# ASSESSING THE BIO-EFFICACY OF A NEW FOOD BAIT-THE GREAT FRUIT FLY BAIT (GFFB), ON SELECTED WATERMELON FIELDS IN THE ADA WEST MUNICIPALITY.

**BY**

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# DECLARATION

This is to certify that this thesis is the result of research undertaken by Boateng Belinda Obenewa and except for references to work of other researchers that have been duly acknowledged this thesis in whole or in part has not been presented for any degree elsewhere.

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# DEDICATION

This work is dedicated to my mother Intarmah Susana (Miss) and my son, Boateng Enoch Nana Yaw.

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| | |
|---|---|
| CL | CueLure |
| F/T/D | Flies per Trap per Day |
| FAO | Food and Agriculture Organisation |
| IAEA | International Atomic Energy Agency |
| ICIPE | International Center of Insect Physiology and Ecology |
| IPM | Integrated Pest Management |
| ISSER | Institute of Statistics, Social and Economic Research |
| MAT | Male Annihilation Technique |
| ME | Methyl Eugenol |
| MOFA | Ministry of Food and Agriculture |
| PPRSD | Plant Protection and Regulatory Services Directorate |
| RCBD | Randomised Complete Block Design |
| SIT | Sterile Insect Technique |

# ABSTRACT

The bio-efficacy of the Great Fruit Fly Bait (GFFB) as a food bait was compared with the standard, SUCCESS APPAT (GF-120) for the management of fruit flies in watermelon farms in the Ada West District of Greater Accra Region, Ghana within the period (1st May, 2015-12th June, 2015). The experimental design used for the layout was Randomised Complete Block Design (RCBD). Bait was sprayed-delivered at 50ml per $m^2$ of foliage of watermelons onto the under surface of the leaves but not on fruits at low spray pressure and large droplet size for each of the treatment plots (GFFB and GF-120 plots). Control plots received no treatment. Fruit fly populations in all farms were monitored weekly using two parapheromone attractants- Methyl Eugenol (ME) and CueLure (CL) deployed in homemade Mineral Water Bottle (MWB) traps. A week pre-treatment trapping was carried out before application of the treatments of the three plots. After 4-5 weeks of application a total of 90 fruits were sampled from the treatment plots to determine level of fruit fly infestation. Throughout the study period, a total of 2,554 insects were collected, of which 2,483 (99.68%) were fruit flies and 71 (2.78%) non-target species. In all, one fruit fly species *Bactrocera dorsalis* was identified. Methyl Eugenol traps recorded high fly catches with most of the catches made on the control field. CueLure traps made no catches on both GFFB and control plots but two fly catches on GF-120. The relative fly densities (the number of flies per trap per day) for Methyl Eugenol traps were 6.509, 5.685 and 10.676 for GFFB, GF-120 and control plots, respectively. Those for CueLure were 0.00, 0.019 and 0.00, respectively for GFFB, GF-120 and control. There was record of fruit fly infestation in the fruits incubated from the experimental plots since some fruit fly pupae were collected, although there was no adult emergence. The GFFB was found to be effective in controlling the fruit flies and there was no significant difference between GFFB and GF-120 in reducing infestation levels of the watermelon fruits.

# CHAPTER ONE

# GENERAL INTRODUCTION

Watermelon, *Citrullus lanatus* is a warm seasoned crop in the Cucurbit family. The crop is commercially grown in areas with long frost-free warm periods. Asia grows three-fourth of the world's watermelon with the leading country in production being China (Wehner et al, 2003). It has been cultivated in Africa and the Middle East for thousands of years and in China at least since 900 AD. Watermelon is thought to have originated in South Africa because it is found growing wild throughout the area and reaches maximum diversity there. It has been cultivated in Africa for over 4,000years (Erhirhie et al., 2013).

Records by MOFA, 2015, indicates that watermelon thrive on well drained fertile soil. As such in Ghana, the Northern Savanna, coastal areas and forest zone are identified as areas where it is cultivated the most. Ada-West has been identified as one of such areas in recent times (Yaro et al., 2015).

Farmers of Ada-West who previously cultivated watermelon on small scale now cultivate it on large scale after observation that it was an opportunity to break even, when poor rains affected farming in the district resulting in low crop yields. However, its cultivation is capital intensive and comes with its own challenges like the control of diseases, weeds and insect pests (Gichimu et al., 2008).

Some insect pests of watermelon according to MOFA, (2015) are fruit fly (*Dacus armatus*) and beetles (*Asbecesta cyanipenus*), which are very troublesome, causing major problems to farmers.

Pest tephritids occur in almost all fruit growing areas of the world. The pest attack almost all commercially produced fruits and vegetables. Some tephritids are now pest where they previously did not occur, and are considered invasive species. In such cases, quarantine restrictions have to be imposed to limit further spreading of those fruit fly pests. Such quarantine regulations imposed by an importing country can either deny a producing country a potential export market or force the producer to carry out expensive disinfestations treatments of its horticultural produce (White & Elson Harris, 1992).

Generic control methods such as food-based techniques, although potentially applicable in Africa, have not been validated against most of the locally important flies. Africa has been used as a rich source of natural enemies for biological control effort in other regions but has never been a beneficiary of such programs (Lux et al., 2003).

Current efforts use traps baited with food attractants not only for monitoring, but also for mass trapping. The emphasis is on the development of localized baiting stations, composed of bait, a killing agent (usually a pesticide) and a protective housing. Such methods restrict usage of pesticide even further, and limit contact with fruits and the environment. Standard food baits are produced by several companies in the USA, Europe and Australia, and are relatively inexpensive. However, they are usually formulated as liquid, which does not only increase shipment cost, but also decreases convenience of application and durability in the field (Lux et al., 2003a).

## JUSTIFICATION

In Ghana, agriculture is a major sector that boosts the economy, and therefore any negative effect on agriculture adversely affects the economy. Also, the major exported produce of the country is mostly agricultural produce, so once measures are not put in place to control or eradicate fruit and crop pests like fruit flies, chances of losing international market and its consequence of- affecting the economy is very high

The use of insecticides to get rid of fruit flies in the fields has proven to provide little or no help at all due to the mode of infestation and life cycle of the fly. Therefore, there is the need to try other means like application of food bait. The principle of the food bait is to get the fruit flies attracted to the bait due to their high sugar and protein contents (as a source of food for egg development and growth). However, small quantities of insecticide are added to the protein source to serve as killing agents when the baits are fed on by the flies. These when fed upon by the fruit flies kill them due to the killing agent added to the bait. Because of the limited and restricted use of insecticides in this method of fruit fly management, fruits and vegetables hardly get contaminated or harbor chemical residues in them after harvesting. As a result of its limited likelihood of direct contamination, the method is now widely accepted worldwide, and even in organic farming (Vayssieres et al., 2009).

In Ghana, however, the use of food bait in the management of fruit flies started only in 2009 when one of such products, SUCCESS Appat ® (GF-120) was evaluated in mango and citrus fields, and was found to provide 84-95% protection to the fruits compared to the controlled field (Billah et al, 2010a, b). Based on this evaluation, the Environmental Protection Agency (EPA; Ghana) and the Plant Protection and Regulatory Services Directorate of the Ministry of Food and Agriculture (PPRSD MOFA), allowed its use in the management of fruit flies. Since then, two additional food baits; CeraLure and The Great Fruit Fly Bait (GFFB) have been introduced in the country for use.

Research has also shown that apart from mango and citrus, very little work has been done on other fruits and vegetables and one such crop is watermelon. Watermelons are produced in very high volumes, but as a result of the high levels of fruit fly infestations, farmers lose about 45% to the flies (De Bon et al., 2014). Of the marketable yield left, they always target the local market, as they are not sure of the fate of their produce should they venture into the export of their produce (M.K. Billah, Fruit fly specialist, DABCS, personal comm., 2014). It is in line with the above that this research work was aimed at the use of GFFB against fruit flies in a non-tree crop (watermelons) environment.

**Objectives**

The overall objective of the study was to find alternate management tactic for fruit flies through evaluation of The Great Fruit Fly Bait (GFFB) in watermelon farms in the Ada West Municipality.

**Specific objectives**

The specific objectives include:

1. To determine infestation levels of watermelon fruits from the different treatment plots.
2. To assess the performance of GFFB against fruit flies in a watermelon field, using the food bait product, SUCCESS Appat (GF-120), as a standard.
3. To assess the species composition and relative fly densities from the watermelon farms.

