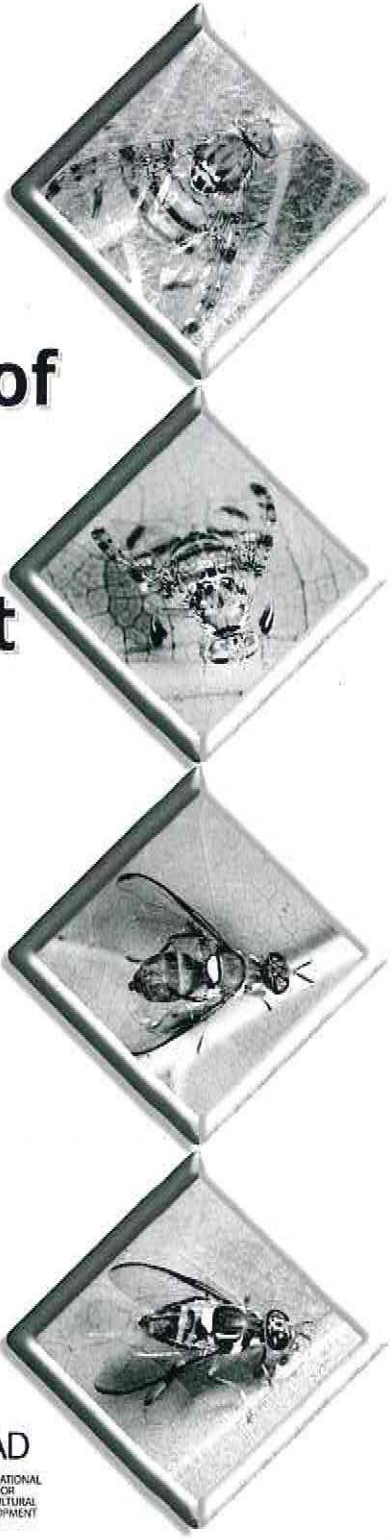
A Field Guide to the Management of Economically Important Tephritid Fruit Flies in Africa

Edited by
S. Ekesi and M. K. Billah

African Fruit Fly Initiative
(Réseau Africain de la Mouche de Fruits)

IFAD
INTERNATIONAL FUND FOR AGRICULTURAL DEVELOPMENT

A Field Guide to the Management of Economically Important Tephritid Fruit Flies in Africa



Edited by
S. Ekesi and M. K. Billah

African Fruit Fly Initiative
(Réseau Africain de la Mouche de Fruits)
IFAD
INTERNATIONAL FUND FOR AGRICULTURAL DEVELOPMENT

Disclaimer
Where specific pesticides and other commercial products have been mentioned in the text, these are generally given as examples and should not be regarded as being exclusive of others. Mention of specific commercial products, pesticides, trade names and specific companies in the text does not imply any preference or advantage over similar products or companies not mentioned by name.

Cover Photographs: From the top: *Ceratitis fasciventris* Bezzi, *Ceratitis rosa* Karsch, *Dacus ciliatus* Loew and *Bactrocera invadens* Drew *(R. S. Copeland)*

Figures: Figure 1: Eggs, puparia *(M. K. Billah)*; larvae *(S. Ekesi) and inset (M. K. Billah)*; adult flies *(R. S. Copeland)*; **Figures 2–9 (inset), Figure 10 (inset):** *(M. K. Billah)*; **11–16 (inset):** *(R. S. Copeland)*; **Figure 17:** *(M. K. Billah)*; **Figures 18D, 19A, B and D, 20A, B and C, 21B, C and D and 22A:** *(I. M. White)*, Natural History Museum (NHM), UK; **Figures 18B, 18C, 19C, 20D and 21C:** *(M. De Meyer)*; **Figure 23:** *(R. S. Copeland)*; **Figures 18A, 22B and C, 24A and B, 25A, B and C, 26A and B, 27A and B** *(M. K. Billah)*

Plates: Plate 1A–F: Courgette *(J.-F. Vayssieres)*; Mango *(M. K. Billah)*; Tomato *(A. Manrakhan)*; **Plates 2–16:** *(M. K. Billah)*; **Plates 17–22:** *(R. S. Copeland)*

A Field Guide to the Management of Economically Important Tephritid Fruit Flies in Africa

S. Ekesi and M. K. Billah (Editors)

ISBN: 92 9064 179 7

Copyediting: D. Osogo
Typesetting and Layout: I. Ogendo
Maps: E. Muchugu
Cover design: I. Ogendo

Published by ICIPE Science Press
P. O. Box 72913-00200, Nairobi, Kenya

Printed by Modern Lithographic (K) Ltd
Nairobi, Kenya

Acknowledgement

We are grateful to the following who provided valuable input and financial support for this manual: The Food and Agriculture Organization (FAO) of the UN, the International Fund for Agricultural Development (IFAD), the African Fruit Fly Initiative (AFFI) and the Dutch Programme for Cooperation with International Institutions (Netherlands-SII). Appreciation is also extended to Eric Muchugu, Ivan Rwomushana, Constance Muholo, Peterson Nderitu and all members of the AFFI programme who helped to make this a better manual.

Contents

List of Illustrations ix

Introduction A-1

CHAPTER 1: Tephritid Fruit Flies in Africa—Fact Sheets of Some Economically Important Species *(Sunday Ekesi)*

Generalised life cycle B-1
Damage symptoms B-2
Species, distribution and host plants B-3
Ceratitis cosyra (Walker) B-3
Ceratitis rosa Karsch B-4
Ceratitis fasciventris Bezzi B-5
Ceratitis anonae Graham B-6
Ceratitis capitata (Wiedemann) B-7
Ceratitis rubivora (Coquillett) B-8
Bactrocera invadens Drew, Tsuruta & White B-9
Bactrocera cucurbitae (Coquillet) B-10
Bactrocera zonata (Saunders) B-11
Dacus bivittatus (Bigot) B-12
Dacus ciliatus Loew B-13
Dacus frontalis Becker B-14
Dacus lounsburyii Coquillett B-15
Dacus punctatifrons Karsch B-16
Dacus vertebratus Bezzi B-17

CHAPTER 2: Fruit Fly Monitoring—Purpose, Tools and Methodology *(Aruna Manrakhan)*

Purpose of monitoring C-1
Trapping tools C-1
Attractants C-1
Para-pheromones C-1
Food Baits C-3
Traps C-4
Trapping survey objectives and applications C-8
Detection surveys C-8
Delimiting surveys C-8
Monitoring surveys C-9
Trapping network C-9
Placement of traps C-9
Public relations C-9

Trapping site C-10
Trapping density C-11
Preparation and handling of traps and attractants C-11
Preparation C-11
Handling C-12
Trap servicing and re-baiting C-13
Servicing C-13
Re-baiting C-13
How to report the trapping results C-14

CHAPTER 3: Fruit Fly Suppression—Purpose, Tools and Methodology ***(Sunday Ekesi and Slawomir A. Lux)***
Purpose D-1
Tools 1
Suppression methods D-1
Recommended primary IPM components D-1
Baiting technique D-1
Preparation of the bait spray D-2
Calibration of the pump for bait spraying D-2
Bait application D-3
Soil inoculation with fungal pathogen D-3
Post-harvest fruit treatment D-3
Recommended secondary IPM components D-4
Orchard sanitation D-4
Mechanical fruit protection D-4
Early harvesting D-4
Biological control D-5

CHAPTER 4: Safety Precautions and Conduct During Monitoring and Suppression ***(Sunday Ekesi)***
Safety and cross-contamination precautions during monitoring E-1
Safety and cross-contamination precautions during suppression E-1
Lure/bait disposal E-3
Storage of bait, fungus and pesticides E-3

CHAPTER 5: Host Fruit Processing—Purpose, Tools and Methodology ***(Robert S. Copeland)***
Background F-1
Purpose of the collection F-1
What to carry with you F-1
Methodology F-3
Field sites F-3

Choosing sites F-3
Accessing sites F-3
Field collections and plant identification F-4
Finding fruits F-5
Collecting fruits F-5
Managing collections in the field F-5
Preparing collection vouchers in the field F-7
Transporting fruits F-7
Processing fruits in the laboratory F-8
Processing reared insects F-10
How to curate the collection F-11
Managing the data F-11

CHAPTER 6: Handling, Packaging and Shipment of Specimens
(Maxwell K. Billah)

Background G-1
Tools and implements G-1
Collection of information and labelling of data G-2
Preparation of specimens G-3
Dry specimen mounting G-3
Pin mounting G-4
Direct/single mounting G-4
Double mounting G-4
Card mounting G-4
Relaxing stored dry specimens G-5
Preparing wet specimens in ethanol G-5
Preparing adult flies G-6
Preparing larval stages G-6
Packing, packaging and shipment G-6
Wet or ethanol-preserved specimens G-7
Dry or pinned specimens G-7
Slide-mounted specimens (for parasitoids/hyperparasitoids which may be reared from fruits) G-7
After specimen preparation (dry, wet or slide-mounted) G-7
Labelling specimens G-10
Labels for dry specimens G-10
Labels for wet specimens G-10
Labels for slide specimens G-11
Specimen storage G-11
Wet collection G-11

Dry collection G-11
Slide collection G-12
Things to note G-12

CHAPTER 7: Fruit Fly Taxonomy and Identification
(M. K. Billah and M. W. Mansell)

Introduction H-1
Fruit flies of major economic importance in Africa H-2
Indigenous species H-2
Invasive species H-2
Key to the common fruit fly species H-3
A. *Ceratitis* species H-3
B. Non-*Ceratitis* species H-10
C. *Trirhithrum* species H-10
1. *Trirhithrum coffeae* Bezzi—Coffee fly H-10
2. *Trirhithrum nigerrimum* (Bezzi) H-10
D. *Dacus* and *Bactrocera* species H-11
E. *Dacus* species H-11
F. *Bactrocera* species H-14

References and Suggested Further Reading I-1

Annex 1: Checklist of host plants of some major tephritid fruit flies in Africa ..... **Annex 1-1**

Annex 2: Fruit fly monitoring datasheet ..... **Annex 2-1**

Annex 3: Sample spreadhsheet for managing fruit fly host fruit processing data ..... **Annex 3-1**

List of Illustrations

FIGURES

Figure 1. Generalised life cycle of tephritid fruit flies **B-1**

Figure 2. Distribution and potential *Ceratitis cosyra* zones in Africa. Inset: Adult *Ceratitis cosyra* **B-3**

Figure 3. Distribution and potential *Ceratitis rosa* zones in Africa. Inset: Adult *Ceratitis rosa* **B-4**

Figure 4. Distribution and potential *Ceratitis fasciventris* zones in Africa. Inset: Adult *Ceratitis fasciventris* **B-5**

Figure 5. Distribution and potential *Ceratitis anonae* zones in Africa. Inset: Adult *Ceratitis anonae* **B-6**

Figure 6. Distribution and potential *Ceratitis capitata* zones in Africa. Inset: Adult *Ceratitis capitata* **B-7**

Figure 7. Distribution and potential *Ceratitis rubivora* zones in Africa. Inset: Adult *Ceratitis rubivora* **B-8**

Figure 8. Distribution and potential *Bactrocera invadens* zones in Africa. Inset: Adult *Bactrocera invadens* **B-9**

Figure 9. Distribution and potential *Bactrocera cucurbitae* zones in Africa. Inset: Adult *Bactrocera cucurbitae* **B-10**

Figure 10. Distribution of *Bactrocera zonata* in Africa. Inset: Adult *Bactrocera zonata* **B-11**

Figure 11. Distribution and potential *Dacus bivittatus* zones in Africa. Inset: Adult *Dacus bivittatus* **B-12**

Figure 12. Distribution and potential *Dacus ciliatus* zones in Africa. Inset: Adult *Dacus ciliatus* **B-13**

Figure 13. Distribution and potential *Dacus frontalis* zones in Africa. Inset: Adult *Dacus frontalis* **B-14**

Figure 14. Distribution and potential *Dacus lounsburyii* zones in Africa. Inset: Adult *Dacus lounsburyii* **B-15**

Figure 15. Distribution and potential *Dacus punctatifrons* zones in Africa. Inset: Adult *Dacus punctatifrons* **B-16**

Figure 16. Distribution and potential *Dacus vertebratus* zones in Africa. Inset: Adult *Dacus vertebratus* **B-17**

Figure 17. Steps involved in the proper packing, packaging and shipment of specimens for identification **G-9**

Figure 18. **(A)** Forewing; **(B)** thoracic colour pattern and **(D)** head showing the male orbital setae of *Ceratitis capitata* (Wiedemann) (the Mediterranean fruit fly/med fly) **C,** thoracic colour pattern of *Ceratitis cosyra* **H-5**

Figure 19. **(A)** Head, **(B)** thorax and **(C, D)** mid leg feathering of *Ceratitis anonae* Graham **H-6**

Figure 20. **(A)** Head, **(B)** thorax and **(C, D)** mid leg feathering of *Ceratitis rosa* Karsch (Natal fruit fly/Natal fly) **H-7**

Figure 21. **(A)** Thorax, **(B)** wing of female and **(C, D)** mid leg feathering of male *Ceratitis fasciventris* (Bezzi) **H-8**

Figure 22. (A) Post-pronotal spot on thorax, (B) costal band on wing and (C) thoracic colour pattern of *Ceratitis cosyra* (Walker) (mango fruit fly/marula fly) H-9
Figure 23. Thorax, abdomen and wings of *Trirhithrum nigerrimum* (Bezzi) H-11
Figure 24. The main distinguishing features of the abdominal tergites between (A) *Dacus* Fabricius and (B) *Bactrocera* Macquart H-16
Figure 25. Thoracic and wing pattern variations in three *Bactrocera* species: (A) Variable thoracic colour patterns of *B. invadens*, (B) wing patterns of *B. invadens* (L) and *B. cucurbitae* (R) and (C) wing patterns of *B. invadens* (U) and *B. zonata* (D). H-17
Figure 26. Thoracic and abdominal features of *Bactrocera invadens* female: (A) Thorax (side view) and (B) abdomen (dorsal view) H-18
Figure 27. General physical appearance of some *Bactrocera* species: (A) *B. invadens* showing some femur and tibia features and (B) comparison of *B. invadens* (1), *B. cucurbitae* (2) and *B. zonata* (3) H-19

COLOUR PLATES

Plate 1 a–c. External damage symptoms on fruit: **a,** courgette; **b,** mango and **c,** tomato **Plate 1 d–f.** Internal damage symptoms on fruit: **d,** courgette; **e,** mango and **f,** tomato B-2
Plate 2. Liquid methyl eugenol C-2
Plate 3. A sachet of methyl eugenol polymeric plug C-2
Plate 4. A Cuelure polymeric plug C-2
Plate 5. A trimedlure polymeric plug C-2
Plate 6. Nulure liquid protein hydrolysate C-3
Plate 7. AFFI yeast product C-4
Plate 8. Biolure—the 3- component lure C-4
Plate 9. Locally made Lynfield trap C-5
Plate 10. The Jackson trap C-5
Plate 11. The Steiner trap C-6
Plate 12. The McPhail trap C-6
Plate 13. The Tephri trap C-7
Plate 14. The Multilure trap C-7
Plate 15. Destruction of fallen fruits infested by fruit flies by putting them in black plastic bags, tying the bags and exposing them to the sun D-5
Plate 16. Mango fruit bagging in an orchard in Kenya to prevent infestation by fruit flies D-5
Plate 17. Pruner and pruner head F-2
Plate 18. Container with polythene bag and fruits F-8
Plate 19. One-litre fruit-holding container with ellipsoidal holes F-9
Plate 20. One-litre fruit-holding container nested on 2-litre container F-9
Plate 21. Large cage for checking emerged insects F-10
Plate 22. Insect (fruit flies) holding cages F-10

Introduction

Fruit and vegetable production is one of the fastest-growing agricultural sectors in Africa, providing both income and employment to growers and exporters alike. The range of fruits and vegetables grown is diverse. Mangoes, citrus, apple, papaya, passion, guava, avocado, cucumber, pumpkin and watermelon are among the most common fruits and vegetables grown for domestic urban markets and for export to major outlets in Europe and the Middle East. This growth is changing the dietary patterns leading to increased consumption of fruits and vegetables. However, different types of insect pests afflict production in Africa, and perhaps none have gained greater notoriety than the fruit flies (Diptera: Tephritidae). The enormous losses they cause through direct damage to fruits and vegetables and loss of market opportunities through imposition of strict quarantine regulations by importing countries to prevent entry and establishment of fruit flies demand urgent need for implementation of sustainable management practices for fruit flies control. The introduction of uniform and strict quarantine restrictions and the maximum residue level (MRL) regulations in the European Union compound the existing fruit fly problem and jeopardise the lucrative export of fresh fruits and vegetables from Africa. Lack of local expertise in fruit fly management makes it difficult to respond in a timely and efficient manner to the challenges imposed by fruit flies. The correct identification of fruit flies occurring in a particular area and their damage symptoms is a first step towards developing appropriate management strategies.

At the concluding meeting of the first phase of an FAO TCP project on surveillance and management of the invasive fruit fly species *Bactrocera invadens* in East Africa, and the Dutch Programme for Cooperation with International Institutions (Netherlands-SII) and IFAD-sponsored International Group Training Course on Fruit fly Management in October 2005, representatives of national plant protection organisations (NPPOs) of participating countries expressed the need for development of a field manual for management of economically important tephritid fruit flies in Africa in view of the fruit fly-related trans-boundary invasions arising from increased travel and trade in fruits and vegetables. A request was therefore made to FAO to provide funds for the development of the manual in support of their fruit fly management activities in the region and the International Centre of Insect Physiology and Ecology (ICIPE) was mandated to develop the manual.

