Identification, Monitoring and Control of the Fruit Fly *Bactrocera invadens* (Drew, Tsuruta and White) (Diptera: Tephritidae) in Guava Orchards in Greater *Wad Medani* locality, Gezira State, Sudan

By

Azmey Eizzeldeen Mohammed Sulieman

B.Sc.(Hon.) in Agricultural Science (Department of Pesticides and Toxicology)
Faculty of Agricultural Sciences
University of Gezira (2006)

A Dissertation

Submitted in Partial Fulfillment of the Requirements for the Degree of
Master of Science

in

Pesticides and Toxicology (Pesticides)
Department of Pesticides and Toxicology
Faculty of Agricultural Sciences
University of Gezira

July, 2013
Identification, Monitoring and Control of the Fruit Fly *Bactrocera invadens* (Drew, Tsuruta and White)(Diptera: Tephritidae) in Guava Orchards in Greater *Wad Medani* locality, Gezira State, Sudan

By

Azmey Eizzeldeen Mohammed Sulieman

Supervision committee:

Name

Main Supervisor : Prof. Nabil Hamid Hassan Bashir  ..................

Co-Supervisor :  Dr. Yousif Osman Hussein Assad  ..................

Date : July, 2013
Identification, Monitoring and Control of the Fruit Fly *Bactrocera invadens* (Drew, Tsuruta and White)(Diptera: Tephritidae) in Guava Orchards in Greater *Wad Medani* locality, Gezira State, Sudan

By

Azmey Eizzeldeen Mohammed Sulieman

Examination committee:

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Signature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prof. Nabil Hamid Hassan Bashir</td>
<td>Chairman</td>
<td>.............</td>
</tr>
<tr>
<td>Prof. Yasir Gasmelseed Adam Bashir</td>
<td>External Examiner</td>
<td>.............</td>
</tr>
<tr>
<td>Dr. Abdelaziz Elamin Gesmallah</td>
<td>Internal Examiner</td>
<td>.............</td>
</tr>
</tbody>
</table>

Date of Examination: 31/7/2013
DEDICATION

This work is dedicated to

My father and mother

My brothers & sister

To my friends and my colleagues

With love and respect

Azmey
ACKNOWLEDGEMENTS

Praise be to Allah, the most gracious and merciful for giving me the courage, strength and patience to start and finish this work with success.

Thanks are extended to my main supervisor Prof. Nabil Hamid Hassan for his close supervision, continuous guidance, valuable advise and endless patience. My sincere thanks and appreciation extended to my co – supervisor, Dr. Yousif Assad for his valuable remarks, high support and continuous help.

A lot of thanks are extended to the Staff of soil laboratory(Faculty of Agricultural Sciences, University of Gezira) for their continuous support.

Deep appreciation goes to the Insect Collection Unit of the Agricultural Research Corporation, Wad Medani for their help in identification of specimens. Thanks are also extended to Dr. Sidig Eisa, for his help in statistical analysis. Sincere thanks are due to my future wife Eslam and my close friend Abdallah. Thanks are extended to my colleagues in Plant Protection Directorate, Kosti, especially Department of Plant Quarantine.
Identification, Monitoring and Control of the Fruit Fly *Bactrocera invadens* (Drew, Tsuruta and White) (Diptera: Tephritidae) in Guava Orchards in Greater *Wad Medani* locality, Gezira State, Sudan

Azmey Eizzeldeen Mohammed Sulieman

M. Sc. in Pesticides and Toxicology (Pesticides) (July, 2013)

Department of Pesticides and Toxicology

Faculty of Agricultural Sciences

University of Gezira

ABSTRACT

Fruit flies (Diptera: Tephritidae) are recently declared to be pests of national importance, as they cause extensive damage to several fruit and vegetable crops. This study was aimed to identify the prevailing species in Greater Wad Medani locality, Gezira State, Sudan, study the season abundance and fluctuations of *Bactrocera invadens* and other FF species, if present; evaluate the performance of Deltamethrin (Decis®) 12.5% UL as a fogging treatment for controlling the adults in the orchards, evaluate the performance of neem seed powder extract (NSPE), when sprayed on the fruits before infestation and evaluate the performance of Methyl Eugenol and sticky traps for monitoring and control. The fieldwork was carried out in two locations (Hantoub and Gezirat-elfil), Greater Wad Medani locality, Gezira State, Sudan. Four orchards (one feddan each) were selected. Yellow sticky and Methyl Eugenol traps were used to collect and monitor FF species. Deltamethrin UL and NSPE were used against adults and immature stages, respectively. Deltamethrin was applied at three rates: (0.25, 0.5 and 1L/F) using a fogging machine. One orchard was selected and divided into 4 blocks; each block contained three treatments in addition to the control. The fogging was
repeated according to the population density. Ten fruits per tree were collected randomly and taken to the laboratory. Number of pupae per fruit and number of emerged adults were recorded. The same was adopted following treatment with two concentrations of NSPE (25 and 50 g/L of water). NSPE was applied every two weeks. The results revealed that all tested concentrations of Deltamethrin and NSPE significantly reduced the number of pupae and the number of emerged adults of *B. invadens* on treated fruits, compared to the control. Methyl Eugenol (ME) with Malathion® 57%EC proved effective and is recommended for controlling adults of *B. invadens*. The highest population of *B. invadens* was detected during July and September in Gezirat-elfil area), whereas the lowest population was found during July and August in Hantoub area. Deltamethrin and neem seed powder extract (NSPE) inhibited the emergence of *B. invadens* adults.
تعريف، مراقبة و مكافحة ذبابة الفاكهة  

Bactrocera invadens (Drew, Tsuruta and White) (Diptera: Tephritidae) 

في بساتين الجوافة بمحليه ومدني الكبرى، ولاية الجزيرة، السودان

عزمي عزالدين محمد سليمان

ماجستير العلوم في المبيدات و السميات (مبيدات) (يوليو، 2013)

قسم المبيدات و السميات

كلية العلوم الزراعية

جامعة الجزيرة

الخلاصة

لقد أدرجت ذبابة الفاكهة (Diptera: Tephritidae) ضمن قائمة الافات القومية لأنها تسبب
تلفا فادحاً للعديد من محاصيل الخضروات والفواكه. هدفت هذه الدراسة للتعرف على الأنواع السائدة بمحلية ود مدني الكبرى، ولاية الجزيرة، دراسة التواجد الموسمي و تذبذبات النوع Bactrocera invadens و الأنواع الأخرى، بالإضافة إلى تقييم أداء مبيد (12.5% UL Deltamethrin (Decis) كمعاملة كيميائية بالرش الضبابي ضد الحشرة الكاملة في البساتين و تقييم أداء مستخلص بذور النيم التي رشت علي الثمار قبل وضع البيض و تقييم أداء المصائد الفرمانية و الصفراء اللاصقة لمراقبة و مكافحة ذبابة الفاكهة. نفدت هذه التجربة في موقعي (حنتوب و جزيرة الفيل) بمحلية ود مدني الكبرى، ولاية الجزيرة، السودان. تم اختيار أربعة بساتين (فان لكل مزرعة). أستخدمت نوعين من المصائد (الصفراء اللاصقة والفرمانية) لجمع و مراقبة أنواع ذبابة الفاكهة. تم استخدام مبيد Deltamethrin و مستخلص بذور النيم ضد الأطوار البالغة وغير البالغة علي التوالي. تم تطبيق Deltamethrin بثلاثة معدلات (0.25 و 0.5 و 1 لتر/الفدان) باستخدام ماكينة الرش الضبابي. تم اختيار بستان واحد و قسم إلى أربعة مربعات. كل مربع يحتوي علي ثلاث معاملات بالإضافة للشاهد. تم تكرار الرش الضبابي حسب الزيادة في كثافة العشيرة. تم جمع عشيرة ثمار من كل شجرة عشائيا ثم اخزنت للمعمل. سجل عدد كل من العذارى و الحشرات البالغة. تم إتباع نفس الطريقة بعد استخدام تركيزين من مستخلص بذور النيم (25 و 50 جم/لتر ماء). تم تطبيق مستخلص بذور النيم
كل إسبوعين. أثبتت النتائج أن كل التراكيز المختبرة من مبيد Deltamethrin و مستخلص بذور Deltamethrin في الثمار المعالمة Bactrocera invadens قد خفضت عدد العذارى والحشرات الكاملة من B. invadens. الفيرمون Methyl Eugenol 57% EC مع مبيد المثاثيون برهن أنه فعال برصنة الثمار غير المعالمة. الفيرمون Methyl Eugenol 57% EC شبه الفيرمون Methyl Eugenol B. invadens ضد الحشرات البالغة من B. invadens. أكبر عدد من عشيرة B. invadens كان في شهر يوليو و سبتمبر في منطقة جزيرة الفيل بينما أقل عدد من عشيرة B. invadens كان في شهر يوليو و أغسطس في منطقة حنتوب. مبيد Deltamethrin و مستخلص بذور النيم ثبط خروج الحشرات B. invadens الكاملة من
# LIST OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEDICATION</td>
<td>iii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>iv</td>
</tr>
<tr>
<td>ENGLISH ABSTRACT</td>
<td>v</td>
</tr>
<tr>
<td>ARABIC ABSTRACT</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF CONTENTS</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>x</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xi</td>
</tr>
<tr>
<td>LIST OF PLATES</td>
<td>xii</td>
</tr>
<tr>
<td>LIST OF APPENDICES</td>
<td>xiii</td>
</tr>
<tr>
<td>CHAPTER ONE : INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>CHAPTER TWO : LITERATURE REVIEW</td>
<td>3</td>
</tr>
<tr>
<td>2.1 <em>Bactrocera spp.</em></td>
<td>6</td>
</tr>
<tr>
<td>2.1.1 The Invasive FF (<em>Bactrocera invadens</em>)</td>
<td>6</td>
</tr>
<tr>
<td>2.1.1.1 Distribution</td>
<td>6</td>
</tr>
<tr>
<td>2.1.1.2 Description</td>
<td>7</td>
</tr>
<tr>
<td>2.1.1.3 Damage</td>
<td>7</td>
</tr>
<tr>
<td>2.1.1.4 Host–range</td>
<td>7</td>
</tr>
<tr>
<td>2.1.1.5 Life-history</td>
<td>7</td>
</tr>
<tr>
<td>2.1.2 Oriental FF, <em>Bactrocera dorsalis</em></td>
<td>8</td>
</tr>
<tr>
<td>2.1.2.1 Distribution</td>
<td></td>
</tr>
<tr>
<td>Section</td>
<td>Title</td>
</tr>
<tr>
<td>---------</td>
<td>-------</td>
</tr>
<tr>
<td>2.1.2.2</td>
<td>Host-range</td>
</tr>
<tr>
<td>2.1.2.3</td>
<td>Life-history</td>
</tr>
<tr>
<td>2.1.3</td>
<td>Peach FF(Guava FF), <em>Bactrocera zonata</em></td>
</tr>
<tr>
<td>2.1.3.1</td>
<td>Distribution</td>
</tr>
<tr>
<td>2.1.3.2</td>
<td>Symptoms and damage</td>
</tr>
<tr>
<td>2.1.3.3</td>
<td>Host-range</td>
</tr>
<tr>
<td>2.1.3.4</td>
<td>Life-history</td>
</tr>
<tr>
<td>2.2</td>
<td><em>Ceratitis</em> spp.</td>
</tr>
<tr>
<td>2.2.1</td>
<td>Mango FF(Marula FF), <em>Ceratitis cosyra</em></td>
</tr>
<tr>
<td>2.2.1.1</td>
<td>Distribution</td>
</tr>
<tr>
<td>2.2.1.2</td>
<td>Description</td>
</tr>
<tr>
<td>2.2.1.3</td>
<td>Symptoms and damage</td>
</tr>
<tr>
<td>2.2.1.4</td>
<td>Host-range</td>
</tr>
<tr>
<td>2.2.1.5</td>
<td>Life-history</td>
</tr>
<tr>
<td>2.2.2</td>
<td>Mediterranean FF, <em>Ceratitis capitata</em></td>
</tr>
<tr>
<td>2.2.2.1</td>
<td>Distribution</td>
</tr>
<tr>
<td>2.2.2.2</td>
<td>Description</td>
</tr>
<tr>
<td>2.2.2.3</td>
<td>Symptoms and damage</td>
</tr>
<tr>
<td>2.2.2.4</td>
<td>Host-range</td>
</tr>
<tr>
<td>2.2.2.5</td>
<td>Life-history</td>
</tr>
<tr>
<td>2.2.3</td>
<td>The Five-spotted FF(<em>Ceratitis quinaria</em>)</td>
</tr>
</tbody>
</table>
2.2.3.1 Distribution........................................... 14
2.2.3.2 Description........................................... 14
2.2.3.3 Host range ........................................... 15

