Insect Pests Of Sweet Berry (Richardella Dulcifica) (Schumach And Thonn) Baehni In Ghana

Atuahene - Mensah F., Osekre E. A

Abstract: A study on sweet berries was conducted in three towns representing three regions in Ghana; Nsawam (Eastern region), Nkonya (Volta region) and Wiamaase (Aschanti region) to (i) identify important insect pests of sweet berry, Richardella dulcifica (Schumach and Thonn) Baehni and the damage they cause and (ii) identify their management strategies. 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 f Lorella 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.

Keywords: Damage, Defoliation, Ghana, Insect pest, Ovipositional puncture, Plantation, Seasonality

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 Bcomplex, 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 reawakened 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 the Spanish Pharmacist and Entrepreneur has recently expressed an interest in its cultivation and planned to support the establishment of a commercial plant in the country with the mission of securing a strong regulatory position for the miracle fruit in the European Union and developing a sustainable supply chain to meet international safety and quality standards (Nutraceutical Company/Spain, 2015. Personal communication). 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 focus mainly on the identification of the insect pests of sweet berry and their management strategies. Besides, the study sought to highlight on the following specific research objectives, to:
1) identify the importance insect pests of sweet berry,
2) determine the seasonal occurrence of the insect pests,
3) determine the injury (damage) they cause, and
4) identify management strategies against the pests.

2.0 MATERIALS AND METHODS

2.1 The Biophysical Characteristic of the Study Area

The study was conducted in three towns representing three regions in Ghana; Nsawam (Eastern region), Nkonya (Volta region) and Wiamaase (Aschanti region).

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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 km². Nsawam lies within the wet semi-equatorial climatic zone, characterized by two rainfall maxima, followed by a prolonged dry season. The annual mean rainfall is between 1,500 and 2,150 mm. The mean annual temperature is 28°C with relative humidity of 67%. (Akuapem-South Municipal Assembly, 2006).

Nkonya
This town is located in the Biakoye District of the Volta Region. The annual rainfall total ranges between 1100 mm and 1500 mm, averaging 1300 mm. The rainfall pattern is bimodal with two distinct rainy seasons. The area falls within the forest-savannah transitional ecological zone of Ghana, with the forest part at its north-eastern sectors. (Biakoye District Assembly, 2012).

Wiamoase
This town is located in the North Central part of Ashanti Region. The mean annual rainfall ranges between 855 mm and 1,500 mm. Temperatures are generally high throughout the year with mean monthly temperature of about 27°C. Humidity is high during the rainy season and very low during dry season. (Sekyere-South District Assembly, 2006).

2.2 Sources of data

2.2.1 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 INFOMET-BIOVISION (www.Infornet-biovision.org/PlantHealth/Pests/Fruit flies), 10 traps were produced from ‘blue band’ plastic containers to capture the insects.

Sweep netting sampling
Generally, arboresal insect species associated with the sweet berry plants were sampled using a sweep net (30 cm diameter).

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.

Pan trap sampling
Following a protocol described by Potts (2005), pan traps were made to capture the insects.

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. 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.

2.2.2 Identification of insects’ species
Insect species captured were identified using the morphological characteristics of the species and were stored temporarily in insects’ tray boxes and 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.

2.2.3 Statistical Analysis
The insect pests’ species captured from the three regions as described in the field procedures were pooled together for analysis of the abundance and distribution in the seasonal occurrence. Data was tested for the normal distribution and Non Parametric Test (NPar Test) was used. They were then subjected to analysis of variance and the means separated by the Wilcoxon Signed Ranks Test for pair wise comparison at α = 0.01 level which considered at

2.2.6 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.

3.0 RESULTS

3.1 Identification of insects’ species
Insect pests collected on the plant are shown in Table 1. These insects are mainly from five orders; Lepidoptera, Diptera, Hymenoptera, Orthoptera and Blattodea an overall significant. All analysis was performed with the SPSS version 16.
### Table 1: Major and minor insect pests of sweet berry, *Richardella dulcifica* in Ghana.