This field guide provides agricultural scientists, extension workers and quarantine specialists with information on the life cycle, damage symptoms, distribution and host plants of major fruit fly species of fruits and vegetables in Africa. The purpose, tools and methodology for fruit fly monitoring, suppression and host fruit processing and handling are also comprehensively covered. Additionally, brief sections on safety precautions

during monitoring and suppression, and packaging, handling and shipment of specimens to facilitate identification are provided. The field guide also provides a simple, user-friendly taxonomic key to all the common fruit fly species to allow for rapid identification of the major species found on fruits in Africa. This manual is to be considered as a 'working document' to be regularly updated as fruit fly taxonomy and management techniques continue to improve and global experience in control programmes continues to expand.

CHAPTER 1

Tephritid Fruit Flies in Africa—Fact Sheets of Some Economically Important Species

Sunday Ekesi
International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya

Generalised life cycle

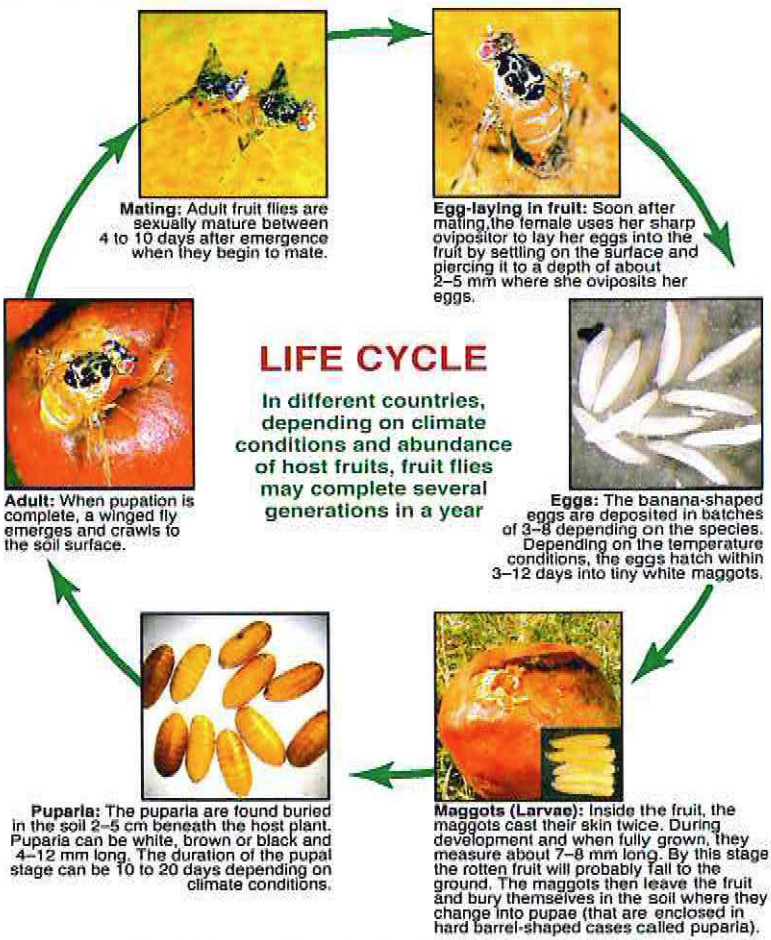


Figure 1. Generalised life cycle of tephritid fruit flies

Damage symptoms

Direct damage: Direct damage begins when the female fly punctures the fruit skin and lays eggs underneath it. Damage symptoms vary from fruit to fruit **(Plate 1 a–f).** During egg laying, fruit-rotting bacteria from the intestinal flora of the fly are introduced into the fruit. These bacteria multiply and cause the tissues surrounding the egg to rot. When the eggs hatch, the rotten fruit tissue makes it easier for the larvae to feed. The puncture and feeding galleries made by developing larvae **(Plate 1 d–f)** provide access for pathogens to develop and increase the fruit decay. Generally, the fruit falls to the ground as, or just before the maggots pupate.

Indirect losses: Nearly all fruit fly species are quarantine pests. Indirect losses result from quarantine restrictions that are imposed by importing countries to prevent entry and establishment of unwanted fruit fly species.

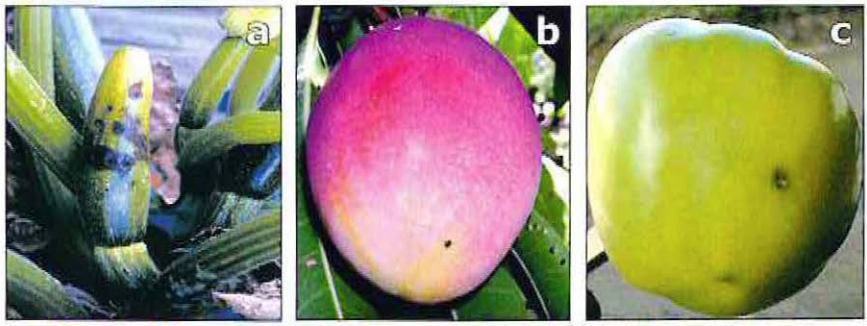


Plate 1 a–c. External damage symptoms on fruit: **a,** courgette; **b,** mango; **c,** tomato

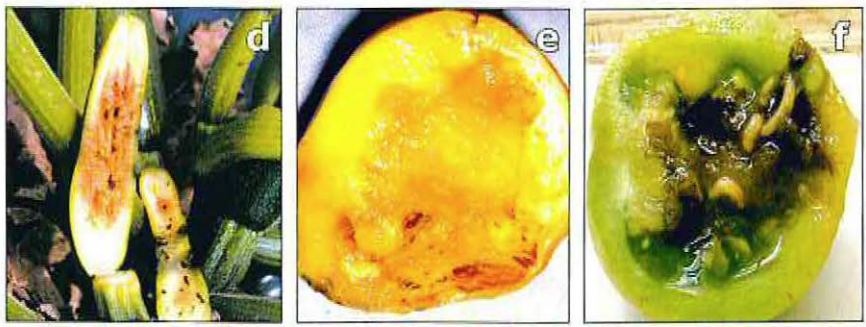


Plate 1 d–f. Internal damage symptoms on fruit: **d,** courgette; **e,** mango; **f,** tomato

Species, distribution and host plants

Ceratitis cosyra (Walker) (Diptera: Tephritidae)

Common name: Mango fruit fly

Distribution: *Ceratitis cosyra* **(Figure 2, inset)** is widespread in Africa and has been reported from Benin, Democratic Republic of Congo, Côte d'Ivoire, Kenya, Madagascar, Malawi, Mali, Mozambique, Namibia, Nigeria, Sierra Leone, South Africa, Sudan, Tanzania, Uganda, Zambia and Zimbabwe (White and Elson-Harris, 1992; S. Ekesi, unpublished data) **(Figure 2).**

Host plants: Typical host range of *C. cosyra* includes mango (*Mangifera indica*), guava (*Psidium guajava*), sour orange (*Citrus aurantium*), marula (*Sclerocarya birrea*), wild custard apple (*Annona senegalensis*) and wild apricot (*Landolphia* sp.) (White and Elson-Harris, 1992; S. Ekesi, unpublished data) **(Annex 1).** There are also other records from the following families; Anacardiaceae, Anisophylleaceae, Annonaceae, Apocynaceae, Chrysobalanaceae, Combretaceae, Ebenaceae, Fabaceae, Flacoutiaceae, Lauraceae, Myrtaceae, Passifloraceae, Rosaceae and Rubiaceae (De Meyer *et al.*, 2002b) **(Annex 1).**

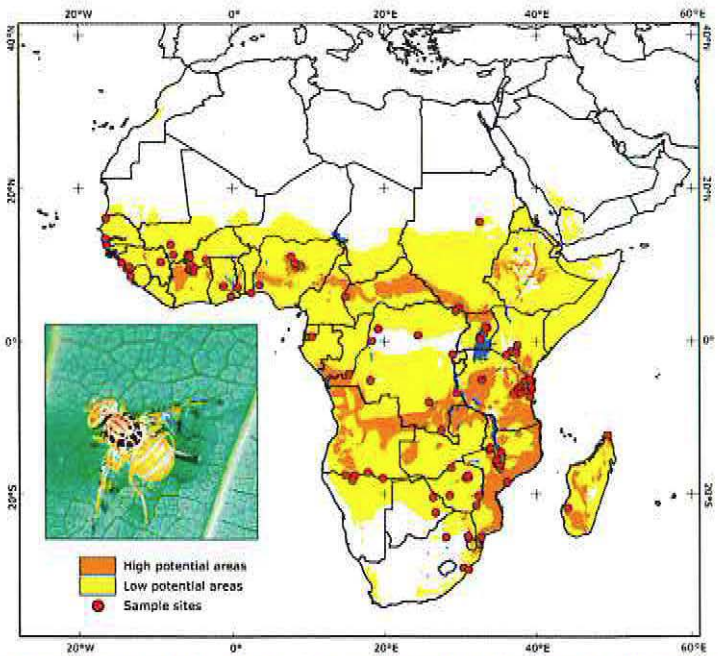


Figure 2. Distribution and potential *Ceratitis cosyra* zones in Africa. Inset: Adult *Ceratitis cosyra*

(See page B-18 for notes on species distribution maps.)

Ceratitis rosa Karsch (Diptera: Tephritidae)

Common name: Natal fruit fly

Distribution: *Ceratitis rosa* **(Figure 3, inset)** is known from Angola, Ethiopia, Democratic Republic of Congo, Kenya, Malawi, Mali, Mauritius, Mozambique, Nigeria, Réunion, Rwanda, Seychelles, South Africa, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe (White and Elson-Harris, 1992) **(Figure 3).**

Host plants: The host range of *C. rosa* is broad, recorded from over 100 fruit species (White and Elson-Harris, 1992; De Meyer *et al.*, 2002b) **(Annex 1).** In most of Africa, it damages mango (*Mangifera indica*), papaya (*Carica papaya*), guava (*Psidium guajava*) and custard apple (*Annona reticulata*). It is also a common pest of coffee (*Coffea arabica*) in eastern Africa **(Annex 1).**

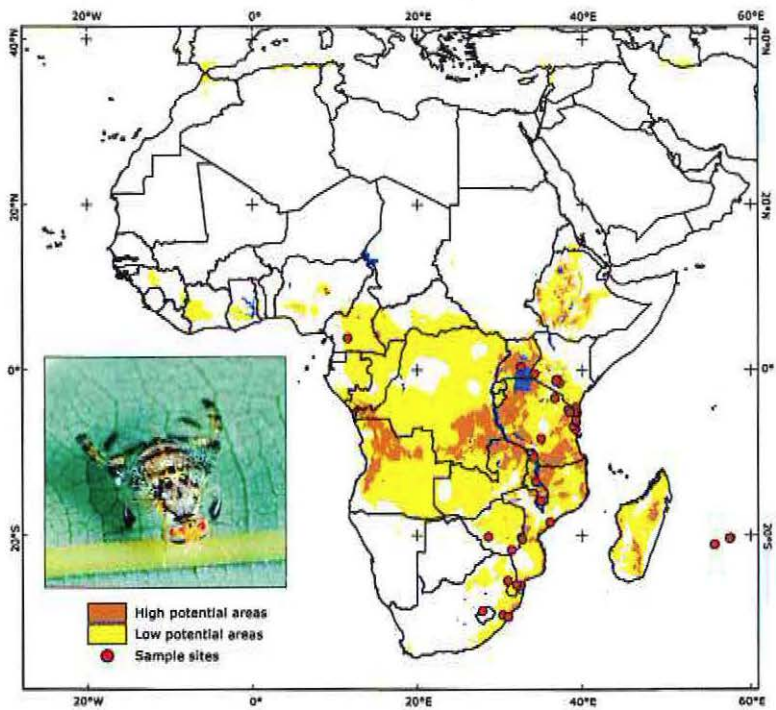


Figure 3. Distribution and potential *Ceratitis rosa* zones in Africa. Inset: Adult *Ceratitis rosa*

Ceratitis fasciventris Bezzi (Diptera: Tephritidae)

Distribution: *Ceratitis fasciventris* **(Figure 4, inset)** was formerly regarded as a variety of *C. rosa*. It occurs in Côte d'Ivoire, Democratic Republic of Congo, Ethiopia, Ghana, Guinea, Kenya, Mali, Nigeria, Sao Tomé & Principé, Tanzania and Uganda (White and Elson-Harris, 1992; M. Billah, unpublished data) **(Figure 4).**

Host plants: Recorded from over 40 plant species (De Meyer *et al.*, 2002b) **(Annex 1).** It is a major pest of mango (*Mangifera indica*), guava (*Psidium guajava*) and coffee (*Coffea arabica*) in eastern and western Africa **(Annex 1).**

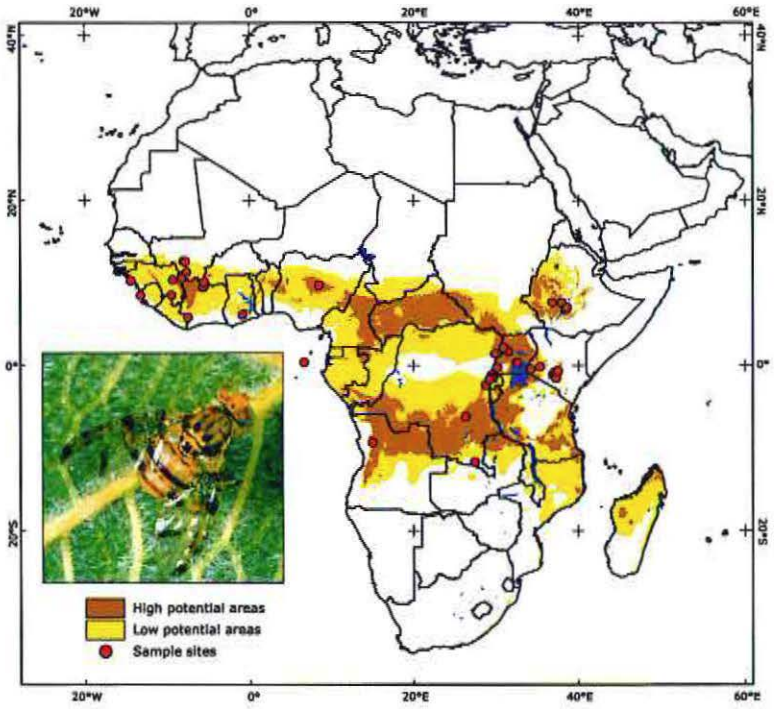


Figure 4. Distribution and potential *Ceratitis fasciventris* zones in Africa. Inset: Adult *Ceratitis fasciventris*

Ceratitis anonae Graham (Diptera: Tephritidae)

Distribution: *Ceratitis anonae* **(Figure 5, inset)** is found in Cameron, Central African Republic, Côte d'Ivoire, Democratic Republic of Congo, Gabon, Ghana, Guinea, Kenya, Sao Tome & Principe, Togo, Tanzania and Uganda (White and Elson-Harris, 1992) **(Figure 5).**

Host plants: Attacks nearly 50 fruit species. In most of the countries where it is found, it has been reared from guava (*Psidium guajava*). It is a common pest on mango (*Mangifera indica*) in West Africa (White and Elson-Harris, 1992; De Meyer *et al.*, 2002b; M. Billah, unpublished data) **(Annex 1).**

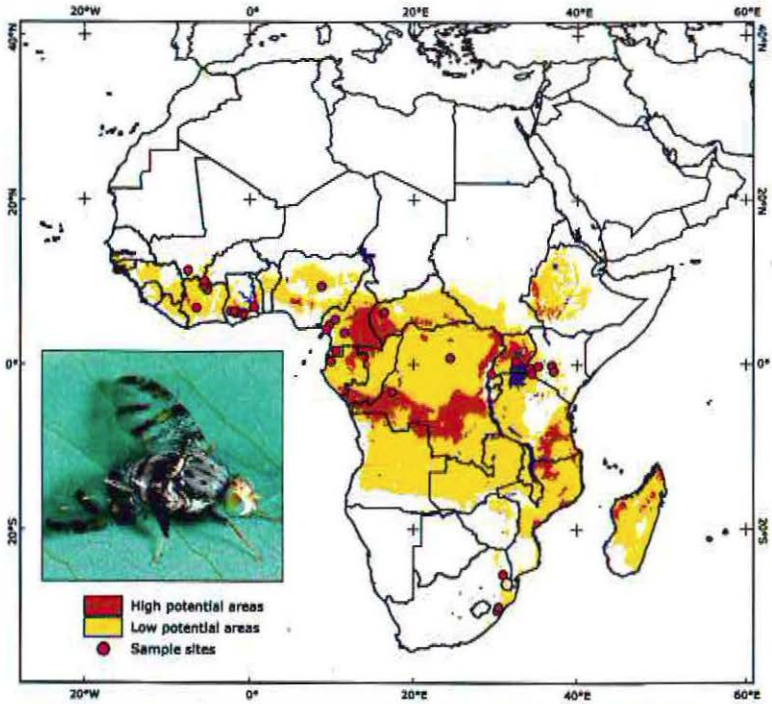


Figure 5. Distribution and potential *Ceratitis anonae* zones in Africa. Inset: Adult *Ceratitis anonae*

Ceratitis capitata (Wiedemann) (Diptera: Tephritidae)
Common name: Mediterranean fruit fly

Distribution: *Ceratitis capitata* **(Figure 6, inset)** is the most widely distributed pest fruit fly species. In Africa, it is recorded from Algeria, Angola, Benin, Burkina Faso, Burundi, Cameron, Congo, Democratic Republic of Congo, Egypt, Ethiopia, Gabon, Ghana, Guinea, Côte d'Ivoire, Kenya, Liberia, Libya, Malawi, Morocco, Mozambique, Niger, Nigeria, Senegal, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda and Zimbabwe (White and Elson-Harris, 1992) **(Figure 6).**

Outside its aboriginal home of Africa, it has also been reported in Australia, several European countries, Central, North and South America, the Middle East, Oriental Asia, the Atlantic Islands, Indian Ocean Islands, Pacific Ocean Islands, the West Indies and nearby islands (White and Elson-Harris, 1992).