# CHAPTER TWO

# 2.0 LITERATURE REVIEW

## 2.1 Watermelon

### 2.1.1 Origin of watermelon

Watermelon is thought to have originated in South Africa because it is found growing wild throughout the area and reaches maximum diversity there. It has been cultivated in Africa for over 4,500 years (Paris, 2015). In 1857, David Livingstone (the noted Missionary) reported watermelon grows profusely after unusually heavy rainfall in Kalahari Desert (the current nations of Namibia and Botswana) and semitropical regions of Africa. De Candolle in 1882, considered the evidence sufficient to prove that watermelon was indigenous to tropical Africa, more specifically the Southern parts of Africa (Mallick et al., 1986).

### 2.1.2 Distribution of watermelon

African slaves and European Colonists contributed in the distribution of watermelon worldwide. It was transported to New Zealand, Eastern North America, the West Indies, Brazil, the Islands of the Pacific and then Australia (Maynard et al, 2006). Within the periods of 1629 and 1822, records indicate that watermelons were cultivated in places like Massachusetts, the Florida, Indies, the Midwest, by Indian tribes along the Colorado River, and Illinois. However, watermelons are currently found growing world-wide in the warm regions (Wehner, 2008).



### 2.1.3 Botany of watermelon

Watermelon belongs to the genus Citrullus, consisting of numerous species in the flowering plant family Cucurbitaceae (Weng and Sun, 2012). The plant grows by trailing on the ground. Just when the cotyledons emerge to the surface of the soil, the root system begins to form and becomes more extended when flowering begins. Watermelon has a highly branching taproot which extends about 1m into the soil. The stem is very long, and highly branched. Watermelon trails, especially the younger shoots are protected from overheating by long wholly hairs which cover them. Watermelon leaves are dark green and have large veins (Osman and Milan, 2006). The plant is monoecious, having yellow, five-petalled flowers.

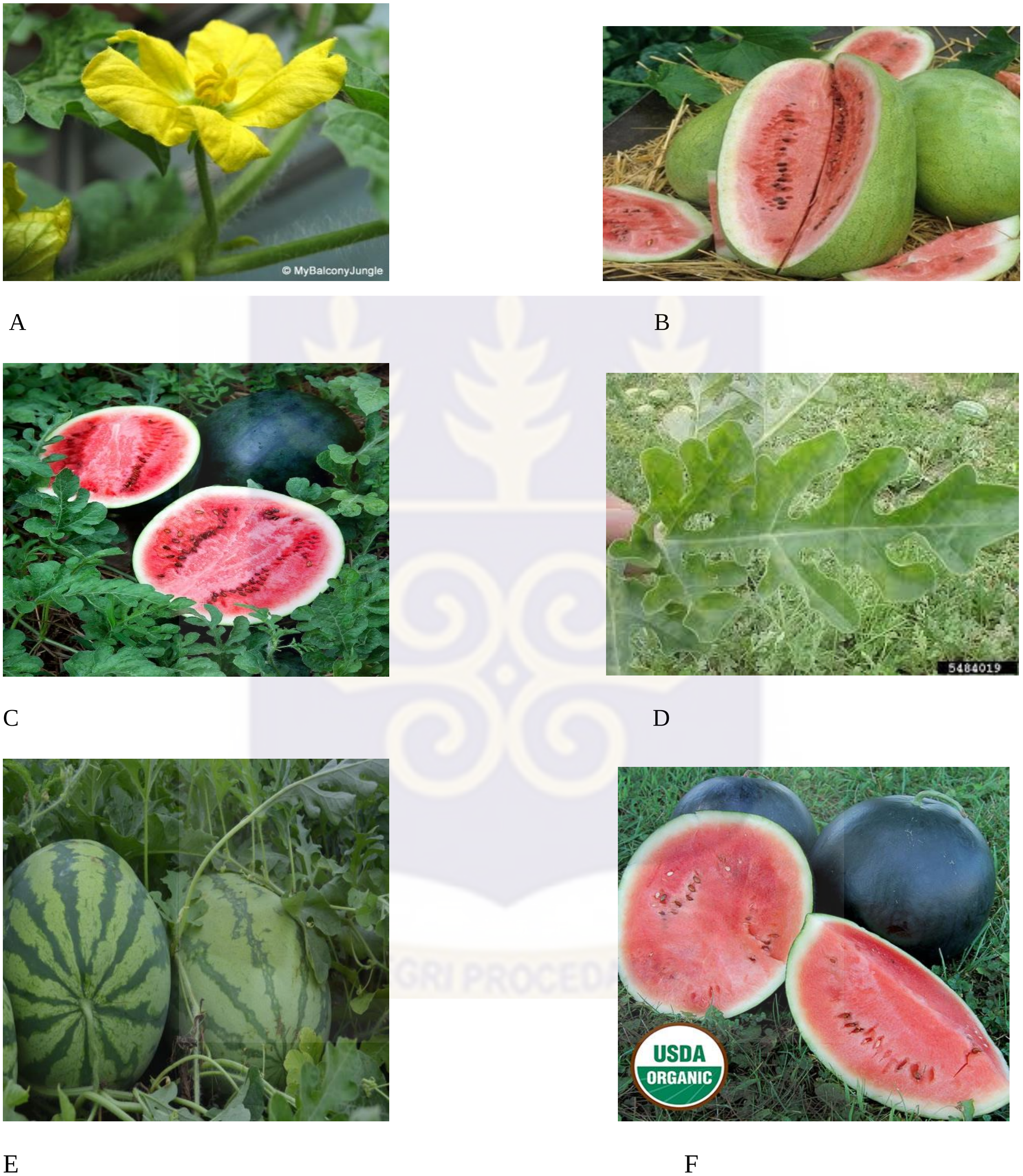


**Fig 2: Nature of the watermelon plant (source:** Guide, C. P. C. Fall Vegetable Garden**)**

**A:** Yellow, five-petalled flower**.** **B:** Sole pale green skin fruit **C:** Sole dark green skin fruit **D:** Dark green large veined leaf **E:** green striped with yellow skin fruit **F:** Edible pink flesh with many flat oval black seeds

The fruit has varied shape, size and skin colour. The shape and skin colour ranges respectively from round to cylindrical and green striped with yellow or a sole green. The edible flesh which is mostly pink with many flat oval black seeds can as well exist as orange yellow or white flesh and Seedless. (Meena et al., 2016).

#### 2.1.4 Watermelon cultivars

The most important decision the producer must make, is in selecting the best watermelon variety. The variety must be suitable for the available market, have acceptable yield, adapted to production area and highly pest resistant. Records indicate that watermelon fruits that are light- green and grey-green in colour do not easily have sunburn injury compared to the striped and dark-green varieties. Another important varietal feature is the cultivars resistance to races of Fusarium wilt and Anthracnose disease. However, there are no known varieties resistant to insects or nematodes.

### 2.2 Watermelon production in Ghana

#### 2.2.1 Watermelon cultivars in Ghana

Cultivars of watermelon in Ghana include Sugar Baby, Kaolack, Top Harvest, Monac, Sweet Dragon and Trimson Sweet.

#### 2.2.2 Climatic conditions of watermelon production

Watermelons are very sensitive to temperatures. They require temperatures between 18$^{o}$C and 35$^{o}$C for maximum growth but temperatures above 35$^{o}$C or below 10$^{o}$C will slow growth and maturation of crop. (Wahid et al., 2007).

### 2.2.3 Nutritional value of watermelon

Watermelon's high levels of lycopene are very effective at protecting cells from damage and may help lower the risk of heart disease, according to a study at Purdue University. Also, the fruits concentration of citrulline and arginine are good for the heart. Arginine can help improve blood flow and may help reduce the accumulation of excess fat. The lycopene in watermelon makes it an anti-inflammatory fruit. Lycopene is an inhibiter for various inflammatory processes and also acts as an antioxidant to neutralize free radicals. Additionally, watermelon contains choline which helps keep chronic inflammation down according to a 2006 article published in shock medical journal. Watermelon water content keep the body hydrated and their juice is full of good electrolytes that can even help prevent heat stroke (Branch, 2011). Watermelon contains fibre which encourages a healthy digestive tract. Vitamins A are a stellar for the skin and just a cup of watermelon contains nearly one quarter of the daily recommended intake of it. Vitamins A help keep skin and hair moisturised and it also encourages healthy of new collagen and elastic cells according to the Cleveland Clinic. Drinking watermelon juice before an intense workout helps reduce next day muscle soreness and heart rate according to 2013 study published in the journal of Agriculture and Food Chemistry. This can be attributed to watermelon amino acids citrulline and arginine which help improve circulation. Watermelon maybe helpful in reducing the risk of cancer, through their antioxidant properties. Lycopene in particular has been linked to reducing prostate cancer cell proliferation according to the National Cancer Institute (Liu, 2004).