2.2.4 Natal FF, Ceratitis rosa ............................... 15
2.2.4.1 Distribution......................................... 15
2.2.4.2 Description .......................................... 15
2.2.4.3 Host-range ........................................... 16
2.2.4.4 Life-history .......................................... 16

2.3 NATURAL PRODUCTS AND INSECTICIDES .......... 16
2.3.1 Natural Products ..................................... 16
  2.3.1.1 Natural Products as Pesticides ................ 16
      2.3.1.1.1 Neem ........................................ 17
2.3.2 Synthetic Insecticides: Deltamethrin (Decis®) UL .... 18
  2.3.2.1 Trade names .................................... 18
  2.3.2.2 Chemical structure ............................ 18
  2.3.2.3 Mechanism of Action ......................... 18
  2.3.2.4 Physical and Chemical Properties ............ 19
  2.3.2.5 Toxicological Effects ......................... 19
    2.3.2.5.1 Potential health effects ................ 19
    2.3.2.5.2 Toxicity ................................ 20
      A. Acute .......................................... 20
      B. Chronic ...................................... 20
2.3.2.5.3 Environmental fate, persistence and degradability 20

2.4 Pheromones ................................................................. 21

2.4.1 Methyl Eugenoul(ME) ............................................. 21

2.4.1.1 Environmental impact of ME ................................. 22

2.4.1.2 Toxicological effects of ME ................................. 22

2.5 Control measures ....................................................... 23

2.5.1 Cultural practices .................................................... 23

2.5.1.1 Clean orchards .................................................. 23

2.5.1.2 Early harvesting .................................................. 23

2.5.1.3 Growing less susceptible varieties ......................... 24

2.5.1.4 Ploughing ......................................................... 24

2.5.1.5 Irrigation ......................................................... 24

2.5.1.6 Pruning ............................................................. 24

2.5.2 Trapping devices and bait spray of fruit fly ............. 25

2.5.3 Biological control .................................................... 25

2.5.3.1 Natural enemies ................................................ 25

2.5.3.2 Predators and parasites ..................................... 26

2.5.3.3 Microbial agents ............................................... 26

A. Fungi ................................................................. 26

B. Bacteria ............................................................... 26

C. Nematodes ............................................................ 27

2.5.4 Sterile Insect Technique .......................................... 27
CHAPTER THREE : MATERIALS AND METHODS .......................................................... 30

3.1 THE STUDY AREA ...................................................................................... 30

3.2 MATERIALS ............................................................................................ 30

3.2.1 Trapping materials .............................................................................. 30

3.2.2 Deltamethrin (Decis®) UL vs. Need Seed Powder Extract (NSPE) .......... 30

3.2.3 Fogging Machines ............................................................................... 31

3.3 METHOD .................................................................................................... 34

3.3.1 Season Abundance of FF Species ....................................................... 34

3.3.2 Collection of adults ............................................................................ 34

3.3.2.1 Using pheromones ........................................................................ 34

3.3.2.2 Using yellow sticky traps ................................................................. 34

3.3.3 FF Rearing Facilities ........................................................................... 35

3.3.4 Chemical control ................................................................................ 35

A. Deltamethrin 12.5% UL ................................................................. 35

B. Neem Seeds Powder Extract (NSPE) ............................................. 36

CHAPTER FOUR : RESULTS AND DISCUSSION .............................................. 41

4.1 SPECIES IDENTIFICATION ....................................................................... 41

4.2 POPULATION INCIDENCE OF Bactrocera invadens ......................... 41

4.2.1 Using Methyl Eugenol as a male attractant .................................... 41

4.2.2 Using yellow sticky traps ................................................................. 41
4.3 The Effect of NSPE on Fruit Fly infestation ........................................ 46
  4.3.1 The Number of Pupae/Fruit .................................................. 46
  4.3.2 The Number of Emerged Adults/Fruit ..................................... 46
4.4 The effect of Deltamethrin (Decis®) 12.5% UL on fruit fly infestation .......................................................... 50
  4.4.1 The Number of Pupae/Fruit .................................................. 50
  4.4.2 The Number of Emerged Adults/Fruit ................................. 50

CONCLUSIONS .................................................................................. 53
REFERENCES .................................................................................. 54
APPENDICES .................................................................................. 72
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table number</th>
<th>Page</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>48</td>
<td>The effect of Neem Seeds Powder Extract (NSPE) on fruit fly infestation in (Gezirat-elfil area), Greater Wad Medani locality.</td>
</tr>
<tr>
<td>2</td>
<td>49</td>
<td>The effect of Neem Seeds Powder Extract (NSPE) on fruit fly infestation in Hantoub area, Greater Wad Medani Locality.</td>
</tr>
<tr>
<td>3</td>
<td>51</td>
<td>The effect of Deltamethrin 12.5% UL in controlling the FF infestation on Guava in Hantoub area, Greater Wad Medani Locality, Gezira State.</td>
</tr>
</tbody>
</table>
The effect of Deltamethrin 12.5% UL in controlling the FF infestation on Guava in Gezirat-elfil area, Greater Wad Medani Locality, Gezira State

LIST OF FIGURES
<table>
<thead>
<tr>
<th>Figure number</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Counts of <em>B. invadens</em> captured during the period from July to October (2011) using Methyl Eugenol on guava</td>
</tr>
<tr>
<td>2</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>Pre spray counts of FF adults caught during the period from July to October (2011) using the yellow sticky traps hanged on guava trees</td>
</tr>
<tr>
<td>3</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>Post spray counts of FF adults caught during November (2011) using the yellow sticky traps hanged on guava trees</td>
</tr>
</tbody>
</table>
### LIST OF PLATES

<table>
<thead>
<tr>
<th>Plate number</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plate 2.1</td>
<td><em>Bactrocera invadens</em></td>
<td>72</td>
</tr>
<tr>
<td>Plate 2.2</td>
<td>Adult female of <em>Ceratitis cosyra</em></td>
<td>72</td>
</tr>
<tr>
<td>Plate 3.1</td>
<td>Map of the study area</td>
<td>32</td>
</tr>
<tr>
<td>Plate 3.2</td>
<td>Fogging machine</td>
<td>33</td>
</tr>
<tr>
<td>Plate 3.3</td>
<td>Plastic containers containing a mixture of ME and Malathion</td>
<td>37</td>
</tr>
<tr>
<td>Plate 3.4</td>
<td>Yellow sticky trap</td>
<td>38</td>
</tr>
<tr>
<td>Plate 3.5</td>
<td>Experimental layout used in Shegede orchard (Gezirat-elfil) and Abuzaied orchard (Hantoub)</td>
<td>39</td>
</tr>
<tr>
<td>Plate 3.6</td>
<td>Experimental layout used in Abdo orchard (Gezirat-elfil) and Elboraie orchard (Hantoub)</td>
<td>40</td>
</tr>
<tr>
<td>Appendix number</td>
<td>Page</td>
<td></td>
</tr>
<tr>
<td>-----------------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>Appendix (A)</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>Appendix (B)</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>Appendix (C)</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>Appendix (D)</td>
<td>74</td>
<td></td>
</tr>
</tbody>
</table>

**Appendix (A)**
The morphological features of *Bactrocera invadens*  

**Appendix (B)**
The morphological features of the mango fruit fly *Ceratitis cosyra* (Walker)  

**Appendix (C)**
Counts of *B. invadens* adults captured during the period from July to October (2011) using Methyl Eugenol on guava.  

**Appendix (D)**
Pre spray counts of FF adults caught during the period from July to October 2011 using the yellow sticky traps hanged on guava trees.
CHAPTER ONE

INTRODUCTION

Fruit flies (FFs; Diptera: Tephritidae) are major pests of fruits and vegetables throughout the tropical and subtropical worldwide. FFs are of great economic importance as the majority of them cause extensive damage to many fruit and vegetable crops. Females lay eggs in the sound fruits. The eggs hatch into larval instars that feed in the flesh of the fruits and vegetables. The infested fruits quickly become rotten and inedible or may drop to the ground prematurely, thus, causing considerable losses in production (qualitatively and quantitatively).