Host plants: Extremely polyphagous and reared from over 300 commercial and wild host plants (White and Elson-Harris, 1992; De Meyer *et al.*, 2002b) **(Annex 1).**

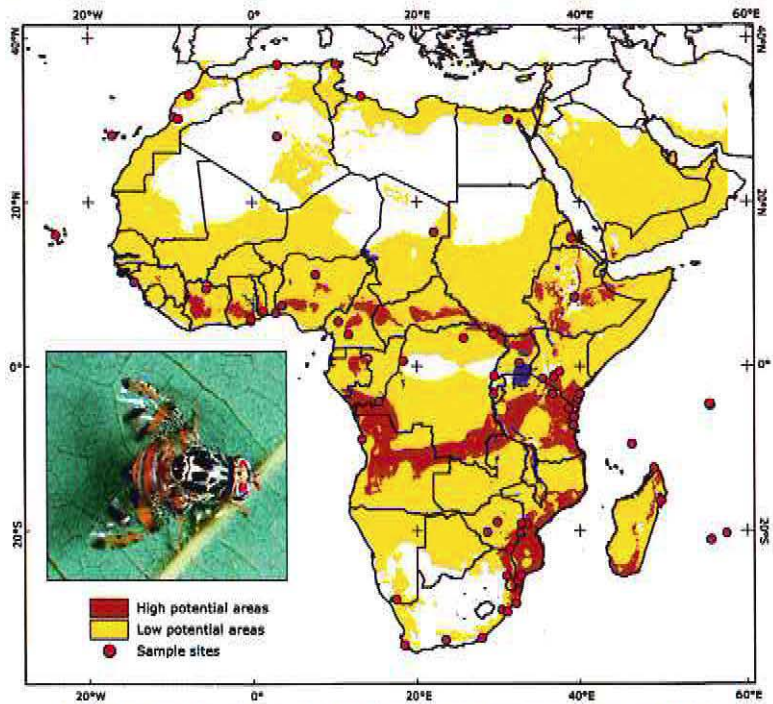


Figure 6. Distribution and potential *Ceratitis capitata* zones in Africa. Inset: Adult *Ceratitis capitata*

Ceratitis rubivora (Coquillett) (Diptera: Tephritidae)
Common name: Blackberry fruit fly

Distribution: *Ceratitis rubivora* **(Figure 7, inset)** is recorded from Cameroon, Kenya, Malawi, Tanzania, South Africa, Uganda and Zimbabwe (White and Elson-Harris, 1992) **(Figure 7).**

Host plants: Principally a pest of berry of the genus *Rubus*, occurring on blackberry (*R. fruticosa*), loganberry (*R. loganobaccus*) and raspberry (*R. idaeus*) (White and Elson-Harris, 1992; De Meyer *et al.*, 2002b) **(Annex 1).**

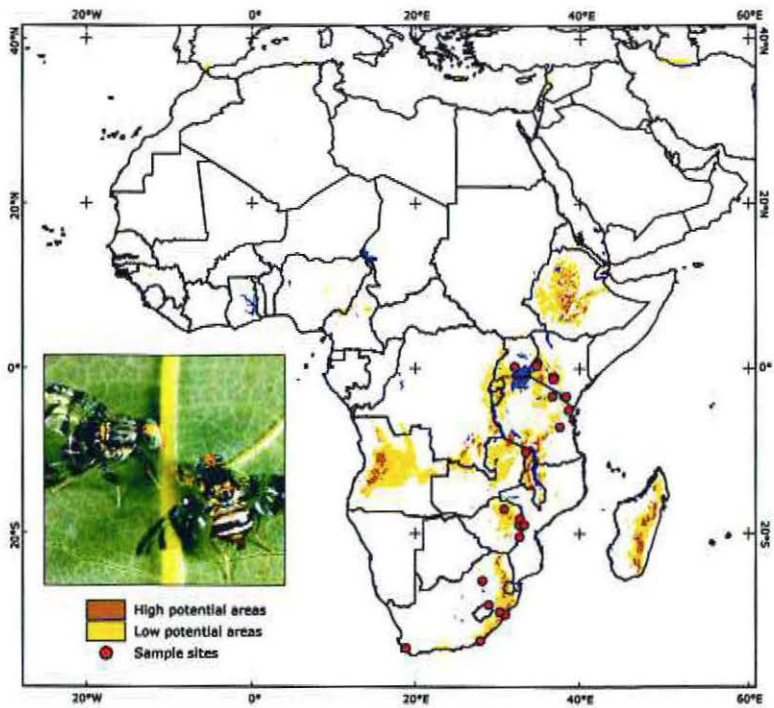


Figure 7. Distribution and potential *Ceratitis rubivora* zones in Africa. Inset: Adult *Ceratitis rubivora*

***Bactrocera invadens* Drew, Tsuruta & White (Diptera: Tephritidae)**

Common name: African Invader Fly

Distribution: *Bactrocera invadens* **(Figure 8, inset)** is a recently described invasive fruit fly species of Asian origin (Drew *et al.*, 2005). In Africa it has been recorded from Benin, Cameroon, Democratic Republic of Congo, Ethiopia, Gabon, Ghana, Guinea, Kenya, Mali, Nigeria, Senegal, Sudan, Tanzania, Togo and Uganda (Drew *et al.*, 2005; S. Ekesi *et al.*, unpublished data; R. Hanna *et al.*, unpublished data) **(Figure 8).** It was discovered in Sri Lanka soon after it was reported from Africa (Drew *et al.*, 2005).

Host plants: It has been reared from mango (*Mangifera indica*), lemon orange (*Citrus limon*), tomato (*Lycopersicum esculentum*), banana (*Musa* spp.), guava (*Psidium guajava*), marula (*Sclerocarya birrea*), custard apple (*Annona muricata*), Indian almond (*Terminalia catappa*), *Sorindea* sp. and avocado (*Persea americana*) (I. Rwomushana, unpublished data; Z. Seguni et al., unpublished data) **(Annex 1).** Mango, however, appears to be the primary host plant (Ekesi *et al.*, 2006).

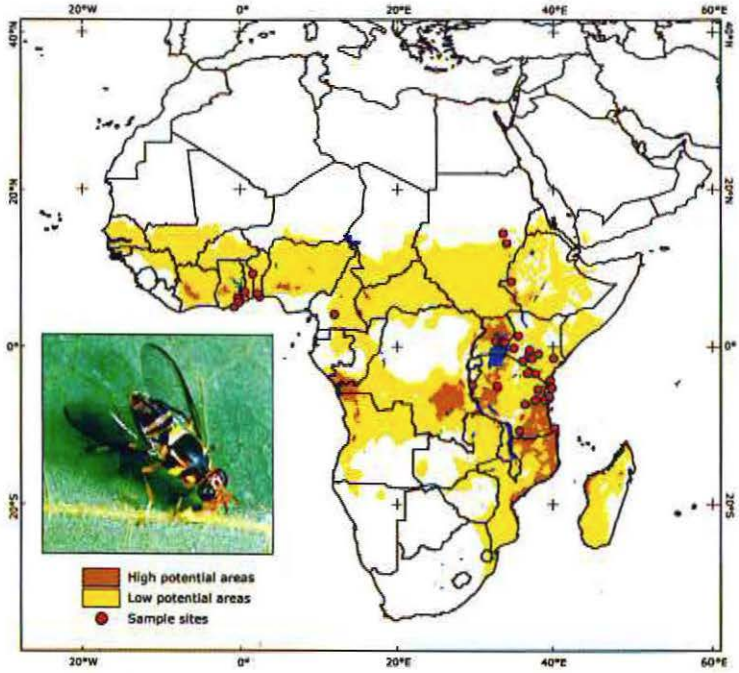


Figure 8. Distribution and potential *Bactrocera invadens* zones in Africa. Inset: Adult *Bactrocera invadens*

Bactrocera cucurbitae (Coquillet) (Diptera: Tephritidae)
Common name: Melon fly

Distribution: *Bactrocera cucurbitae* **(Figure 9, inset)** is an invasive pest species in Africa and is recorded from Benin, Cameron, Egypt (Lower Nile Valley), Ghana, Kenya, Nigeria and Tanzania (White and Elson-Harris, 1992; R. Hanna *et al.*, unpublished data; M.K. Billah, unpublished data) **(Figure 9).**

It is native to Oriental Asia and has also been reported from Hawaii, Iran, the Indian Ocean Islands of Mauritius and Reunion, and the New Guinea area (White and Elson-Harris, 1992).

Host plants: This pest has been reared from over 125 fruit species. Plants in the family Cucurbitaceae are, however, the usual hosts **(Annex 1).**

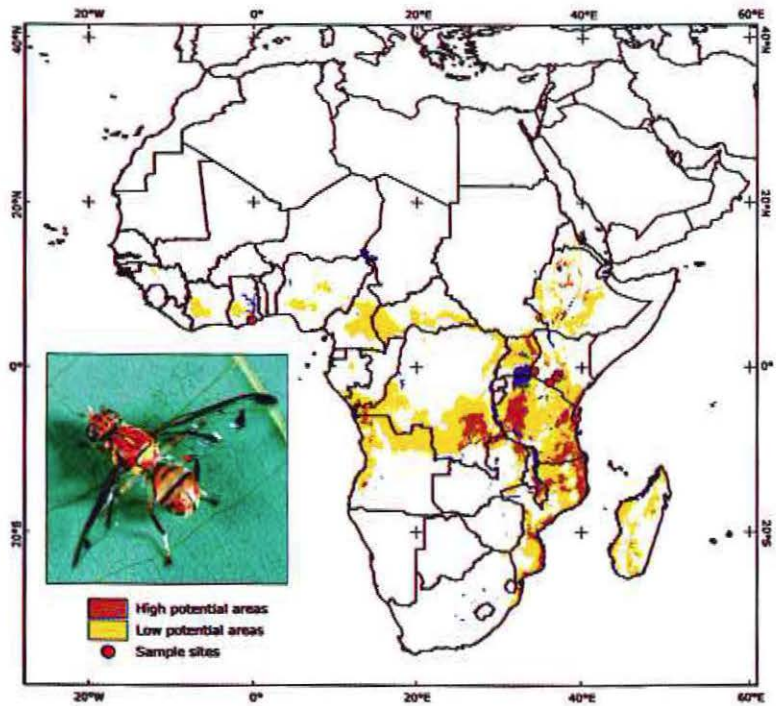


Figure 9. Distribution and potential *Bactrocera cucurbitae* zones in Africa. Inset: Adult *Bactrocera cucurbitae*

***Bactrocera zonata* (Saunders) (Diptera: Tephritidae)**

Common name: Peach fruit fly

Distribution: *Bactrocera zonata* **(Figure 10, inset)** is native to South and Southeast Asia. In Africa it occurs in Egypt and the Indian Ocean island of Mauritius **(Figure 10).** It has also been reported from Israel.

Host plants: Attacks over 20 host plants (White and Elson-Harris, 1992). It is a major pest of mango (*Mangifera indica*) in Egypt and Mauritius **(Annex 1).**

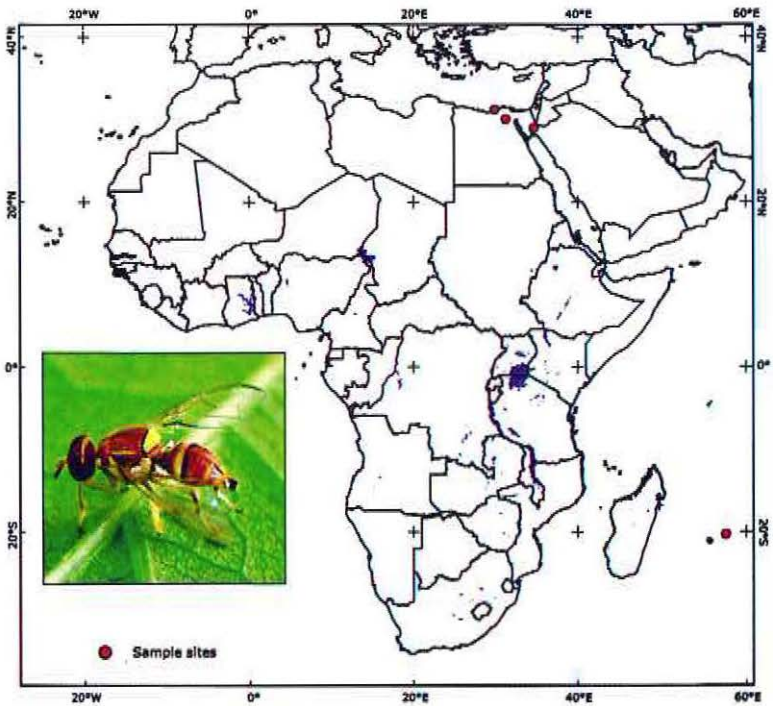


Figure 10. Distribution of *Bactrocera zonata* in Africa.
Inset: Adult *Bactrocera zonata*

Dacus bivittatus (Bigot) (Diptera: Tephritidae)

Common name: Pumpkin fly

Distribution: *Dacus bivittatus* **(Figure 11, inset)** is known from Angola, Cameron, Democratic Republic of Congo, Ghana, Kenya, Malawi, Mozambique, Nigeria, Senegal, Sierra Leone, South Africa, Tanzania, Uganda and Zimbabwe (White and Elson-Harris, 1992) **(Figure 11).**

Host plants: Mainly attacks cucurbits and has been reared from cucumber (*Cucumis sativus*), cantaloupe (*Cucumis melo*), watermelon (*Citrullus lanatus*), white egusi (*Cucumeropsis mannii*), African horned cucumber (*Cucumis metuliferus*), bitter gourd (*Momordica charantia*), chayote (*Sechium edule*), luffa (*Luffa aegyptiaca*), oysternut (*Telfairea pedata*), pumpkin (*Cucubita pepo*) and white flower gourd (*Lagenaris siceraria*). A few other non-cucurbit hosts have also been recorded (White and Elson-Harris, 1992) **(Annex 1).**

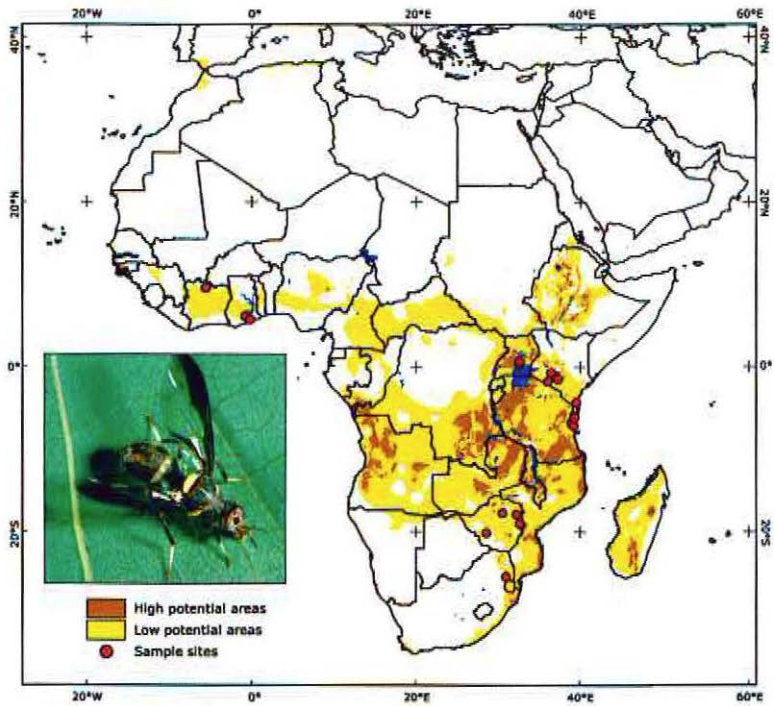


Figure 11. Distribution and potential *Dacus bivittatus* zones in Africa. Inset: Adult *Dacus bivittatus*

Dacus ciliatus Loew (Diptera: Tephritidae)

Common name: Lesser pumpkin fly

Distribution: *Dacus ciliatus* **(Figure 12, inset)** is widely distributed in Africa occurring in Angola, Botswana, Cameroon, Chad, Democratic Republic of Congo, Egypt, Ethiopia, Ghana, Guinea, Kenya, Lesotho, Malawi, Mozambique, Nigeria, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Tanzania, Uganda, Zambia and Zimbabwe (White and Elson-Harris, 1992) **(Figure 12).**

Host plants: A pest of cucurbit crops recorded from nearly 20 commercial host plants (White and Elson Harris, 1992) **(Annex 1).** A few non-curcubits including beans (*Phaseolus* spp.), cotton (*Gossypium* sp.), okra (*Abelmoschus esculentus*) and tomato (*Lycopersicum esculentum*) are also hosts. Several wild Cucurbitaceae are also host to *D. ciliatus* (White and Elson-Harris) **(Annex 1).**

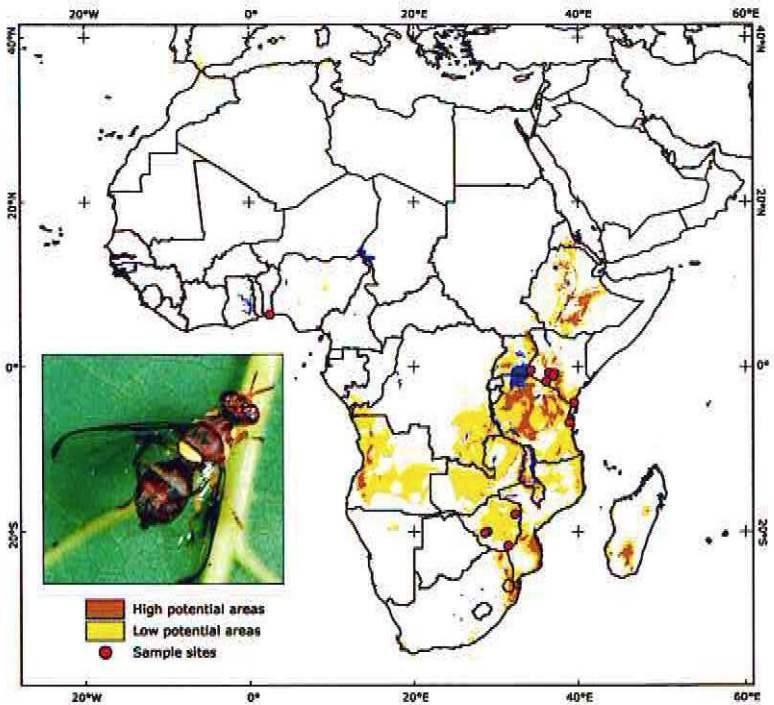


Figure 12. Distribution and potential *Dacus ciliatus* zones in Africa. Inset: Adult *Dacus ciliatus*

Dacus frontalis Becker (Diptera: Tephritidae)

Distribution: *Dacus frontalis* **(Figure 13, inset)** occurs in the Cape Verde Islands, Egypt, Kenya, Lesotho, South Africa, Sudan, Tanzania and Zimbabwe (White and Elson-Harris, 1992) **(Figure 13).** Outside Africa, it occurs in Saudi Arabia and Yemen Arab Republic.