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Order</th>
<th>Family</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Ceratitis punctata</em></td>
<td>Diptera</td>
<td>Tephritidae</td>
</tr>
<tr>
<td><em>Achaeia janata</em></td>
<td>Lepidoptera</td>
<td>Noctuidae</td>
</tr>
<tr>
<td><em>Achaea spp.</em></td>
<td>Lepidoptera</td>
<td>Noctuidae</td>
</tr>
<tr>
<td><em>Grammodes geometria</em></td>
<td>Lepidoptera</td>
<td>Noctuidae</td>
</tr>
<tr>
<td><em>Coelades forestan</em></td>
<td>Lepidoptera</td>
<td>Hesperidae</td>
</tr>
<tr>
<td><em>Catopsilia frorella</em></td>
<td>Lepidoptera</td>
<td>Pieridae</td>
</tr>
<tr>
<td><em>Danaus chrysispus</em></td>
<td>Lepidoptera</td>
<td>Danaidae</td>
</tr>
<tr>
<td><em>Appias Sylvia</em></td>
<td>Lepidoptera</td>
<td>Pieridae</td>
</tr>
<tr>
<td><em>Bicyclus xenaes</em></td>
<td>Lepidoptera</td>
<td>Saturidae</td>
</tr>
<tr>
<td><em>Bicyclus saftza</em></td>
<td>Lepidoptera</td>
<td>Saturidae</td>
</tr>
<tr>
<td><em>Amauris nievius</em></td>
<td>Lepidoptera</td>
<td>Danaidae</td>
</tr>
<tr>
<td><em>Oecophila longinoda</em></td>
<td>Hymenoptera</td>
<td>Formicidae</td>
</tr>
<tr>
<td><em>Tetramorium aculeatum</em></td>
<td>Hymenoptera</td>
<td>Formicidae</td>
</tr>
<tr>
<td><em>Zonocerus variegatus</em></td>
<td>Orthoptera</td>
<td>Acrididae</td>
</tr>
<tr>
<td><em>Microtermes natalensis</em></td>
<td>Blattodea</td>
<td>Termitidae</td>
</tr>
</tbody>
</table>

### 3.2 Insect pests associated with fruit damage

#### 3.2.1 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 1, 2, 3, 4, 5, 6, 7 and 8).
3.2.2 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 overripe 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 9, 10, 11, 12, 13, 14, 15 and 16).
3.2.3 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 17, 18, 19, 20, 21 and 22).
3.3 Types 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 2).

Table 2: Types and percentage damage caused to sweet berry, Richardella dulcifica by the various insect pests at BioResource Institute Farm (BRI-Farm), Nsawam.

<table>
<thead>
<tr>
<th>Insect Causing Damage</th>
<th>Types of Damage to Berries</th>
<th>Percentage Damaged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceratitis punctata</td>
<td>Ovipositional punctures</td>
<td>55 (550)</td>
</tr>
<tr>
<td>Grammodes geometrica</td>
<td>Bored and sucked berries</td>
<td>19 (192)</td>
</tr>
<tr>
<td>Appias sylva</td>
<td>Bored and sucked berries</td>
<td></td>
</tr>
<tr>
<td>Bicyclus xenaes</td>
<td>Bored and sucked berries</td>
<td></td>
</tr>
<tr>
<td>Bicyclus safa</td>
<td>Bored and sucked berries</td>
<td></td>
</tr>
<tr>
<td>Amaurus nienius</td>
<td>Bored and sucked berries</td>
<td></td>
</tr>
<tr>
<td>Coelides forestan</td>
<td>Bored and sucked berries</td>
<td></td>
</tr>
<tr>
<td>Catopsilia forelula</td>
<td>Bored and sucked berries</td>
<td></td>
</tr>
<tr>
<td>Danaus chrysipus</td>
<td>Bored and sucked berries</td>
<td></td>
</tr>
<tr>
<td>Achaea spp.</td>
<td>Partially consumed berries</td>
<td>14 (143)</td>
</tr>
<tr>
<td>Achaea janata</td>
<td>Partially consumed berries</td>
<td></td>
</tr>
<tr>
<td>Oecophylla longinoda</td>
<td>Fruits with creamy spots</td>
<td>12 (115)</td>
</tr>
<tr>
<td>Tetramorum aculeatum</td>
<td>Fruits with creamy spots</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td>100 (1000)</td>
</tr>
</tbody>
</table>

Numbers in parenthesis are damaged fruits of each damage type.
3.4 Insect pests associated with defoliation

3.4.1 Damage by Lepidopteran Larvae
The older larvae of Achaea spp., notably Achaea janata, Grammodes geometrica, Coelades 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 23, 24, 25 and 26).