In the Sudan, the production of fruits and vegetables is seriously affected by the FFs. The infestation and damage reached in Guava crop 70-100% in the Northern State, while in the River Nile State, it was ca. 65%, (Gubara and Abu ElGasim (2004). The Ministry of Agriculture and Forestry declared FFs as national pests, i.e. is similar to rats, quelea birds and desert locusts. The control of this noxious pest needs more collaborative efforts and intensive studies at all levels to fully understand every thing about it and fill the research and information gaps, and consequently minimize the damage. The integrated pest management programs should be the ultimate goal of the control activities.

The present study focused on the effects of the natural product neem seeds powder extract (NSPE) treatment and the pyrethroid insecticide Deltametherin (Decis® 12.5% UL) as a fogging treatment against adults, to protect fruits from FFs infestation and reduce residues on the fruits to the minimum possible.
The main objectives of the present study are:

1. To identify the prevailing FF species in Greater Wad Medani Locality.
2. To study the season abundance and fluctuations of *Bactrocera invadens* and other FF species, if present.
3. To evaluate the performance of Deltamethrin (Decis®) 12.5% UL as a fogging treatment for controlling the adults in the orchards.
4. To evaluate the performance of neem seed powder extract (NSPE), when sprayed on the fruits before infestation
5. To evaluate the performance of Methyl Eugenol and sticky yellow traps for monitoring and control.

CHAPTER TWO

22
LITERATURE REVIEW

The dipterous fruit flies (FFs), belongs to family Tephritidae, is one of the largest and most diversified family of the order Diptera. Tephritidae includes about 4257 species, arranged in 500 genera, among these 1400 species are known to be developed in fruits (White and Elson-Harris, 1992). Equatorial Africa is the original home of 915 FF species, belonging to 148 genera, out of which 299 species develop in either wild or cultivated plant fruits (Thompson, 1999). Tropical species of the genera Ceratitis, Bactrocera, Dacus and Anastrepha have several generations per year, thus, the potential for heavy fruit losses is very high (Mohammed, 2003).

Bactrocera spp. (formerly included in Dacus) are native to tropical Asia, Australia, and the south pacific regions, with a few species found in Africa and warm–temperature areas of Europe and Asia (Drew et al., 2005). The genus Bactrocera is the most economically significant genus, with about 40 species considered to be important pests (White and Elson-Harris, 1992). Ceratitis spp attack a wide range of fruits, and are native to tropical Africa. This genus is endemic to Afro-tropical region, and contains about 65 species, the majority of which are highly polyphagous (White and Elson-Harris, 1992).

FFs deposit their eggs on host fruits when they are physiologically ripe. On hatching, maggots bore their way to the interior and feed on the pulp. Area fed by the maggot is discolored, due to rottin of the fruit, and the fruit drops prematurely. FFs are polyphagous pests with high reproductive potential, wide host-range, overlapping of generations and adaptability to climate, FFs management is rather difficult (Vinodkumar and Agarwal, 1998).

Ekesi et al., (2005) stated that FFs are of great economic importance as majority of them cause extensive damage to many fruits and vegetables.
Female FFs laid eggs in fruit and ruin more than 400 different fruits and vegetables, including mango, guava, citrus, melon, papaya, peach, plum and apple. They are considered as high priority quarantine pests. Damage caused by FFs in West Africa has been recognized as a quarantine problem for fruits destined to the European market for many years.

In India, a total loss of 2,558 and 26,902 million rupees was estimated due to FFs with or without control measures, respectively (Stonehouse, 2001). In Egypt total losses due to FFs damage to the main fruit crops estimated at $US177 million/yr (FAO,2010).

In the Sudan, FFs firstly reported by Venkatrman and Elkhidir (1965) on egg plant, *Solanum melongena*, and guava, *Psidium sp.* Ali (1967) found FFs in the northern region (Shendi and Hudebia). In 1969, Schumutterer reported that the family Tephritidae was considered the fourth group of insect pests causing serious damage to fruit crops in the Sudan. Siddig (1984) and Deng (1990) reported that Mediterranean fruit fly, *Ceratitis capitata* (Weidman), is the major pest of guava. According to Bejie et al., (1998), the main species of FFs found in Kassala and Gash Delta were *Dacus ciliates* (Loew) and *Bactrocera cucurbitae* (Coquillet) on melon, beside, *C. capitata* and *Ceratitis cosyra* (Walker) on guava and mango. Also, Gesmallah (2000) stated that *D. ciliatus* was the major problem facing production and export of melon in Gash and Tokar Deltas in the eastern Sudan. Abbas (1998) reported that the population abundance of medfly has two peaks in autumn (August and September) and winter (January and February). Gubara and Abu ElGasim (2004) reported that the percentage of damage due to FFs infestation reached 70-100% on guava in the Northern State of the Sudan, while in the River Nile State the infestation reached 65% on guava and 85-90% on mango.

However, in the River Nile State, *C. cosyra* was the dominant species on mango and second to it was *B. invadens* (Abdallah,2007). In North and South
Kordufan States of the Sudan, C. cosyra was the commonly occurring species on fruit trees, followed by B. invadens (Bashir, 2007, and Ali and Abbas, 2008). FFs reared out from guava fruits collected from Sinnar State of the Sudan in July, 2008, were mostly B. invadens (Mohammed and Ali, 2008).

An earlier study in the Gezira State of the Sudan showed that C. cosyra was the predominant species of FFs on four mango varieties (Mohammed, 2001). Recently, it was found that B. invadens is the most prevalent species, followed by C. capitata and C. cosyra in the second place on mango and guava in the Gezira area (Mohammed and Ali, 2008). Mahmoud (2005), detected Bactrocera sp., which was identified in the Agricultural Research Corporation (ARC)–Insect Taxonomy Unit by the head of the Taxonomy Unit Prof. Musa Abdallah Ahmed (Currently retired). Then in March 2005, this species was identified as B. invadens in the Natural History Museum –London by Dr. White and others. In July 2011, B. zonata was recorded for the first time in the Sudan from traps in Gezira (Salah et al., 2011).

2.1 Bactrocera spp.

The genus Bactrocera is a group of FFs containing more than 450 species
(Drew and Hancock 2000; White 2000), and several *Bactrocera* species are serious pests of fruits and vegetables (Allwood *et al*., 1999). Losses are due to direct feeding damage and loss of export market opportunities through quarantine restrictions imposed by importing countries to avoid entry and establishment of unwanted FFs. Singh (1991) reported that, warm and humid weather is considered to be favorable for *Bactrocera* FFs, since its population build up coincides with mango ripening, while the population decreases during dry periods.

2.1.1 The Invasive FF, *Bactrocera invadens* (Drew, Tsuruta and White)

*B. invadens* was not found in the Sudan and the whole Africa prior to 2003, and then within two years since that time it was in several African countries including the Sudan (De Meyer *et al*., 2008). Currently, this species is the most prevalent in the country, and apparently is displacing the indigenous species *Ceratitis cosyra* and *Ceratitis capitata* (Mohammed and Ali, 2008).

2.1.1.1 Distribution

*B. invadens* originates from Asia and has invaded various parts of Africa. Since the first report (2003), the insect has rapidly spread across the African continent, and in addition to Kenya, it is now known from 20 other countries, including Angola, Benin, Burkina Faso, Cameroon, Comoros Island, Congo, DR Congo, Equatorial Guinea, Ghana, Guinea, Ivory Coast, Mali, Niger, Nigeria, Senegal, Sierra Leone, the Sudan, Tanzania, Togo, and Uganda (Drew *et al*., 2005 and Ekesi *et al*., 2006). *B. invadens* is thought to have invaded Africa from the Indian subcontinent, and it was discovered in Sri Lanka after it was first reported from Africa (Drew *et al*., 2005), where it has become a
significant pest of quarantine and economic importance (Mwatawala et al., 2004; Vayssie`res et al., 2006 and Ekesi et al., 2006).

2.1.1.2 Description

This species is quite large (~ 1 cm). It has two yellow thoracic lines and an orange-colored abdomen traced with a central T. The wings are mostly transparent, with neither blotches nor macula, but the anal stripe is often quite distinctive. Several scutum color patterns may be present (plate 2.1; Appen. A) (Vayssières et al., 2006).

2.1.1.3 Damage

The females pierce the fruit using their ovipositors to lay their eggs in the pulp. Each female can laid on average 700 eggs, depending on the host. The species is multivoltine (several generations/yr) with an average life-span of about 3 months (Ekesi et al., 2006). B. invadens, causes considerable damage to mangos. Sampling at regular intervals of infested fruit during the mango season indicates that seasonal cultivars and late cultivars are attacked much more than early ones in Benin (Vayssières et al., 2006).

2.1.1.4 Host–range

The host-range of this species includes mango, guava, citruses, papaya, tomato and some other wild African hosts, e.g. Strychnos spp. (Lux et al., 2003 and Mwatawala, 2004), and banana (Gesmallah, 2010).

2.1.1.5 Life-history

According to Ekesi et al.,(2006) egg incubation required 1 day, larval development 11 days, and puparia–adult development 12 days. About 55% of eggs developed to the adult stage; life expectancy at pupal seclusion was 75 days in females, and 86 days in males. Average net fecundity and net fertility were 794 and 608 eggs, respectively, while average daily oviposition was 18
eggs. Mean generation time was 31 days. In the Sudan, the period from oviposition to adult emergence was 23 and 25-30 days (Elsheikh, 2005).

2.1.2 Oriental FF, *Bactrocera dorsalis* (Hendel)

2.1.2.1 Distribution

According to (CABI, 1994, and Vargas *et al.*, 2007), this pest is distributed in:

Asia: Bangladesh, Bhutan, Cambodia, China, Hong Kong, India, Indonesia, Japan, Laos, Malaysia, Myanmar, Nepal, Ogasawara Islands, Pakistan, Philippines, Sri Lanka, Taiwan, Thailand, Vietnam.

North America: USA (Hawaii, California and Florida; Mau, 2007).