Host plants: It is a pest of cucurbits attacking cucumber (*Cucumis sativus*), pumpkin (*Cucurbita pepo*), sweet melon (*Cucumis melo*) and watermelon (*Citrullus lanatus*). Colocynth (*Citrullus colocynthis*) is an important alternative host. It also attacks a species of gourd (*Coccinia* sp.) and a squash (*Cucurbita* sp.) (White and Elson-Harris, 1992) **(Annex 1).**

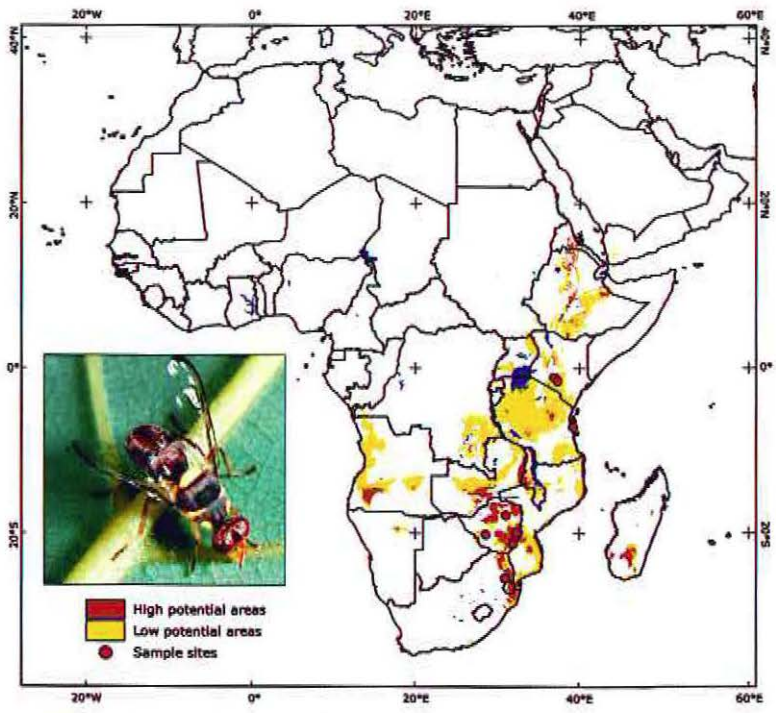


Figure 13. Distribution and potential *Dacus frontalis* zones in Africa.
Inset: Adult *Dacus frontalis*

Dacus lounsburyii Coquillett (Diptera: Tephritidae)

Distribution: *Dacus lounsburyii* **(Figure 14, inset)** is reported from Angola, Kenya, South Africa and Zimbabwe (White and Elson-Harris, 1992) **(Figure 14).**

Host plants: It is a rare species that attacks mainly cucurbits including pumpkin (*Cucurbita pepo*), sweet melon (*Cucumis melo*) and watermelon (*Citrullus lanatus*) (White and Elson-Harris, 1992) **(Annex 1).**

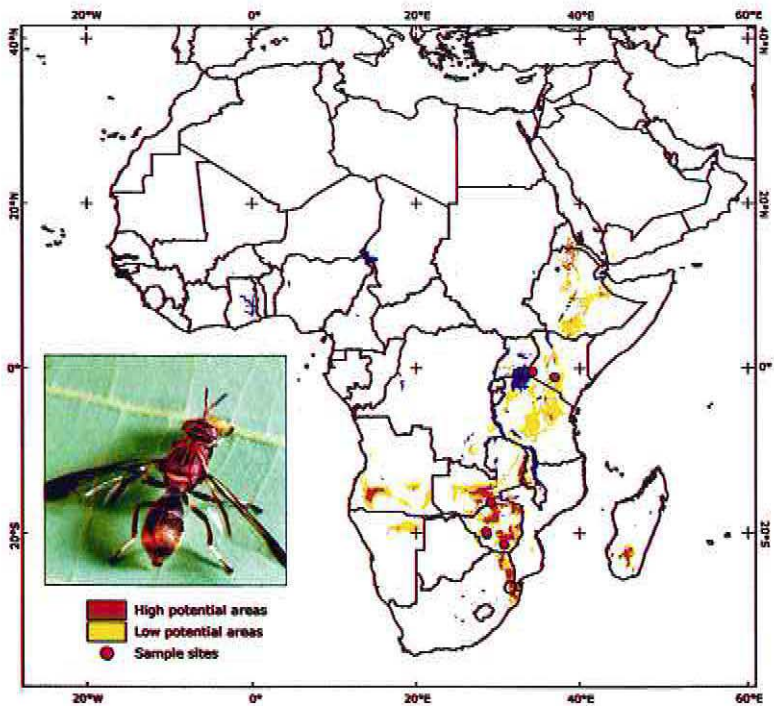


Figure 14. Distribution and potential *Dacus lounsburyii* zones in Africa. Inset: Adult *Dacus lounsburyii*

Dacus punctatifrons Karsch (Diptera: Tephritidae)

Distribution: *Dacus punctatifrons* **(Figure 15, inset)** occurs in Angola, Cameroon, Ghana, Nigeria, Kenya, Sierra Leone, South Africa, Tanzania, Uganda, Zambia and Zimbabwe (White and Elson-Harris, 1992) **(Figure 15).** It also occurs on the Indian Ocean island of Mauritius and in Yemen.

Host plants: It has been reared from pumpkin (*Cucurbita pepo*), cucumber (*Cucumis sativus*), bitter gourd (*Momordica charantia*), chayote (*Sechium edule*) and wild watermelon (*Passiflora foetida*) and a few wild Cucubitaceae (White and Elson-Harris, 1992) **(Annex 1).**

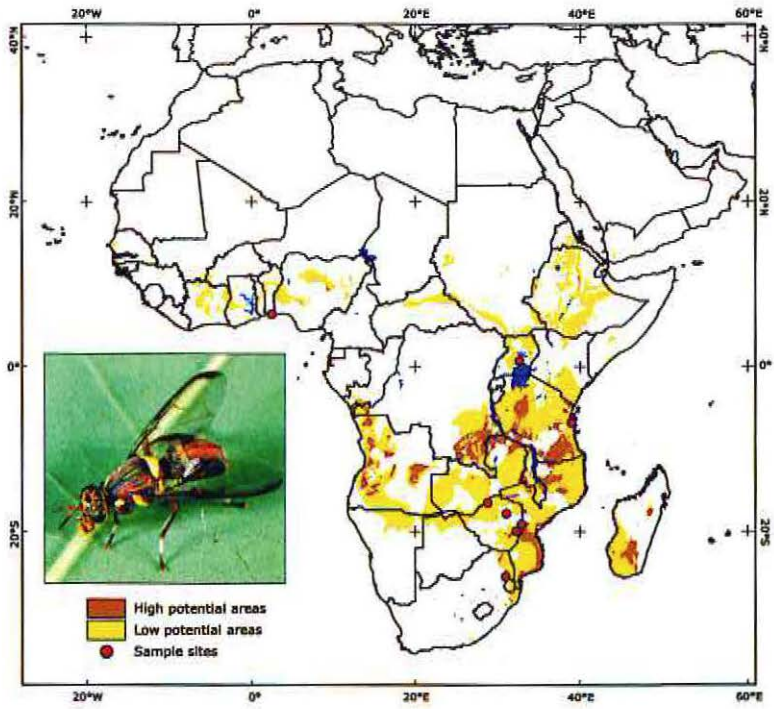


Figure 15. Distribution and potential *Dacus punctatifrons* zones in Africa. Inset: Adult *Dacus punctatifrons*

Dacus vertebratus Bezzi (Diptera: Tephritidae)

Common name: Jointed pumpkin fly

Distribution: This pest **(Figure 16, inset)** is found in Angola, the Gambia, Ghana, Kenya, Nigeria, Senegal, South Africa, Tanzania, Zambia and Zimbabwe (White and Elson-Harris, 1992) **(Figure 16).** It also occurs in the Indian Ocean island of Madagascar, and in Saudi Arabia and Yemen.

Host plants: A pest of cucurbits with strong preference for watermelon (*Citrullus lanatus*). It also attacks cantaloupe (*Cucumis melo*), cucumber (*Cucumis sativus*), squash (*Cucurbita maxima*) and white egusi (*Cucumeropsis mannii*) **(Annex 1).** Several other wild Cucurbitaceae are also attacked (White and Elson-Harris, 1992).

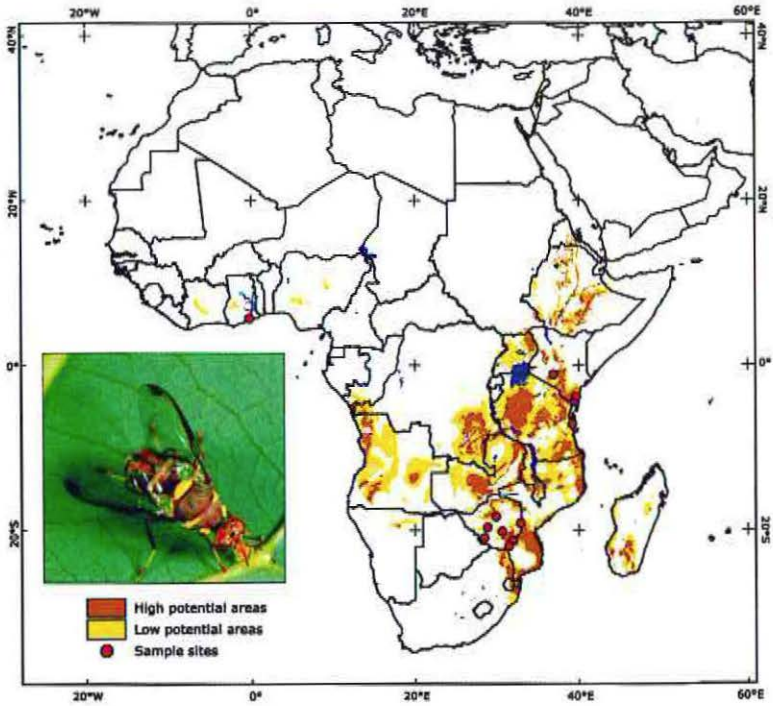


Figure 16. Distribution and potential *Dacus vertebratus* zones in Africa. Inset: Adult *Dacus vertebratus*

Species distribution maps

The distribution maps for all the fruit fly species were generated using geographic information system (GIS) software. Geo-positioned data on species occurrence from our own sampling data and from the literature (indicated on maps as sample sites) were used to characterise the environment where each fruit fly species was found. GIS was then used to interpolate beyond the sampling sites to locate all areas that share similar environments (potential zones). Although White and Elson-Harris (1992) listed different countries for each fruit fly species, countries where specific coordinates of sample sites could not be obtained were not included for predictions. The potential zones (high and low) were generated using the following ecological parameters: precipitation (annual) and temperature (annual, minimum coldest month and maximum warmest month). Due to paucity of geo-positioned data, no predictions were made for *B. zonata*.

CHAPTER 2

Fruit Fly Monitoring—Purpose, Tools and Methodology

Aruna Manrakhan
Department of Conservation Ecology and Entomology, Faculty of Agrisciences, University of Stellenbosch, Matieland, South Africa

Purpose of monitoring

Fruit fly monitoring helps to (i) identify fruit fly pests in an area, (ii) determine distribution of pest species, (iii) identify local hot spots with high populations of the pest, (iv) track changes in population levels, (v) determine efficacy of control measures, and (vi) facilitate early detection of new fruit fly pests in a particular area.

Trapping tools

Tools used in fruit fly monitoring consist of attractants, pesticides, traps and host fruits. (Refer to chapters 3 and 5 for host fruit surveys and processing, and pesticides, respectively.)

Attractants

The two main types of attractants used in fruit fly monitoring include: (1) para-pheromones or male lures and (2) food baits (Cunningham, 1989; Heath *et al.*, 1997; Lux *et al.*, 2003).

Para-pheromones

Para-pheromones attract only male fruit flies. They are highly species-specific and are known to have a high efficacy in attracting flies from long distances (Cunningham, 1989; Economopoulos and Haniotakis, 1994; White and Elson-Harris, 1992). Para-pheromones are available in both liquid form and as polymeric plugs in the form of a controlled-release formulation. Male lures in liquid form last between 2–4 weeks in the field, while polymeric plugs can last for up to 6 weeks. Minimum intervals between traps baited with para-pheromones should be 30–50 m.

Methyl eugenol (ME) **(Plates 2 and 3):** Methyl eugenol attracts male *Bactrocera* species (e.g. *B. invadens*, *B. zonata* and *B. dorsalis*). It also attracts a few *Dacus* species. ME can be chemically described as benzene,

Plate 2. Liquid methyl eugenol

Plate 3. A sachet of methyl eugenol polymeric plug

1,2-dimethoxy-4-(2-propenyl). Methyl eugenol is also a naturally occurring compound reported from 10 different plant families.

Cuelure (CUE) **(Plate 4):** Cuelure attracts males of *Bactrocera* and *Dacus* species (e.g. *B. cucurbitae, D. bivittatus, D. punctatifrons* and *D. frontalis)*. Its chemical description is 4-(*p*-hydroxyphenyl)-2-butanone acetate. CUE does not occur in nature but the most closely related analogue is raspberry ketone, which occurs in plants.

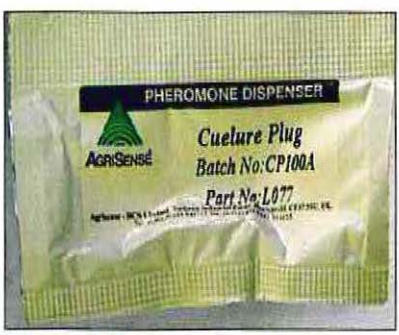


Plate 4. A Cuelure polymeric plug

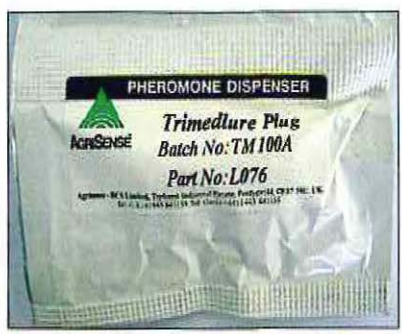


Plate 5. A Trimedlure polymeric plug

Trimedlure (TML) **(Plate 5):** Trimedlure, Ceralure or Capilure attracts males of some *Ceratitis* species (e.g. *C. capitata* and *C. rosa*). Its chemical description is tert-butyl 4 (and 5)-chloro-2-methylcyclohexane-1-carboxylate. It is a synthetic compound and is not found in nature.

Terpinyl acetate: Terpinyl acetate is a natural ester compound. It is moderately attractive to males of many *Ceratitis* species including *C. cosyra, C. rosa* and *C. capitata*. Its chemical description is alpha,alpha,4-trimethyl-3-cyclohexene-1-methanol.

Vertlure: Vertlure attracts only males of *D. vertebratus*. Its chemical description is methyl-4-hydroxybenzoate.

Food baits

Food baits attract both male and female fruit flies. They are not species-specific and are known to have a lower efficiency compared to male lures (White and Elson-Harris, 1992). Food baits can also attract a number of non-target insects, including beneficial ones. They are available in both liquid and dry synthetic forms. Ammonia is the principal attractant emanating from food baits. There are a variety of commercially available food baits. These include liquid protein hydrolysates, yeast products, ammonium salts and the three-component lure (consisting of putrescine, ammonium acetate and trimethylamine) (Mazor *et al.*, 1987; Heath *et al*, 1997; Lux *et al.*, 2003; IAEA, 2003). Field longevity of protein hydrolysates, yeast products and ammonium salts is usually between 1–2 weeks while the three-component lure can last between 4–6 weeks. Minimum distance interval between food-baited traps should range from 10–30 m.

Protein hydrolysates: Some commercially available protein hydrolysates include Nulure (Miller Chemical & Fertilizer Corporation, Hanover, USA) **(Plate 6),** Buminal (Bayer SA, Puteaux, France), Corn Steepwater (Corn Products, Summit Argo, USA), Hym-Lure RTU (Robertsons [PTY] Limited, Durban, South Africa), Pinnacle Protein Fruit Fly Bait (Mauri Yeast Products, Brisbane, Australia) and Solbait (US Department of Agriculture, Weslaco, USA).