### 2.2.4 Uses of watermelon

The watermelon fruit is entirely edible. In china for instance, the watermelon is used as a vegetable when stir-fried, stewed and pickled (Lee et al., 2006).

The juicy sweet interior flesh according to food network in 2015 is blended and used as drinks, beverages and cocktails. Sliced watermelon fruits are used as salad and snacks when mixed with other fruits. Also, watermelons are consumed as a skewer when stab with a wooden skewer and used in preparation of soups.

### 2.2.5 Watermelon production in the world

Over half of all the 102 million tons of watermelon annually produced around the world are grown in Asia. China is the largest producer growing over two thirds of the world's watermelons (Wehner and Maynard, 2003).

According to the statistical agency of the United Nations FAO, during the period between the year 2008 and 2012, watermelon production in the world increased continuously. In 2008 production amounted to 94656 billion kilos, in 2009 it totaled 98737 billion kilos and in 2010 it exceeded the hundred billion barrier with a total of 101342 billion kilos. World production in 2011 was 103310billion kilos and in 2012 production amounted to 105372 billion kilos (Turhan et al., 2012).

**Table 2.1: Top ten watermelon producing countries as at 2012**

| COUNTRIES | PRODUCTION | WORLD'S SHARE % |
|---|---|---|
| **China** | 70000 bilion kilo | 66.43 |
| **Turkey** | 4446 bilion kilo | 3.84 |
| **Iran** | 3800 bilion kilo | 3.60 |
| **Brazil** | 2079.55 bilion kilo | 1.97 |
| **Egypt** | 1874.71 bilion kilo | 1.78 |
| **USA** | 1770.63 bilion kilo | 1.68 |
| **Algeria** | 1495.08 bilion kilo | 1.42 |
| **Russia** | 1453.31 bilion kilo | 1.38 |
| **Uzbekistan** | 1350 bilion kilo | 1.10 |
| **Kazakhston** | 1154.90 bilion kilo | - |

(Source FAOSTAT, 2012)

During 2014, a total of over 3,500 million kilos of watermelons were purchased worldwide, according to data from the Statistics Division of the United Nations (UN).

Watermelon purchases by all countries of the world at the said year amounted to a total volume of 3,538.31 million kilos worth 1,137.88 million Euros; with a kilo averagely costing 0.322 Euro ( POPESCU, 2012). .

**2.2.5.1 Importers**

The Netherlands, the United Kingdom, France, Germany and Canada are in order the five countries out of the world's ten largest watermelon importers countries noted for paying the best prices. The total volume of watermelons bought by the USA in 2014 amounted to 654.33 million kilos, 18.49 percent of the total, for which they paid 223.66 million Euro, with an average price of 0.342 Euro per kilo.

The second largest buyer was Iraq, with a volume of 605.43 million kilos (17.11% of the total), a value of 106.04 million Euros and an average price of 0.175 Euro per kilo ( POPESCU, 2012).

In 2014, Germany bought a total of 313.19 million kilos (8.85%), paying 145.73 million Euro for them, with an average price of 0.465 Euro per kilo. The fourth among the world's largest watermelon importers is China, which bought 214.61 million kilos of this fruit (6.07%). China paid the rest of the world an average price of 0.143 Euro per kilo, with a total value of its purchases totalling 30.63 million Euros. Canada stands fifth in the ranking, with watermelon imports reaching 213.59 million kilos (6.04%) worth 85.89 million Euros and an average price of 0.402 Euro per kilo. The UAE imported 175.32 million kilos (4.95%) worth 33.91 million Euro with an average price of 0.193 Euro/kg. France's purchases amounted to 118.41 million kilos (3.35%) worth 56.61 million Euros, with an average price of 0.478 Euro per kilo. Poland bought 108.39 million kilos (3.06%), for 29.54 million Euro, at an average price of 0.273 Euro per kilo. The Netherlands ranks ninth in the world ranking after buying 106.62 million kilos of watermelons

(3.01%) for 69.24 million Euro at an average price of 0.649 Euro/kilo. The tenth place in the ranking of global watermelon buyers was for the UK, with 92.1 million kilos (2.6%), 46.71 million Euros and an average price of 0.507 Euro per kilo ( POPESCU, 2012).

#### 2.2.5.2 Suppliers

The largest watermelon suppliers for the U.S. were Mexico, with 568.9 million kilos, Guatemala, with 77.98 and Honduras with 4.5 million kilos. Spain sold 13,000 kilos.

Iraq bought its watermelons mainly from Iran, with 594.9 million kilos. Other suppliers were Turkey, with 10.46 million kilos and Kuwait, with 36,000 kilos.

Germany imported 200.97 million kilos of watermelons from Spain, 68.07 million from Italy and 13.36 million kilos from Greece (POPESCU, 2012). .

### 2.2.6 Commercial watermelon production in Ghana

The Ghana Agricultural News digest in 2014 revealed that, the Ada West District which previously was associated with tomatoes cultivation is rapidly becoming one of the largest watermelon growing areas in Ghana. Generally, the plant does well in low-lying areas, making the flat plains of the district ideal for their cultivation. Watermelon is planted between January and March against the minor rainy season and from September to October during the major raining season. Despite its name, watermelon doesn't need much water for grow. The flat plains of the district are an ideal place for their cultivation as they do well in low-lying areas.

In the district, the crop could be seen on display for sale under sheds and table tops as one drives through the towns of Addokope, Hwakpo, Koluedor, Matsekope, and Sege along the Accra -Aflao Highway.

According to the Ada West District Agriculture Officer, Mr Reuben Adase, the varieties of watermelon grown in the district are the Sugar Baby, Kaolack, Top Harvest, Monac, Sweet Dragon and Trimson sweet. The Sweet Dragon variety is produced most because of the high demand for it by the big supermarkets and other large vegetable selling shops.

#### 2.2.7 Constraints to watermelon production in Ghana

According to the elected Assembly member for the Addokope Electoral Area, Adi Senor, who also cultivates watermelon, watermelon water farming is capital intensive. The plant cultivation also comes with challenges like pricing, which can fall as low as one Ghana Cedi for a sizeable watermelon as the season comes to an end. This is just one of the many challenges faced by the small-scale rural farmers.

### 2.3 Grades and standards

The general appearance of watermelon is used to grade it. Defects considered on the watermelon fruit include Anthracnose, decay, and sunscald. Other characteristics used are the appearance of the rind based on the area of the rind affected by the defects. The different weights and the presence of defects is used as standards at the various shipping points and destination for variations in grading and handling (Kirnak and Dogan, 2009).

Grades of watermelons are in three categories based on the United States of America's system of grading being;

***U.S. Fancy consisting of watermelons which meet the following requirements:

a) Basic requirements:

1) Mature;

2) Similar varietal characteristics;

3) Fairly well formed;

4) Not overripe;

b) Free from:

1) Anthracnose;

2) Decay;

3) Sunscald;

4) Whiteheart;

c) Free from damage by any means.

d) For tolerances.

***U.S. No. 1 consisting of watermelons which meet the following requirements:

a) Basic requirements:

1) Mature;

2) Similar varietal characteristics;

3) Fairly well formed;

4) Not overripe;

b) Free from:

1) Anthracnose;

2) Decay;

3) Sunscald;

c) Free from damage by any means.