2.1.2.2 Host-range

*B. dorsalis* occurs on a wide range of fruit crops apples (*Malus pumila*), bananas (*Musa paradisiaca*), guavas (*Psidium guajava*), mangoes (*Mangifera indica*), oranges (*Citrus sinensis*), peaches (*Prunus persica*), plums (*Prunus domestica*), and tomatoes (*Lycopersicon esculentum*) (Clausen *et al.*, 1965; Koyama, 1989).

2.1.2.3 Life-history

*B. dorsalis* are laid their eggs below the skin of the host fruit. These hatch within a day and the larvae feed for another 6-35 days, depending on seasonal temperatures. Pupation takes place in the soil under the host-plant and lasts for 10-12 days, but may be delayed for up to 90 days under cool conditions. The mature larva emerges from the fruit, and drops to the ground forms a tan to dark brown puparium. Adults occur throughout the year, and begin mating about 8-12 days after emergence; they may live 1-3 months depending on temperature (up to 12 months in cool conditions; Christenson and Foote, 1960).
2.1.3 Peach FF (Guava FF), *Bactrocera zonata* (Saunders)

2.1.3.1 Distribution

PFF is native to tropical Asia, and widely distributed in Asia (India, Thailand, Philippines, Pakistan, Vietnam, Sri Lanka, Bangladesh, and Nepal), it also occurs in Mauritius and Reunion (White and Tsuruta, 2001). PFF had become established in the Arabian Peninsula including Saudi Arabia, Oman, and Yemen (White, 2006). In Egypt, because of the spread of *B. zonata*, the Mediterranean fruit fly, *Ceratitis capitata* has become more restricted in the horticulture areas (Hashem *et al.*, 2001) and Sudan (Salah *et al.*, 2011).

2.1.3.2 Symptoms and damage

This pest is known to infest over 30 species of commercial fruits and vegetables, causing up to 100% losses, if left without control (FAO, 2003).

2.1.3.3 Host-range

PFF attacks some of the main commercial fruit and vegetable crops including citrus, peach, mango, guava and tomatoes (Gasoma, 2005).

2.1.3.4 Life-history

Eggs are laid below the skin of the host fruit. These hatch within 1-3 days, and the larvae feed for another 4-35 days. Pupariation take place in the soil under the host plant and adults emerge after 1-2 wk (longer in cool conditions) and adults occur throughout the year (Christenson and Foote, 1960).

2.2 *Ceratitis* spp.
The genus *Ceratitis* is endemic to Afro-tropical region, and contains about 65 species, the majority of which are highly polyphagous (White and Elson-Harris, 1992). The genus contains several subgenera: *Acropteromma, Ceratalaspis, Ceratitis, Hoplolophomyia, Pardalaspis* and *Pterandrus*. In the Sudan *C. cosyra* was recorded in the Gezira, North and South kordufan and River Nile states (Ali and Abbas, 2008).

### 2.2.1 Mango FF (Marula FF), *Ceratitis cosyra* (Walker)

#### 2.2.1.1 Distribution

*C. cosyra* is a serious pest in smallholder and commercial mango across sub-Saharan Africa, and has been recorded in Kenya, South Africa, Tanzania, Uganda, Zambia and Zimbabwe (Malioz, 1979 and Lux et al., 1998) and the Sudan (Kabbashi, 2004).

#### 2.2.1.2 Description

The body and wing color yellowish; sides and posterior of thorax prominently ringed with black spots; dorsum yellowish, except for two tiny black spots centrally, and two larger black spots near scutellum; scutellum with three wide, black stripes separated by narrow yellow stripes. Wing length 4–6 mm; costal band and discal crossband joined. Adults are similar in size, coloration, and wing to Medfly. However, the thorax of Medfly has much more black, and the apex of its scutellum is solid black; the costal band and discal crossband of the Medfly wing are not joined. *C. cosyra* differs also from the Natal fly, the latter being larger, lacking black spots laterally (postpronotal) on the thorax, and the costal band and discal cross band are not joined (Steck, 2003; plate 2.2, Appen. A).

#### 2.2.1.3 Symptoms and damage
Adults most often lay their eggs in the fresh flesh of fruits. The eggs hatch into larvae (maggots), which most often feed on the inside of the fruit, resulting in a soft, mushy mess (Russell, 1999). In the Sudan, this pest causes enormous damage, ranging from 10 to 100% (Mohammed, 2003). On average, about 20-30% of mango is lost due to this pest alone (Elhewaris, 2003 and Mohammed, 2003). Gesmallah (2010) reported that guava fruits was infested by *C. cosyra* and *B. invadens* in Singa area, the Blue Nile State; and the infestation ranged from 80-90% and 84.5% respectively, for the two species.

### 2.2.1.4 Host-range


### 2.2.1.5 Life-history

Life stage durations are approximately as follows: the egg 2-3 days; the larva, five or more days, 9-15 days in laboratory colonies; the pupa 9-12 days; the adult up to 41 days (60 days in laboratory rearing). Females first oviposit five days of age, and oviposition continues up to age two weeks, with up to eight weeks in laboratory colonies. The fruits are heavily infested, with an average of 50 larvae/fruit (Malioz, 1979). In the Sudan, Mohammed (2001) described the eggs of *C. cosyra* as tiny white in color, measuring about 0.8 mm in length, and the maggots are white or yellow. Mohammed(2001) study results revealed that the life cycle of *C. cosyra* ranges between 22 and 33 days. Elmukashfi(2004)reported that the mean life cycle for *C. cosyra* was 23.6 days.

### 2.2.2 Medfly or Mediterranean FF, *Ceratitis capitata* (Weidman)
2.2.2.1 Distribution

Medfly is widespread in Africa (Angola, Congo, Ethiopia, Guinea, Kenya, Malawi, Mali, Mauritius, Mozambique, Nigeria, Reunion, Rwanda, South Africa, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe and Sudan (CABI, 2004). It has been recorded in Iran, Jordan, Lebanon, Saudi Arabia, Syria, Turkey, Yemen, Albania, Croatia, Cyprus, France, Greece, Italy, Malta, Portugal, Spain, Switzerland, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Argentina, Bolivia, Brazil, Columbia, Ecuador, Paraguay, Peru, Uruguay, and Venezuela (CABI, 2004).

2.2.2.2 Description

Body length: 4.00 (3.45-4.60) mm; wing length: 4.12 (3.65-4.55) mm. Head. Antenna yellow or more orange; first and second segment and base of third segment sometimes darker. Third antennal segment twice as long as second segment. Arista with short hairs, mainly on base and only distinct dorsally. Frons convex to flat; yellow, sometimes with darker orange or orange-brown patches including darker band near antennal implant, occasionally with faint silvery shine; with short scattered hairs which are largely the same color as frons. Frontal and ocellar bristles black; lower orbital modified, stem pale and shorter than arista with apical end dark and diamond-shaped; upper orbital weakly developed, black. Face yellow-white. Genal bristle pale, genal setulae pale or reddish, weakly developed. Postocellar and outer vertical pale. Thorax. Postpronotum white, with distinct black spot. Mesonotum: ground color black, microtrichiae pattern silvery with ashgrey shine, spots black except sutural white spots, prescutellar white markings merged. Scapular setae pale. Scutellum yellow-white, basally with two dark spots, separate or narrowly touching, apically with three merged spots, only slightly incised. Anepisternum pale with
lower half darker yellow, pilosity variable but at least partly dark in lower half. Legs yellow; setation typical for subgenus, mainly pale especially on femora. Fore femur posterodorsally with bush of longer orange-coloured hairs along entire length, basally these hairs darker red or brown but not distinct black; posteriorly hairs much shorter; ventral spines yellow-orange; anteroventral row of hairs short and yellow-orange. Hind femur with longer hairs dorsally and ventrally on apical fourth. Wing. marginal band usually with clear and complete interruption, occasionally narrowly or partly touching; cubital band free; medial band absent; crossvein r-m at or near middle of discal cell. Vein R beyond or equal with crossvein r-m. Orientation crossvein dm-cu variable. Abdomen. Yellow. Setation and banding typical for subgenus (De Meyer and Copeland, 2001).

2.2.2.3 Symptoms and Damage

In Central America, losses to coffee crops were estimated at 5 to 15%; the berries will mature early and fall to the ground with reduced quality (Enkerlin et al., 1989).

2.2.2.4 Host-range

The Medfly, attacks >260 different fruits, flowers, vegetables, and nuts. The host list includes apple, apricot, avocado, bell pepper, coffee, dates, fig, grape, grapefruit, guava, lemon, lime, loquat, mango, nectarine, orange, papaya, peach, pear, plum, pomegranate, tomato, and walnut (USDA, 2006).

2.2.2.5 Life-history

Under optimum conditions, Medly complete its life cycle, which consists of four stages (adult, egg, larvae and pupae), within 21 days. The female laid eggs in groups, 10-14 eggs. The eggs hatch within a few days and the emerging
maggots or larvae feed on the fruit pulp. A medfly maggot requires 7-24 days to reach its third and final instars. When mature, they make their way to the surface of the fruit, drop to the ground, and tunnel into the soil and pupate. The adult fly is formed within the pupae and emerges within 8-46 days. The newly emerged adults require about 2-3 days for maturity before starting laying eggs (Anonymous, 2004).

2.2.3 The Five-spotted FF(Rhodesian FF, and Zimbabwean FF), Ceratitis quinaria (Bezzi)

2.2.3.1 Distribution

The Five-spotted FF is reported in:

Africa: Botswana, Malawi, Namibia, South Africa, the Sudan, Zimbabwe.
Asia: Yemen (EPPO/CABI, 1990).

2.2.3.2 Description

Body length: 4.20 (3.60-4.75) mm; wing length: 3.93 (3.50-4.50) mm.

Head. Antenna yellow to yellow-orange. Third antennal segment twice as long as second segment. Arista with short hairs over entire length. Frons pale yellow, centre usually deeper yellow colored; with short scattered hairs which are largely the same color as frons; concave to flat, in lateral view not distinctly projecting forwards at antennal implant. Chaetotaxy normal for subgenus, except more reddish. Thorax. Postpronotum white or white-yellow, unspotted. Ground colour of mesonotum pale; mesonotal pattern variable, dorsocentral spots often less distinct. Chaetotaxy normal for subgenus. Scapular setae pale. One anepisternal bristle. Scutellum white basally, otherwise yellow with three apical and two subapical small black spots; basally without dark spots, only slight darker coloration. Subscutellum completely pale. Legs yellow; setation

2.2.3.3 Host-range

*C. quinaria* has been recorded from apricots (*Prunus armeniaca*), *Citrus*, guavas (*Psidium guajava*) and peaches (*Prunus persica*) (EPPO/CABI, 1996).