Plate 6. Nulure liquid protein hydrolysate

Yeast products: Torula yeast is an autolysed yeast protein and is available commercially as dry pellets. AFFI yeast product **(Plate 7)** is a locally made product by the African Fruit Fly Initiative (AFFI), of the International Centre of Insect Physiology and Ecology, Nairobi, Kenya. Although still under development, it has proved to be effective in field monitoring.

Plate 7. AFFI yeast product

Ammonium salts: Some ammonium salts such as ammonium carbonate or ammonium acetate can be used in fruit fly monitoring.

Biolure—the 3-component lure: Biolure **(Plate 8)** is a commercially available dry attractant and consists of three components: putrescine, ammonium acetate and trimethylamine. These components are available as membrane-based dispensers. The 3-component lure has been found to be a highly attractive female lure for *C. capitata*.

Plate 8. Biolure—the 3-component lure

Traps

Traps used for fruit fly monitoring are dependent upon the nature of the attractant (IAEA, 2003). These include:

Lynfield trap: The Lynfield trap **(Plate 9)** is a simple 'bucket' type of trap that is composed of a cylindrical plastic container with four equidistant holes at the upper third, a lid and a wire hanger with bait basket. The Lynfield trap can be locally made. Lynfield traps can be used either with para-pheromones or with food baits such as protein hydrolysates, yeast and

ammonium salts. The para-pheromone is usually placed in the bait basket, which is suspended at the top of the trap. When a polymeric plug dispenser is used, an insecticidal strip is placed at the bottom of the trap to kill any attracted flies. When used with liquid food bait, the baits are poured into the bottom of the trap.

Plate 9. Locally made Lynfield trap

Jackson trap: The Jackson trap **(Plate 10)** is a delta-shaped trap made of waxed cardboard material. The trap is mainly used with para-pheromone lures to capture male fruit flies. The lure is suspended at the top of the trap, usually in a bait basket. A sticky insert is placed at the bottom of the trap, which captures flies once they land on the surface.

Plate 10. The Jackson trap

Steiner trap: The Steiner trap **(Plate 11)** is a horizontal, clear cylinder with a large opening at each end. This trap uses the male-specific para-pheromone lures. The lure is suspended in the middle of the trap. An insecticide placed on the floor of the trap has to be used to prevent flies escaping and predation of captured flies. A wire hanger is placed on top of the trap body and is used to hang the trap from the tree branches.

Plate 11. The Steiner trap

McPhail trap: The McPhail trap **(Plate 12)** is a two-piece transparent plastic pear-shaped invaginated container. The upper part of the trap and the base can be separated allowing the trap to be serviced and re-baited. This trap can be used with liquid food bait. The liquid food bait is poured at the bottom of the trap. An entrance hole at the bottom of the trap allows access of flies into the trap. The upper part of the trap is transparent and contrasts with the yellow base, which enhances the trap's ability to attract fruit flies.

Plate 12. The McPhail trap

Tephri trap: The Tephri trap **(Plate 13)** is a modified McPhail trap with a yellow base and a clear top, which can be separated to facilitate servicing. The trap has entrance holes around the top of the periphery of the yellow base and an invaginated opening in the bottom. Inside the clear top is a platform, which houses the attractants. The trap can be used with liquid protein bait, the 3-component lure as well as para-pheromones. If used as a wet trap and with the side holes blocked, no insecticide is required since the liquid (protein bait or water) serves as the retention system. The liquid is usually poured at the base of the trap. If used as a dry trap and with the

side holes, an insecticide must be used to kill attracted flies. The attractant is placed on the platform at the top of the trap and the insecticide at the bottom of the trap.

Plate 13. The Tephri trap

Multilure trap: The Multilure trap **(Plate 14)** is a newer version of the McPhail trap. It consists of a two-piece plastic cylinder-shaped invaginated container. The upper and base of the trap can be separated allowing the trap to be serviced and baited. The transparent upper part contrasts with the yellow base, which enhances the trap's ability to attract fruit flies. The trap can be used with the liquid protein bait and Biolure, as well as with para-pheromones (as polymeric plugs). The liquid protein bait is placed at the bottom of the trap. When used with Biolure, membrane dispensers of the three components (putrescine, trimethylamine and ammonium acetate) are stuck to the wall of the upper part of the trap with water and Triton®-X 100 serving as the retention medium. When used with para-pheromones, the lure can be suspended in the bait basket incorporated at the top of the trap. If used as a dry trap, with either Biolure or male lure polymeric plug, a killing strip such as DDVP (2,2-dichlorovinyl dimethyl phosphate) is placed at the bottom of the trap.

Plate 14. The Multilure trap

Trapping survey objectives and applications

There are three types of trapping surveys with the following different objectives:

1. **Detection surveys** determine if species are present in an area.
2. **Delimiting surveys** determine the boundaries of an area considered to be infested or free from pests, and
3. **Monitoring surveys** are ongoing surveys to verify the characteristics of a pest (IAEA, 2003).

According to IAEA (2003), trapping surveys are applied:

1. In infested areas to determine presence of fruit fly pest species and monitor established populations.
2. In treated areas (e.g. after suppression with bait sprays or in areas treated with entomopathogens) to measure efficacy of control.
3. To determine the presence of species which are under exclusion measures.

Detection surveys

Since majority of fruit flies are quarantine pests, detection surveys are important and must be carried out routinely to prevent entry and establishment of unwanted fruit flies. In these surveys, both para-pheromone- and food-based traps are recommended. The para-pheromones used in detection programmes include: (1) methyl eugenol (ME) which attracts *B. invadens*, *B. zonata* and other *Bactrocera* species of quarantine importance and (2) Cuelure, which attracts other *Bactrocera* spp. of quarantine importance not attracted to ME.

It is essential to also use food-baited traps in detection surveys since they attract a broad range of fruit flies and may capture other fruit flies that do not respond to the other two para-pheromones described above. Lynfield or McPhail traps baited with liquid protein bait (e.g. Nulure) and multilure traps baited with synthetic food bait (e.g. Biolure), should also be included in detection programmes.

Delimiting surveys

Delimiting surveys are usually carried out over a large area and are particularly sensitive surveys requiring efficient traps and attractants. Para-pheromone-based traps are therefore recommended. Prior information on the type of male lure that attracts the target insect to be surveyed is important. Once this is known, Lynfield traps baited with appropriate para-pheromones are recommended. Lynfield traps can be made locally and are easy to handle and service.

Monitoring surveys

Monitoring surveys in infested areas under no control measures are carried out to determine species presence and monitor established fruit fly populations. Fluctuations in population of fruit fly species can be determined over time. This will help determine appropriate time for control actions in a specific area. For this type of survey, both food-based and para-pheromone-based traps are recommended. The food-based trap will help determine the species complex of the area and the para-pheromone-based trap will help determine population fluctuations of the target species. The type of trap recommended for both liquid protein bait and para-pheromones is the Lynfield trap.

Monitoring surveys carried out in suppression areas aim to determine efficiency of control measures in reducing fruit fly populations within these areas. Lynfield or McPhail type traps baited with food baits are recommended for this type of survey since they attract both sexes and allow the male and female population fluctuations of the fruit fly complex to be depicted over time.

Trapping network

The trapping network adopted in a particular survey depends on the characteristics of an area (IAEA, 2003). In areas of continuous blocks of commercial orchards, the traps are arranged in a grid system. In areas where orchards have a scattered distribution interspersed with settlements and backyard host trees or in marginal areas with wild and commercial hosts, traps are arranged in a system that follows a road network to allow access to the host areas (IAEA, 2003). For early detection, there is no defined layout, except that it has to be at points of entry (e.g. airports) and points of fruit trade (e.g. local markets).

Placement of traps

Public relations

Trappers are frequently in contact with the public and should therefore adopt the following practices:

1. Good public relations, appearance and conduct.
2. Make proper contacts with the homeowner or fruit grower and ask for permission to place the traps. Provide adequate explanations before trap placement.
3. Be considerate of the inhabitants of an area and their property.
4. Display courteous driving habits and gestures.

Trapping site

Before placing traps, label all components of the trap (i.e. base, lid) with the institution name, code with trap ID number and permanently mark as being used for a particular attractant (ME/CUE/TML/Nulure/PTA).

The selection of a proper trapping site is critical in any trapping survey. It is important to develop a list of fruit fly host trees for the fruit fly species that needs to be monitored and be familiar with these host trees. Host trees can be either commercial or wild fruit trees. Traps must be placed on host trees or close to host trees. Whenever possible, a fruiting host tree should be chosen for setting traps. If there are no fruiting host trees, traps should be placed on host trees, which contain a food source for the flies such as honeydew. Honeydew is an excretion produced by insects such as aphids, scales, mealybugs and whiteflies. Sooty mould usually grows on leaves covered by honeydew and the leaves eventually turn black. The presence of sooty mould is an indication that the tree contains honeydew. In areas with no hosts, traps should be placed on trees that can offer shelter, protection and food to adult fruit flies.

The trap should be placed about 2–4 m above the ground within the canopy layer, in a semi-shaded spot, preferably in the upwind part of the canopy. Where appropriate, a hook should be used to facilitate placement of traps. The trap should be hung in such a manner that branches and leaves are nearby, but not touching the trap (to provide resting places for arriving flies, but not entry points for ants).

When using dry traps such as Lynfield traps baited with para-pheromones, coat the wire hanging with a thin layer of 'stickem' (Tanglefoot®). This will prevent entry of ants, which would feed on captured specimens. The Tanglefoot should not be applied on the hook of the trap, as this would not allow for cleaning and servicing of traps.

Use ribbons (or paint spray) to mark the position of each trap, in such a manner, that the ribbon can be seen easily from the main access road.
A sketch of the survey route and trap position should be plotted. The references of the trap location should include visible landmarks. In case traps are placed in settlement areas, references should include the full address of the property. The application of geographic positioning systems (GPS) can be a very effective tool in both trap location as well as analysis of trap captures. Geographical coordinates of each trap should therefore be referenced, if a GPS device is available.

In a datasheet **(Annex 2),** the trap ID number, location (area), trap station (e.g. farm or forest name or house property), habitat type (e.g. mango orchard, forest or settlement), trap type, trap lure, date of placement, date of collection and GPS coordinates should be noted as well as details on the fruit fly and non-target species caught.

Trapping density

It is very important to consider the trapping density in a survey. Density will depend first of all on the objective of the trapping survey. Density will also depend on lure/attractant efficiency, trap efficiency, altitude, location (orchards or settlement or marginal areas or points of entry), and the presence of hosts, the climate, topography and fruit fly species (IAEA, 2003).

Points of entry: Early detection should be carried out at points of entry, as mentioned above. Usually these points of entry include airports, seaports, border points and marketplaces for fruit trade. For para-pheromone- or food-based traps, trap density at points of entry should be between 4–10 traps/ km^2.

Delimiting surveys: Para-pheromone-based traps should be placed at every 20–30 km along transects that use main road networks.

Monitoring surveys: Trap density should be higher in production areas compared to marginal areas. Trap density in marginal areas should also be higher compared to settlement areas. For food-based traps, the following trap densities are recommended in the different locations listed above:

Production areas — 4 to 8 traps/km^2
Marginal areas — 2 to 4 traps/ km^2
Settlement — 0.5 to 1 trap/ km^2.

Preparation and handling of traps and attractants

Preparation

Before setting out for trapping surveys, it is recommended to prepare attractants (dilution and mixtures with insecticide) in the lab. Use glass-measuring cylinders to carry out dilutions or mixtures. It is important to determine beforehand **the type and amount of attractant, and number of traps required.** Carry the required amount of attractant and traps that would be needed. It is advisable to carry a few spare traps in case of accidental damage or non-functionality of traps.

Liquid protein food bait: For trapping using liquid food bait, a 2% protein bait solution (dilution with water) is recommended. Each Lynfield trap should contain 250 ml of the diluted solution. Eight grams of borax should be added to each trap to slow down decomposition of trapped specimens.

Dry synthetic food bait: When Multilure traps baited with dry synthetic food bait (putrescine, trimethylamine and ammonium acetate) are used as wet traps, each trap should contain 270 ml of water to which 1–2 drops of Triton®-X 100 (0.1%) or propylene glycol (10%) are added to break the surface water tension. When Multilure traps are baited with dry synthetic food baits and used as dry traps, a DDVP strip (1 to 1.5 cm in length) should be placed at the bottom of each trap to kill attracted flies. The dry food lures are available as sachets containing the membrane dispensers and can be carried as such to the field. The DDVP can be cut in strips of 1–1.5 cm in length and carried to the field in a tight jar.

Male lures: Liquid male lures such as methyl eugenol can be combined with an insecticide such as malathion in the ratio 4:1 (4 parts male lure to 1 part insecticide). Cotton wicks soaked in the lure and insecticide mixture till saturation (but not dripping) can be used as dispensers. The soaked cotton wicks can be stored in an airtight jar and transported to the field.

Para-pheromone polymeric plugs that are available in sachets can be taken to the field in that form. DDVP strips (each 1 to 1.5 cm length) should be prepared and placed in a tight jar for placement at the bottom of the trap. Each trap should contain one DDVP strip. Pack traps and attractants separately to avoid any spillage and trap contamination during transport.

Handling

Liquid food bait should be poured carefully inside the trap without any spillage on the external surface of the trap body. Make sure that no liquid bait contacts the surface between the top and bottom parts of McPhail traps since this would not allow for easy opening of traps. For membrane dispensers of dry synthetic baits, place them on the sides at the top part of the Multilure trap in such a way as not to obstruct the closing of the trap.

When using male lure/insecticide mixture soaked on cotton wick, pick the cotton wick using a pair of forceps and place in the bait basket. Avoid touching the external surface of the trap. Use different forceps for different lures and store them separately.

When using para-pheromones in polymeric plugs, gently tear open the sachet and push the plug into the bait basket without directly touching the plug with your fingers or touching the outside of the trap with the plug. Using gloves, place a new DDVP strip at the bottom of the trap. The DDVP strips should be prepared in the laboratory in advance and placed in separate airtight jars for easy handling.

Trap servicing and re-baiting

Servicing

Servicing interval depends on the objectives of the trapping survey and the type and formulation of attractant that is being used. During servicing of traps, record the date of collection in the datasheet and if no flies are caught, record nil captures for the particular trap in question.

Baited traps should be opened with care in case there are live flies inside the trap. Note that for detection and delimiting surveys, this is important as presence or absence of flies in particular areas should be confirmed. In the case of a trap that uses a liquid retention system, the live flies can be carefully removed by aspiration. In case of a dry trap that uses an insecticide as retention system, the entry holes of the trap can be blocked. Ensure that you wear gloves if you use hands to block the holes. This will concentrate the insecticide vapour inside the trap and facilitate fast kill of the flies inside.

Re-baiting

Food baits: Traps containing liquid baits (protein baits or water in synthetic food bait traps) in hot and dry climates should be re-baited twice per week, while those in hot and humid or cool climates should be re-baited once per week. The liquid should be poured in a container through a sieve to recover the trapped specimens. The specimens can be collected using a fine brush or a pair of soft forceps.

For the dry synthetic food baits, the membrane dispensers remain active for 4–6 weeks. If servicing is done within this period, the dispensers can be left inside the trap. After 4–6 weeks, the membrane dispensers should be replaced. Following re-baiting, traps should be closed and left for a similar interval at the same spot or they can be rotated within a production area depending on the trapping survey objectives.

Male lures: Specimens in a trap containing male lure can be collected using a fine brush or a pair of soft forceps. Make sure to use a different brush or forceps for each type of lure used in the survey and label the brush or forceps accordingly (e.g. ME, TML, CUE). Usually a cotton wick baited with attractant and insecticide mixture can last for up to 4 weeks in the field. If serviced within this period, the cotton wick can remain in the trap after specimen collection.

When polymeric plug dispensers and killing strips are used, it should also be noted that both remain active for a period of 6 weeks. If a trap baited with this type of dispenser is serviced within this period, both the

dispenser and the killing strip can remain in the trap if they are still active. After 6 weeks, the dispenser and killing strips should be carefully removed with different pairs of forceps. Gently tear open a new sachet of dispenser and push the plug (of the same lure) into the bait basket without touching the plug with your fingers or touching the outside of the trap with the plug. Using gloves, place a new DDVP strip at the bottom of the trap. Remove the gloves and close the trap.

How to report the trapping results

The outcome of trapping activity should be reported as flies per trap per day. This is a population index representing the average number of flies captured in one trap in one day that the trap is exposed to in the field (IAEA, 2003). The function of this population index is to have a relative measure of the size of the adult population in a given space and time. It can be used to compare fly populations between regions, determine population fluctuations in time and determine differences in size of adult population between different areas (e.g. untreated areas vs suppression areas).

It is calculated as follows: $F = F/T \times D$

Where F = Total number of flies
T = Number of serviced traps
D = Average number of days traps were exposed in the field.

CHAPTER 3

Fruit Fly Suppression—Purpose, Tools and Methodology

Sunday Ekesi[1] and Slawomir A. Lux[2]
[1]International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya
[2]05-510 Konstancin-Jeziorna, Ujejskiego 7, Poland

Purpose

The purpose of fruit fly suppression is to reduce loss in fruit and vegetable yield due to fruit fly infestation and enhance their quality by eliminating fruit fly maggots and blemishes caused by the insects.

Tools

The materials and tools required for fruit fly suppression include:

(a) Baits and traps
(b) Killing agents (which can be pesticides or microbial insecticides)
(c) Sprayers.

Suppression methods

There are several methods of fruit fly suppression including application of bait sprays, male annihilation technique, sterile insect technique, orchard sanitation and use of biological control agents such as parasitoids and pathogens. There are also a number of remedy methods, which although they do not directly suppress fruit fly populations, they prevent or reduce the damage caused by them. Such methods are fruit bagging or wrapping, early harvesting and post-harvest fruit treatment.

Because a complex of fruit fly species commonly co-exist in the fragmented production systems in Africa, the approach that is being promoted in Africa is a combination of methods, i.e. integrated pest management (IPM) technique.