***U.S. No. 2 consisting of watermelons which meet the following requirements:

a) Basic requirements:

1) Mature;

2) Similar varietal characteristics;

3) Not overripe;

4) Not badly misshapen;

b) Free from:

1) Anthracnose;

2) Decay;

3) Sunscald;

c) Free from serious damage by any means.

d) For tolerances

(Kader, 2002)

**2.4 Major insect pests of watermelon**

The Melon fly (*Zeugodacus* (=*Bactrocera) cucurbitae*), a fruit fly of the family Tephritidae is native to India, and is distributed throughout most parts of the country. It can be found throughout most of Southern Asia, several countries in Africa, and some island groups in the Pacific. In the United States, it was the first tephritid fruit fly species established in Hawaii. It was introduced there from Japan around 1895, and by 1897, when it was first observed, it had already become a serious pest. Not yet established in the continental United States, it is often intercepted at ports. Occasionally, an infestation is established, but is then eradicated. The latest such incident was several flies discovered in August 2010, in Kern County, California. The area is now under quarantine and an eradication program is underway (Dhillon et al., 2005).

### 2.4.1Fruit flies

Fruit flies (Diptera: Tephritidae) are classified among the most economically important insect pests in the Afro-Tropical Region. Their damage to fruits and vegetables run in millions of dollars, posing major constraint to commercial and subsistence farming in the region (De Meyer and White, 2004). Pest tephritids occur in almost all fruit growing areas of the world. Some species are considered invasive because they have become pests in regions far from their native range. In such cases, quarantine restrictions have to be imposed to limit further spreading of those fruit fly pests. Such quarantine regulations imposed by an importing country can either deny a producing country a potential export market or force the producer to carry out expensive disinfestations treatments of its horticultural produce (White & Elson Harris, 1992).

Generic control methods such as food-based techniques, although potentially applicable in Africa, have not been validated against most of the locally important flies. Africa has been used as a rich source of natural enemies for biological control effort in other regions but has never been a beneficiary of such programs (Lux et al., 2003a).

Current efforts use traps baited with food attractants not only for monitoring, but also for mass trapping. The emphasis is on the development of localized baiting stations, composed of bait, a killing agent (usually a pesticide) and a protective housing. Such methods restrict usage of pesticide even further and limit its contact with fruits and the environment. Standard food baits are produced by several companies in the USA, Europe and Australia, and are relatively inexpensive. However, they are usually formulated as liquid, which does not only increase shipment cost, but also decreases convenience of application and durability in the field (Lux et al., 2003a).

### 2.4.2 Classification of fruit flies

About 70 species of fruit flies are considered important agricultural pests, and others are minor or potential pest. True fruit flies belong to the family Tephritidae, and include about 4000 species arranged in 500 genera. As such, it is amongst the largest family of Diptera (true flies) and of the most economically important (White & Elson-Harris, 1992).

### 2.4.3 General biology and life cycle of fruit flies

A basic understanding of the life cycle of fruit fly helps to put the appropriate measures in place to effectively control it.

#### 2.4.3.1 Stages of the life cycle

The life cycle of fruit flies involves four main stages, the egg to larva (maggot), to pupa and then to the adult. The matured female fly lays (between 1-20) eggs into the maturing fruit of the host plant. The presence of the fly is unlikely to be noticed at this stage. Within 2-4 days, the eggs in the fruit hatch into larvae which feed profusely on the flesh of the fruit. At this stage, it is likely to detect the presence of the fly in the fruit if cut open. As the fruit ripens and fall to the ground, fully matured larvae move out of the fruit and burrow into the soil to pupate. The adult flies may emerge from the pupae within seven days or beyond base on temperature condition, high temperatures encourage early emergence while low temperatures late emergence. The adult fly looks for protein sourced nourishment to mature sexually. At this stage of the cycle, the adult fly may easily be recognized around fruits (Ekesi and Billah, 2009).

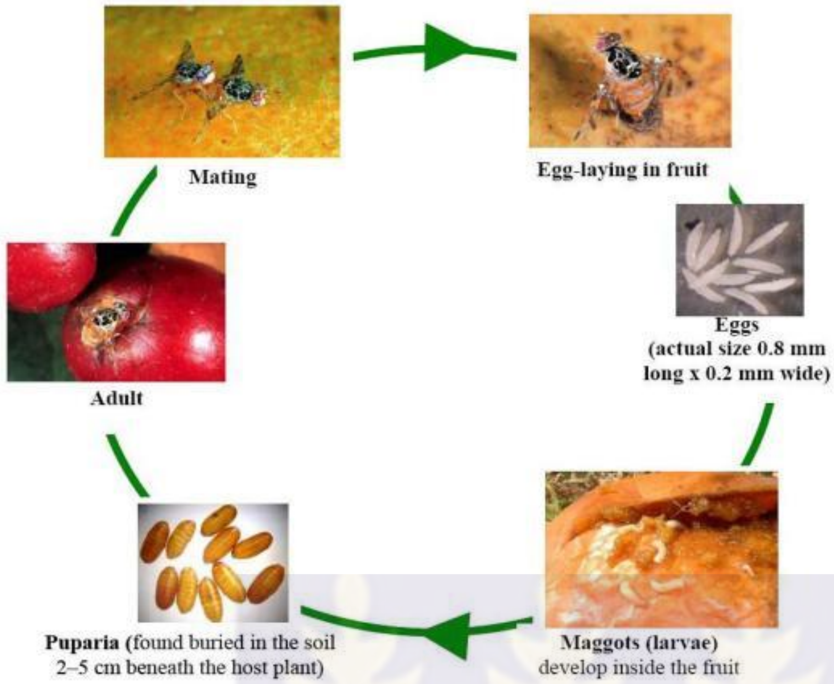


**Fig 2.2: Generalised life cycle of Tephritid fruit flies (source: Ekesi & Billah, 2009)**

### 2.4.4 Economic importance of fruit flies

Fruit flies are very important economically not only because of the damage they cause to fruits and vegetables by direct losses in yield and increased cost of production, but also losses of export market and or additional cost incurred in treatment of farm produce (APHIS, 1988). Fruit flies are one of the worst pests of fruits and vegetables causing damage which runs into millions of dollars annually (Ekesi & Billah, 2007). Without control, direct damage has been reported from 30 to 80% depending on fruit variety, location and fruit season (Mwatawala et al., 2006a). Studies conducted in Tanzania, where *B. dorsalis* was detected in 2003, reported losses ranging from 20 to 61.7% while in Ghana and Benin losses were estimated between 60 and 85% (Ekesi et al., 2006). In addition, losses due to quarantine restriction imposed by importing countries have been enormous.

### 2.4.5 Economically-important fruit flies of watermelon

The Melon fruit fly damages over 81 plant species. Based on the extensive surveys carried out in Asia and Hawaii, plants belonging to the family Cucurbitaceae are preferred most (Allwood et al., 1999). Doharey in 1983 reported that it infests over 70 host plants, among which, fruits of bitter gourd (Momordica charantia), muskmelon (Cucumis melo), snap melon (Cucumis melo var. momordica) and snake gourd (Trichosanthes anguina and T. cucumeria) are the most preferred hosts. However, White and Elson-Harris (1994) stated that many of the host records might be based on casual observations of adults resting on plants or caught in traps set in non-host plant species.

### 2.4.6 Status of fruit fly management in Africa

Farmers in Ghana are using several measures to control fruit flies (including *B. dorsalis*). The measures include, trapping, cultural control and the use of insecticides. Some farmers in their quest to minimize losses incurred from fruit fly infestation, combine several measures in an IPM fashion (Billah et al., 2011).

## 2.5 Management of flies

The eradication approach and the Integrated Pest Management approach are the two main strategies used to manage fruit fly populations (Lux et al., 2003a; Ekesi and Billah, 2006). The IPM technique helps keep fruit fly populations in check so as to reduce yield losses. The eradication approach on the other hand involves creating a fruit fly free zone by getting rid of the target fruit fly population in that area.

### 2.5.1 The IPM approach

Previous knowledge in the management of fruit fly indicates that a single approach has never been efficient. However, a combination of several compatible strategies is always fruitful. The combined strategies according to Ekesi and Billah (2007) include regulatory control, culture and sanitation, chemical control, biological control, mechanical control, protection, male suppression, field monitoring, host plant resistance, and to some extent, chemical control.

### 2.5.2 Regulatory/ quarantine control

A pest control method that has legal backing of a country. According to Dhillon et al., (2005), the main means of the spread of insect pests occurs when infested plant material are imported or exported without post-harvest treatment from one area or country to another non-infested place. The spread can be blocked or prevented through tight quarantine and treatment of fruits at the import and export ports.

