berries have been used in local cultures for centuries to improve the palatability of sour foods and drinks such as kenkey, palm wine and pito. F.W. Daniell made the following observations in 1852 on the local uses of sweet berries: *"The purposes for which the natives of the Gold Coast usually reserve them are but few, the principal consisting in rendering their stale and acidulated kankies more palatable, and in bestowing sweetness on sour palm wine and pitto. In Akrah this is the more necessary from the circumstances that few or no palm trees flourish in its vicinity, and hence the wine has to be conveyed a considerable distance inland from Aquapim, and from the time occupied in transmission, the acetous fermentation has frequently commenced*

before its arrival, to remove which the previous employment of these berries is considered indispensable" (Holloway *et el.,* 1996).

Local uses for sweet berry as a sweetening and flavouring agent in food and beverages continue in the rural as well as urban communities especially among those who cannot afford more expensive foreign substitutes. This long history of use by man is strong affirmation of the safety and non-toxic nature of the berries (Holloway *et al.,* 1996).

Over the past 20 years several interesting applications and food formulations based on Miraculin have been developed. There are several major potential applications of Miraculin that have been published in the scientific and patent literature. These applications include improving palatability of citrus fruit juices derived from lemon, lime and grapefruits which are normally acidic to taste (Holloway *et al.,* 1996).

Fermented beverages such as wines, vinegar and cider provide another natural extension of applications. A Japanese patent has been issued using Miraculin to enhance the taste of vinegar. Another related category is carbonated beverages comprising a large diversified market including tonics and sodas. Miraculin can also be used to moderate the sour taste of dairy products such as yoghurt, ice cream, cheeses and milk. Miraculin will impart low-calorie sweetening effects to confectionery, candies, chewing gums and chocolates (Holloway *et al.,* 1996).

Miraculin can be offered as a table-top spice and seasoning agent for adding flavour and masking sour taste of fresh fruits, vegetable and salads. Miraculin may also be used as a condiment in serving leafy foods such as cabbages, spinach, collard greens as well as eggplant, squash and green beans. Masking the taste of unsavory medicines offers another vital market niche for Miraculin as a pharmaceutical ingredient. These applications include sweetening syrups, flavouring tablet formulations and coating pills. Flavouring pet foods and supplementing animal feed and fodder also present new dimensions of market opportunities. More exotic applications include flavouring toothpaste, lipgloss and lipstick as well as coating the filter tips of cigarettes. A US patent has been issued for a method of applying Miraculin to the mouthpiece of beverage straws to condition the palate for all sorts of drinks (Holloway *et al.*, 1996).

It is clear from the diverse range of applications that Miraculin has become a highly versatile taste-masking and sweetening agent, flavour enhancer, condiment, appetizer, food, pharmaceutical as well as cosmetic ingredient.

2.6 Export volume of sweet berry

Scientists at Bio-Resource International in collaboration with Pharmacia Biotech which is a worldwide leader in protein purification technologies based in Sweden have developed a proprietary procedure in Ghana for processing sweet berries and producing purified Miraculin to a stable form for export to other parts of the world.

Recently, a sizeable tonnage of samples of berries and Miraculin were exported to the industrialized countries including a number of major pacific rim companies in Japan (Mitsubishi Oil Company, Hasegawa and Kyowa Hakko) which fetched around $ 40 per kg and the current gate price for the berries is GH ¢ 15.00 per kg (BRI-Ghana Ltd., 2009).

2.7 Insect pests' species associated with other related berries and how they are managed

One major constraint to food crop production in the tropics is the attack by different types of pests, particularly, insects which cause considerable losses in the field (Obeng-Ofori *et al.*, 2007). Insect pests that attack berries inflict severe losses to berry farmers by reducing yield, reducing quality and killing the plant. The most damaging insect pests are those which attack the leaves (including the buds), destroying the fruits or threaten survival of the plants (Meyer and Cline, 1997).

Worldwide, the most important insect pests associated with sweet berry and other related berries' productions are fruit feeders and defoliators which cause stress and injury of the plant (Charmayne, 2010). Several insect pests are documented to be associated with blueberry, strawberry and raspberry in the temperate region.

For blueberry alone, more than 300 insect species have been reported on it, but only 20 to 25 ever become abundant enough to cause economic losses and only five or six of these are chronic problems that require control every year (Meyer and Cline, 1997). Some of these documented

pests species in the temperate zones include; Ants, Aphids, Leafhoppers, Japanese beetle and Cercropia moth etc. (Liette *et al.*, 2013).

Cultural and chemical methods are the management options adopted by the farmers to suppress the species. The cultural measures involved in the management include, proper farm sanitation through the clearing of weeds and bushes on and around the farm margins in order to destroy the hiding places and expose the pests to unfavourable conditions or to kill them. Regular cultivation of the soil to kill insects that pupate under the dead leaves or near the soil surface as well as placement of yellow sticky traps on the farm to manage some of the pests species (e.g. leafhoppers) is a common management strategy. Prompt harvesting is carried out to prevent attacks by pests' species.

Pesticides with lower toxicity are adopted by farmers against the pests. Application of a high petroleum oil or dormant oil as an insecticide to manage scale insects and other pests is common. Chemical agents such as Malathion and Guthion are also applied against the pests to suppress their population. Besides, Diazinon is used to manage ants by drenching the mounds with a dilute solution (Meyer and Cline, 2007).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area

The study was conducted from November, 2010 to June, 2012 in Nsawam (Eastern region), Kpando (Volta region) and Agona-Wiamoase (Ashanti region).

Nsawam

This area lies within latitudes 5° 45°N to 6° 30°N and longitudes 0° 00°W to 1° 00°W. It covers area of about 7414 km^2. The Eastern Region is on the north by Brong-Ahafo region, south by Central region, west by Ashanti region and east by Volta region and South-east by Greater Accra region. Nsawam lies within the wet semi-equatorial climatic zone, characterized by two rainfall maxima, followed by a prolonged dry season. The first rainy season is from May to June with the heaviest rainfall in June and the second rainy season is from September to October. The annual mean rainfall is between 1,500 and 2,150 mm. The mean annual temperature is 26 °C with relative humidity of 67 %. The main vegetation zone and the soil type are moist semi-deciduous forest and lithosol, respectively and the indigenous population is Ga (Akuapem-South Municipal Assembly, 2006).

Kpando

This area lies within latitudes 6° 20°N and 7° 0.5°N and longitudes 0° 17°E. It shares boundaries with Biakoye District in the North, Hohoe District to the East and the newly created South Dayi District in the south. The Volta Lake which stretches over 80 km of the costal line, demarcates the Western boundary. The area covers a total land area of 820 km^2 representing 4.5 % of the Volta Region with almost 30 % of the land being submerged by the Volta Lake.

The mean annual temperature is about 27 °C whereas the daily mean ranges from 22 °C to 33 °C. The town falls within the tropical zone and it is generally influenced by the South West Monsoons wind from the South Atlantic Ocean and the dry Hammattan winds from the Sahara. The months of February and March are generally the hottest while July and August are relatively cooler. The average relative humidity is 80 % and average annual rainfall ranges from 900 mm to 1,300 mm with considerable variations with the time of onset, duration and intensity over the years. The double maxima rainfall pattern experienced (i.e. the major rainy season occurs from mid-April to early July and the minor from September to November) in Kpando puts the town at comparative advantage in food production and food security. The main vegetation zone is characterized by a mix of guinea savannah woodland and semi-deciduous forest with indigenous population of Ewe (Kpando Municipal Assembly, 2006).

Agona-Wiamoase

This town is located in the North Central part of Ashanti Region. It shares boundaries with five districts, namely, Ejura-Sekyedumase to the North, Sekyere west to the East, Sekyere East and Kwabre to the South and Offinso to the West. The climate of the area is equatorial and it has a double rainfall maxima regime with the major rainy season occurring between March and July and the minor rainfall season also occurs between September and November. The mean annual rainfall ranges between 855 mm and 1,500 mm and average number of rainy days for the year is between 110 and 120 days. The months, December to March are usually dry and characterized by high temperatures and early morning moist/fog and cold weather conditions.