Recommended primary IPM components

Baiting technique

Fruit fly suppression is mainly based on use of food baits (hydrolysed proteins or their ammonium mimics) combined with a killing agent such as pesticide and applied in localised spots. This method targets adult flies,

mainly females, and aims at attracting (and killing) them before they infest fruits (lay eggs into the fruits). The bait attracts the fruit flies from a distance to the spot of application, where the flies feed on the bait, ingest the pesticide and die. After mixing the bait with a pesticide, it is normally applied to a 1 square metre spot on the canopy of each tree in the orchard. This is applied on a weekly basis starting from when the fruits are about 1.3 cm (1/2") in size and continues until the very end of the harvest.

A number of commercial baits are available on the market such as Nulure, Buminal and SolBait that can be mixed with pesticides such as spinosad and applied as above. Another commercial product is GF-120 (Success®). This bait is already pre-mixed with pesticide (Spinosad®) and can be applied using the on-label information on the container.

A major problem in the use of baits in Africa is that they have to be imported, thus making them expensive and inaccessible to a large number of fruit and vegetable growers. Research at the International Centre of Insect Physiology and Ecology (ICIPE) has shown that a protein bait from brewer's yeast (obtained as an industrial by-product), when applied in low volumes as spot spray to 1 square metre of mango canopy or to the mango trunk, provided good control of mango-infesting fruit flies. Research is, however, continuing at formulating the bait to enhance its attractiveness to fruit flies and such bait, once fully developed, should be available in the near future as a cost-effective alternative to the imported products.

Preparation of the bait spray

The bait spray can be applied with a 15-litre knapsack sprayer or any other spraying device with a coarse adjustable nozzle. Label the sprayer with a permanent marker indicating its specific use. Measure the amount of bait required for the day's treatment (based on site parameters). Inspect the sprayer for operation prior to filling by adding water, applying pressure and spraying. Pour the mixture through the knapsack sprayer filtering system. Do not fill beyond the working specifications of the sprayer.

Calibration of the pump for bait spraying

The sprayer is pressurised and the nozzle is adjusted for coarse droplets. Spray 50 ml of bait into a small graduated container by pressing the trigger (approximately 12 times) until the required amount of bait is dispensed. Alternatively, one can press the trigger continuously to deliver 50 ml of the bait. Note the duration in seconds. Both measures may vary according to pressure, nozzle settings of the sprayer and the person pressing the trigger. Note that the same person spraying has to do the calibration. The calibration should be repeated several times to ensure correct dosage delivery.

Bait application

Approximately, one square metre of foliage is sprayed with the bait in such a way that the bait drift does not hit the fruits on the tree. Depending on tree architecture some branches may be very low. Spray downwind to avoid bait drifting towards you. Every tree is sprayed unless agreed otherwise. If other tree species grow in the same treatment plot, apply the bait to their foliage as well to keep a dense application grid. Weekly application on each tree is placed on a different spot on the foliage to avoid accumulation of bait and to eventually increase the treated surface over time.

If a considerable amount of rains occur (> 25 mm) within 24/48 hours after spray application, the procedure has to be repeated to replace bait that could have been washed off. In the event of equipment failure (i.e. nozzle-clogging), stop immediately, rectify the problem and reapply the full dosage to the same tree.

Soil inoculation with fungal pathogen

During development, mature fruit fly maggots drop from the fruits to the ground, burrow into the soil and form a resting stage called the puparia (White and Elson-Harris, 1992). An important part of fruit fly suppression research at ICIPE includes soil treatment with fungal pathogens to kill the mature maggots and puparia. The active ingredient is the fungus *Metarhizium anisopliae*, a naturally-occurring fungus isolated from the soil that is being used worldwide as a biological pesticide for controlling different kinds of insect pests. The fungus is formulated as granules and can be dispersed by hand and then raked into the soil. It can persist in the soil for over a year. Removal of excessive leaf litter before application enhances activity of the fungus. The fungal granules are compatible with most commonly available pesticides but should not be mixed directly with insecticides, fungicides and fertilisers meant for soil application, as they may delay activity of the fungus. This is a new method of fruit fly control, targeting the immature stages of fruit flies (maggots and puparia), which is currently under development at ICIPE, and which is expected to be environment friendly and used as a supportive measure to the bait sprays. Additional research on formulation of the fungus is ongoing and the product should be available in the near future.

Post-harvest fruit treatment

Without post-harvest treatment to provide quarantine security, export of fruits and vegetables to lucrative markets abroad is limited due to quarantine restrictions. Therefore, effective post-harvest quarantine treatments that are

not harmful to either the produce or people coming in contact with or consuming the fruit must be applied to the export commodities. The available quarantine treatment technologies (as alternatives to toxic fumigation) include (1) heat treatment to increase temperature of host fruit above thermal limits of the fruit fly (2) cold treatment to decrease temperature of host fruit below the thermal limit of the fruit fly and (3) irradiation to kill the fruit fly. In Africa, the parameters for treating fruits against fruit flies have not yet been established but once developed, these treatments should increase the export potential of tropical fruits and vegetables from Africa.

Recommended secondary IPM components

Orchard sanitation

Poorly managed or abandoned orchards and a variety of wild hosts can result in high population build up of fruit flies. Orchard sanitation, which entails the collection and destruction of all infested fruits found on the tree and fallen fruits containing fruit fly maggots on the ground, can contribute significantly to reduction of fruit fly populations in the orchard. This is a laborious exercise but can be quite effective if the fruits are collected regularly and destroyed twice a week for the entire season. The collected fruits should be destroyed by either burning, burying or tying them in black plastic bags **(Plate 15)** and exposing them to the heat of the sun for a few days until the fruits are rotten and all the maggots in the bags are dead. When practising fruit burying, ensure that the fruits are buried at least 50 cm (about two feet) deep to prevent the emerging adult flies from reaching the soil surface.

Mechanical fruit protection

Notwithstanding the presence of fruit flies in the orchard, wrapping or bagging of individual fruits with newspaper or paper bags **(Plate 16)** to prevent adult fruit flies from laying eggs on the fruits is also a practice of producing fruits that are free from fruit flies attack. To be effective, the fruits must be wrapped or bagged well before fruit fly attack, i.e. at least one month before harvest. Although laborious, it is an effective method for high value fruit produced for export or fruits produced in backyard gardens for family use.

Early harvesting

Fruit fly development does not occur in certain fruits such as papaya, banana and sapodilla when they are 100% green. Only the ripe fruits are good hosts.

Thus early harvesting to evade fruit fly infestation is an important technique in the production of these fruits. Although early harvest is practised for mango, especially in Kenya, this practice is not effective as some fruit fly species like *Bactrocera invadens* and *Ceratitis cosyra* are capable of infesting even immature or mature green mangoes.

Biological control

Although successes have been generally limited, the use of natural enemies (parasitoids and predators) for the suppression of fruit flies has always had a wide appeal because it is relatively safe, permanent and economical. Several species of parasitoids and predators abound in fruits and vegetable agroecosystems, which can contribute to the suppression of fruit flies. Efforts to conserve these natural enemies through efficient management based on the primary and secondary components of fruit fly management described above may contribute to the overall suppression of fruit flies. The search for and research on biological control of fruit flies especially the invasive species in Africa should also remain an integral part of the fruit fly suppression campaign: But natural enemies cannot be relied upon as sole control agents and biological control methods must be complemented with the other management options.

Plate 15. Destruction of fallen fruits infested by fruit flies by putting them in black plastic bags, tying the bags and exposing them to the sun

Plate 16. Mango fruit bagging in an orchard in Kenya to prevent infestation by fruit flies

CHAPTER 4

Safety Precautions and Conducts During Monitoring and Suppression

Sunday Ekesi
International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya

Safety and cross-contamination precautions during monitoring

- Before starting your trap servicing, prepare a container for disposing materials.
- Wear fresh disposable gloves (or cover hands with new plastic bags) while handling lures/bait.
- Avoid dropping lures/bait on the ground. In case this happens, and if feasible, remove the contaminated material and dispose of properly.
- All contaminated material (e.g., gloves, tissue, empty lure bags) should be collected in an airtight container and taken to the laboratory for safe disposal.
- Baited traps must be handled with extreme care to avoid external contamination.
- During transport, baits must be stored in tight containers and separated one from the other.
- Carry only the necessary quantity of lures/bait to the field.

Safety and cross-contamination precautions during suppression

- Strictly transport baits separately (i.e., use different tightly closed containers per bait).
- Carry only the necessary quantity of baits and fungus to the field.
- Avoid accidental spillage into the transport vehicle. In the event of contamination, use soap and water to clean the spill thoroughly. Use gloves and dispose of as indicated below.
- Wear fresh disposable gloves (or cover hands with new plastic bags) while handling each bait or fungus.
- Do not spill bait on the ground. In case of spillage, if feasible, remove the contaminated material and dispose of properly (similar to other materials, e.g. bait). If cleaning is not possible, the site must be changed.

- Gather all contaminated materials (e.g. gloves, tissue, empty bait containers), double-pack and dispose of safely (e.g. by incineration, burial).
- After application, wash hands, arms and face thoroughly with soap and water before eating, drinking or smoking.
- Always carry water and soap with you in the event of contamination. Flush eyes if spray gets into them. If bait is ingested drink large quantities of water. In either case seek medical attention immediately.
- Avoid inhaling fungal dust.
- Wear proper safety equipment when applying insecticides (i.e. gloves, boots and eye protection).
- If protective clothing is not provided, carry along a second set of clothing in the event of contamination.
- If contamination occurs, immediately remove the affected clothing and bath yourself if necessary.
- Clothes should be disposed of if soaked with bait spray.
- Wash treatment clothes separately from other clothing.
- Do not eat, drink or smoke while mixing or applying the baits/fungus, or before you have washed yourself.
- Baited traps must be handled with extreme care to avoid spillage.
- Re-bait only one trap at a time.
- Before mixing, read the product label and follow the recommendations carefully.
- Check all spray equipment to ensure that it is in good condition. Especially check for blocked pipes and nozzles.
- Wear impermeable gloves, glasses, mask and boots (underneath your trousers).
- Always ensure that your mixtures are prepared outdoors, preferably near a tap of running water.
- Do not prepare more than the quantity needed for the exercise at hand.
- Do not store unused mixture for more than 24 h.
- Do not spray for more than 3 to 4 h per day.
- Do not spray in strong winds or high temperatures.
- Do not treat near source of water (wells, dams, river, etc.)
- Do not blow into blocked tubes with the mouth.
- Wash off any splashes on your skin immediately.
- After treatment wash all equipment used away from water sources.
- Wash off the interior and exterior of empty containers and make them unusable for domestic purposes by perforating or crushing them.
- On completion, wash yourself carefully with soap and water or take a proper shower, change clothes and wash the dirty clothes.

Lure/bait disposal

- Methyl eugenol lures should be double-packed and incinerated or handed over to a disposal service.
- Under no circumstances should lures be left in the vicinity of the monitoring site, laboratory or in the vehicle.

Storage of bait, fungus and pesticides

- Store products, equipment and tools in a securely locked cupboard away from habitations and especially children.
- Ensure that fire extinguishers are kept close to storage rooms.
- Store all baits separately in tightly closed containers in well-ventilated or air-conditioned rooms or in a refrigerator, if possible.
- Store fungal granules in original bags in a dry area, within a temperature range of 5–10°C.
- Check your products regularly to ensure that they are not leaking.
- Place some absorbent materials near the store in case of accidental leaks and spills.

CHAPTER 5

Host Fruit Processing—Purpose, Tools and Methodology

Robert S. Copeland
International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya

Background

The following recommendations evolved out of a four-year study of the insects reared from wild fruits of Kenya. The material we used and the methods we followed served us well during our study. However, there are many ways to tackle a problem and we have no doubt that alternative approaches may be as useful as, or superior to, ours.

Purpose of the collection

There are many reasons for collecting fruits. The more obvious ones are to:

1. Produce a reference collection of tephritids (and other insects) to provide specimens of species that are, or may become, pests of commercial fruits currently grown, or being considered for cultivation, in a particular region.
2. Determine the geographical distribution of tephritid species and their hosts.
3. Identify indigenous reservoir hosts of known pest tephritid species.
4. Explore for parasitoids of pest tephritids.
5. Monitor infestation of cultivated fruits.

What to carry with you

The tools that you carry will largely determine the success of your fieldwork. The following items made collecting simple and quick.

1. Hand-held pruner (secateurs).
2. Long-arm pruner with extension poles **(Plate 17).** Pruner heads can sometimes be found in the larger local hardware shops, but they may have to be purchased from abroad (c. USD 50–75). The head is armed with two opposed cutting blades, controlled by a pulling rope. The pruner head has a circular metal fitting that fits over a pole. Normally, you will supply the poles. The pruner head should be permanently fixed with screws to a wooden pole. Wooden broom handles are available locally (and cheaply), and make good poles. Extension poles (for reaching fruits high off the ground) are also

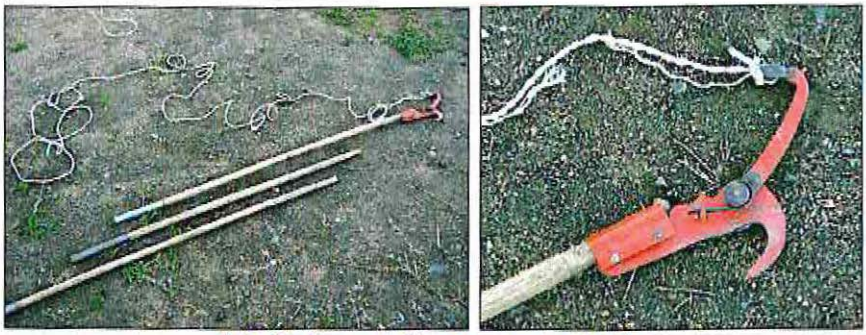


Plate 17. Pruner (left) and pruner head (right)

made from broom handles. Fix a short steel cylinder to one end, so that each extension pole has a wooden end and an end with a steel cylinder into which the wooden end of the next extension pole fits. In this fashion, when out in the field, the length of the long-arm pruner can be extended to an appropriate height. We have found that up to four (c. 2 m) extensions can be used in the field without becoming too unwieldy. Make extra poles because you will misplace some.

3. Polythene bags for carrying and transporting fruits.
4. Plastic containers. We used rectangular 2-litre white plastic 'ice cream' containers. In Kenya, these are inexpensive and available in the larger general stores. In those cases where you sample extremely large fruits (e.g. jack fruit, *Artocarpus heterophyllus*) you will need to place them in other containers, such as buckets or cardboard boxes.
5. Container covers (these are normally included with the containers at no extra cost), the tops of which have been partially cut away and replaced with fine-mesh fabric or screening. Be sure the mesh gauge is small enough to retain the smaller parasitoids. Prepare the tops in advance. After cutting away a portion of the plastic top (8 x 12 cm or slightly larger is fine), score the *underside* with a dull kitchen knife, making crosshatched lines around the perimeter of the hole, within about 1 cm of it. This provides a surface to which you can glue the mesh fabric. After gluing the mesh to the *underside* of the covers, leave them to air dry for a few days.
6. One or more plant presses.
7. Plant identification manuals and books. In Kenya, Beentje's (1994) *Kenya Trees, Shrubs and Lianas* and Agnew and Agnew's (1994) *Upland Kenya Wildflowers* are essential. Blundell's (1994) *Wildflowers of East Africa* is also useful. Elsewhere, regional guides are available for many regions and some of these are excellent, as are the more comprehensive flora guides (e.g. *Flora of Tropical East Africa*, etc.)

with separate numbers published for each family. A note about local names of fruits: These are often available and can be useful as a first step in the identification process. However, do not assume that local people know more about plants than you do. Sometimes they do, and sometimes they do not.

8. Bread boxes for carrying items 1, 3, 4, 5 and 7 above.
9. An inexpensive digital camera (3+ megapixels) with macro capabilities (when travelling, keep it on a soft seat or cushion) for making photographic vouchers of collections in the field.
10. GPS receiver.
11. Old foam mattresses to cushion fruits in transit.
12. Extra rope.
13. Machete/cutlass.
14. Old towels or cloths to moisten for covering fruit containers, particularly when working in hot arid areas.
15. Plenty of water for drinking, for the vehicle, and for item 14 above.
16. Blank paper or notebook (Notebooks with waterproof paper are best but are not sold locally), pencils, pens and one small ruler.

Methodology

Field sites

Choosing sites

A field site can be anything from an undisturbed primary forest, to a small orchard of fruit trees in mixed subsistence farmland, to a tree-lined street running alongside an ocean port facility. Depending on the research interests, one person's dream site is another person's waste of time. Obviously, you will not be spending much time in pristine high altitude forest if you are interested in monitoring potential pest-tephritid breeding in fruit trees near a port from which mango growers ship their crop. But you may be very interested in such a site if your task is to document the availability of animal protein (in the form of tephritid and other insect larvae) in the diet of a threatened frugivorous hornbill.

Accessing sites

(a) Getting permission. One should always request permission before sampling on private property, and, in a more general sense, it is simply polite to announce one's presence in a new area, particularly in the countryside. This serves two purposes. First, reporting to the local chief's (or other appropriate functionary's) office will eliminate

suspicion of the purposes of your work. Second, this allows you to request the services of local people (most productively, local teenagers) who know the area and perhaps, even, where fruits are currently available. (One necessity—even if local people insist that there are no fruits available, look for them yourself; there will be some, virtually any time of the year.)

(b) Sampling in gazetted National Parks and Forests: This requires official permission. In Kenya, the relevant authorities are found at the Kenya Wildlife Service (Director of Research) and at the Forest Department (Conservator of Forests). Prepare a one or two page project outline, including your goals, to justify your request. It is helpful if you state explicitly that you will provide them with the results of your work, in the form of publications or, at the least, a report summarising your data. Delivering on this promise will create goodwill and facilitate future cooperation with these authorities. If you work within a scientific institute or university, requests should originate from the department (e.g. environmental studies, conservation, ecology) that routinely deals with these authorities.