3.4.2 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 27, 28 and 29).
3.5 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 3).

Table 3: Mean percentage defoliation recorded on canopy levels in sweet berry plantation at the Bio-Resource Institute Farm, Nsawam.

<table>
<thead>
<tr>
<th>Canopies Levels</th>
<th>Mean Percentage Defoliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Canopy</td>
<td>5</td>
</tr>
<tr>
<td>Middle Canopy</td>
<td>10</td>
</tr>
<tr>
<td>Lower Canopy</td>
<td>7</td>
</tr>
</tbody>
</table>

3.6 Insect pests associated with root and stem damage

3.6.1 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 (Plates 30 and 31).
3.7 Beneficial insect species found on sweet berry plantations

3.7.1 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 32 and 33).

3.7.2 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 and 5).

3.8 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, 5, 6 and 7).

Table 4: Seasonality of insect pests of sweet berry, Richardella dulcifica and growth stage that cause damage.
<table>
<thead>
<tr>
<th>Season/Time of the year</th>
<th>Insect pests</th>
<th>Stage that cause damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Flowering and ** Fruiting</td>
<td>Achaea janata</td>
<td>Larva</td>
</tr>
<tr>
<td></td>
<td>Achaea spp.</td>
<td>Larva</td>
</tr>
<tr>
<td></td>
<td>Grammodes geometrica</td>
<td>Larva</td>
</tr>
<tr>
<td></td>
<td>Coeliades forestana</td>
<td>Larva</td>
</tr>
<tr>
<td></td>
<td>Catopsilia frorella</td>
<td>Larva</td>
</tr>
<tr>
<td></td>
<td>Danaus chrysipus</td>
<td>Larva</td>
</tr>
<tr>
<td></td>
<td>Appias sylvia</td>
<td>Larva</td>
</tr>
<tr>
<td></td>
<td>Bicyclus xenaes</td>
<td>Larva</td>
</tr>
<tr>
<td></td>
<td>Bicyclus saftza</td>
<td>Larva</td>
</tr>
<tr>
<td></td>
<td>Amauris nivius</td>
<td>Larva</td>
</tr>
<tr>
<td></td>
<td>Microtermes natalensis</td>
<td>Larva</td>
</tr>
<tr>
<td></td>
<td>Zonocerus variegatus</td>
<td>Larva</td>
</tr>
<tr>
<td></td>
<td>Oecophylla longinoda</td>
<td>Larva</td>
</tr>
<tr>
<td></td>
<td>Tetramorium aculeatum</td>
<td>Larva</td>
</tr>
<tr>
<td></td>
<td>* February to March — Minor Season and September to Early October — Major Season</td>
<td></td>
</tr>
<tr>
<td></td>
<td>** Late March to May — Minor Season and Early October to November — Major Season</td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Seasonality of insect pests of sweet berry, Richardella dulcifica and growth stage that cause damage.