2.2.4 Natal FF, *Ceratitis rosa* (Karsch)

2.2.4.1 Distribution

*C. rosa* is restricted to eastern and southern Africa. Records of *C. rosa* from central, western or southwestern Africa, refer to *C. fasciventris*. It is occurrence in Kenya (De Meyer and Freidberg, 2006).

2.2.4.2 Description

Length of the fly is 4 to 5 mm. This fruit fly closely resembles the Mediterranean fruit fly (Medfly) in appearance. It averages slightly larger and has the characteristic picture wings and dark black spots on the thorax. The arista of the antenna is plumose, while that of the Medfly bears only short pubescence. The frons of the male lacks the pair of conspicuous spatulate setae, which is found on the male Medfly. The mesothoracic tibiae of the males are clothed with dorsal and ventral brushes of elongated bluish-black scales, lacking in the Medfly. The ovipositor sheath of the female is shorter than the width at its base (White and Elson-Harris, 1994).
2.2.4.3 Host-range

Its primary hosts include citrus, coffee. Other common hosts include peach, apricot, plum, apple, pear, fig, guava, avocado, and mango. Nut crops appear to be immune from attack (CABI, 2004).

2.2.4.4 Life-history

Eggs laid in ripe or unripe fruit. Eggs usually hatch within four days after oviposition. The three larval stages and a prepupal stage occupy a period of about 12 days. Pupation takes place in the soil, and the pupal stage lasts 10 to 20 days. Adults may live for several months (White and Elson-Harris, 1994).

2.3 NATURAL PRODUCTS AND INSECTICIDES

2.3.1 Natural Products

Botanicals are materials or products of plants origin valued for their pesticidal, medicinal or therapeutic properties. Phyto-pesticide materials range from whole fresh plants to purely isolate bioactive phyto-chemicals or their formulations which are effective against pests and pathogens (Prakash and Rao, 1997). Their pesticidal or microbiocide property was attributed to their secondary metabolites which are triterpenoids and non-terpenoids (Finar, 1986; Hellpap and Dryer, 1995).

2.3.1.1 Natural Products as Pesticides

The interest in botanical insecticides has increased as a result of environmental concerns and insect resistance to conventional chemicals (Ayvaz et al., 2010). Sukmar et al.,(1991) reported 99 families, 267 genera and 346 species of plants to have insecticidal properties. During co-evolution between
plant and insect, the former produced several metabolic by-products, which act as repellents, growth disruptors or regulators, larvicides, and antifeedant against invading insect (Patil et al., 2006).

2.3.1.1 Neem

Neem or neem oil (N.O.) is extracted from seeds of the neem tree, *Azadirachta indica* A. Jus., belongs to family Meliaceae a native of India. The seed kernels are rich in azadirachtin (AZ) (Rembold, 1989). AZ content of neem oil varies from 300ppm to over 2500ppm depending on the extraction technology and quality of the neem seeds crushed (Puri, 1999). AZ belongs to the C-seco limonoids group of alkaloids and occurs only in the neem tree (Ley et al., 1993).

![Chemical structure of Azadirachtin](image)

Chemical structure of Azadirachtin

Mode of action of AZ is excreted and retained as the un metabolized compound and its accumulation in the neurosecretory system of the pars intercerebrals of the insect brain was detected penetrating the blood brain barrier, it becomes highly concentrated in the corpus cardiacum. As a consequence, it disturbs the endocrine situation (Rembold, 1989). Neem has some systemic activity in plants, and has an activity against a variety of sucking and chewing insect (Eileen and Sydney, 2006).
2.3.2 Synthetic Insecticides: Deltamethrin (Decis®) UL

The IUPAC chemical name of Decis is cyano(3-phenoxy-phenyl) methyl; 3-(2,2dibromoethenyl)-2,2-dimethylcyclopropanecarboxylate. Deltamethrin is a pyrethroid insecticide that kills insects on contact and through digestion. It is used to control aphids, caterpillars, mealy bugs, scale insects, and whitefly on cucumbers, tomatoes, peppers, potted plants, and ornamentals. There are no known incompatibilities with other common insecticides and fungicides (Thomson, 1992).

2.3.2.1 Trade names

Butoflin, Butoss, Butox, Cislin and Cresus (Briggs, 1992).

2.3.2.2 Chemical structure

![Chemical Structure of Deltamethrin]

2.3.2.3 Mechanism of Action

Deltamethrin rapidly paralyze the insect nervous system giving a quick knockdown effect (Haug, 1990). Mode of action is thought to be mainly central in action, or at least originate in higher nerve centers of the brain. And death of insects seems to be due to irreversible damage to the nervous system occurring when poisoning lasts more than a few hours (Leahey, 1985).
2.3.2.4 Physical and Chemical Properties

Table (2.1) Showing physical and chemical properties of Deltamethrin

<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>Colorless crystalline powder; white or slightly beige powder.</td>
</tr>
<tr>
<td>Solubility in water</td>
<td>Less than 0.1 mg/L. Insoluble: &lt; 1 ppm at room temperature. 0.002 mg/l at 20 °C. Almost insoluble.</td>
</tr>
<tr>
<td>Solubility in other solvents</td>
<td>Kerosene and isoalkanes, &lt;0.5, isopropanol 0.6, ethanol 1.5, xylene 25, methylene chloride 70 (all in g/100 g at 20 °C). In acetone 500g/l, benzene 450 g/L, dimethyl sulfoxide 450 g/L, cyclohexanone 750 g/L, dioxane 900 g/L all at room temperature, toluene 250 g/L.</td>
</tr>
<tr>
<td>Melting point</td>
<td>98-101 °C.</td>
</tr>
<tr>
<td>Boiling point</td>
<td>Decomposes on distillation.</td>
</tr>
<tr>
<td>Vapor pressure</td>
<td>2 x 10 to the minus 8 mbar at 25 °C. Non-volatile: &lt;1 x 10 to the minus 7 mmHg.</td>
</tr>
</tbody>
</table>

2.3.2.5 Toxicological Effects

2.3.2.5.1 Potential health effects

According to (WHO, 1990), Studies of Deltamethrin metabolism have been performed in human volunteers. Samples of blood, urine, saliva and feces were collected at intervals over a 5 day period. Clinical and biological examinations, performed every 12 hr during the trial and one wk after termination, revealed no abnormal findings. Apparent elimination half-life was between 10.0 and 11.5 hr and the radio-label detected in blood cells and saliva was extremely low. Urinary excretion was about 50% of the initial radioactivity and 90% of the radio-label was excreted during the initial 24 hours following administration.
The apparent half-life of urinary excretion was 10.0 to 13.5 hr (consistent with plasma levels). Fecal elimination at the end of the observation period represented 10-26% of the dose and the total of fecal plus urine elimination was approx. 64 to 77% of the initial dose after 96 hr. On the basis of this information, human oral absorption is assumed to be at least 50%.

2.3.2.5.2 Toxicity

A. Acute:

Oral toxicity: LD$_{50}$ in male rats ranged from 128 mg/kg to >5,000 mg/kg, the LD$_{50}$ for female rats was 52 mg/kg (Fairchild, 1977). The intravenous LD$_{50}$ in rats was 2 to 2.6 mg/kg, and the dermal LD$_{50}$ was >2,940 mg/kg (Hayes and laws, 1990). The acute precutaneous: LD50 for rats was reported to be >2,000 mg/kg; >4,640 mg/kg for ducks (Worthing, 1983).

B. Chronic:

In 2-yr feeding trials, the reported no effect level (NEL) was 12 mg/kg diet for mice; and 2.1 mg/kg diet for rats. The dose without activity in rats over a 90-day period was 10 mg/kg/day (Worthing, 1983).

2.3.2.6 Environmental fate, persistence and degradability

Deltamethrin in pond water was rapidly adsorbed, mostly by sediment, in addition to uptake by plants and evaporation into the air (Haug, 1990). About 10 days after use, there are no deltamethrin residues observed on plants. There is no known phytotoxicity to crops (Bhanuet et al., 2011).
2.4 Pheromones

Pheromones, come from Greek word pherein (to transport), and hormone (to stimulate) defined as chemical compounds secreted by an animal, which mediate behavior of another animal belonging to the same species (Karlson and Butenandt, 1959). Pheromones are subdivided into several types based on thenature of the interaction. Examples include: a) sex pheromones (released by members of one sex to attract the opposite sex), b) aggregation pheromones (attract both males and females to a small area), c) alarm pheromones (alert individuals to danger), and d) trial pheromones (deposited on a substrate by one member of a species and followed by another member of the same species) (Gordh and Headrick, 2001). The first insect sex pheromone identified was bombykol (E, Z)-10,12-hexade-cadien-1-ol (Butenandt et al., 1959), which is released by the female silkworm moth, Bombyx mori (L.), to attract mates.

Paraphermones can be defined as chemical compounds of anthropogenic origin, not known to exist in nature, but structurally related to natural pheromone components, that in some way affect physiologically or behaviorally the insect pheromone communication system, eliciting a similar response to that of a true pheromone (Rennou and Guerrero, 2000). Males of many tephritidae species are strongly attracted to specific chemical compounds, which either occur naturally in plants (e.g. methyl eugenol; ME) or are synthetic analogues of plant-borne substances (e.g. Cuelure; Cunningham, 1989, and Fletcher, 1987).

2.4.1 Methyl Eugenoul (ME)

ME (1,2–dimethoxy-4-(2-propenyl) benzene) is a widely distributed natural plant product and occurs in more than 200 plant species in 32 families found mainly in the tropics (Tan and Nishida, 1996). ME is being widely used
for male annihilation technique (MAT) for management of *Bactrocera spp.* (White and Elson-Harris, 1992). Drew *et al.*, (1982) recommended use of dichlororvos along with ME for successful kill of fruit flies. ME belong to the class of organic compounds referred to as phenyl propanoids (Friedrich, 1976).

Phenyl propanoids are attractive to numerous species of Dacine FFs, which are among the most economically important pests attacking soft fruits worldwide. ME, the most powerful of the male lures and the first structure that was identified, was discovered serendipitously by Howlett (1912), while working in Pusa, India. Howlett first discovered that citronella oil was attractive to fruit flies and subsequently determined that the most attractive component was ME (Howlett, 1915).