(c) Use local youth when exploring for fruits. People are usually intensely interested in what you are doing and willing to help, particularly if you offer some compensation (small or more generous, depending on the means available to your project). They can help with carrying the bags of fruit you hopefully will have collected, but their real value comes in locating and reaching fruits. It was my experience that local people were far superior to me at finding fruits, particularly when these were on trees or lianas high above the ground. They were also immeasurably better at climbing to reach them when they are too high for a long-arm pruner to reach.

Field collections and plant identification

When collecting fruits in the field, sampling strategies depend on several factors. The most important of these are:

1. Fruit availability.
2. Fruit accessibility.
3. Vehicular capacity.
4. Available field and laboratory manpower.
5. Laboratory space.

In general, a good rule of collecting is to maximise the quantity and diversity of sampled fruits, i.e. try to return to the rearing facility with a vehicle more or less packed full of fruits. This will increase the probability of finding pest species as well as rare ones. That said; however, logistical and time constraints may force you to be selective among species of fruit

encountered in the field. You may want to spend less time sampling from fruits that, based on previous data from rearing of the same or related fruit species, are not likely to produce fruit flies.

Finding fruits

1. Use binoculars to locate fruits in higher trees, especially at the edge of forests where the view is unobstructed.
2. In forests, if possible, work in teams of two or more. This will improve safety and thoroughness. Maximise coverage by spreading out. Walk in parallel lines, and maintain voice contact so no one becomes lost. (This is yet another good reason to work with local people. You may become lost, but they will not.)
3. Listen for bird and primate chatter; they may lead you to fruits.
4. If using a vehicle, drive along forest tracks or edges. If you have a roof rack, fruit spotters should sit on top of the vehicle.

Collecting fruits

1. Collecting from the ground. You **must verify the source of the fruit.** Assigning a tephritid to an incorrectly determined host is worse than providing no host information at all. This can be difficult, particularly in forests, where a tangle of shrubs, climbers and trees are potential sources. Use your binoculars. Lie on your back on the ground to steady yourself.
2. Collecting from a plant:
   (a) Use your hand-held pruner or the long-arm pruner with/without extension.
   (b) While collecting along the side of a road or a track within forest or woodland, if you have a suitably strong vehicle, use it for added reach by climbing on top of the vehicle. This will give you an extra 2 m or so of height.
   (c) You can also climb the tree.
3. Whenever possible, collect a plant specimen as a voucher for each fruit collection. If a tree is the souce of a fruit, but is too high to get a plant specimen, use your binoculars to view its leaves and record as many of their characteristics as possible (see below).

Managing collections in the field

1. Before beginning to collect, write the date at the top of the page on a new page in your field notebook, or on a blank sheet of paper. Beneath the date, write the site name. You are now ready to collect.

2. Place each collection of fruit in its own plastic (polythene) bag. **Never mix or combine different species of fruits,** even if you are short of bags.
3. Make a small collection-note, providing the following data:
   (a) Plant name. If you do not know it, be as descriptive as you can be (e.g. 'unknown tree', 'woody climber'),
   (b) Site,
   (c) Date,
   (d) Note number. (On any particular date, note numbering starts at 1 and proceeds sequentially. Should more than one site be sampled **on the same date,** note numbering **does not revert** to the beginning [i.e. to number 1], but rather continues to increase sequentially. Only on a new sampling date does note numbering revert to 1.)
4. Place the note inside the polythene bag, on top of the fruits.
5. Keep plastic bags out of direct sunlight. (If possible, **avoid using** black bags.)
6. After making each collection, immediately make detailed notes about it in your field notebook or on the blank sheet of paper. Do not wait until later—you will forget important details.
   (a) Note number (The same note number that is included in the bag containing the fruit sample).
   (b) Name of the plant, if known.
   (c) Type of habitat (e.g. forest, shrubland, urban roadway).
   (d) GPS coordinates and altitude. (**Note:** In forests, you may not be able to acquire satellite signals. In this case, record GPS data at the nearest clearing or at the forest edge.)
   (e) Type of plant (e.g. shrub, tree, climber, liana, herbaceous plants, etc.).
   (f) Plant characteristics:
      i. Woody or herbaceous, height, presence or abscence of thorns and latex, bark colour and texture.
      ii. Leaf characters (these are usually illustrated in plant books)
         1. Type—simple or compound.
         2. Overall leaf or leaflet shape.
         3. Shape of leaf base and apex.
         4. Hairiness.
         5. Leaf edge characteristics.
         6. Petiole length and characteristics.
      iii. Fruit characters:
         1. Unripe, ripe, rotting.
         2. On ground, or from plant.
         3. Colour when ripe.
         4. Type (e.g. fleshy, pod, capsule).
         5. Shape, size (range), diameter or, if not round, length and width.

6. Type of infructescence (when in flower, this is called an inflorescence, e.g. cyme, raceme, umbel). These are usually illustrated in plant books.
7. Location of infructescence (axillary, inter-axillary, terminal, on trunk).
8. Pedicel (and peduncle, if present) length an characteristics.

Preparing collection vouchers in the field

1. Pressing plant specimens. For advice on collecting, pressing and preserving plants, visit a herbarium or refer to guides either online or in books. An excellent and free resource is *Herbarium Essentials* (Victor *et al.*, 2004), available on request from sabonetpub@nbi.ac.za. They will mail you a copy.
   (a) For each collection, press at least one plant specimen.
   (b) Arrange specimens within a single sheet of newspaper. At minimum, the same four species of information accompanying the fruits (plant name, date, collection location, note number) should also accompany the plant specimen. Write this information on the newspaper.
   (c) Arrange the specimen so that the important characters of the plant can be easily seen on examination. Do not include too much material, as this will produce a poor specimen.
2. Field photography (yes, **photographs can make excellent vouchers**).
   (a) Place the plant specimen and fruits on the ground (soil with leaves, stones and twigs removed makes an excellent background).
   (b) Arrange the plant and fruits to best demonstrate important characters.
      i. Simplicity—photograph an uncluttered image.
      ii. Include a ruler or pen for scale.
      iii. Include variation in fruit characteristics, e.g. colour, size, shape.
      iv. Include important plant characters, e.g. leaves, thorns, flowers.
   (c) Take many photos (some will be better than others; digital images are free). Shoot at different distances and angles to include the plant parts you wish to highlight. Use macro mode for close-ups. **Always** turn off the flash. The flash, particularly in close-ups, usually produces poor images.

Transporting fruits

1. Place each collection in its own container.
2. Place the polythene bag containing the fruit collection in a large plastic container. Pull the bag up and over the rim of the container, and then

down, lifting the fruits off the bottom of the container **(Plate 18).** Secure the bag in place with the container cover. During transport, this serves to hold the bag and fruits above the bottom of the container and limits bruising and damage to the fruits when driving on rough roads.

Plate 18. Container with polythene bag and fruits

3. Use breadboxes to organise collections. Place them on inexpensive foam to cushion fruits during travel.
4. Cover containers with cloth to shield fruits from dust, heat and sun. Moisten cloth if humidity is low.

Processing fruits in the laboratory

1. Each collection is assigned a **unique** project number. Numbers are incremented sequentially (1, 2, 3, and so on) from the beginning of the project. No number is ever repeated. For example, if you make 2437 separate collections of fruits in your project, the last collection is assigned collection number 2437.
2. Completely remove leaves and stems from a sample. This is important as some insects mine leaves or bore in stems. Galls on leaves and stems can also produce insects. Incorrect processing can yield incorrect results.
3. Count the fruits from each collection, and weigh the entire sample.
4. In our work, each fruit sample was placed in a 1-litre, rectangular, plastic ice-cream container that had c. 0.5 x 2.5 cm ellipsoid holes cut into the bottom **(Plate 19, centre).** An ellipsoid (but not circular) shape prevented fruits from clogging the holes. A mesh-covered top was fitted over the container.

Plate 19. One-litre fruit-holding container with ellipsoidal holes

5. This container was then nested inside a 2-litre, rectangular, plastic container containing moistened sterile sand **(Plate 20).** The holes in the smaller container allowed mature tephritid larvae and other insects to fall into the larger container below, after exiting host fruits.

Plate 20. One-litre fruit-holding container nested on 2-litre container

6. An adhesive label is affixed to the outside of the large container. On this label, write (in pencil) the same information found on the label accompanying the sample from the field (i.e. plant name, date, location, note number) and, **most importantly, the unique project collection number assigned to the sample in the laboratory.**
7. Hold fruits for 2–3 months. Spray with water as needed. Avoid spraying fruits that are prone to fungal growth. Most fruits will be dry and shrivelled by the end of the holding period. Large, moist fruits may be held for longer periods. Dissect and examine them for larvae or puparia before discarding the fruits.

8. In the tropics, fruits may be held under ambient conditions, although it may be necessary to supplement water vapour during dry periods. In our project, we filled several large containers with water to maintain relatively high humidity in the rearing room. Also, containers with fruit samples were arranged on metal shelves, the legs of which were placed in water-filled containers. This supplemented humidity while simultaneously acting as an ant barrier.

Processing reared insects

1. Check daily for emerged insects by opening containers inside a large cage **(Plate 21).** We used a 50 x 35 x 38 cm transparent, Plexiglas (Perspex) cage with a fabric sleeve through which the containers were passed into the cage.
2. Transfer insects (except moths) to a holding cage. We used a 20 x 14.5 x 15 cm cage with one or more mesh sides **(Plate 22).** Flies should be held for 4 to 5 days to set their colours and harden their exoskeleton. Wasps and beetles can be killed after 1–2 days. Moths should be killed immediately and pinned the same day.

Plate 21. Large cage for checking emerged insects

Plate 22. Insect (fruit flies) holding cages

3. Provide insects with a three parts sugar and one part brewer's yeast diet. Small droplets of honey should be spotted onto the underside of the roof of the cage and cotton wool soaked with distilled water placed in a small container on the floor of the cage.
4. Process insects by killing them, i.e. by freezing or with an effective and quick acting killing agent (e.g. ethyl acetate) and pin or place them in 70–80% ethanol (and 95% if you intend to extract DNA from a sample). Provide proper temporary labels until permanent labels are made. When permanent labelling is complete, each specimen should have three labels as follows:

(a) The uppermost one should include the country name (in capital letters), the province or region in which the collection was made, the location name, latitude, longitude and altitude, date of the collection and the name of the collector.
(b) The second label should include the name of the plant from which the insect was reared (e.g. 'ex fruit *Coffea arabica*'), the name of the project and the unique collection number assigned to the fruit sample from which it was reared.
(c) The bottom label should include the name of the tephritid (or other insect) species and the name of the person who made the identification. The latter should be preceded by the abbreviation 'det' (short for 'determined by').

How to curate the collection

All the hard work you have done to this point will be of little good if you do not properly curate and label the specimens you have pinned. Specimens should be housed in tightly closed cabinet drawers or insect boxes. Each box or drawer should have a single ball of napthalene (moth ball) secured with pins in one corner. Be sure that the mothball is secured or it will damage specimens when boxes or drawers are moved.

Managing the data

1. Create a spreadsheet file.
2. Think about which variables to include. This will vary depending on the project. In **Annex 3,** we have provided a sample of the spreadsheet we used in our work.

CHAPTER 6

Handling, Packaging and Shipment of Specimens

Maxwell K. Billah
International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya

Background

This chapter has been written primarily for general reference and is not entirely exhaustive. It is written to provide a broader understanding of how specimens are prepared, handled and shipped for identification, to ensure that they are properly managed and that consistent standards are adhered to.

Tools and implements

- A simple dissection microscope (with sufficient lighting)
- Forceps for fly handling. These could be:
  - Lightweight forceps
  - Fine-tipped 'stock bill' forceps for handling unmounted dry specimens
  - Blunt-nosed 'featherweight' forceps for handling larvae
  - Pinning forceps for handling pinned insects
  - Watchmaker's forceps (with fine hard tips). Care must be taken not to drop forceps with fine hard tips as they will bend and not ensure a proper grip.
- Fine (camel hair) brushes
- Ethanol (ethyl alcohol) in squeeze/wash bottles—70% or absolute for dilution
- Pencils (HB) and erasers
- Pair of scissors
- Cavity dishes
- Entomological pins (stainless steel)
- Setting needles (or box of office pins)
- Marker pens
- Masking tape
- Cello tape
- Soft packing materials such as:
  1. Styrofoam or polystyrene in the following forms:
     - Loose chippings
     - Solid block

- Solid flat, and
- Box.

2. Shredded office paper in the following forms:
   - Single-shredded
   - Double-shredded.
3. Bubble-air plastics
4. Plastic air-bags
5. Cotton wool
6. Direct plastic wrapping
7. Fine wood shavings
8. Newspaper wrapping
9. Used shipping material.

Collection of information and labelling of data

A high standard of preparation and documentation is essential for insect collection as it is an indication of its scientific value. Documentation usually depends on the accuracy and details of the collection information and therefore, the scientific value of the collection declines with limited or poor documentation.

Some of the primary information collected that should appear on vials and packaging materials are:

- Country/province or region
- District/locality:
- GPS reading (if possible)
- Date
- Collector
- Method of collection
- Trap number
- Habitat/crop
- Any other collection information or ecological observation from the field.

Remember to keep back-ups of your collection information when shipping specimens.

Note:

The most common mistakes from collection data usually stem from the method of collection and the habitat/crop information. It is not enough to state that the method of collection was 'by trapping': The trap type and lure/attractant must be included. 'Mango' may mean 'from mango orchard' or 'from mango fruit'. If insects are reared from fruits, it should be categorically stated or written as 'ex. fruit'. This is the only way host range

data is collected (i.e. rearing insects from incubated fruits). If they were collected on a fruit, 'on fruit' should be written. It is also useful to add the activity seen (if possible) at the time of collection e.g. 'resting on lower leaf surface', 'mating on fruit or leaf', 'hovering around fruit or lure container'.

Preparation of specimens

On arrival from the field, it is usually tempting to leave your material in the open in the laboratory and return to them the next day. It is advisable to keep them in the right place, e.g. in the cold room, freezer or neatly arranged. Specimens may get deformed, shrink or rot if they are not immediately attended to. This also ensures that any unwanted material from the field will be noticed and disposed of before they go into hiding in the lab.

Here are some guidelines:

- Field-collected specimens should be sorted out into different taxonomic groups and counted.
- Field collection data, coded labels, etc. should be written out in full (in pencil or in permanent ink) on arrival in the laboratory and stored with the specimens.
- Use clean empty vials.
- To collect dry specimens, use fine camel hairbrush or soft forceps.
- For wet or liquid lure traps, strain the insects or flies through fine mesh or sieve.
- Use one vial per trap. If a vial is full, duplicate the label using the same trap number and fasten the vials together.
- Add 70–80% ethanol for preservation. For long-term storage, it is advisable to increase the concentration of ethanol to cater for losses due to evaporation and dilution by body fluids of insects, especially if in large numbers.
- For DNA studies, store specimens in 95% ethanol in a deep freezer.
- Live insect specimens to be stored in ethanol can be killed by placing them directly into 70–80% ethanol, while those to be pinned can be killed with ethyl acetate vapour in a 'killing jar'.
- The easiest way to kill insects without chemicals is to place them in a closed container and deep freeze.

Dry specimen mounting

Dry specimens are particularly fragile and should be handled with great care, especially after pinning. Use a camel hairbrush or soft forceps to collect dry specimens. Dry specimens should not be left uncovered when you are not handling them.

Pin mounting

Direct/single mounting

- Pins must be made of stainless steel. If not, they will corrode and damage specimens.
- Drive the pin through the insect up to 3/4 of the length and leave enough room above the specimen for gripping.
- Use a size 3 entomological pin where possible. The finer sizes 0, 00, 000, 1 or 2 and minuten pins are used for very tiny specimens, e.g. parasitic Hymenoptera.
- Ensure that the legs are not obscured and the antennae are visible.

Double mounting

This involves the use of minuten or micro pins and mounting strips. Minuten pins (number 0.15) are used to pin the smaller specimens either from the side or back (through the thorax) about 2/3 the length. A size 3 entomological pin is passed through one end of a piece of mounting strip or Plastazote® Foam (from polyethylene enclosed-cell foam plastic), and the specimen on the minuten mounted on the strip (~18 x 4 x 5 mm). This method is used for specimens that are too small (under 4 mm) and fragile to have entomological pins pass through them.

Card mounting

This involves the use of special 3-ply card points (Bristol or Ivory Board) cut from a punch, pins and insect-mounting glue. The cards are thin enough, but do not curl when pushing a pin through.

This is how card mounting is done:

- Push the pin through the card at the broader end.
- Bend the pointed tip of the card downwards with a hard pair of forceps (at right angles).
- Smear a small drop of glue on the curved tip.
- Place the specimen on the back with the head to the left.
- Invert the pin and card (with the curved tip pointing upwards).
- Place specimens with wings folded backwards on the left side.
- Press the glued tip against the side of the specimen. There must be no obstruction on any side (top, bottom or other side of the specimen. So that characteristic features obscured by the card and glue on one side can be observed on the other side).
- Align the specimen properly with the forceps and add labels as appropriate.

A second method of card mounting is employed for specimens that are too tiny to stick to the tip of pointed cards. In this method, the cards are rectangular and the specimens (up to four) are glued to the upper surface near one end of the card.

Note:

- Smaller specimens should be mounted using a dissecting microscope.
- If specimens are too brittle and pinning is not possible, collect specimens in fine netting material and place them between 2 layers of cotton wool in a box and seal tightly.
- Any unmounted smaller specimens can be collected in gelatin capsules and stored.
- Add camphor balls during storage to prevent psocids and other insects from destroying them.
- Water-soluble glues are recommended, to allow for removing specimens for future study.