<table>
<thead>
<tr>
<th>Season/Time of the year</th>
<th>Insect pests</th>
<th>Stage that cause damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Ripening</td>
<td>Ceratitis punctata</td>
<td>Larva and Adult</td>
</tr>
<tr>
<td></td>
<td>Achaea janata</td>
<td>Larva and Adult</td>
</tr>
<tr>
<td></td>
<td>Achaea spp.</td>
<td>Larva and Adult</td>
</tr>
<tr>
<td></td>
<td>Grammodes geometrica</td>
<td>Larva and Adult</td>
</tr>
<tr>
<td></td>
<td>Coeliades forestana</td>
<td>Larva and Adult</td>
</tr>
<tr>
<td></td>
<td>Catopsilia frorella</td>
<td>Larva and Adult</td>
</tr>
<tr>
<td></td>
<td>Danaus chrysipus</td>
<td>Larva and Adult</td>
</tr>
<tr>
<td></td>
<td>Appias sylvia</td>
<td>Larva and Adult</td>
</tr>
<tr>
<td></td>
<td>Bicyclus xenaes</td>
<td>Larva and Adult</td>
</tr>
<tr>
<td></td>
<td>Bicyclus saftza</td>
<td>Larva and Adult</td>
</tr>
<tr>
<td></td>
<td>Amauris nivius</td>
<td>Larva and Adult</td>
</tr>
<tr>
<td></td>
<td>Microtermes natalensis</td>
<td>Nymph and Adult</td>
</tr>
<tr>
<td></td>
<td>Zonocerus variegatus</td>
<td>Nymph and Adult</td>
</tr>
<tr>
<td></td>
<td>Oecophylla longinoda</td>
<td>Adult</td>
</tr>
<tr>
<td></td>
<td>Tetramorium aculeatum</td>
<td>Adult</td>
</tr>
<tr>
<td>* June — Minor Season and Late November to December — Major Season</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6: 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.
<table>
<thead>
<tr>
<th>Insect Pests</th>
<th>Parts they attacked</th>
<th>Time of the day insect pests attack</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achaear janata</td>
<td>Leaves</td>
<td>Morning and Late afternoon</td>
</tr>
<tr>
<td>Achaear spp.</td>
<td>Leaves</td>
<td>Morning and Late afternoon</td>
</tr>
<tr>
<td>Grammodes geometica</td>
<td>Leaves</td>
<td>Morning and Late afternoon</td>
</tr>
<tr>
<td>Coeliades forestan</td>
<td>Leaves</td>
<td>Morning and Late afternoon</td>
</tr>
<tr>
<td>Catopsilia frorella</td>
<td>Leaves</td>
<td>Morning and Late afternoon</td>
</tr>
<tr>
<td>Danaus chrysipus</td>
<td>Leaves</td>
<td>Morning and Late afternoon</td>
</tr>
<tr>
<td>Appias sylvia</td>
<td>Leaves</td>
<td>Morning and Late afternoon</td>
</tr>
<tr>
<td>Bicyclus xenaes</td>
<td>Leaves</td>
<td>Morning and Late afternoon</td>
</tr>
<tr>
<td>Bicyclus safzta</td>
<td>Leaves</td>
<td>Morning and Late afternoon</td>
</tr>
<tr>
<td>Amauris rievius</td>
<td>Leaves</td>
<td>Morning and Late afternoon</td>
</tr>
<tr>
<td>Microtermes natalensis</td>
<td>Roots and Stems</td>
<td>Morning, Afternoon and Evening</td>
</tr>
<tr>
<td>Zonocerus variegatus</td>
<td>Leaves</td>
<td>Morning and Late afternoon</td>
</tr>
<tr>
<td>Oecophyilla longinoda</td>
<td>—</td>
<td>Morning, Afternoon and Evening</td>
</tr>
<tr>
<td>Tetramorium aculeatum</td>
<td>—</td>
<td>Morning, Afternoon and Evening</td>
</tr>
</tbody>
</table>