Temperatures are generally high throughout the year with mean monthly temperature of about 27 °C. Humidity is high during the rainy season and the months of December to February, however,

record very low humidity. It must be stressed however that, current trends in the climatic conditions of this area (Agona-Wiamoase) is becoming unpredictable. The main vegetation zone and soil type are rainforest and voltaian; the indigenous population is Akan (Sekyere-South District Assembly, 2006).

3.2 Sources of data

3.2.1 Collection of socio-economic data on sweet berry farmers

Structured questionnaires were administered to 10 sweet berry farmers in each area (region) to gather information on their socio-economic characteristics including their perspectives on the production of the crop. A sample of the questionnaire is in the Appendix.

The socio-economic data captured included gender, age and educational level attained by the farmers which were obtained using one-on-one interview.

3.2.2 Sampling of insect pests associated with fruits' damage, defoliation, root and stem damage

- **Field procedures**

Detailed field work was conducted on one of the farmers' farm selected from each region. Each selected farm was divided into five sections, taken into consideration areas with poor stands, obvious topographical variations in the field and varietal growth differences. Ten sweet berry plants were then selected from each section and tagged for field studies. For each day, two of the five sampling techniques described below were employed to sample insect species between 0600 and 1800 h in each selected farm.

Fruit fly trap ('Blue band' tub trap)

Following the procedure of HYGROTECH EAST AFRICA LTD. – KENYA, 10 traps were produced from 'blue band' plastic containers. Four holes were evenly punctured on their sides, the lids, the wire hangers and the baits baskets. The traps were filled with baits (waste brewers' yeast) and hanged on the sweet berry plants about 1 m above the ground in the upwind part of the canopy. The traps were hanged such that, leaves would not touch them. The traps were hanged 10 to 20 m apart and left on the farms for seven days and monitored daily. The sampling was done during the day, during the ripening stage of two consecutive seasons (i.e. June, for minor season and late November to December, for major season). Insects collected were gently removed and further observed in the laboratory.

Sweep netting sampling

Generally, arboreal insect species associated with the sweet berry plants were sampled using a sweep net (30 cm diameter). The insect species were critically observed to identify the damage they cause. The insects captured were transferred into a killing jar containing cotton wool dipped into ethanol for some few minutes to kill them. These were transported to the laboratory for further processing and identification.

Aspirator sampling

Adult insect species on the tagged plants, including those fluttering around the tagged berries and those hiding or resting in between the shade of the canopy levels (i.e. upper, middle and lower canopies) were collected with hand aspirator and transferred into air-tight vials containing 70 % ethyl alcohol. Prior to the capturing, the activities of these insect species that visited the plants were noted. Samples also were sent to the laboratory for processing and identification.

Pan trap sampling

Following a protocol described by Potts (2005), pan traps were made, where plastics containers of three different colours (yellow, blue and white) measuring 25 cm in diameter were obtained. They were filled with Omo (detergent) solution about 3/4 full and placed at distances of 10 m apart in the open space devoid of the canopy of the crop. Regular daily field monitoring was carried out and the trapped insect species were sent to laboratory for further processing and identification. Daily monitoring of the insects was done to record their activities including damage they cause to the plant.

Grease-banded sampling

A further sampling was undertaken in the selected farms to determine activities of ants and other crawling insect species associated with the plant. Twenty-five sweet berry plants were randomly selected and tagged, five from each section of the farm. The trunks were banded with grease about 30 cm from the ground to prevent the crawling insects from climbing up to the stems, berries and leaves. Another set of 25 plants were not grease-banded to serve as control. These were monitored and observed for four days and insect species which stuck to the grease were collected and transported to laboratory for further processing and identification.

The various sampling techniques were put in place to ensure that as much as possible all the various insect species visiting a sweet berry plantation or farm were sampled. In order not to record unbiased data, each week was devoted to a selected farm but the sequence was varied.

3.2.3 Identification of insects' species

Insects species captured were identified using the morphological characteristics of the species and were stored temporarily in insects' tray boxes or vials containing 70 % ethyl alcohol. Insects that could not be immediately identified were coded and sent to the Zoology Department of the University of Ghana for identification. Due to taxonomic difficulties, the identification of *Achaea* spp. was limited to the genus.

3.2.4 Estimation of number of eggs laid by *Ceratitis punctata* on a fruit in sweet berry plantation

One hundred infested berries (i.e. fruits with ovipositional punctures) were randomly collected from the tagged plants from each section of the farm as described in the field procedures. The infested berries were cut opened and the larvae (eggs) in each were counted to record the total number of eggs that have been laid in the 100 berries collected from the field. This was used to estimate the mean number of eggs of the insect pest, *C. punctata*. This was verified with the number of ovipositional punctures made on each berry.

3.2.5 Culturing of the larvae of Tephritid fruit fly, *Ceratitis punctata*

A sterilized petri dish (34 mm diameter) with a lid and a moist filter paper inside was obtained. Two fresh berries with ovipositional punctures were then placed on the filter paper and covered. Ten of such set-ups were kept under ambient conditions, undisturbed, at the Entomology Laboratory in the Faculty of Agriculture of the Kwame Nkrumah University of Science and

Technology, Ghana. The set-ups were closely monitored to follow the life cycle of the insect. Fresh fruits were supplied to the petri dishes to serve as food source every four days until new adults emerged.

3.2.6 Estimation of damage done to the berries

Various fruit types which were being grown on the various farms were collected. Berries on each of the tagged plants were counted and graded when they became available in order to determine the total number of fruits produced by a plant in a season. Damaged berries including those with ovipositional punctures, brownish or creamy spots, holes and sucked fruits as well as partially consumed ones were also sorted out through careful examination. Percent damaged fruits for the various damage types were calculated.

3.2.7 Estimation of defoliation

From the tagged plants, foliage losses resulting from the feeding of the various defoliators were also estimated visually on a scale of 5 to 50 %, using the method described by Harold (1993). Ten leaflets randomly picked from the upper, middle and lower canopies of the tagged plants were used for the estimation.

3.2.8 Seasonality of the insect pests' species of sweet berry

Regular visits to the fields were made during the growing seasons of the crop, to monitor the following aspects of the insect pest species and the crop; flowering stage, fruiting stage, ripening stage, the growth stage of the insect pests that cause the damage, the particular period of the day the insect pests attack the plant and the parts of the plant they attack. The fields were visited between 0600 and 1800 h on any day of data collection and it was done for two consecutive seasons (i.e. February to June, for minor season and September to December, for major seasons).

CHAPTER FOUR

4.0 RESULTS

4.1 Gender distribution of respondents

The study revealed that, males constitute the majority (70 %) of sweet berry farmers in the areas surveyed.

4.2 Ages of respondents

The age distributions of respondents are shown in Figure 4.1. Out of the 30 farmers interviewed, those aged over 40 years were the majority (67 %) whiles the youth constituted only 33 %.