### 2.5.3 Cultural control and sanitation methods

Fruit fly population usually build-up when farms are poorly managed or abandoned. Based on the knowledge of the life cycle of the fly, where larvae dropped from fruits to pupate in the soil, cultural control method such as farm sanitation and crop hygiene helps to break its reproduction cycle. Infested fruits on trees, falling fruits with maggot infestation, are collected and destroyed by keeping them in thick black airtight polythene bags, and exposed to the sun to be heated up for a period up to two weeks to kill the maggots therein. Report from Egypt confirms a success story of controlling *B. zonata* using killing bags (Mohammed and El-Wakkad, 2003).

### 2.5.4 Chemical control

It is the controlling of the flies by combining baits with different insecticides. By exploiting the attractive properties of the bait and adult mobility, bait spray is generally applied on bands or spots to reduce the area of coverage (Prokopy et al, 2003).

### 2.5.5 Bait spot spraying

Fruit flies need sugars and proteinaceous food to develop and mature. Due to this, they are highly attracted to high quality protein and sugar baits. Therefore, to control the flies little amount of insecticides is added to the commercially protein baits produced. GFFB and GF-120 are examples of such protein baits (Prokopy et al, 2003).

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### 2.5.6 GF-120

It is liquid bait made of protein food substances and a spinosad-based insecticide. Spinosad is very safe to humans. The flies are killed when they feed on droplets dispersed on plant foliage. GF-120 is effective when the protocol is followed rigorously (Vayssieres et al., 2009). It contains 0.02% spinosad and 99.8% inert ingredients (includes water, sugar. protein and attractants). It attracts only targeted insects, fruit flies. The goal is to strategically place large droplets where flies will find them in their normal search for food. The large droplets make it viable in the field for a longer period of time. (Dow Agro Sciences, 2016).

### 2.5.7 GFFB

Great Fruit Fly Bait (GFFB) is a unique formula based on the knowledge of the biological behaviours and dynamics of fruit flies especially their need for special nutrients after emerging from the pupa. Plant sugars and proteins that are highly attractive to tephritid species are the bulk of the bait. It is bio-friendly and very effective against both male and female fruit fly species especially to newly emerged females in search of food source for egg development. Research by Beijing Ecoman Biotech in 2014 revealed GFFB highly reduces average fruit damage rate caused by fruit fly to less than 1% (Billah and Wilson, 2016).

### 2.5.8 Biological control

Although a number of natural enemies have been tried in fruit fly biological control programmes outside Africa with some success, in most cases, the impact of the introduced parasitoids on *C. capitata* populations was rather limited (Knipling, 1992). Biological agents especially predators from the families Staphylinidae, Carabidae, Chrysopidae, Pentatomidae and several mite species are known to attack tephritids (Bateman, 1972). Ants have also been reported to cause up to 38% mortality in *C. capitata* (Wong et al., 1984) with *Oecophilla longinoda*, reported as predators to the flies (Ativor et al., 2012).

### 2.5.9 Mechanical fruit protection

Mechanical fruit protection is a technique that seeks to prevent adult female flies from laying eggs in the fruit by wrapping or bagging of individual fruits with newspaper or paper bags. Ekesi and Billah (2006) asserted that fruits could be bagged at least a month before harvest. This method is very effective for the production of high valued fruits but it is very laborious and may not be very practical on large scale basis.

### 2.5.10 Field monitoring and control with parapheromones

Monitoring involves the use of attractants, traps and insecticides to gather information on the seasonal population fluctuation of the fruit flies. This knowledge helps to make informed decision as to the appropriate control measures to employ (Ekesi and Billah, 2006). Parapheromones (male lures) and food baits are the two main types of attractants used in the monitoring exercise (Lux et al, 2003a). Parapheromones, which attract only male fruit fly, reduces the male population so as to reduce mating to low levels or prevent it in entirety. They are available in both liquid form and polymeric plugs (in the form of controlled-release formulation). The major attractants include, Trimedlure (TML), Methyl Eugenol (ME), Cuelure (CUE), and Terpinyl acetate (TA) (Ekesi and Billah, 2006; COLEACP-CIRAD, 2009).

Unlike Parapheromones, the food baits are effective against all species and sexes. Population of the fruit flies are suppressed as they feed on the food bait containing the killing agent (insecticide) (White and Elson-Harris, 1992). A number of commercial baits are now available in the market such as SUCCESS Appat (GF-120), GFFB, Nulure, Buminal and Solbait that are premixed with insecticides like spinosad for direct application (Ekesi et al, 2009; Vayssieres et al, 2009).

### 2.6 Eradication approach

Eradication approach is aimed at creating a fruit fly-free zone/area by taking an area wide action to eliminate the target fruit fly population (Myers et al., 1998). This approach is justified only when the flies threatens a highly productive industry or when they have just been introduced in the area. This is because it is costly to employ the eradication approach (Wilson, 2006). This method known as Sterile Insect Technique (SIT) is the major means by which eradication is achieved (IAEA, 2003).

#### 2.6.1 Sterile Insect technique or Male annihilation technique

For this control method, artificially sterilized male population are introduced in the wild to mate with fertile females. By so doing, the normal reproductive efforts of the target species are interfered with (Van der Vloedt and Klassen, 2006). The male populations are sterilized by irradiation, exposing them to x-rays, electron beams and most commonly, gamma rays from Cobalt- 60 or Caesium-137 (Robinson, 2005).

# CHAPTER THREE

# 3.0 MATERIALS AND METHODS

## 3.1 Study area

The research work was undertaken in both field and laboratory. The field work was carried out in Adokope in the Dangme West District of The Greater Accra Region of Ghana. The area is a vast grass land located in the outskirt of Accra with farmers cultivating varied vegetables and watermelons. Water melon is grown by some farmers all year round, making use of irrigation, while others grow on the onset of the rains. Three different watermelon farms of sizes, one acre each were chosen for the research work. The area was selected for this research because it is well noted for the cultivation of watermelons on large scale all year round. The laboratory study took place in the Biology laboratory of Ada Senior High school in the Ada East District of the Greater-Accra Region.

## 3.2 Dangme West District

The Dangme West District, located in the coastal savanna agro-ecological zone of Ghana is one of the ten Districts in the Greater Accra Region. It is the largest district in the Region with a landmass of about 41.5%. The total land area, 1,442 sq. km (144, 2001 ha) consists of, a coastline stretches of about 37kms and a total cultivable land of 129,600 hectares. The Dangme West District is situated in the South-Eastern part of Ghana, lying between latitude $5^0$45 South and $6^0$ 05 North and longitude $0^0$05 East and $0^0$ 20 West. The vegetation in the district is mainly coastal savannah. The soil type is mainly sandy but certain areas have sandy-loams. The main agricultural activities undertaken here are livestock, farming and fishing. Crops produced are watermelon, maize, cassava, tomatoes, pepper, onions, okra and garden eggs. There are however a few mango trees scattered in the area.

## 3.3 Treatments and Experimental layout

### 3.3.1 Experimental layout

Three farms which served as blocks were selected for the experiment. Each block was divided into three plots and the baits randomly arranged. The experimental design used for the layout was Randomized Complete Block Design (RCBD) with three replications.

### 3.3.2 Treatments

The treatments used considered two baits, the Great Fruit Fly Bait (GFFB), SUCCESS Appat ® (GF-120) and a control (farmers practice). The treatments per a block were as follows:

1. SUCCESS Appat ® (GF-120)
2. Great Fruit Fly Bait (GFFB)
3. Control (Fa practice)

Where a plot received a single treatment.

#### 3.3.2.1 Treatment application method and rates

A hand-held sprayer (2L) with low spray pressure and large droplet size was used for efficient spray delivery. A sprayer each was provided for the treatment plots, with appropriate labels indicated on them to prevent a mix up during the course of treatment application.

Treatments were imposed 21 days after planting, just at the flowering stage of the plant.

**Application of GF-120**

One part of GF-120 (0.33 L) was added to five parts (1.67 L) of water inside the sprayer. The mixture was vigorously shaken and sprayed-delivered at 50 mL per $m^2$ of foliage of watermelons (especially onto the under surface of the leaves, but not directly on fruits) on weekly basis for the six weeks period of the experiment from 8th May to 12th June 2015. Border vegetation also received the same treatment at regular distance of 20m apart. Spraying was done in the evenings between 4pm and 6pm to prevent a possible spray drift.