**Table 7:** 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.

<table>
<thead>
<tr>
<th>Insect Pests</th>
<th>Ripening stages of the fruit they attack</th>
<th>Parts they attacked</th>
<th>Time of the day insect pests attack</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceratitis punctata</td>
<td>Semi ripe, Ripe and Over-ripe</td>
<td>Fruits</td>
<td>Morning and Late</td>
</tr>
<tr>
<td>Achaear janata</td>
<td>Ripe and Over-ripe</td>
<td>Fruits and Leaves</td>
<td>Morning and Late</td>
</tr>
<tr>
<td>Achaear spp.</td>
<td>Ripe and Over-ripe</td>
<td>Fruits and Leaves</td>
<td>Morning and Late</td>
</tr>
<tr>
<td>Grammodes geometica</td>
<td>Ripe and Over-ripe</td>
<td>Fruits and Leaves</td>
<td>Morning and Late</td>
</tr>
<tr>
<td>Coeliades forestan</td>
<td>Ripe and Over-ripe</td>
<td>Fruits and Leaves</td>
<td>Morning and Late</td>
</tr>
<tr>
<td>Catopsilia frorella</td>
<td>Ripe and Over-ripe</td>
<td>Fruits and Leaves</td>
<td>Morning and Late</td>
</tr>
<tr>
<td>Danaus chrysipus</td>
<td>Ripe and Over-ripe</td>
<td>Fruits and Leaves</td>
<td>Morning and Late</td>
</tr>
<tr>
<td>Appias sylvia</td>
<td>Ripe and Over-ripe</td>
<td>Fruits and Leaves</td>
<td>Morning and Late</td>
</tr>
<tr>
<td>Bicyclus xenaes</td>
<td>Ripe and Over-ripe</td>
<td>Fruits and Leaves</td>
<td>Morning and Late</td>
</tr>
<tr>
<td>Bicyclus safzta</td>
<td>Ripe and Over-ripe</td>
<td>Fruits and Leaves</td>
<td>Morning and Late</td>
</tr>
<tr>
<td>Amauris rievius</td>
<td>Ripe and Over-ripe</td>
<td>Fruits and Leaves</td>
<td>Morning and Late</td>
</tr>
<tr>
<td>Microtermes natalensis</td>
<td>—</td>
<td>Roots and Stems</td>
<td>Morning, Afternoon and Evening</td>
</tr>
<tr>
<td>Zonocerus variegatus</td>
<td>—</td>
<td>Leaves</td>
<td>Morning and Late</td>
</tr>
<tr>
<td>Oecophyilla longinoda</td>
<td>Semi ripe, Ripe and Over-ripe</td>
<td>Fruits</td>
<td>Morning, Afternoon and Evening</td>
</tr>
<tr>
<td>Tetramorium aculeatum</td>
<td>Semi ripe, Ripe and Over-ripe</td>
<td>Fruits</td>
<td>Morning, Afternoon and Evening</td>
</tr>
</tbody>
</table>
3.9 Seasonality, numbers and distribution 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 in both the minor and major seasons (Table 8 and 9). All the crawling insect pests' species captured, except Microtermes natalensis, occurred in large numbers throughout the flowering, fruiting and ripening stages of the crop. The seasonal distributions of the insect pests' species throughout the field, both during the minor and major seasons were irregular (Fig. 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10).

**Table 8:** Mean difference of insect pests' occurrence in both minor and major seasons in sweet berry, Richardella dulcifica plantations in three regions in Ghana.

<table>
<thead>
<tr>
<th>Blocks/Seasons</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 1 Minor -</td>
<td></td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Block 1 Major</td>
<td>15</td>
<td>8.00</td>
<td>120.00</td>
</tr>
<tr>
<td>Block 2 Minor -</td>
<td></td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Block 2 Major</td>
<td>15</td>
<td>8.00</td>
<td>120.00</td>
</tr>
<tr>
<td>Block 3 Minor -</td>
<td></td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Block 3 Major</td>
<td>15</td>
<td>8.00</td>
<td>120.00</td>
</tr>
<tr>
<td>Block 4 Minor -</td>
<td></td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Block 4 Major</td>
<td>15</td>
<td>8.00</td>
<td>120.00</td>
</tr>
<tr>
<td>Block 5 Minor -</td>
<td></td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Block 5 Major</td>
<td>15</td>
<td>8.00</td>
<td>120.00</td>
</tr>
</tbody>
</table>

**Table 9:** Mean difference of insect pests’ occurrence in both minor and major seasons in sweet berry, Richardella dulcifica plantations in three regions in Ghana.

<table>
<thead>
<tr>
<th>Blocks</th>
<th>Block 1</th>
<th>Block 2</th>
<th>Block 3</th>
<th>Block 4</th>
<th>Block 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasons</td>
<td>Minor and Major</td>
<td>Minor and Major</td>
<td>Minor and Major</td>
<td>Minor and Major</td>
<td>Minor and Major</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.001</td>
<td>.001</td>
<td>.001</td>
<td>.001</td>
<td>.001</td>
</tr>
</tbody>
</table>