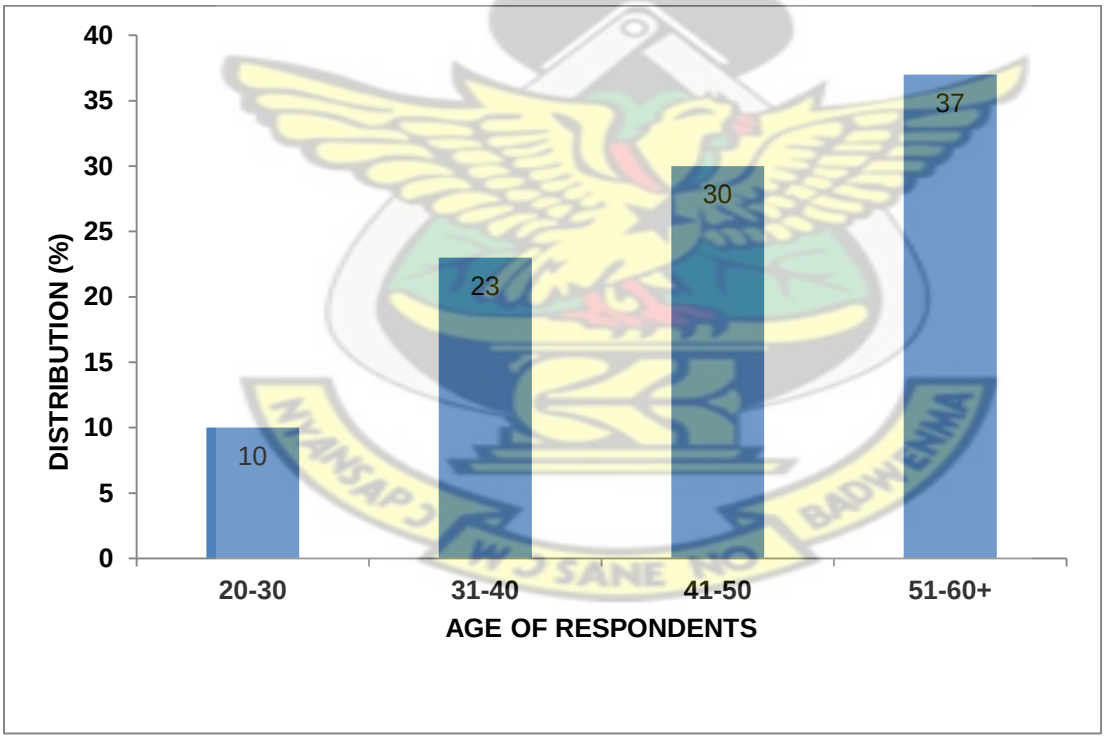

Figure 4.1: Age distribution of respondents in a survey of sweet berry producers in three regions of Ghana.

4.3 Educational level

On education, the majority of the respondents have had at least basic education (Table 4.1).

Table 4.1: Educational level of respondents in a survey of sweet berry farmers in three regions in Ghana.

Educational Level	Number of Respondents
Primary	7 (23.3)
JHS/MSLC	6 (20.0)
SHS/GCE	5 (16.7)
Tertiary	3 (10.0)
No Formal Education	9 (30.0)
TOTAL	**30 (100)**

Figures in parenthesis are percentages of respondents

4.4 Types of sweet berry fruits commonly grown by sweet berry farmers

Seven different types of sweet berry fruits were discovered to be cultivated by the producers. The fruits' types were identified or described based on the sizes, shapes, colours and textures of the fruits (Table 4.2 and Plates 3, 4, 5, 6, 7 and 8).

Table 4.2: Fruit types cultivated by sweet berry, *Richardella dulcifica* farmers in three regions in Ghana.

Fruit Types	Description of Fruit Types	Average Sizes of Fruit Types	Location of Farm
Type One	Bright-red succulent berry with flat bottom	2.0 cm long x 1.5 cm wide	Nsawam and Kpando
Type Two	Bright-red succulent berry with oblong shape	2.5 cm long x 1.6 cm wide	Nsawam and Kpando
Type Three	Bright-red succulent berry with spheroid shape	2.0 cm long x 1.7 cm wide	Nsawam and Kpando
Type Four	Light-red thin-skinned berry with pointed posterior end	2.0 cm long x 1.5 cm wide	Nsawam, Kpando and Agona-Wiamoase
Type Five	Light-red thin-skinned berry with capsule-like shape	2.0 cm long x 1.3 cm wide	Nsawam, Kpando and Agona-Wiamoase
Type Six	Bright-red oval succulent berry	2.0 cm long x 1.5 cm wide	Nsawam, Kpando and Agona-Wiamoase

Plate 3: Type One.

Plate 4: Type Two.

Plate 5: Type Three.

Plate 6: Type Four.

Plate 7: Type Five.

Plate 8: Type Six.

4.5 Farmers' perspectives on sweet berry production

The farmers were of the view that, distribution of printed extension materials on sweet berry would promote improvement in the production of the crop. Another issue raised was insect pests' activities which pose the greatest challenge to sweet berry production in the country.

4.6 Insect pests' management practices adopted by sweet berry, *Richardella dulcifica* farmers

On insect pests' management strategies, all the respondents indicated they usually adopted cultural control measures against the various pests of sweet berry (Table 4.3).

Table 4.3: Management strategies being adopted by farmers in managing insect pests of sweet berry, *Richardella dulcifica* in three regions in Ghana.

Insect Pests Management Tactics Usually Adopted by Farmers	Number of Respondents
Clearing of weeds and bushes on or around the farm or plantation	18 (60)
Prompt harvesting as soon as the berries ripe	10 (33)
Collection and burying of aborted, fallen and rotten berries (debris)	2 (7)
Pesticide application	0 (0)
Biological control	0 (0)
TOTAL	**30 (100)**

Figures in the parenthesis are percentages of respondents

4.7 Identification of insects' species

Insect pests collected on the plant are shown in Table 4.4. These insects are mainly from five orders; Lepidoptera, Diptera, Hymenoptera, Orthoptera and Blattodea.

Table 4.4: Major and minor insect pests of sweet berry, *Richardella dulcifica* in Ghana.

Scientific Name	Order	Family
Ceratitis punctata Wiedm.	Diptera	Tephritidae
Achaea janata Linn.	Lepidoptera	Noctuidae
Achaea spp.	Lepidoptera	Noctuidae
Grammodes geometrica Lat.	Lepidoptera	Noctuidea
Coeliades forestan Stoll.	Lepidoptera	Hesperidae
Catopsilia florella Fab.	Lepidoptera	Pieridae
Danaus chrysipus Linn.	Lepidoptera	Danaidae
Appias sylvia Fab.	Lepidoptera	Pieridae
Bicyclus xenaes Hewiston	Lepidoptera	Saturidae
Bicyclus saftza Westwood	Lepidoptera	Saturidae
Amauris nievius Linn.	Lepidoptera	Danaidae
Oecophylla longinoda Lart	Hymenoptera	Formicidae
Tetramorium aculeatum Mayr.	Hymenoptera	Formicidae
Zonocerus variegatus L.	Orthoptera	Acrididae
Microtermes natalensis Hev	Blattodea	Termitidae

4.8 Oviposition by *Ceratitis punctata*

The adult females lay their eggs using their short ovipositors under the skin of partially ripe, ripe and over-ripe berries leaving punctures on the berries. The female lays three to four eggs in a berry but lays one or two eggs at a time and returns to lay the rest a day or two later.