Balasubramaniam *et al.*, (1972) and Lakshmanan *et al.*, (1973) reported that 1% ME along with 0.5% malathion or 0.1% carbaryl is most effective against *B. dorsalis*. They advocated monthly replenishment of ME. Singh (1993) reported a significant reduction in the *B. dorsalis* population by using 0.1% ME baited traps in the guava orchard. According to Makhmoor and Singh (1998) 1% concentration of ME was significantly superior to all other treatments for the control of guava FF, *B. dorsalis*, in guava orchard.

### 2.4.1.1 Environmental impact of ME

The use of male lures for fruit fly control may impact non target insects or risk possible extinction of small endemic populations in large-scale fruit fly eradication programs (Asquith and Messing, 1993).

### 2.4.1.2 Toxicological effects of ME

ME has relatively low acute toxicity by the oral route with an acute LD$_{50}$ of about 1g/kg in rats and acute precutaneous toxicity LD$_{50}$ of about 2g/kg in rabbits. Hazard identification data indicate that ME induces heptaocellular,
carcinomas along with tumors at several other sites in rats and hepatocellular carcinoma in mice. However, the relevance of these results remain in question (Steven and Dana, 2006). There is no link between ME consumption and health effects in humans because of a limited number of studies in humans and absence of epidemiology data (Steven and Dana, 2006).

2.5 Control measures

2.5.1 Cultural practices

2.5.1.1 Clean orchards

The collection and destruction of fallen, damaged and overripe fruits is strongly recommended to reduce the resident population of FFs. To eliminate or reduce the reservoir of the resident population of FFs, field sanitation should be the essential component in the control programs (Allwood and Leblane, 2001), and the removal of infested fruits can contribute significantly to reduction of FF population (Rwomushana, 2008). Mau et al., (2007) stated that the most effective practice in FF control is field sanitation. In the Sudan, Abbas (1998) conclude that cleaning of the orchards from infested and dropped fruits must be practiced to minimize the next season infestation by the FFs.

2.5.1.2 Early harvesting

The term early harvest means; harvest of the fruits at full physiological maturity and before ripening, and harvest of the fruits before pest expectable outbreak. The ripe fruits of mango, guava and citrus found to be susceptible to fruit fly infestation more than the mature or immature fruits (Abbas, 1998 and Mohammed, 2001).
2.5.1.3 Growing less susceptible varieties

With the advent of a standard for testing the susceptibility of various fruits and vegetables to FFs, there is an option now for growing varieties that may be less susceptible or not susceptible to FFs. In the Sudan meagre work was done to investigate the resistant of some fruits and vegetables to FFs, there are an option now to be able to grow varieties that varieties to the FF, among mango, Alphans variety found to be the least susceptible (Mohammed, 2001).

2.5.1.4 Ploughing

Ploughing inside orchards as practice should be adopted to improve soil physical conditions and facilitate plant root nutrition. A series of laboratory experiments were carried out to investigate the FFs pupation habitats, it mostly concludes that the larvae showed a strong preference toward pupating in shaded rather than un-shaded area, in moist rather than dry soil, and in soil with larger particle sizes(Alyokhin et al., 2001).

2.5.1.5 Irrigation

The applicability of this cultural practice in fruit orchards is quite possible from time to time to control FFs pupae in the soil (Abbas, 1998). In the heavy clay soil, 6 hr of water immersion impeded the exclusion of 75% of the pupae, while, 12 hr gave the same result in the sandy and silt soil (Abbas, 1998, and Yokoyama, 2007).

2.5.1.6 Pruning

Pruning is usually carried out to shape trees and open up the centers, allowing free movement of air and sunlight into the tree. This facilitates the control of the pests and diseases. The ability of sunlight to penetrate the tree enhances the color of the fruit and improves quality (Poffey and Owens, 2006).
2.5.2 Trapping devices and bait spray of fruit fly

Different traps and lures have been developed and used over decades to survey FFs population. The first attractants for male FFs was ME, for *B. zonata*, followed by kerosene for *C. capitata* (Severin, 1913). Angelica seed oil (*Angelica archangelica*) was used to medfly trap (Steiner *et al.*, 1957). Beroza *et al.*, (1961) discovered trimedlure (TML) to be effective for *C. capitata*. Food baits based on protein, fermented sugar solution, fruit juices and vinegar had been used since 1918 to capture females of several FF species.

The McPhail trap was the first device to be used with protein baits (McPhail, 1939). Steiner traps were developed in 1957 (Steiner *et al.*, 1957) and Jackson traps in 1971 for TML (Harris *et al.*, 1971). These traps are currently being used in various countries for FF survey, control activities and eradication campaigns. The FF is attracted to the deposits of the protein materials, which contains nutrients essential for their sexual development, and quickly ingest enough to kill it. The contact action of the deposits and contamination of natural food sources also contribute to fly mortality (Narayanan and Batra, 1960).

2.5.3 Biological control

Biological control is potentially useful approach in suppressing FF densities (Wharton, 1989; Knipling, 1992; Waterhouse, 1993; Sivinuki *et al.*, 1996). Recently, natural enemies were used to reduce the population of *C. capitata* (Wong and Ramadan, 1992; Headricks and Godden, 1996).

2.5.3.1 Natural enemies

Several natural enemies can contribute to the suppression of FFs. Major natural enemies are parasitic wasps (parasites the maggots of FFs) and predators such as rove beetles (*Aleochara bilineata*), weaver ants (*Oecophylla smaragdina*),
spiders and birds and bats. In particular weaver ants have been shown to be very efficient in protecting fruit trees from pests, including FFs. These ants pray on FFs, but most important their presence and foraging activity hinders the FFs from laying eggs, resulting in reduced FF damage (Van Mele et al., 2007). Birds and rodents were reported to consume infested fruits, resulting in a high level of larval mortality (Drew, 1987).

2.5.3.2 Predators and parasites

Common larval and pupal predators of FFs include: Formicidae, and predaceous wasps (Hymenoptera); Dermaptera; Staphylinidae, Carabidae, and Coccinellidae(Coleoptera); Chrysophidae (Neuroptera), Pentatomidae, and Coreidae(Hemiptera), crickets(Orthoptera), mites, and myriapods(Back and Pemberton, 1918, and Bateman, 1972).

2.5.3.3 Microbial agents

A. Fungi

The genera, *penicillium* and *Mucorae* were reported to cause considerable mortality to the larvae and pupae of *B. dorsalis* (Newel and Haramoto,1968). Studies carried out by Ekesi et al., (2002) proved *Metarhizium anisopliae* have very high potential in suppressing FF population.

B. Bacteria

*Bacillus thuringiensis* (Beliner) sub species *darmadiensis*, when mixed with a protein diet and sugar and introduced as bait was found to kill Mexican fruit fly (*Anastrepha ludens*) (loewin) (Robarker et al., 1996, and Martinez et al., 1997).
C. Nematodes

*C. capitata* was susceptible to the entomopathogenic nematode *Steinernema felitiae* (Filipjevi). Emerging adults and pupae were not susceptible to the nematode, but the third instar suffered high mortalities (50-90%), when exposed to high nematodes population (Lindegren *et al*., 1990). Field exposure of mature larvae to a dose of 500 nematodes/cm² yielded high mortality of *C. capitata* (Lindegren *et al*., 1990).

2.5.4 Sterile Insect Technique (SIT)

The SIT has been successfully used to eradicate flies in the world. Early examples are the eradication of the melon fly from the Mariana Islands (Steiner *et al*., 1965), and Kume Islands in Japan (Iwahashi, 1977), as well as the oriental FF from Guam as result of which Japan has been declared free of the oriental and melon flies (Kawasaki, 1991).

SIT has been extensively investigated in 13 species of tephritids (Hooper, 1989). The use of (SIT) is not a simple procedure and involves a high degree of technical expertise, and there are several discrete components of the (SIT) that must be investigated to ensure success of the project, and these have been reviewed by Hooper (1991). SIT has been attempted in Thailand (Sutantawong, 1991) and the Philippines (Manoto, 1991) on only a pilot scale.

2.5.5 Eradication

Populations of oriental FF, med fly, melon fly and several other species of tropical FFs are regularly intercepted and eradicated by the authorities. The medfly was eradicated from Mexico (Hendrichs *et al*., 1982) and the government has expanded this to a large national campaign for the elimination of 4 species of native *Anastrepha* (Zavala *et al*., 1991). The medfly eradication program in
Guatemala has enabled 57% (62,000 km²) of the country to be free of the pest, and is continuing to achieve total elimination (Linares, 1991).

2.5.6 Legislative control

Circumvent transferring infested fruits from a highly infested area to slightly infested area or pest-free areas without, post harvest treatment, such as quarantine disinfection and prevent planting of different types of hosts at one place in order to break the food cycle of the fly around the year (FAO, 2004).

2.5.7 Chemical control

The use of insecticides is only recommended as a last resort for controlling adult populations. To control FFs, growers sometimes resort to pesticides that are distributed for cotton production (Sinzogan et al., 2008). Singh (1991) reported that aldrin dust 5% a.i, when mixed in soil provided the highest residual toxicity to fallen mature larvae (23.4% after 15 days), as compared with BHC endosulfan and the OP quinalphos. Yee (1987) concluded that weekly application of OP malathion for 3 months also provided effective control. Without chemical control, the damage from C. capitata and fertile punctures can be as high as 60% (Pena, 1998).

In pakistan, dimethoate at the rate of 75ml of 400g/L spray should be applied at 6,4,2,1 wk before harvest (Panhwar, 2005). Also, deltamethrin 0.002% at given 83% control, i.e. 2g a.iis, therefore, 40g are needed, malathion 75g a.i+8 kg sugar +100water as bait and Diptrex® 75 ml/L was effective when applied at weekly intervals (Panhwar, 2005). FFS can be controlled by solution having mercaptothion 25% at above 300g + 8kg sugar/ 100 L of water.