**GFFB preparation and application**

The Great Fruit Fly Bait (GFFB) was acquired from the imported trial consignment from Matrix Innovations Ltd., Accra. One part of the Great Fruit Fly Bait (500mls/0.5liters) was mixed with three parts (1500mls/1.5liters) of water (Manufacture's recommended rate) and poured into the hand-held sprayer and vigorously shaken for uniform mixture. The bait was then sprayed-delivered at 50 ml per $m^2$ of foliage of watermelons (especially onto the under surface of the leaves, but not directly on fruits) on weekly basis. Border vegetation around each plot also received the same treatment at regular distance of 20m apart.

Each treatment was totally separated from the other by a row of vegetation of size 50 $m^2$ to prevent treatment interference. Vines of watermelons in each plot were spot sprayed at an interval of 3 meters to create a total of 20 spots per plot.

**Control treatment**

The control was farmer practice, where no treatment with any of the food baits was applied to control fruit flies.

### 3.4 Trapping of fruit flies

Fruit fly populations in all plots (treated and control) were monitored using two parapheromone attractants - Methyl Eugenol (ME), which mostly attracts *Bactrocera* species and a few *Dacus* species, and CueLure (CL), which mostly attracts *Dacus* species and a few other *Bactrocera* species. The *Dacus* and *Bactrocera* species are known to be the main fruit fly pests of the cucurbits (White and Elson-Harris, 1992; Ekesi and Billah, 2007; Billah et al., 2013). The parapheromone attractants were deployed in homemade Mineral Water Bottle (MWB) traps (Nboyine et al., 2012; Wih & Billah, 2012). A trap of each parapheromone (1 ME + 1 CL) were randomly placed per plot. A total of 6 traps were set up on a block, making a total of 18 traps for all three blocks.

**Fig 3: A trap suspended by a wire hanger onto a stick planted in the soil**

The traps were suspended by a wire hanger onto a stick planted in the soil at 20 meters interval to minimize inter-trap interference. To prevent ants and other predators from feeding on trap catches, the wire hangers were smeared with carpenter's glue. Traps were inspected on weekly basis for six weeks and insects collected preserved in 70% ethanol for further analyses in the laboratory.

### 3.5 Baseline studies on fruit fly species presence and population dynamics

A pre-treatment trapping was carried out before application of the treatments for the three blocks. It was done by collecting and counting trap catches for a week before food bait (GFFB and GF-120) was applied. This was done on 1st May, 2015, after which the traps were monitored on weekly basis for six weeks (8th May, 2015- 12th June, 2015).

### 3.7 Data collection

Flies were collected on weekly basis into plastic vials and labelled in the field accordingly. Flies in each trap per farm were counted and preserved in 70% ethanol in the laboratory and stored in a dark place to prevent discoloration. Flies population per trap per day was recorded to determine fluctuation in fly population during the experimental period for each farm.

This was calculated using the formula:

Relative Density= F/T/D

Where F= Total number of flies collected

T= Number of traps used in study

D= Number of days traps were exposed in the field.

#### 3.7.1 Identification of trap catches

The insects were identified using the taxonomic keys developed by the African Fruit Fly Initiative (AFFI) (Ekesi and Billah, 2009) and confirmed by Dr Billah, a fruit fly Taxonomist. All identified insects were sexed counted and the results entered into a fruit fly trapping data collection sheet.

### 3.8 Fruit sampling and incubation

#### 3.8.1 Sterilisation of sand for fruit incubation

In the laboratory, clean sand collected from the Ada beach was thoroughly washed to get rid of the salt, sieved to get rid of debris, dried and heat sterilized in an oven of $120^{o}$ C for at least three hours to kill microscopic pathogens in it. The sand was then spread in cages provided.

#### 3.8.2. Fruit incubation

After 4-5 weeks of application, a total of ninety (90) fruits were sampled from the treatment plots, weighed and incubated separately to rot for assessment of larvae. The cumulated weight of the sampled fruits for the GF-120, GFFB and control plots were 52.1 kg, 48.7 kg and 55.8 kg respectively. The incubation involved placing the watermelon samples on wire gauze over the pre-sterilized sand which served as the pupation medium when larvae emerge from fruits. To avoid drying and wrinkling of fruits, water was sprinkled unto them when needed. Matured larvae drop from fruit to pupate in the sand, so the sand was sieved at 3- 4-day intervals for puparia. After 2-3 weeks of incubation, fruits were dissected, examined for larvae or puparia before being discarded.

#### 3.8.3. Data analysis

Trap performance was compared by log-transforming [log ($x$ + 1)] the raw data to normalise the variance before analyzing, using the General Linear Model (Proc GLM, SAS Inc. 2003). When ANOVAs were significant, means were separated using Student-Newman-Keuls (SNK) test at $P$=0.05.

Infestation levels of watermelon fruits from the different treatment plots was determined, by dividing number of puparia for each treatment plot by the total weight of fruit collected on that plot.

# CHAPTER FOUR

# RESULTS

## 4.1 Trap Catches

Throughout the study period, a total of 2,554 insects were collected, of which 2,483 (97.22%) were fruit flies and 71 (2.78%) non-target species. In all, one fruit fly species *Bactrocera dorsalis* belonging to the genus Bactrocera was identified.

Before treatment begun, each of the plots recorded the following baseline, the assigned Control plots recorded the highest baseline captures of 71 fruit flies while GF-120 assigned plots recorded the least fruit flies catches of 27 and GFFB assigned plots recorded 34 fruit flies. Again, for the treatment periods, control plots recorded the highest (1087) fruit flies catches and the least (587) by GF-120 while GFFB recorded 669 fruit flies.

### 4.1.1 Fruit fly captures

Fruit flies catches for each of the plots was expressed as fruit fly density i.e. number of flies per trap per day (F/T/D) (IAEA, 2003). This index gives the relative measure of the size of the adult population in a given space and time.

Throughout the experimental period, control plots recorded the highest *B. dorsalis* F/T/D figure of 10.7, while the lowest value, 5.7 was recorded by the GF-120 and GFFB recorded 6.5 (Table 4.1).

**Table 4.1: Summary of fly catches in Methyl Eugenol (ME) and Cuelure (CL) baited traps.**

| Field | Fruit fly species | No. of flies | No of traps | Exposure period (Days) | Flies/Trap/Day |
|---|---|---|---|---|---|
| GFFB Treatment Plot | *B. dorsalis* (ME) | 703 | 3 | 36 | 6.5 |
| | *B. dorsalis* (CL) | 0 | 3 | 36 | 0.0 |
| GF-120 Treatment Plot | *B. dorsalis* (ME) | 595 | 3 | 36 | 5.7 |
| | *B. dorsalis* (CL) | 2 | 3 | 36 | 0.0 |
| Control plot | *B. dorsalis* (ME) | 1153 | 3 | 36 | 10.7 |
| | *B. dorsalis* (CL) | 0 | 3 | 36 | 0 |

### 4.1.2 **Methyl Eugenol trap catches**

**GFFB plots**

The weekly trap catches for ME baited traps were recorded. For the pre-treatment week (week 1), the period before treatment begun, the least *B. dorsalis* catches (34) was observed on the assigned GFFB plots. For the treatment weeks which begun from week 2 to week 7, it was observed that the highest catches were made in week 6 (226) and the least catches on week 3 (54). The fly catches kept fluctuating from week 2 to week 7 (Fig 4.1).

**GF-120 plots**

The GF-120 plots during the pre-treatment (week 1) trapping period recorded the least *B. dorsaliss* catches (26). During the treatment period (week 2-7) however, the highest flies trapping occurred in week 6 (149) with week 5 recording the least catches (42). Flies trapped throughout the period fluctuated from week to week (Fig4.1).

**Control plots**

Trap catches at the control plots recorded the least (71) value during the pre-treatment period (week1) as well. For the treatment period (week2-7), week 4 recorded the highest (303) value and week 7 the least (77) value. It was observed that from week 2 to week 3, there was a reduction in fly catches and a massive increase in flies catches from week 3 to week 4. However, after week 4, there was a gradual value fall in flies catches till the least value was recorded in week 7 (Fig. 4.1).