4.9 Life cycle of tephritid fruit fly, *Ceratitis punctata*

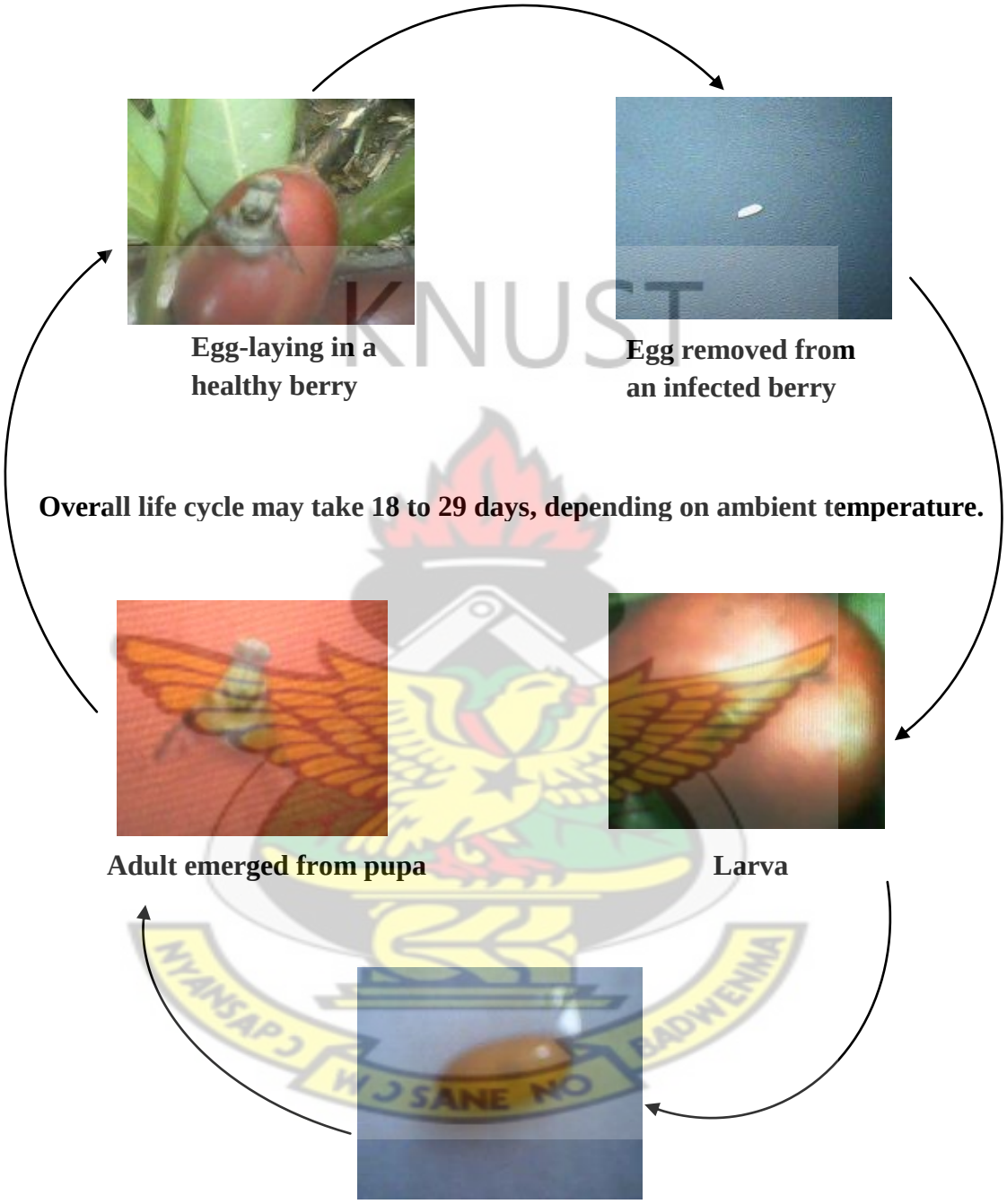

Figure 4.2: Growth stages of tephritid fruit fly, *Ceratitis punctata*.

4.10 Behaviour of *Ceratitis punctata* in sweet berry plantation

The adult flies spend reasonable time on the vegetation surrounding the cultivated areas (i.e. bushes around sweet berry farms or plantations) and within the canopies of sweet berry plants. They are found among the foliage on dense plants, bushes or trees, sometimes a considerable distance from the host plants. During afternoon (hot days) they rest on the underside of leaves or in shaded areas. Flight is most common in the morning and late afternoon (Plate 9).

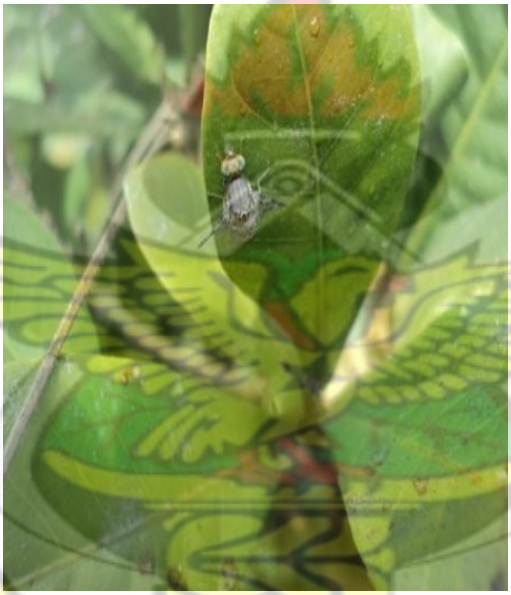

Plate 9: Adult *Ceratitis punctata* resting on underside of sweet berry leaf.

4.11 Insect pests associated with fruit damage

4.11.1 *Ceratitis punctata*

The adult females inflict ovipositional punctures to berries which are just beginning to ripen (i.e. partially ripe berries), ripe and over-ripe berries which later predispose the berries to fungal and bacterial infection, leading to serious rot. The infested berries become soft and dark red in colour and eventually drop after four to five days. The eggs are laid in groups of three to four which hatch after two to three days. Sometimes, the unripe berries also get attacked, causing the berries to become soft resulting in premature ripening and later drop. In addition to the direct effect on the berries, the exit holes of mature larvae on the berries serve as entry points for attack by small weevils which finally bore into the seed to destroy it. The study also revealed that, the adult females frequently create about one or two ovipositional punctures at a time on the berries, which later cause the deformation of infested berries (Plates 10, 11, 12, 13, 14, 15, and 16).

Plate 10: Ovipositional punctures by *Ceratitis punctata* on partially ripe berries.

Plate 11: Ovipositional punctures by *Ceratitis punctata* on ripe berries.

Plate 12: Ovipositional punctures *by Ceratitis punctata* on over-ripe berries.

Plate 13: Bored berry by *Ceratitis punctata* larva after leaving for pupation.

Plate 14: Rotten berries becoming brownish and serving as entry point for attack by small weevils.

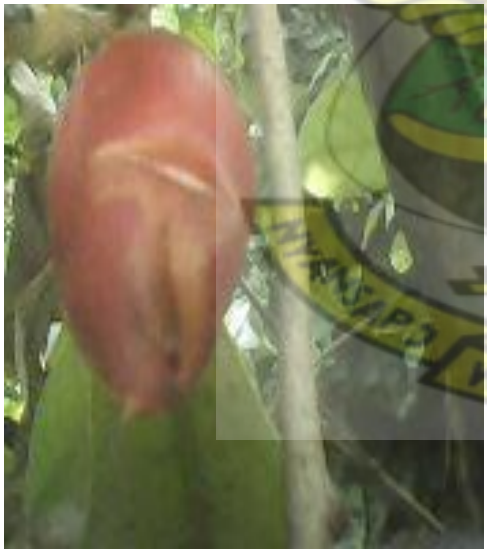

Plate 15: Infected berry by *Ceratitis punctata* becoming soft and dark red in colour.

Plate 16: *Ceratitis punctata* larva feeding on the pulps of a berry.

4.11.2 Damage by Lepidopteran insect species

Generally, the adults of *Achaea* spp. especially *Achaea janata*, together with *Grammodes geometrica, Coeliades forestan, Catopsilia frorella, Danaus chrysipus, Appias sylvia, Bicyclus xenaes, Bicyclus saftza and Amauris nievius* attack berries approaching ripening stage (i.e. partially ripe stage). The adults pierce the berries and sucked the juice which causes some of the berries to shrink and others to swell while still hanging on the plant; some of them drop. Discoloration results from the point of injury after four to five days, followed by secondary infection of rot organisms leading to decay and dropping of the berries. The caterpillars of *Achaea* spp. notably *A. janata* bore into the berries, eat the pulp surrounded the seed and leave a sunken area around the entry point, which serve as avenues for pathogenic invasion. The exit holes of caterpillars of *Achaea* spp. also later serve as entry points for attack by small weevils. Sometimes the ripe and over-ripe berries are consumed by the older caterpillars of *Achaea* spp. The adults and larvae of these insects attack the berries in the morning and late evening (Plates 17, 18, 19, 20, 21, 22, 23 and 24).

Plate 17: Bored fruit by caterpillars of *Achaea* spp.

Plate 18: Partially consumed fruit by older larvae of *Achaea* spp.

Plate 19: Ripe berries partially consumed to expose the seeds (by older larvae of *Achaea* spp.)

Plate 20: Over-riped berry partially consumed by older larvae of *Achaea* spp.

Plate 21: Shrunk berry turned brownish after piercing and sucking by Lepidopteran species.

Plate 22: Swollen berry resulting from piercing and sucking by adult Lepidopteran species.

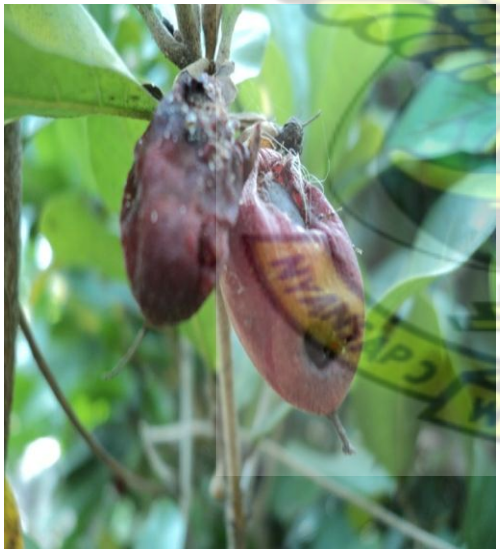

Plate 23: Shrunk berries turned dark red after piercing and sucking by adult Lepidopteran species.