Differences were tested with Wilcoxon Signed Ranks Test.
Fig. 1: (a) and (b): Normal and detrended normal of seasonal distribution of insect pests collected in block 1 in minor season of sweet berry, Richardella dulcifica farms in three regions in Ghana.
Fig. 2: (a) and (b): Normal and detrended normal of seasonal distribution of insect pests collected in block 2 in minor season of sweet berry, Richardella dulcifica farms in three regions in Ghana.
Fig. 3: (a) and (b): Normal and detrended normal of seasonal distribution of insect pests collected in block 3 in minor season of sweet berry, Richardella dulcifica farms in three regions in Ghana.
Fig. 4: (a) and (b): Normal and detrended normal of seasonal distribution of insect pests collected in block 4 in minor season of sweet berry, Richardella dulcifica farms in three regions in Ghana.
Fig. 5: (a) and (b): Normal and detrended normal of seasonal distribution of insect pests collected in block 5 in minor season of sweet berry, Richardella dulcifica farms in three regions in Ghana.
Fig. 6: (a) and (b): Normal and detrended normal of seasonal distribution of insect pests collected in block 1 in major season of sweet berry, Richardella dulcifica farms in three regions in Ghana.
Fig. 7: (a) and (b): Normal and detrended normal of seasonal distribution of insect pests collected in block 2 in major season of sweet berry, Richardella dulcifica farms in three regions in Ghana.
Fig. 8: (a) and (b): Normal and detrended normal of seasonal distribution of insect pests collected in block 3 in major season of sweet berry, Richardella dulicifera farms in three regions in Ghana.
Fig. 9: (a) and (b): Normal and detrended normal of seasonal distribution of insect pests collected in block 4 in major season of sweet berry, Richardella dulcifica farms in three regions in Ghana.
Fig. 10: (a) and (b): Normal and detrended normal of seasonal distribution of insect pests collected in block 5 in major season of sweet berry, Richardella dulcifera farms in three regions in Ghana.

4.0 DISCUSSION

4.1 Insect pests of sweet berry, Richardella dulcifera

The study identified a tephritid, C. punctata, as the major insect pest, as far as economic losses in sweet berry production are concerned (Table 2). 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.

4.2 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 and 5). 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 flowering 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. It was observed that, the seasonal distributions of the insect pests’ species throughout the plantations both during the minor and major seasons was not regular due to both the biotic and abiotic factors (Fig. 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10). The difference of the insect pests’ occurrence between both the minor and major seasons was significant at the 0.01 level of probability (Table 8 and 9). Majority of the insect pests occurred in the major season than the minor. The majority of the insect pests attack during the adult stage whereas others do damage when in the larval or nymphal stages, allowing the insect pests to seriously cause economic damage (Table 4 and 5). 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.

4.3 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 11 and 12). 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%). 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 3). 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.

4.4 Management of insect pests of sweet berry, Richardella dulcifica

4.4.1 Management tactics at flowering stage
Cultural management measures during the flowering stage can be used to manage the population of Achara spp, notably Achara janata, Grammodes geometrica, Coeliades forestan, Catopsilia forellia, Danaus chrysisipus, 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 32 and 33), 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 established 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.

4.4.2 Management tactics at fruiting and ripening stages
Ceratitis punctata, Oecophylla longinoda, Tetramorium aculeatum (all attack only at ripening stage), Achara spp. notably Achara janata, Grammodes geometrica, Coeliades forestan, Catopsilia forellia, Danaus chrysisipus, 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 devise a well thought-out plan to manage insect pests.
5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion
The study indicated that, all the sweet berry farmers usually employed cultural measures to manage insect pests of the crop. The study further revealed that, the fruit feeders (i.e. Ceratitis punctata, Achara spp. notably Achara janata, Grammodes geometrica, Cossiates forestan, Catopsilia frorella, Danaus chrysipus, Appias sylvia, Bicyclus xenaes, Bicyclus sattza, Amarius niuvius, 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.

5.2 Recommendation
Therefore, the sweet berry farms should be intercropped with other fruit crops in order to reduce pests’ activities. Administering insecticides to manage insect pests of sweet berry farms should target the middle and lower canopy levels to suppress their populations. Finally, 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.

ACKNOWLEDGEMENT
Deep thanks and appreciation go to Dr. M. K. Billah and Mr. H. E. Davis of the University of Ghana, for the identification of the insects collected, Authorities of Bio-Resource Institute (BRI)-Farm, Nsawam and all other sweet berry farmers involved in the present study.

REFERENCES