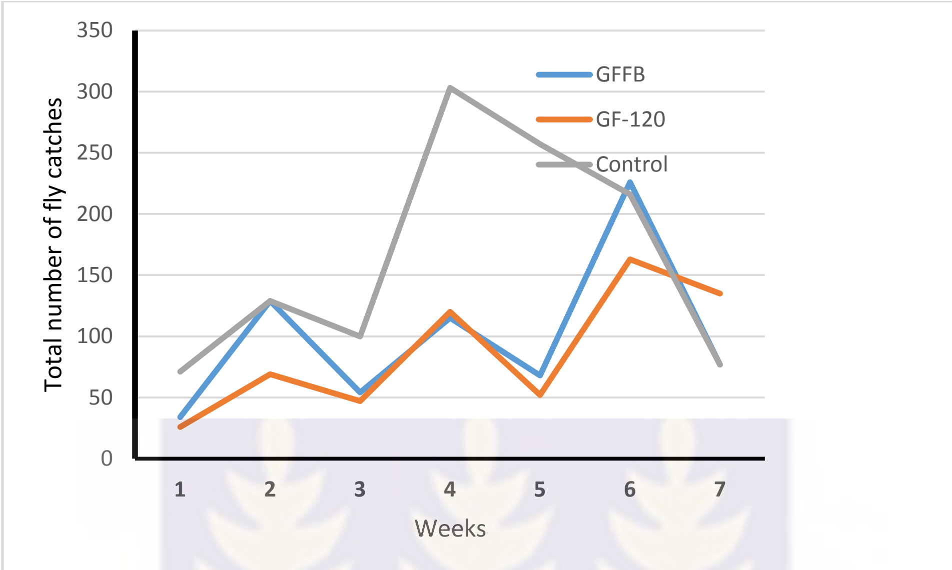


**Fig 4.1: Total weekly trap catches per treatment using Methyl Eugenol traps.**

### *4.1.2.1 Trap catches of fruit flies at various plots*

The performance of the various ME traps in the plots were observed (Fig. 4.2). Control plots in all blocks recorded the highest catches, GFFB recorded the second highest catches and GF-120 the least. The sum of all catches in the plots for each treatment indicated that, the highest *B. dorsalis* catches (1153) was recorded on the control plot. GFFB and GF-120 plots respectively recorded 703 and 610, indicating that the least *B. dorsalis* catches were on the GF-120 plots.

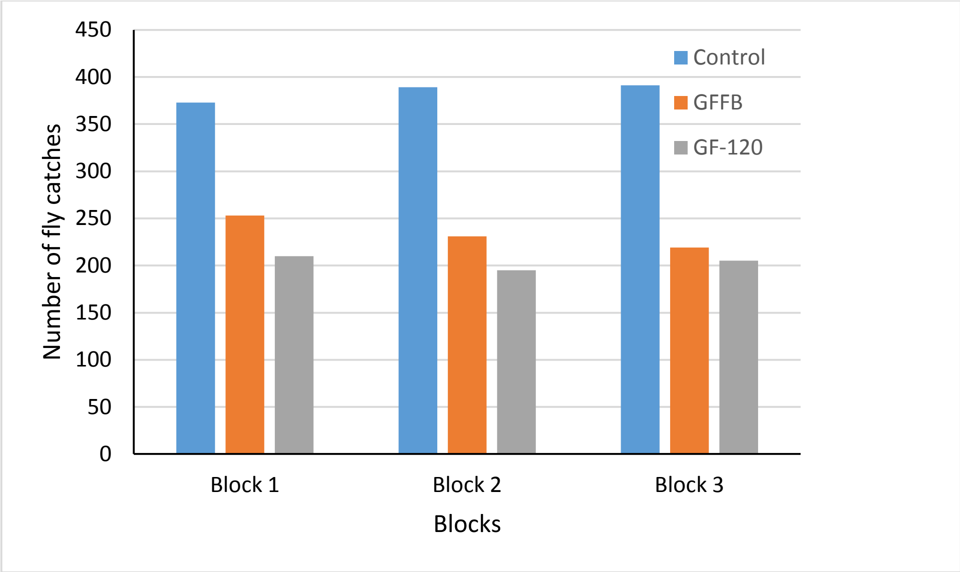


**Fig. 4.2:** *B. dorsalis* catches with Methyl Eugeniol traps in the various blocks

### 4.1.3 Cuelure trap catches

For the Cuelure baited traps, except for the GF-120 plots where 1 *B. dorsalis* each was recorded for week 1 and 2 all the other traps made no catches.

### 4.1.4 Mean fly catches for the treatments

Mean fly catches for week one (pre-treatment week) was low in all three treatment while week two to seven (treatment weeks) recorded higher catches. For week one there was significant difference in the mean value for all the treatments. A least significant value of 10.8 was observed. Weeks two, three, and seven recorded mean values which showed no significant difference in GFFB, GF-120 and control plots for fruit fly catches. However, there was significant difference in mean fly catches in the treatments for weeks four and five. Weeks four and five recorded means of least significant values of 50.3 and 11.1 respectively

**Table 4.2 Mean fly catches for each treatment during the study period**

| Treatments | Week1 | Week2 | Week3 | Week4 | Week5 | Week6 | Week7 |
|---|---|---|---|---|---|---|---|
| **GFFB** | 11.3 | 43.0 | 23.0 | 38.3 | 22.7 | 75.3 | 26.0 |
| **GF-120** | 9.0 | 23.3 | 18.0 | 40.0 | 17.3 | 49.7 | 45.0 |
| **Control** | 23.7 | 43.0 | 33.3 | 101.0 | 85.7 | 72.0 | 26.0 |
| **LSD** | 10.8 | NS | NS | 50.3 | 11.1 | NS | NS |

LSD: Least Significant Difference

In all, number of fruit flies captured by the GFFB ME traps were consistently higher than in traps baited with CL. Throughout the treatment period, ME traps significantly outperformed CL with a mean number of 223.0±19.22. CL on the other hand made no catches. Trap catches for the pre-treatment period were significantly different from the GF-120 treatment. ME treated plots recorded the highest mean of 194±12.73 as against 0.3±12.73 for CL during the period. GF-120 treatment plot catches for the lures were significantly different (Table 4.3). For the control plots, there were significant difference in the performance of ME and CL lures. ME traps recorded high fly catches with most of the catches made on the control plots.

**Table 4.3 Performance of the different lures in terms of fly catches in the plots**

| Lures | statistical parameters | Trap catches | | |
|---|---|---|---|---|
| | | **Pre-treatment Period** | **Treatment period** | **Total catches (pre-trt+trt)** |
| | | **GFFB** | | |
| CL | | 0 a | 0 a | 0 a |
| ME | | 11.3 ± 6.4 a | 223.0 ± 19.2 b | 234 ± 21.4 b |
| | *F* | 3.1 | 134.7 | 119.9 |
| | *DF* | 2 | 2 | 2 |
| | *P* | 0.22 | 0.007 | 0.008 |
| | | **GF-120** | | |
| CL | | 0.3 ± 2.2 a | 0. 3 ± 12.7 a | 0.7 ± 14.8 a |
| ME | | 8.7 ± 2.2 a | 194 ± 12.7 b | 203.3 ± 14.8 b |
| | *F* | 14.5 | 233 | 189 |
| | *DF* | 2 | 2 | 2 |
| | *P* | 0.062 | 0.04 | 0.005 |
| | | **Control** | | |
| CL | | 0 a | 0 a | 0 a |
| ME | | 23.7 ± 2.7 b | 360.7 ± 14.3 b | 384.3 ± 15.0 b |
| | *F* | 75.2 | 632.1 | 615.2 |
| | *DF* | 2 | 2 | 2 |
| | *P* | 0.013 | 0.002 | 0.002 |

*Means in the same column followed by different letters are significantly different (at p=0.05), using GENSTAT test.

### 4.1.5 Non-target insect capture

Throughout the study period a total of 71 non-target insects were collected. The control plot recorded the highest number of non-target insects followed by the GF-120 plot and then GFFB plot. The non-target insects were from four insects Orders. The Coleoptera Order recorded the highest number, followed by Order Hymenoptera, then Diptera, with Lepidoptera recording the least (Table 4.4).