Plate 24: Partially consumed berry by older larvae of *Achaea* spp.

4.11.3 Damage by *Oecophylla longinoda* Lart and *Tetramorium aculeatum* Mayr.

The adults of these insect species secrete brownish or creamy substances on the berries, preferably, on semi ripe, ripe and over-ripe berries while foraging on the berries. They secrete about one to fourteen of these substances to cover the entire surfaces of the berry, leading to deformation. The adults surround the berries in groups any time during the day (Plates 25, 26, 27, 28, 29 and 30).

Plate 25: A creamy substance secreted by *Oecophylla longinoda* and *Tetramorium aculeatum* on partially ripe berry.

Plate 26: Brownish substances secreted by *Oecophylla longinoda* and *Tetramorium aculeatum* on ripe berries.

Plate 27: Brownish substances secreted by *Tetramorium aculeatum* and *Oecophylla longinoda on over-ripe berry.*

Plate 28: *Tetramorium aculeatum* secreting a creamy substance on a ripe berry.

Plate 29: *Oecophylla longinoda* secreting a brownish substance on a ripe berry.

Plate 30: Adults *Oecophylla longinoda* foraging on a ripe berry to secrete creamy substances.

4.12Types of damage on berries

Out of the four different berry damage types identified, ovipositional punctures constitute the highest of 55 %, followed by bored and sucked berries with 19 % and partially consumed berries 14 %, others, 12 % (Table 4.5).

Table 4.5: Types and percentage damage caused to sweet berry, *Richardella dulcifica* by the various insect pests at Bio-Resource Institute Farm (BRI-Farm), Nsawam.

Insect Causing Damage	Types of Damage to Berries	Percentage Damaged
Ceratitis punctata	Ovipositional punctures	55 (550)
Grammodes geometrica	Bored and sucked berries	19 (192)
Appias sylvia	Bored and sucked berries	
Bicyclus xenaes	Bored and sucked berries	
Bicyclus safza	Bored and sucked berries	
Amauris nievius	Bored and sucked berries	
Coeliades forestan	Bored and sucked berries	
Catopsilia frorella	Bored and sucked berries	
Danaus chrysipus	Bored and sucked berries	
Achaea spp.	Partially consumed berries	14 (143)
Achaea janata	Partially consumed berries	
Oecophylla longinoda	Fruits with creamy spots	12 (115)
Tetramorium aculeatum	Fruits with creamy spots	
TOTAL		**100 (1000)**

Numbers in parenthesis are damaged fruits of each damage type

4.13 Insect pests associated with defoliation

4.13.1 Damage by Lepidopteran Larvae

The older larvae of *Achaea* spp., notably *Achaea janata, Grammodes geometrica, Coeliades forestan, Catopsilia frorella, Danaus chrysipus, Appias sylvia, Bicyclus xenaes, Bicyclus saftza* and *Amauris nievius* eat the leaf tissues leaving several holes in the leaves. Sometimes, they feed on the leaf starting from the margins and the leaf veins. In severe infestation, the entire leaf gets eaten. Sometimes the attack causes the leaf to dry up while still attached to the branches and others eventually fall off. The young larvae sometimes feed on the undersides of leaves and produce a light mottling appearance of the upper surfaces. The young larvae are found on both defoliated and undefoliated plants whiles the pupae hide in leaves webbed together. The older larvae are often found around buds of the plants and sometimes on undersides of the leaves. Their feeding sometimes results in the deformation of the entire leaves. They often cause extensive damage during and shortly after the dry season. Both the young and older larvae appear in the morning and late afternoon to attack, but sometimes they appear in the afternoon and settle in the middle and lower canopy levels of the plants (Plates 31, 32, 33 and 34).

Plate 31: A consumed sweet berry leaf by Lepidopteran Larvae showing several holes.

Plate 32: Older larva of *Achaea* sp. attacking sweet berry leaf from underside.

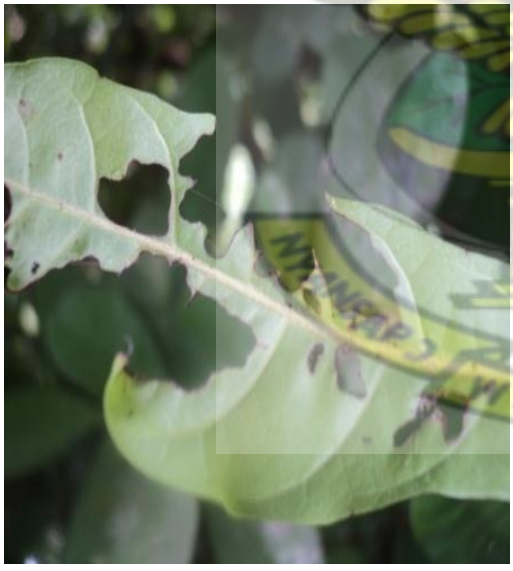

Plate 33: Sweet berry leaf's veins and tissues consumed by Lepidopteran Larvae.

Plate 34: Old larva of *Danaus chrysipus* attacking sweet berry leaf from underside.

4.13.2 Damage by *Zonocerus variegatus*

The nymphs and adults of *Z. variegatus* eat the leaves starting from the margins, leaving several holes in the leaves. Sometimes, the leaves turn yellowish or brownish and eventually drop. Both the nymphs and adults emerge in groups, in the morning and late afternoon to attack. Sometimes, they appear in the afternoon to defoliate when they settle in the middle and lower canopy levels of the plants (Plates 35, 36 and 37)

Plate 35: Partially consumed leaf of sweet berry by *Zonocerus variegatus* making leaf turn yellowish.

Plate 36: Adult *Zonocerus variegatus* attacking sweet berry leaf from the margin.

Plate 37: Partially consumed leaves of sweet berry by *Zonocerus variegatus* making the leaf turn brownish.

4.14 Estimation of defoliation

The study showed that, of the three canopy levels of sweet berry plants, the middle canopy level suffer the highest defoliation of about 10 % and the least in the upper canopy (Table 4.6).

Table 4.6: Mean percentage defoliation recorded on canopy levels in sweet berry plantation at the Bio-Resource Institute Farm, Nsawam.

Canopies Levels	Mean Percentage Defoliation
Upper Canopy	5
Middle Canopy	10
Lower Canopy	7

4.15 Insect pests associated with root and stem damage

4.15.1 Damage by *Microtermes natalensis*

The workers attack the roots and stems of sweet berry plants, especially the immature plants. They tunnel into the stem and cover the stem with earth especially, the base of the stem. Often they hide to feed on the bark and cut the plant at ground level leading to death. The trunks of the infested plants are sometimes covered with galleries. Sometimes, they ring-bark both the matured and immature plants resulting in the death of the plants. They appear throughout the day, but are found in the galleries to attack and their damage activities are much pronounced during the dry seasons (Table 4.14; Plates 38 and 39).

Plate 38: *Microtermes natalensis* gallaries on a stem of sweet berry plant.

Plate 39: *Microtermes natalensis* gallaries constructed on a stem of sweet berry plant.

4.16 Beneficial insect species found on sweet berry plantations

4.16.1 Beneficial activities of *Ammophila clava* Anold *and Synagris anali* Saussure

The adults of *Ammophila clava* Anold and *Synagris anali* Saussure prey on most of the insect pests' species of sweet berry at different stages of their life cycle. They occur throughout the flowering, fruiting and ripening stages of the crop during the minor and major seasons. The adult insects appear in the morning, late afternoon and sometimes early evening of the day to prey on their hosts (Plates 40 and 41).

Plate 40: *Ammophila clava* preying on Lepidopteran larva.

Plate 41: *Synagris anali* preying on Lepidopteran larva.