In the Sudan, Bashir (2007) found that incorporation of or treatment with neem seed kernel oil (NSKO), neem seed kernel powder (NSKP) and Spionsad 240 SC at laboratory level proved effective in inhibiting emergence of C. cosyra
adults. Spinosad was effective at very low doses and as low as 0.1 % totally inhibited the emergence at *C. cosyra*.
CHAPTER THREE

MATERIALS AND METHODS

3.1 THE STUDY AREA

The fieldwork was carried out during July-October, 2011 in two locations separated by the Blue Nile (Plate 3.1) and dominated by guava (*Psidium guajava*) plantations, the first is Hantoub, 3km north of Wad-Medani town (the capital of Gezira State, latitude: 14° 24’ N, longitude: 33° 31’ E, 167 km South-East of Khartoum, capital city of the Sudan). The second is Gezirat-elfil (The Island of the Elephant, latitude: 14° 6’ N and longitude: 33° 6’ E), which is considered to be part of Wad-Medani, about 2 km east of the center of the Town. Two orchards were selected for each location to carry out this study, the experimental area for each orchard is about one feddan (F= 4200 m²).

3.2 MATERIALS

3.2.1 Trapping Materials

Plastic containers containing a mixture of Methyl Eugenol (ME) and Malathion ®(OP insecticide) 57% EC and yellow sticky traps painted with altirat® as a sticky material were used to collect the FF adults during this study.

3.2.2 Deltamethrin (Decis®) UL vs. NSPE

Deltamethrin (Decis®) 12.5% UL was used as a fog against FF adults; NSPE was used for treating the fruits as a repellent to prevent fruit fly infestation.
Neem seeds (NS) were collected from El Nisheshiba area, Wad-Medani. Seed coat was manually removed to obtain the bulb. The latter was ground into a powder using an electric blender-mixer.

### 3.2.3 Fogging Machines

Deltamethrin (Decis®) UL was applied by using fogging machine (portable Thermal fogger, puls FOG K-10/O). The tank capacity of this machine was 10 L. This machine can treat 150,000 square feet (13935m²) in as little as 45 min (Stahl and Sohn, 2008). Plate (3.2).
Plate 3.1

Map of the study area

○ Hantoub
○ Geziratelfil
○ Wadmedani
Plate 3.2 Fogging machine
3.3 METHODS

3.3.1 Season Abundance of FF Species

The season abundance, *i.e.* population incidence of FF species, was monitored using the above-mentioned traps.

3.3.2 Collection of adults

3.3.2.1 Using pheromones

Methyl Eugenol (*O*-methyl eugenol) is a male-lure specialized in attracting adults, which are belonging to species of the genera *Bactrocera* and *Dacus*. Plastic containers (12 x 4 cm²) were used with a mixture of ME and Malathion® 57% EC to collect the adults FF (Plate 3.3). A small cotton was soaked in 2 ml of ME; to it a few drops of malathion were added (Chen *et al.*, 2006). Two traps were randomly distributed in each Hantoub and Gezirat-elfil orchards.

The traps were positioned at 50 m apart to avoid any interaction. Traps were hanged on guava fruiting trees, on 1.5 m. It is important to avoid hiding the trap in the foliage, thus facilitating entry for the FFs. The traps must not be located in direct sunlight. Traps were labeled and located on a designated location. The captured FFs in each trap were counted and identified on weekly basis.

3.3.2.2 Using yellow sticky traps

This type of traps has the ability to attract different FF species, in addition to other non-targeted insects present in the same area. These traps were made from wood (40 cm in length x 30 cm in width), covered with yellow plastic painted and covered with Altirat® glue as a sticky material (Gesmallah, 2010). These traps are cheap and easy to make (Plate 3.4). Four traps were used for
each orchard to monitor the populations of FFs. Traps were hanged on branches of the guava trees at a height of 1.5 m from the ground and distributed randomly in the orchards of guava in both Hantoub and Gezirat-elfil area. Distance between traps was set at 50 m. The captured FFs in each trap in Hantoub and Gezirat-elfil area were counted and identified on weekly basis. The yellow plastic sheets with the sticky materials were changed on weekly basis (Gesmallah, 2010).

3.3.3 Rearing Facilities

Raising larvae to adulthood is the best way to identify the FF species; hence, identification was done according to the morphological characters of the adults. Infested fruits were collected from guava trees and placed inside clean plastic containers, third-filled with sand to prevent desiccation of fruits and for the pupation of the final larval instars. Fruits were removed after formation of the pupae. Emerged adults were kept in small vials. Within a few days, the adults completed their development and coloration. The adults were identified by the staff of the Insect Collection Unit, Crop Protection Center, Entomology Section, Agricultural Research Corporation, Wad Medani, Sudan.

3.3.4 Chemical Control

Chemical control experiments were designed to evaluate the performance of the pyrethroid Deltamethrin as an UL formulation against FF adults when applied by fogger, and the performance of NSPE as fruit treatment (at mature green stage) aiming at preventing FF infestation.

A. Deltamethrin 12.5 % UL

Deltamethrin UL was diluted with diesel fuel at ratio 1:2 (1 L of Deltamethrin : 2 L of diesel fuel/F) prior to application. The Deltamethrin was applied against the adult FFs at three rates: low (0.25 L/F), medium (0.5 L/F)
and high (1 L/F) using a previously mentioned thermal fogging machine. One orchard was selected and divided into 4 blocks; each block contained three treatments, in addition to the control (Plate.3.5). The fogging was repeated according to the increase in the population density. The result was evaluated on the basis of the number of adult FFs captured/yellow sticky trap, taken 24 hr before treatment and 48 hr after application, also, on the basis of FF development, i.e. 10 fruits/tree were collected randomly from the different treatments, in addition to the control, taken to the laboratory and treated as in 3.3.3 above. Percentage of infested fruits/concentration/treatment was calculated. The number of pupae/fruit and number of emerged adults were recorded.

B. Neem Seeds Powder Extract (NSPE)

Neem seeds (NS) were collected from the Nisheshiba area. Seed coat was manually removed, to obtain the kernel. Then the neem seed kernel was ground into a powder using an electric blender. Randomized Complete Block Design (RCBD) design with 3 replications was used to carry out this experiment. Two concentrations of NSPE were used i.e. 25g and 50g of NSP/L water. The fruits were treated from three levels (lower, L, medium, M and upper, U, of the tree). Fruits were immersed in the different concentrations while they are in their trees as a treatment. This treatment was repeated every two weeks (Plate.3.6). Ten fruits from each treated and untreated trees were collected randomly, and transported to plastic containers (25 x 8 cm²) in the laboratory for rearing facilities until the emergence of the adult FFs, the number of emerged adult/treatment was recorded.
Plate. 3.3 Plastic containers containing a mixture of ME and Malathion.
Plate 3.4 Yellow sticky trap
Plate 3.5 Experimental layout used in Shegede orchard (Gezirat-elfil) and Abuzaied orchard (Hantoub).
Plate. 3.6 Experimental layout used in Abdo orchard (Gezirat-elfil) and Elboraie orchard (Hantoub).

- ♠: Guava tree, 1 to 2: The plastic containers containing the mixture of ME and Malathion® traps; traps for monitoring the level of the B. invadens population. y1 to y4: Yellow sticky traps.
- ♣: Guava tree treated by NSPE.
- ♣: Control.
CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 SPECIES IDENTIFICATION

Results of this study showed that all fruit fly adults emerged from guava fruits during the period from July to October were identified as *Bactrocera invadens* (Drew, Tsuruta and White). Identification was carried out by Mr. Abdelgadir Mohammed Abdallah, the National Insect Collection Museum of the Agricultural Research Corporation, Wad Medani, Sudan. This results agreed with Gesmallah (2012), who found that *B. invadens* was the dominant fruit fly species in Gezira State representing 98.4% of the FF species composition.

4.2 POPULATION INCIDENCE OF *B. invadens*

4.2.1 Using Methyl Eugenol (ME) as a male attractant

ME was used to monitor the prevailing FF species and to determine the population of FFs that belong to the genus *Bactrocera* in the surveyed area (Gezirat-elfil and Hantoub area, Greater Wad Medani Locality). Results showed that *B. invadens* was present throughout the year on guava in Greater Wad Medani Locality. The highest population was observed during 4th week of July (298 adults/trap/week) and 4th week of September (168 adults/trap/week) in Shegede and Abdo orchards respectively (Gezirat-elfil area), whereas the lowest number of adults were recorded in 2nd week of September (3 adults/trap/week) in Elboraie orchard (Hantoub area; Fig.1; Appen. C). However, 1st week of September showed the highest number of adults(67 adults/trap/wk) in Abuzai
orchard (Hantoub area; Fig.1). Some workers related the increase in population of most FF species to climate conditions, mainly temperature and RH% during the rainy season, *i.e.* July and September in Egypt (Bashir, 2007).

### 4.2.2 Using yellow sticky traps

The numbers of *B. invadens* caught using yellow sticky traps were very low in the two locations (Hantoub and Gezirat-elfil). The population of this species in Hantoub area proved to be lower than that in Gezirat-elfil. The highest population was observed in Shegede orchard (Gezirat-elfil area) during September (8) and October (10) adults/trap/month (Fig.2; Appen. D). The population of *B. invadens* was relatively low during August, September and October (1 adult/tap/month) in Hantoub area (Fig.2). The same figure showed that *B. invadens* was very rare during July in Hantoub area.

Yellow sticky traps were used also as a monitoring device to evaluate the effect of insecticides in the two locations (Hantoub and Gezirat-elfil). The results showed low numbers of *B. invadens* following the application of the insecticides. The highest numbers of *B. invadens* were observed during 4th week of October (6 adult/tap/week) in Shegede orchard (Gezirat-elfil area) before application (Fig.2), where as the lowest numbers of *B. invadens* were recorded during 2nd week of November (1 adults/tap/week) in Elboraie orchard (Hantoub area; Fig. 3) after the application.
**Fig (1):** Counts of *B. invadens* captured during the period from July to October (2011) using the methyl Eugenol on guava.
Fig (2): Pre spray counts of FF adults caught during the period from July to October (2011) using the yellow sticky traps hanged on guava trees.
Fig (3): Post spray counts of FF adults caught during November (2011) using the yellow sticky traps hanged on guava trees.
4.3 The Effect of NSPE on Fruit Fly Infestation

4.3.1 The Number of Pupae/Fruit

The two tested concentrations 25 and 50 g/L of NSPE resulted in fewer number of pupae/fruit when compared with the untreated control. The highest number of pupae/fruit were recorded from the untreated fruits (2.39), while the lowest number of pupae/fruit were recorded from fruits treated with 25 and 50 g/L of NSPE, i.e. 0.7 and 0.99, respectively in Gezirat-elfil. Table (1). No significant differences were found between the two tested concentrations.