**Table 4.4 Number of non-target species**

| Non-target species | GFFB | | | GF-120 | | | CONTROL | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| | Plot 1 | Plot2 | Plot3 | Plot 1 | Plot 2 | Plot 3 | Plot 1 | Plot 2 | Plot 3 | |
| Coleoptera | 3 | 3 | 2 | 5 | 3 | 4 | 7 | 5 | 4 | **36** |
| Hymenoptera | 1 | 2 | 2 | 2 | 1 | 2 | 3 | 4 | 2 | **19** |
| Diptera | 0 | 2 | 1 | 3 | 0 | 1 | 4 | 3 | 1 | **15** |
| Lepidotera | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | **1** |
| **TOTAL** | **4** | **7** | **5** | **10** | **4** | **7** | **15** | **12** | **7** | **71** |
| | **16** | | | **21** | | | **34** | | | |

### 4.1.6 Incubated fruits

No fruit flies were reared from the incubated fruits though rotten fruits contained maggots. The pupa collected from all plots did not emerge (Table 4.5).

**Table 4.5 Fruit flies and non-tephritid species reared from sampled watermelon fruits from the different plots**

| Treatment | No. Fruits | Wt. fruits (kg) | No. puparia | Infestation level (pup/kg) | Diff (C-T) | % Reduction (C-T)/C |
|---|---|---|---|---|---|---|
| GF-120 | 30 | 55.3 | 19 | 0.34 | 0.31 | 47.7 |
| GFFB | 30 | 58.7 | 16 | 0.27 | 0.38 | 58.5 |
| CONTROL | 30 | 57.1 | 37 | 0.65 | - | - |

No. fruits: number of fruits, Wt. fruit: weight of fruits, No. puparia: number of puparia, Infestation level= number of pupa/weight of fruits, diff: infestation level of control- infestation level of treatment, % reduction: (infestation level of control-infestation level of treatment)/infestation level of control

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| **Farm (Block)** | 2 | 8 | 4 | 1 | |
| **TREATMENTS** | 2 | 774 | 387 | 96.75 | <.001 |
| **Error** | 4 | 16 | 4 | | |
| **Total** | 8 | 798 | | | |

Fisher's protected least significant difference test

| | Mean | |
|---|---|---|
| GFFB | 16.00 | a |
| GF-120 | 19.00 | a |
| CONTROL | 37.00 | b |

*Means with same letters are significantly not different (at p=0.001), using GENSTAT

# CHAPTER FIVE

# DISCUSSION

## 5.1 Composition of fruit fly species at the study plots

Fruit fly species recorded during the study showed one species, B. *dorsalis*. Trap catches of flies from the start of the study increased steadily but numbers peaked during the maturity stages of the fruits which indicated that the fruits were attractive for infestation. Fly numbers dropped as the season drew to a close which could be attributed to unavailability of suitable host for multiplication.

In all fields, the fly species captured was the *B. dorsalis*. This result deviates from the findings of Doharey (1983) which indicates *B. cucurbitae* as the dominant species in watermelon fields.
The relative abundance of flies is affected by climatic conditions such as humidity, temperature, rainfall as reported by Vayssierres et al., (2009b). This also could be attributed to the fluctuations in fly population throughout the experimental period resulting in no clear pattern in weekly fly catches.

However, because all three farms were in the same locality, the climatic conditions were same, and could not have resulted in the differences in number of fly catches made on the different farms but the weekly catches made in the individual field resulting in the fluctuations. Also, the lowest catches were made during the pre-treatment period but increased during the treatment period. This could be as a result of the short life span of the watermelon crop making the time of bait application to coincide with the maturation of the fruits.

As reported by Pinero et al., (2010), that Methyl Eugenol could be used to suppress the male population, it was evident in the findings made since all flies caught were males.

The high population could also be attributed to re-infestation from dropped fruits in nearby farms.

**5.2 Performance of GFFB against GF-120 bait**

Research indicates that combining bait with pesticides could reduce the fly infestation rate. During the study period, the two baits with lures attracted a number of flies. There was no significant difference between GFFB and GF-120 treatment (p= 0.05). Although GFFB attracted more fruit flies than GF-120, there was no significant difference between their means (Table 4.2).

Fruits collected from GFFB and GF-120 treated fields did not have fruit flies emerging from the pupa collected from them. More flies especially the female was attracted to the treated areas for feeding and were killed before infesting fruits as indicated by Ekesi *et al.*, (2010). This resulted into low infestation rate of fruits as GFFB 58.5% reduction of infestation and GF-120, 47.7% (Table 4.5). GFFB again performed relatively better than GF-120 in combination with the lures which attracted and killed B. *dorsalis*, 703 and 595 respectively. Control plot recorded the highest (0.65) infestation rate followed by GF-120 plot (0.34) with GFFB plot recording the least (0.27). This was so because the control plots were not protected especially from the female flies that were searching for suitable host for oviposition. The GFFB bait recorded the least infestation because the bait provided higher protection for the fruits.

### 5.3 Non-target captures

A total of 71 non-target organisms were captured during the period. The control plot attracted the highest, 34 then followed by GF-120 with 21 catches whilst GFFB attracted the least, 16. The non-target insects attracted fell under four main insect Orders, namely Coleoptera, Hymenoptera, Diptera and Lepidoptera. Coleoptera recorded the highest, 36 and Lepidoptera the least, 1. Hymenoptera and Diptera recorded 19 and 15 respectively (Table 4.4). Most of the non-target insects were attracted probably due to the flies captured because they wanted to feed on them but were knocked down by the killing agent. The percentage of the non-target captured, 2.78% as compared to the 97.22% of the flies attracted confirms that the attractant used could not have been responsible for the non-target insects captured. Also, no beneficial insects like honey bee was captured which makes the attractants used ecologically friendly.

# CHAPTER SIX

# CONCLUSIONS AND RECOMENDATIONS

## 6.1 Conclusions

### 6.1.1 Species composition and relative fly densities

*Bactrocera dorsalis* of fruit flies was the only species collected over the study period with most catches collected using the ME lure. Fly density (F/T/D) for treatment periods were at 6.509, 5.685 and 10.676 for GFFB, GF-120 and control plots respectively.

### 6.1.2 Infestation levels of watermelon fruits

The infestation levels of watermelon fruits were 0.34, 0.27 and 0.65 for the plots GF-120, GFFB and control respectively. This indicated that fruits treated with GFFB were least infected.

### 6.1.3 Performance of the two food baits

GFFB and GF-120 (the standard) both performed well in controlling the number of flies on their individual fields by reducing the number of catches since most of the flies which came to the field could have been killed by feeding on the food bait resulting in the least number of catches on the two fields. Also since both baits made the same catches of fruit flies species.

## 6.2 Recommendations

Per the performance of GFFB with the lures, it can be used in place of the GF-120, the standard. Farmers now have options to choose from without a single importer monopolizing the market. Non-tree crop farmers can be encouraged to use these baits to control fruit fly infestations on their farms. However, the bait application alone cannot help manage the flies but should be incorporated into an Integrated Pest Management (IPM) strategy for sustainable fruit and vegetable production.

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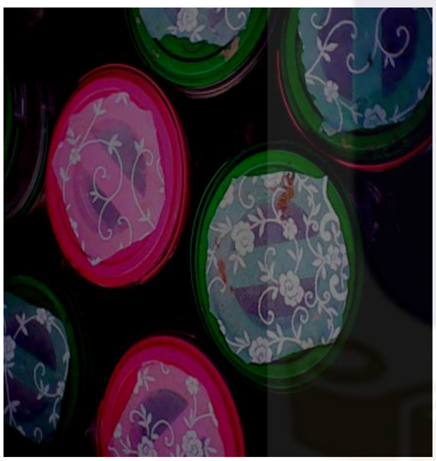
**APPENDICES**

*Bacrocera dorsalis*

*Incubation chamber*



*Incubation chamber*

*Pupae*

| Date | Treatment | Trap No. | *B. dorsalis* | | | | | | | | | | | | | | | | | | Non-targets | Remarks |
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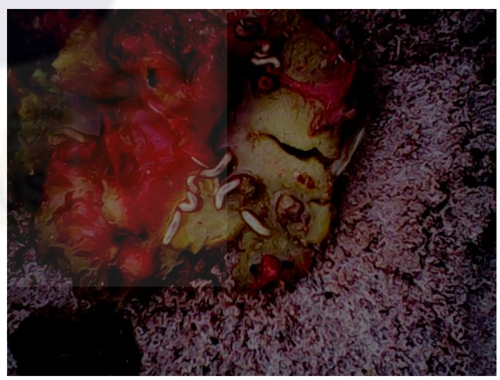
**Fruit fly trapping data sheet**

*Incubating chamber*

*Mineral bottle trap*

*Watermelon field*



*Maggot infested watermelon fruit*