4.16.2 Beneficial activities of *Oecophylla longinoda* Lart and *Tetramorium aculeatum* Mayr.

Their presence and foraging activity hinder oviposition by some of the insect pests' species (i.e. *Ceratitis punctata* and Lepidopteran species). They occur throughout the minor and major seasons during the flowering, fruiting and ripening stages of the crop any time of the day (Tables 4.7, 4.8 and 4.14).

4.17 The seasonal occurrence of the insect pests' species of sweet berry, *Richardella dulcifica*

All the insect pests' species recorded, occurred during flowering, fruiting and ripening stages of sweet berry, except the fruit fly, *Ceratitis punctata* which occurred only during the ripening stage (June and December). Most of the recorded pests' species also attack the crop plant in the morning and late afternoon and the berries and leaves are the parts mostly attacked (Tables 4.7, 4.8, 4.9 and 4.10).

Table 4.7: Seasonality of insect pests of sweet berry, *Richardella dulcifica* and growth stage that cause damage.

Season/Time of the year	Insect pests	Stage that cause damage
***Flowering and ** Fruiting**	*Achaea janata.*	Larva
	Achaea spp.	Larva
	Grammodes geometrica	Larva
	Coeliades forestan	Larva
	Catopsilia frorella	Larva
	Danaus chrysipus	Larva
	Appias sylvia	Larva
	Bicyclus xenaes	Larva
	Bicyclus saftza	Larva
	Amauris nievius	Larva
	Microtermes natalensis	Nymph and Adult
	Zonocerus variegatus	Nymph and Adult
	Oecophylla longinoda	Adult
	Tetramorium aculeatum	Adult

*** February to March– Minor Season and September to Early October– Major Season**

**** Late March to May– Minor Season and Early October to November– Major Season**

Table 4.8: Seasonality of insect pests of sweet berry, *Richardella dulcifica* and growth stage that cause damage.

Season/Time of the year	Insect pests	Stage that cause damage
* **Ripening**	*Ceratitis punctata*	Larva and Adult
	Achaea janata	Larva and Adult
	Achaea spp.	Larva and Adult
	Grammodes geometrica	Larva and Adult
	Coeliades forestan	Larva and Adult
	Catopsilia frorella	Larva and Adult
	Danaus chrysipus	Larva and Adult
	Appias sylvia	Larva and Adult
	Bicyclus xenaes	Larva and Adult
	Bicyclus saftza	Larva and Adult
	Amauris nievius	Larva and Adult
	Microtermes natalensis	Nymph and Adult
	Zonocerus variegatus	Nymph and Adult
	Oecophylla longinoda	Adult
	Tetramorium aculeatum	Adult

*** June– Minor Season and Late November to December– Major Season**

Table 4.9: Insect pests collected on sweet berry, *Richardella dulcifica* showing the parts of the plant they attack and the time of the day they attack during flowering and fruiting stages.

Insect Pests	Parts they attacked	Time of the day insect pests attack
Achaea janata	Leaves	Morning and Late afternoon
Achaea spp.	Leaves	Morning and Late afternoon
Grammodes geometrica	Leaves	Morning and Late afternoon
Coeliades forestan	Leaves	Morning and Late afternoon
Catopsilia florella	Leaves	Morning and Late afternoon
Danaus chrysipus	Leaves	Morning and Late afternoon
Appias sylvia	Leaves	Morning and Late afternoon
Bicyclus xenaes	Leaves	Morning and Late afternoon
Bicyclus saftza	Leaves	Morning and Late afternoon
Amauris nievius	Leaves	Morning and Late afternoon
Microtermes natalensis	Roots and Stems	Morning, Afternoon and Evening
Zonocerus variegatus	Leaves	Morning and Late afternoon
Oecophylla longinoda	–	Morning, Afternoon and Evening
Tetramorium aculeatum	–	Morning, Afternoon and Evening

Table 4.10: Insect pests collected on sweet berry, *Richardella dulcifica* that attack different ripening stages of the fruit, parts of the plant they attack and the time of the day they attack during ripening stage.

Insect Pests	Ripening stages of the fruit they attack	Parts they attacked	Time of the day insect pests attack
Ceratitis punctata	Semi ripe, Ripe and Over-ripe	Fruits	Morning and Late afternoon
Achaea janata	Ripe and Over-ripe	Fruits and Leaves	Morning and Late afternoon
Achaea spp.	Ripe and Over-ripe	Fruits and Leaves	Morning and Late afternoon
Grammodes geometrica	Ripe and Over-ripe	Fruits and Leaves	Morning and Late afternoon
Coeliades forestan	Ripe and Over-ripe	Fruits and Leaves	Morning and Late afternoon
Catopsilia frorella	Ripe and Over-ripe	Fruits and Leaves	Morning and Late afternoon
Danaus chrysipus	Ripe and Over-ripe	Fruits and Leaves	Morning and Late afternoon
Appias sylvia	Ripe and Over-ripe	Fruits and Leaves	Morning and Late afternoon
Bicyclus xenaes	Ripe and Over-ripe	Fruits and Leaves	Morning and Late afternoon
Bicyclus saftza	Ripe and Over-ripe	Fruits and Leaves	Morning and Late afternoon
Amauris nievius	Ripe and Over-ripe	Fruits and Leaves	Morning and Late afternoon
Microtermes natalensis	—	Roots and Stems	Morning, Afternoon and Evening
Zonocerus variegatus	—	Leaves	Morning and Late afternoon
Oecophylla longinoda	Semi ripe, Ripe and Over-ripe	Fruits	Morning, Afternoon and Evening
Tetramorium aculeatum	Semi ripe, Ripe and Over-ripe	Fruits	Morning, Afternoon and Evening

4.18 Seasonality and numbers of insect pests collected in sweet berry, *Richardella dulcifica* farms in three regions in Ghana.

Most of the arboreal insects occurred in large numbers during the ripening stage of the crop. All the crawling insect pests' species captured, except *Microtermes natalensis*, occurred in large numbers throughout the flowering, fruiting and ripening stages of the crop (Tables 4.11, 4.12, 4.13 and 4.14).

Table 4.11: Seasonality and numbers of insect pests collected in sweet berry, *Richardella dulcifica* plantations in three regions in Ghana.

Season/Month	Number of Insect Pests Collected			
Minor Season	*Ceratitis punctata*	*Achaea janata*	Other *Achaea* spp.	*Grammodes geometrica*
February	0	49	57	44
March	0	37	44	33
April	0	39	30	21
May	19	35	47	46
June	247	61	75	55
Major Season				
September	0	53	69	46
October	5	42	56	35
November	231	51	66	44
December	253	70	78	59

Table 4.12: Seasonality and numbers of insect pests collected in sweet berry, *Richardella dulcifica* plantations in three regions in Ghana.

Season/Month	Number of Insect Pests Collected			
Minor Season	*Coeliades forestan*	*Catopsilia frorella*	*Danaus chrysipus*	*Appias sylvia*
February	51	35	50	21
March	46	38	39	19
April	32	49	27	13
May	54	51	44	15
June	66	70	59	27
Major Season				
September	55	71	48	22
October	47	65	40	17
November	63	67	51	19
December	77	80	68	25

Table 4.13: Seasonality and numbers of insect pests collected in sweet berry, *Richardella dulcifica* plantations in three regions in Ghana.

Season/Month	**Number of Insect Pests Collected**			
Minor Season	*Bicyclus xenaes*	*Bicyclus saftza*	*Amauris nievius*	*Zonocerus variegatus*
February	53	46	56	131
March	49	34	41	154
April	32	21	30	106
May	50	46	37	168
June	60	69	70	101
Major Season				
September	57	55	42	62
October	31	44	35	186
November	43	57	41	203
December	56	70	67	287

Table 4.14: Seasonality and numbers of insect pests collected in sweet berry, *Richardella dulcifica* plantations in three regions in Ghana.

Season/month	Number of Insect Pests Collected		
Minor Season	*Oecophylla longinoda*	*Tetramorium aculeatum*	*Microtermes natalensis*
February	163	175	43
March	169	184	30
April	131	167	21
May	177	173	17
June	205	289	11
Major Season			
September	183	197	27
October	172	189	34
November	280	319	105
December	231	278	121

CHAPTER FIVE

5.0 DISCUSSION

5.1 Socio economic background

Most of the sweet berry farms in the Eastern, Volta and Ashanti Regions are owned by males. This may be attributed to the fact that, in Ghana land is mostly owned by men. Since sweet berry production is a long term investment, men are in a better position to go into such ventures.