Similarly, lower number of pupae/fruit (0.67) were recorded from fruits treated with NSPE compared with the control (2.0) in Hantoub location Table (2). Randen et al., (1998) reported that the neem-based insecticides in an artificial diet resulted in decrease in pupal formation and subsequent adult emergence of the western cherry FF, *Rhagoletis indifferens* (Curran).

4.3.2 The Number of Emerged Adults/Fruit

The two tested concentrations 25, and 50 g/L were significantly reduced the numbers of emerged adults/fruit (0.71) when compared to the control (1.77) in Gezirat-elfil area Table (1). No significant differences between means of the two concentrations were detected. Following the same trend, the highest number of emerged adults/fruit was recorded from the untreated fruits (1.34), when compared with the that of the treated fruits (0.71) for the two tested NSPE concentrations, the differences were significant between the values obtained from the two NSPE concentrations and control in Hantoub area, Table (2).

However, adult emergence was not affected by any concentrations of NSPE in two locations (Gezirat-elfil and Hantoub) Table(1) and Table (2). This result was in agreement with Khattach et al., (2009) who found that, none of the
neem extracts (1%, 2% and 3% neem seed powder water extract), affected adult emergence of the melon FF (*Bactrocera cucurbitae*).
Table (1): The effect of Neem Seeds Powder Extract (NSPE) on fruit fly infestation in (Gezirat-elfil area), Greater Wad Medani locality.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Mean No. of pupae/fruit</th>
<th>Mean No. of emerged adults /fruit</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 g/L water</td>
<td>0.66 b (0.99)</td>
<td>0.0 b (0.71)</td>
</tr>
<tr>
<td>25 g/L water</td>
<td>0.00 b (0.70)</td>
<td>0.0 b (0.71)</td>
</tr>
<tr>
<td>Control</td>
<td>5.33 a (2.39)</td>
<td>2.67 a (1.77)</td>
</tr>
<tr>
<td>S.E±</td>
<td>0.30</td>
<td>0.14</td>
</tr>
<tr>
<td>C.V.%</td>
<td>35.1%</td>
<td>9.09%</td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test (DMRT) at (p=0.05).

* Figures in parentheses indicates transformed value (√x+0.5).
**Table (2):** The effect of Neem Seeds Powder Extract (NSPE) on fruit fly infestation in **Hantoub area**, Greater Wad Medani Locality.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Mean No. of pupae/fruit</th>
<th>Mean No. of emerged adults/fruit</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 g/L water</td>
<td>0.67 b</td>
<td>0.0 b (0.71)</td>
</tr>
<tr>
<td>25 g/L water</td>
<td>0.67 b</td>
<td>0.0 b (0.71)</td>
</tr>
<tr>
<td>Control</td>
<td>2.00 a</td>
<td>1.33 a (1.34)</td>
</tr>
<tr>
<td>S.E±</td>
<td>0.25</td>
<td>0.15</td>
</tr>
<tr>
<td>C.V%</td>
<td>30.0%</td>
<td>12.9%</td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test (DMRT) at (p=0.05).

* Figures in parentheses indicates transformed value (√x+0.5).
4.4 The Effect of Deltamethrin (Decis®) 12.5% UL on Fruit Fly Infestation

4.4.1 The Number of Pupae/Fruit

The three tested concentrations of Deltamethrin 12.5% UL (0.25, 0.5 and 1 L/F), were significantly reduce the number of the pupae/fruit. The results of the treatments 0.25, 0.5 and 1 L/F were 0.99, 1.29 and 0.70 pupae/fruit, respectively, compared with the control (2.32) in Hantoub location Table (3).

In Gezirat-elfil location, the concentration 0.25 L/F of Deltamethrin resulted in higher number of pupae/fruit (3.0) when compared with 0.5 and 1 L/F (1.3 and 1.0 pupae/fruit, respectively), These means were significantly different from the control (9.7 pupae/fruit; Table (4).

4.4.2 The Number of Emerged Adults/Fruit

The three tested concentrations of Deltamethrin in most cases reduced the numbers of the emerged adults/fruit (0.70), compared to the control at Hantoub. The highest number of emerged adults were recorded from the untreated fruits (1.86 adults/fruit) Table (3).

The same trend was observed when applying Deltamethrin in Gezirat-elfil, when the lowest No. of emerged adults was recorded from tested concentrations (0.70) compared to (2.47) adults/fruit recorded from the control Table (4). Hence, there is no significant differences between the tested doses and the control were detected Table (4). Therefore, the lowest dose must be adopted to cater for the residues on the fruits, the environmental pollution, etc. Fox et al., (2004) found that the pyrethroid Gardstar® (permethrin) resulted in 62% mortality, and 52% wing deformation of emerging Caribbean FF, Anastrepha suspense, whereas diazinon effected 79% mortality and 1% wing deformation.
Table (3): The effect of Deltamethrin 12.5% UL in controlling the FF infestation on Guava in Hantoub area, Greater Wad Medani Locality, Gezira State.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Mean No. of pupae /fruit</th>
<th>Mean No. of emerged adults /fruit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25 L/F</td>
<td>0.33 b (0.99)</td>
<td>0.0 b (0.70)</td>
</tr>
<tr>
<td>0.5 L/F</td>
<td>0.67 b (1.29)</td>
<td>0.0 b (0.70)</td>
</tr>
<tr>
<td>1.0 L/F</td>
<td>0.00 b (0.70)</td>
<td>0.0 b (0.70)</td>
</tr>
<tr>
<td>Control</td>
<td>5.0 a (2.32)</td>
<td>3.0 a (1.86 a)</td>
</tr>
</tbody>
</table>

S.E+        | 0.29                     | 0.16                             |
C.V%        | 32.1%                    | 13.6%                            |

* Means followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test (DMRT) at (p= 0.05).

* Figures in parentheses indicates transformed value (√x+0.5).
Table (4): The effect of Deltamethrin 12.5% UL in controlling the FF infestation on Guava in Gezirat-elfil area, Greater Wad Medani Locality, Gezira State.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Mean No. of Pupae/fruit</th>
<th>Mean No. of emerged adults/fruit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25 L/F</td>
<td>3.0 b</td>
<td>1.0 b (1.17 b)</td>
</tr>
<tr>
<td>0.5 L/F</td>
<td>1.3 c</td>
<td>0.0 b (0.70 b)</td>
</tr>
<tr>
<td>1.0 L/F</td>
<td>1.0 c</td>
<td>0.0 b (0.70 b)</td>
</tr>
<tr>
<td>Control</td>
<td>9.7 a</td>
<td>5.7 a (2.47 a)</td>
</tr>
<tr>
<td>S.E ±</td>
<td>0.46</td>
<td>0.39</td>
</tr>
<tr>
<td>C.V %</td>
<td>22.3%</td>
<td>18.7%</td>
</tr>
</tbody>
</table>

* Means followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test (DMRT) at (p=0.05).

* Figures in parentheses indicates transformed value (√x+0.5).
CONCLUSIONS

From the results obtained, it is concluded that:

1. *Bactrocera invadens*(Drew, Tsuruta and White) is the major FF species on Guava in Greater Wad Medani Locality, Gezira State.

2. *B. invadens* was present throughout the season of Guava in Greater Wad Medani Locality.

3. Methyl eugenol, showed a strong potential to attract the males of *B. invadens* in the orchards.

4. The highest population of *B. invadens* was recorded during the humid months (July and August).

5. Deltamethrin UL at 0.25 L/F was found to be effective against *B. invadens* adults.

6. Deltamethrin and Neem Seed Powder Extract(NSPE) inhibited the emergence of *B. invadens* adults.
REFERENCES


EPPO/CABI.(1990). Data sheets on Quarantine Pests *Ceratitis quinaria*.


FAO.(2003). Proposal for a FAO Regional technical cooperation project (TCP); Emergency task force to prevent the establishment of the peach fruit fly, *Bactrocera zonata*, Saunders (Diptera: Tephritidae) in the Middle East and North Africa regions.


Singh, G. (1998). Neem (*Azadirachta indica*), Seed kernel extracts and Azadirachta as oviposition deterrents against the melon fly (*Bactrocera cucurbitae*) and the oriental fruit fly (*Bactrocera dorsalis*).


Steck, G.J.(2003). DPI Entomology circular 403, one of a series of featured creatures from the Entomology and Nematology Department, Florida Cooperative Extension Services, Institute of Food and Agriculture Sciences, University of Florida.


APPENDICES

Appendix (A) : The morphological features of *Bactrocera invadens*

![Plate 2.1 Bactrocera invadens](image)

Appendix (B) : The morphological features of the mango fruit fly *Ceratitis cosyra* Walker

![Plate 2.2 Adult female of Ceratitis cosyra](image)
Appendix (C): Counts of *B. invadens* captured during the period from July to October (2011) using Methyl Eugenol on guava.

<table>
<thead>
<tr>
<th>Month</th>
<th>Wk</th>
<th>Mean No. of adults /orchard/trap/wk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Shegede Orchard</td>
</tr>
<tr>
<td>July</td>
<td>1</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>86</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>298</td>
</tr>
<tr>
<td>August</td>
<td>5</td>
<td>102</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>49</td>
</tr>
<tr>
<td>Sept</td>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>118</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>128</td>
</tr>
<tr>
<td>October</td>
<td>13</td>
<td>105</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>96</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>48.4</td>
</tr>
<tr>
<td>SE±</td>
<td></td>
<td>8.23</td>
</tr>
<tr>
<td>C.V%</td>
<td></td>
<td>71.97</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix (D): Pre spray counts of FF adults caught during the period from July to October (2011) using the yellow sticky traps hanged on guava trees.

<table>
<thead>
<tr>
<th>Month</th>
<th>Wk</th>
<th>Mean No. of adults /orchard/trap/wk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Shegede Orchard</td>
</tr>
<tr>
<td>July</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>August</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Sept</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>October</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>1.24</td>
</tr>
<tr>
<td>SE±</td>
<td></td>
<td>0.34</td>
</tr>
<tr>
<td>C.V%</td>
<td></td>
<td>99.46</td>
</tr>
</tbody>
</table>