Sweet berry farmers aged over 40 years constitute the majority as compared to the other age groups (Figure 4.1); perhaps the elderly have access to land. Besides, they form the active labour force that is capable of contributing significantly to berries' production in the country.

It came to light from the study that, men and women who have formal education form the majority of those actively involved in sweet berry production (Table 4.1).

Most of the farmers practice monoculture which is creating favourable conditions for the insect species to multiply rapidly to cause significant damage to the crop. Obeng-Ofori *et al.* (2007) noted that, monoculture system of farming promotes multiplication of pest species in the presence of abundant supply of their preferred food and shelter. It was observed that, farmers who intercrop sweet berry with other crops have reduced insect pest damage to the plants.

The study further revealed that, the activities of the insect pests pose the greatest challenge to sweet berry production, since there are no effective insect pests' management practices in place to combat them. Sweet berry farmers would need to consider the adoption of integrated insect

pest management founded on cultural practices to manage these insect pests. Braima *et al.* (2010) suggested that, by incorporating integrated pest management (IPM) into plant production practices, farmers will be able to reduce pest problems and crop losses in a sustainable manner. Sweet berry farmers' request of the distribution of simple printed extension materials on sweet berry by technical experts to assist promotion and improvement in the production of sweet berry in the country needs serious consideration.

5.2 Insect pests of sweet berry, *Richardella dulcifica*

The study identified a tephritid, *C. punctata*, as the major insect pest, as far as economic losses in sweet berry production are concerned (Table 4.5). The management of this pest, probably, would significantly reduce losses incurred in the production of the crop. The basis of the argument is that, this insect attacks the berries directly, rendering them unmarketable.

Oecophylla longinoda and *T. aculeatum* are best known as predators of other insect pests in other fruit crop plantations. However, these insects are contributing significantly to reducing the quality of the berries by the deposition of the creamy substances on them. Even though this activity is of grave concern to farmers, their foraging activities also hinder the activities of other pests. It appears prompt harvesting may be the antidote to their deposition of the creamy substances as that would contribute to minimise losses resulting from that activity.

The lepidopterans (*Achaea* spp. notably *Achaea janata, Grammodes geometrica, Coeliades forestan, Catopsilia frorella, Danaus chrysipus, Appias sylvia, Bicyclus xenaes, Bicyclus saftza*

and *Amauris nievius*) collected pierce and suck the berries thereby destroying them. To ensure that their activities do not become severe, stringent measures are required to prevent big losses.

Zonocerus variegatus and Lepidopterans' larvae are serious defoliators of many species of plants, including sweet berry. *Z. variegatus* is gregarious and usually attack sweet berry plants in large swarms, leading to reduced number of berries per plant. The immediate surroundings of the farm and any suitable laying sites, including the immature stages (nymphs and larvae) should be inspected and treated with pesticides periodically to destroy the breeding sites and immature stages so as to reduce the build-up.

Microtermes natalensis is occasionally serious pest of the crop, shortening the life of a plant in the farm and the management of this pest through grease-banding would suppress their activities.

5.3 Seasonal occurrence of the insect pests of sweet berry, *Richardella dulcifica*

The study revealed that, the seasonality of the insect pests of sweet berry in the country relates to the phenology of the plant. Each growing stage attracts specific insect pest species to the crop (Table 4.7 and 4.8).

The crop bears fruits twice a year, following the rainy season between February to June (minor season) and September to December (major season), causing the flowering stage to occur between February to early March (minor season) and September to early October for the major season, attracting defoliators as well as root and stem feeders.

The fruiting stage is also recorded between late March to May (minor season) and early October to November (major season), when the defoliators, root and stem feeders continue to feed voraciously on the preferred plant parts, followed by the ripening stage which occurs in June (minor season) and late November to December (major season).

All the insect pests recorded occur during flowering, fruiting and ripening stages of the crop, except the fruit fly, *C. punctata*, which occur only during ripening stage. The majority of the insect pests attack during the adult stage whiles others do damage when in the larval or nymphal stages, allowing the insect pests to seriously cause economic damage (Table 4.7 and 4.8). This confirmed the earlier findings that, within the order, lepidoptera and some others, the larva is the economically damaging life stage (www.imp.ncsu.edu/AG271/agpests.htm). Since at the larval and nymphal stages a lot of damage is caused, it would be appropriate for the farmers to tailor pest management measures to specific stages of the insect pests so as to suppress their build-up. It sounds reasonable to suggest that, once *C. punctata* attacks the berries at specific periods, their damage activities can be drastically reduced by protecting the berries in one way or the other. One of the ways would be to apply insecticides such as; Dimethoate, Parathion, Malathion, Dialiphos etc. just when the berries are mature or just before ripening is initiated as this will protect the berries.

5.4 Damage incidence in sweet berry, *Richardella dulcifica* plantation

The study revealed six different types of damage are caused by the insect pests on sweet berry in the field. These include; ovipositional punctures, bored and sucked berries, partially consumed

berries, brownish or creamy deposition on the berries, defoliation as well as roots and stems feeding.

The study further showed that, the ovipositional punctures on the berries by *C. punctata* later predispose the berries to fungal and bacterial infection, leading to serious decay. As reported by National Research Council (1992), it is obvious that, fruit flies are the most serious horticultural pests worldwide. They cause millions of dollars of damage to fruits and their presence in the tropics hamper the development of the horticultural industry especially, fruit plantations.

The study has also shown that, the adults of lepidoptera species generally attack the berries when approaching ripening stage. The adults pierce the berries and suck the juices which cause some of the berries to shrink, swell while still hanging on the plant or cause others to drop. Besides, the caterpillars of *Achaea* spp. notably *Achaea janata* bore into the berries, eat the pulps surrounded the seed and leave a sunken area around the entry point, which serve as avenues for pathogenic invasion of bacteria and fungi. Sometimes the ripe and over-ripe berries are consumed by the older caterpillars of *Achaea* spp., leading to poor quality of the berries which would not be marketable (Plates 19 and 20). In a related study, Hodgson (1970) explained that, *Achaea* spp. attack all citrus varieties in season, except probably the grapes and lemon fruits. In addition to citrus, they attack other fruit crops.

The foraging activities of the ants' species really pose threats to sweet berry plantations or farms, with particular reference to the berries, as the quality of the berries is compromised, causing rejection by buyers or consumers. The consequence of this is loss of revenue which would discourage investment by the farmers. Controlling the ants has its consequences as they also play a significant role in managing other pests by their predatory and foraging activities which hinder the activities of the other pests. It appears the best way to manage the situation would be by harvesting the berries promptly.

It is estimated that, ovipositional damage alone, represents 55 % of the damage on fruits in the field, followed by bored and sucked berries (19 %) (Table 4.5). This is a clear indication that, exporters and other people who are in sweet berry business are facing a lot of challenges as far as insect pests are concerned. The tephritid fruit fly, *Ceratitis punctata*, is the major insect pest in sweet berry production in the country.

Defoliation poses a challenge to miracle fruit production, since the various defoliators feed voraciously on the leaves. *Zonocerus variegatus* alone, being a polyphagous, attacks sweet berry, cassava (*Manihot esculenta*) and many other crops in the tropics, and has become a major pest of cassava within the last 30 years as a result of interrelated factors which include; the reduction in the area of dense evergreen forest in favour of derived savannah; an increase in cassava cultivation as a monocrop; and the rapid spread of the Siam weed, *Chromolaena odorata* (Obeng-Ofori *et al.,* 2000).The study showed that defoliators prefer the middle canopy of the plant (Table 4.6). Afreh-Nuamah (1985, 1999) noted that, the humid type of climate in the

tropics and the perennial nature of the tree crops as well as the vegetation associated with them favour the occurrence of large number of arthropods that form a settled balance ecosystem on the trees where there is a shade. The voracious feeding by the defoliators in sweet berry production causes reduction of photosynthetic leaf area, thus resulting in stunted growth and eventual death in extreme cases lead to reduced number of berries per plant. This supports the research by (Obeng-Ofori *et al.,* 2007) that, voraciously feeding on the leaves by defoliators adversely affects yield.

Roots and stems feeding by *Microtermes natalensis* in sweet berry production are common. There are various species of termites causing damage to a wide range of crops (i.e. as polyphagous insects) by tunneling into the stem or building mounds to engulf the base of the stem. Entwistle (1972) explained that, the hard nature of plants was a factor for termites' species selection for food and sweet berry plants being woody perennial shrubs are subject to termites attack. *Microtermes natalensis* tunnel into the rooting systems and stems of sweet berry plants, destroying the whole rooting system, weakening the plant and eventually shortening the life of a plant in the plantations. Harris (1969) noticed that, in coconut plantations, galleries in growing tissues caused by termites can also lead to bacterial invasion which will cause the plants death.

5.5 Management of insect pests of sweet berry, *Richardella dulcifica*

- **Management tactics at flowering stage**

Cultural management measures during the flowering stage can be used to manage the population of *Achaea* spp. notably *Achaea janata, Grammodes geometrica, Coeliades forestan, Catopsilia frorella, Danaus chrysipus, Appias sylvia, Bicyclus xenaes, Bicyclus saftza, Amauris nievius,*

Microtermes natalensis and *Zonocerus variegatus* and other insect pests to a level below economic threshold.

The farmers employ several cultural measures to manage these insect pests' species. These include; farm sanitation, where weeds and bushes on or around the farm are cleared, depriving the different stages of the insect pests' species of hiding places and exposing them to various predators and the intense heat of the sun. Regular monitoring of sweet berry leaves and flowers for eggs and larvae of lepidopterans species could help to reduce their population. The most appropriate time to apply these management measures should be between February to early March and September to early October.

Several predators (i.e. biological control agents) can contribute to the suppression of pests' species of sweet berry. Major predators are *Ammophila clava, Synagris anali, Tetramorium aculeatum, Oecophylla longinoda,* spiders, birds, bats and reptiles. In particular, *A. clava, S. anali* (Plates 40 and 41), *T. aculeatum* and *O. longinoda* are the very predators protecting sweet berry plants from Lepidopteran species and *Z. variegatus,* particularly, larvae and nymphs. The presence and foraging activity of *O. longinoda* and *T. aculeatum* in orchards hinder the fruit flies and other insect pests from laying eggs, resulting in reduced fruit flies and other insect pests' damage (Van Mele *et al.,* 2007; Afreh-Nuamah, 1985). Ants usually live in association with fruit crops whereby the crop plants provide housing or food for the ants which in turn protect their host (sweet berry plant) against defoliators and other fruity feeders.

Although natural enemies alone do not give satisfactory control of insect pests, efforts should be made to protect them and to complement their effect on pests of sweet berry. According to Obeng-Ofori *et al.* (2007), pests' populations are reduced effectively and naturally by high populations of natural enemies. This is against the backdrop that, they are relatively slow acting, secretive in action and lack the dramatic 'killing effects' associated with pesticide control and therefore takes time to establish.

Braima *et al.* (2010) also explained that, in conservation of biocontrol, action should be taken to enhance the effectiveness of natural enemies already present in agroecosystem. This may involve leaving or planting flowering plants around the farm in order to attract natural enemies, providing suitable nesting sites for them or reducing the amount of synthetic chemicals in a farm to allow natural enemy numbers to increase. The good thing about biological control is that, when fully establishes and left undisturbed, it is permanent and self-perpetuating, which would not require further intervention from the farmers to ensure their continued success in managing pests. That is why farmers should be encouraged to manage their sweet berry farms well so that they optimize benefits from the indigenous biological control agents. The use of pesticides is recommended against these insect pests at this stage, to suppress their build-up.

- **Management tactics at fruiting and ripening stages**

Ceratitis punctata, Oecophylla longinoda, Tetramorium aculeatum (all attack only at ripening stage), *Achaea* spp. notably *Achaea janata, Grammodes geometrica, Coeliades forestan, Catopsilia frorella, Danaus chrysipus, Appias sylvia, Bicyclus xenaes, Bicyclus saftza, Amauris*

nievius, Microtermes natalensis and *Zonocerus variegatus* are the most important insect pests at the fruiting and ripening stages of the plant growth.

The following cultural measures should be considered, so as to manage the pests; the berries should be harvested promptly, as soon as they ripe, to reduce attacks by the fruit fly, *C. punctata,* and Lepidopterans.

Also the aborted, fallen or rotten berries (debris) should be collected and buried about 5 cm deep in the soil so as to break the life cycle of the fruit flies and thereby reduce their population and infestation.

Trunks of sweet berry plants should be banded with grease, about 3 cm from the ground, to prevent the crawling pests from climbing up the plants. Banding of the plants should be strictly maintained throughout the year to keep such crawling pests population at a low level. Besides, regular inspection should be carried out for climbers, mistletoes, epiphytes and other parasitic plants that connect the sweet berry plants to the ground and cut to prevent the crawling pests from climbing. Periodically, insecticide application can be used to complement cultural control strategies to manage the insect pests.

Between late March and May and early October to November (for fruiting stage) as well as between June to late November and early December (for ripening stage) may be the appropriate periods to target these insect pests.

Considering the complex nature of the biological interactions that exist in the sweet berry plantations or farms, there is the need to device a well thought-out plan to manage insect pests.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The study indicated that, the majority of sweet berry farmers were males with ages over 40 years. Similarly, majority of them have had at least basic education. All the farmers usually employed cultural measures to manage insect pests of the crop.

The study further revealed that, the fruit feeders (i.e. *Ceratitis punctata*, *Achaea* spp. notably *Achaea janata*, *Grammodes geometrica, Coeliades forestan, Catopsilia florella, Danaus chrysipus, Appias sylvia, Bicyclus xenaes, Bicyclus saftza, Amauris nievius, Oecophylla longinoda* and *Tetramorium aculeatum*), defoliators (i.e. *Zonocerus variegatus* and Larvae of lepidopterans' species) as well as root and stem feeders (i.e. *Microtermes natalensis*) were the most important insect pests of sweet berry in the field in the country. Although *O. longinoda and T. aculeatum* are beneficial insects in sweet berry farms, their foraging activities pose a threat to the berries' quality.

The damage recorded on sweet berries include ovipositional punctures, bored and sucked berries, partially consumed berries, brownish or creamy substances on the berries, defoliation as well as root and stem damage.

The insect pests recorded in the various sweet berry farms occur mostly during the flowering (February to March and September to Early October), fruiting (Late March to May and Early October to November) and ripening stages of the crop, except the fruit fly, *Ceratitis punctata,* which occur only during the ripening stage in June and late November to December.

Most of the recorded insect pests attack the crop plant in the morning and late afternoon and the berries and leaves are the parts mostly attacked. The larval, nymphal and adult stages are the most important stages of the insect pests that cause economic damage to sweet berry.

6.2 Recommendation

The following are recommended:

i. Sweet berry farms should be intercropped with other fruit crops in order to reduce pests' activities.

ii. Administering insecticides to manage insect pests of sweet berry farms should target the middle and lower canopy levels to suppress their populations.

iii. Further studies should be carried out to find out whether there are other insect pests that can cause injury (damage) to the crop and how to manage them.

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APPENDIX

A: QUESTIONNAIRE ON SOCIO-ECONOMIC BACKGROUND OF SWEET BERRY FARMERS IN THREE REGIONS IN GHANA

1) Location of farm……..
2) Name of respondent……
3) Sex: Male……Female…….
4) Age……
5) Educational level:

   Primary…….

   JHS/MSLC……

   SHS/GCE…….

   Tertiary……

   No formal education……

B: QUESTIONNAIRE ON THE PRODUCTION OF SWEET BERRY IN THREE REGIONS IN GHANA

1) What type of fruits or cultivars do you produce?

Fruit Types	Response
Type One	
Type Two	
Type Three	
Type Four	
Type Five	
Type Six	

2) Do you experience insect pests' attacks on the crop?

Yes…… No……

3) Do you sometimes get some information on the crop from the extension officers?

Yes…….. No……

4) How do you control or manage the insect pests when you do experience their attacks?

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