Relaxing stored dry specimens

Freshly killed insects need no preparation before handling but those that have been stored dry, i.e. layered between tissue paper, must be relaxed in a moisture chamber or 'insect relaxer' before handling.

For relaxing dry specimens before pinning do the following:

- Use plastic or airtight glass container.
- Cover the bottom with wet cotton wool.
- Add a few drops of phenol or chlorocresole crystals to prevent growth of mould.
- Place a grille or wire mesh on the wet cotton wool.
- Add another layer of dry cotton wool on the grille.
- Place the dry specimens in a Petri dish on the dry cotton wool in the container.
- Spray inside part of the airtight lid with a little water (avoid dripping water onto the specimens).
- Replace the lid and leave the specimens for a few days until soft enough to handle.

Note:

Specimens should be checked often to avoid rot or discolouration. Labels in the chamber **must** be written in pencil.

Preparing wet specimens in ethanol

This method is used for soft-bodied insects and larvae. It is also used for storing large numbers of one species collected from the same locality.

Specimens kept in ethanol must not be allowed to dry out. If samples in an open container are to be left for a while, they should be covered and the microscope lamp switched off. When removing specimens from vials, remove those stuck to the sides by rinsing out with a squeeze bottle of ethanol or with a fine brush. Do not pull out with forceps!

Preparing adult flies

- Use clean empty vials.
- Use one vial per trap. If a vial is full, duplicate the label and use the same trap number.
- Write collection information on the label in pencil and place inside the vial (not stuck outside the vial).
- Always preserve in 70–80% ethanol (to prepare these concentrations, mix 70 or 80 ml absolute ethanol with 30 or 20 ml water, respectively).
- Use wide-mouthed vials to facilitate specimen removal for examination.
- Tight-fitting caps will prevent ethanol leakage.
- For collections of up to 10 specimens, mount all of them.
- For 10–50 specimens, mount the first 10 and then half of the remainder.
- For more than 50 specimens, mount 30.
- After mounting, include labels stating 'duplicate specimens in alcohol' to the first 10 specimens, and 'duplicate specimens mounted' to alcohol-preserved specimens.

Preparing larval stages

- Heat water to near boiling point (just off the boil) and remove from heat source.
- Dip live larvae in hot water for 5 to 10 seconds, making sure not to 'cook' larvae.
- Remove larvae and store in 75% ethanol.
- Add a few drops of glycerine to alcohol (to prevent rotting).

Packing, packaging and shipment

The purpose of shipping specimens is to get materials to the final destination; (1) in good time by courier service or registered mail (not ordinary post), (2) safely with sufficient addressing and precise content declaration, and (3) intact and in good condition to enable identification.

Wet or ethanol-preserved specimens

- Use small screw cap vials.
- Too much space between the level of alcohol and the lid will cause a 'local storm' in the vial and destroy the specimens. If this happens, push cotton wool inside and place specimens on top.
- Tape vials together in reasonable numbers (4–10) depending on size **(Figure 17A).**

Dry or pinned specimens

Pack dry or pinned specimens in small strong boxes with styrofoam-layered bottoms. If a styrofoam bottom does not fit tightly, drive office pins through the box at the lower part from the four sides to hold the styrofoam in place.

Each specimen (with all necessary labels) should be pinned with enough room to prevent them from touching each other.

For specimens with big abdomens, long legs or fragile antennae, entomological pins should be used by pinning a 'cross' beneath them for support.

Place one ball of camphor (in a camphor box or wrapped in a netting material) in a corner and fasten hard to prevent movement and destruction of the specimens.

Slide-mounted specimens (for parasitoids/hyperparasitoids which may be reared from fruits)

Because slide-mounted specimens are usually tiny, any slight movement or handling of the cover slip may result in destroying or distorting the specimen. For this reason, slide mounts are usually shipped in special grooved boxes to keep them in place and separate them one from another. Hold slides in place with masking tape at the edges before closing the top. This prevents slides from slipping out accidentally when the package is opened.

Slides are packed with the upper surface facing the same upward direction. Cover slips are likely to slide off or away from specimens when temperatures in the package become too hot and slides are facing downwards. Therefore, the direction of slides MUST always be indicated on the package.

After specimen preparation (dry, wet or slide-mounted)

- Pack in a small box with bubble packing material or styrofoam **(Figure 17B** and **C).**

- Seal the small box and pack again in a stronger cardboard box **(Figure 17C** and **D).**
- Place additional typed collection data on small box **(Figure 17E),** add more packing material and seal **(Figure 17F).**
- Provide the recipient's full name and mailing address (including telephone, fax, e-mail) on at least two sides **(Figure 17G).**

For example:

TO:

DR S. K. RONNIE-HALLIB
DEPARTMENT OF ENTOMOLOGY
FRUIT FLY RESEARCH LABORATORY
2531 BACTROCERA AVENUE
P.O. BOX 3131 – 00001
NAIROBI – KENYA

TEL: +254-20-777666
FAX: +254-20-777555
CELL: +254-721-999333
E-mail: FFRL@GOODTAXONOMY.COM

- Write the sender's full name and address as above.
- Provide exact content declaration and purpose of mailing (for customs inspectors/port authorities).

For example:

FRAGILE!

DRY INSECT SPECIMENS FOR SCIENTIFIC RESEARCH—NO COMMERCIAL VALUE

DEAD INSECT SPECIMENS IN 70% ALCOHOL FOR SCIENTIFIC RESEARCH—NO COMMERCIAL VALUE

- After packing, conceal all glaring previous written material on the shipment box to avoid confusing port authorities. Only labels of the present content and addresses should be visible and clearly displayed **(Figure 17G).**
- Indicate any handling instructions e.g. 'FRAGILE', 'DO NOT SHAKE', 'THIS SIDE UP' or with an upward-pointing arrow '↑'.
- Send specimens by registered mail or courier service (NOT by ordinary mail or post).
- Registration and sufficient addressing are essential for tracing items lost in transit.

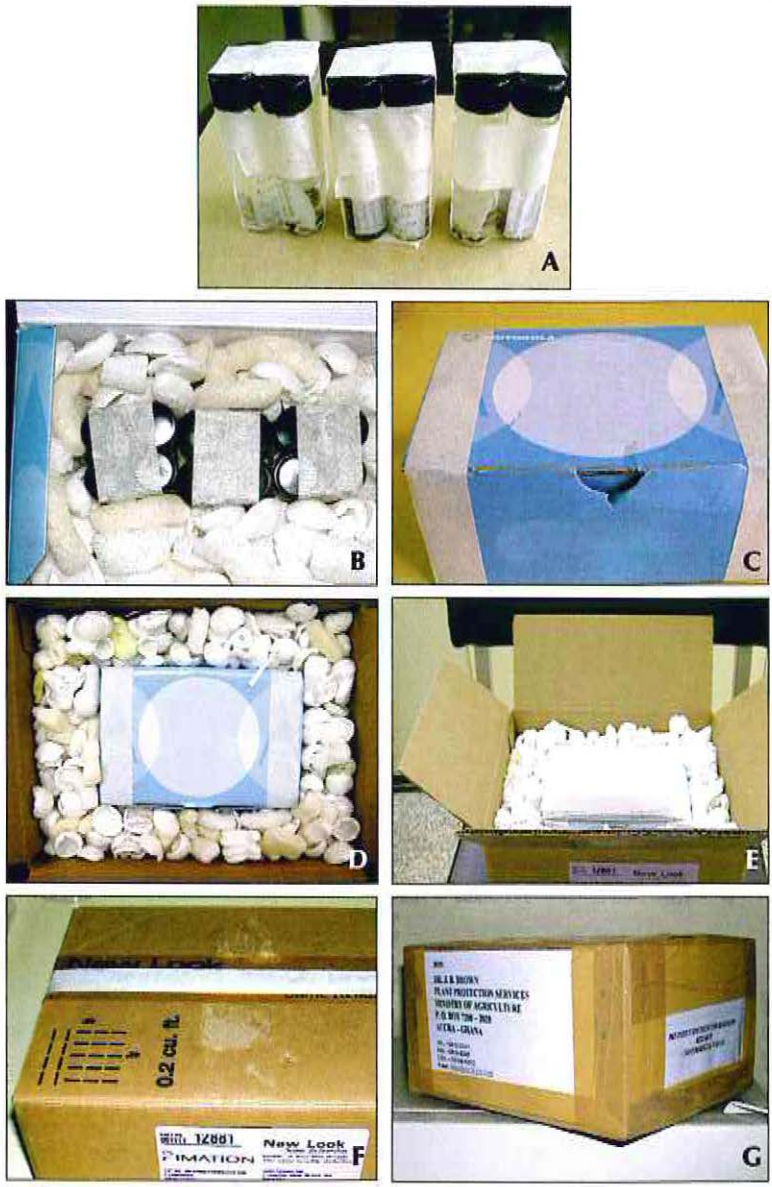


Figure 17. Steps involved in the proper packing, packaging and shipment of specimens for identification. **A,** Small sizeable vials taped together for easy packing; **B,** taped vials packed in box with packing material and properly sealed; **C, D** and **E,** small box packed in a second one with packing material and a copy of the collection data sheet **(E); F** and **G,** second cardboard box completely sealed **(F)** with sufficient addressing and full content declaration **(G).**

- Since materials are always sent by courier service, the airway bills or registration numbers should be sent by e-mail or fax to the recipient to facilitate tracking of the shipment.

Note:
There are no hard and fast rules or specifications in terms of materials used in the packing, packaging and shipment of specimens. They are all based on the three principal aims of shipment: getting the specimens to the final destination in good time, safely and in good condition. To achieve these aims, individual creativity, originality and ingenuity prominently come to the fore. Any type of strong cardboard box can be used for shipment, depending on the number of specimens to be shipped.

Labelling specimens

Because labels must last as long as the specimens, it is important that great care is taken in preparing them.

- Legibility: If labels are handwritten they should be small and legible.
- For dry specimens, paper size should be 12 x 8 mm. For ethanol, paper size can be up to 35 x 12 mm, depending on the size of the vial.
- Use scientific names for permanent labels.
- Use drawing pen with fine nib (0.18) or computer-generated labels with appropriate font type and size (laser print or better).
- Care should be taken not to alter field data during writing, e.g. *cosyra* and *cosyrae*. The former is a tephritid fruit fly species (Diptera), while the latter is a braconid parasitoid (Hymenoptera).

Labels for dry specimens

- Three labels are usually used for:
  - Locality information,
  - Host/trapping information
  - Identity information (insect and determiner).
    For example: *Bactrocera invadens*, Det: M. Billah

Use lasting adhesives that will not dry and peel off after a few weeks. Pass the pin through the middle of the label for direct/single mounted specimens and near the edge of the label for card or double-mounted specimens.

Labels for wet specimens

Because the labels for wet specimens are going to be placed in a preservative (ethanol) and for a very long time, the two most important criteria are

the quality of the paper and colourfastness of the ink. The sequence of information is the same as for pinned specimens, but can be written on one label (as it is considerably larger). When some of the specimens are mounted, indicate 'duplicate specimens mounted' on the specimen label or on an additional label and place it in the specimen container.

- Good quality paper (with a strong and smooth surface) should be used. Poor quality paper tends to 'dissolve' with time.
- Some ink may run in ethanol. Therefore, the use of durable ink (black, waterproof, quick-drying ink) is recommended.
- For printed or written labels, allow 5 minutes drying time before placing in alcohol.
- Lettering with HB pencil on good quality paper may also last for long.
- The labels should be placed inside the vial—not stuck outside the vial—with the lettering against the wall of the vial (so that it can be read without disturbing the contents).
- Avoid placing folded labels in vials with specimens as they may destroy or hide specimens during removal for examination.

Labels for slide specimens

Slide labels (usually two) are placed on either side of the specimen on the slide. The first or left label usually carries the identification data, while the second or right one carries the collection information.

Specimen storage

Wet collection

- For long-term storage, use 75% alcohol to cater for losses due to evaporation.
- Once in a while (at 6–12-month intervals), inspect your material to make sure the alcohol is not completely evaporated. If so, top up.
- Keep specimens away from direct sunlight. They should be stored in a cool dark room under lock and key.

Dry collection

- Pin in airtight insect boxes and mount as drawers in cabinets.
- Add naphthalene or camphor balls to keep away other insects.
- The collection room **must** be free of moisture and dust.
- Movement to and from the collection room must be highly restricted.

Slide collection

- This method is used for microscopic/very small insects or parts of insects for close examination under the microscope.
- Glass slides are usually 76 x 25 mm and 0.8 or 1.0 mm thick, with ground edges.
- Cavity slides—standard slides with one or two shallow depressions in the middle (for larger/bulky specimens/parts which cannot be accommodated under normal cover slips).
- Place a drop of mounting medium on the slide, carefully arrange specimen/parts in the medium and gently lower a coverslip over the specimen and medium.
- For permanent slides, use mountants such as Canada balsam.
- Slides should be dried in an oven at 35–40°C for 3–5 weeks.
- Store in slide boxes and keep away from direct sunlight and high temperatures.

Things to note

- Do NOT surprise your specialists! Always send a prior notification by mail to inform them about your intention to ship materials for identification. They may be away or too busy at the time.
- Explain the reasons for identification, e.g. for research, survey or thesis, and when the specimens are likely to be sent.
- Indicate the approximate number of specimens, the taxonomic group(s) involved (so that if the insects are not in their field, they can refer you elsewhere), the stages involved (adults or immatures) and the level of identification required (e.g. to species, genus or family level).
- For identifications in major projects, seek cooperation at the planning stage. If not, it is unlikely your request for mass identifications will be treated sympathetically because of other commitments.
- Poorly prepared specimens add up unnecessary 'non-identification' technical work to the specialist. He has more to do than sorting insects! Poorly mounted or damaged specimens are time-consuming to examine, and often cannot be identified.
- Full data labels and any other ecological information must be added to the specimens. Field labels or coded labels are not adequate.
- Keep a contact list of all the people you deal with (with full physical and postal addresses).
- Always indicate where your specimens were identified and fully acknowledge this in your reports and publications. It adds authenticity to your work. This is how it is done: "Specimens were sent to I. M. White (Natural History Museum, UK), M. De Meyer (Royal Museum of

Central Africa, Tervuren, Belgium), M. W. Mansell (USDA-APHIS, SA), R. A. Wharton (Texas A&M University, USA) or M. Billah (AFFI-ICIPE, Kenya) for identification or confirmation."

- Indicate where voucher specimens of your studied/experimental material have been placed (usually in recognised institutions, e.g. museums). This serves as your natural back up and independent source for future reference and verification.
- Once in a while, inspect your stored materials and remind yourself of the sources of the materials. These are occasions when name changes, evaporated alcohol or vapourised camphor balls changes can be made.

CHAPTER 7

Fruit Fly Taxonomy and Identification

M. K. Billah[1] and M. W. Mansell[2]

[1]International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya
[2]United States Department of Agriculture - Animal and Plant Inspection Service, International Service (USDA-APHIS), Pretoria, South Africa

Introduction

The family Tephritidae includes about 4000 species in 500 genera. It is one of the largest families of Diptera (the flies), and also one of the most economically important groups of insects. The larvae of many species develop in the seed-bearing organs of plants—hence the name 'fruit flies'. About 35% of species attack soft fruits including a wide variety of crops, while 40% of species develop in the flowers of Asteraceae (Compositae). Larvae of the remainder invade flowers of other species or mine in leaves, stems or roots of plants. Several species are beneficial and are used as biocontrol agents of weeds.

Fruit flies are of great economic importance for many reasons, including the following:

- Fruit pest tephritids occur in almost all fruit and vegetable-growing areas of the world.
- They attack commercially produced fruits and vegetables.
- Several species have extended ranges into new areas, and continue to expand, especially in Africa.
- Consequently, expensive quarantine restrictions have to be imposed to limit further spread.
- Such quarantine regulations by importing countries can either deny producing countries potential markets or force them to implement expensive disinfestation treatments.
- Fruit flies compete with humans for food resources and have a significant negative impact on sustainable rural livelihoods.

Most attention has been focused on the medfly, *Ceratitis (Ceratitis) capitata* (Wiedemann), but there are at least 15 species of Tephritidae that are currently of economic significance in Africa. Of particular concern are three species, which have recently invaded the continent. The most important species in Africa from an economic perspective are treated below.

Fruit flies of major economic importance in Africa

Indigenous species

- *Ceratitis (Ceratitis) capitata* (Wiedemann)—Mediterranean fruit fly
- *Ceratitis (Pterandrus) rosa* Karsch—Natal fruit fly
- *Ceratitis (Pterandrus) fasciventris* Bezzi
- *Ceratitis Pterandrus) anonae* Graham
- *Ceratitis (Ceratalaspis) cosyra* (Walker)—Marula fruit fly
- *Dacus (Dacus) bivittatus* (Bigot) —Pumpkin fly
- *Dacus (Dacus) punctatifrons* Karsch
- *Dacus (Didacus) ciliatus* Loew—Lesser pumpkin fly
- *Dacus (Didacus) vertebratus* Bezzi—Jointed pumpkin fly
- *Dacus (Didacus) frontalis* Becker
- *Dacus (Didacus) lounsburyii* Coquillet
- *Trirhithrum nigerrimum* (Bezzi)
- *Trirhithrum coffeae* Bezzi—Coffee fly
- *Bactrocera (Daculus) oleae* (Gmelin)—Olive fly

Invasive species

- *Bactrocera (Zeugodacus) cucurbitae* (Coquillet)—Melon fly
- *Bactrocera (Bactrocera) invadens* Drew, Tsuruta & White—'African Invader fly'
- *Bactrocera (Bactrocera) zonata* (Saunders)—Peach fruit fly

NB.
The following is a pictorial key to the common fruit fly species listed above. It is oversimplified, not exhaustive and meant for all those dealing with fruit flies. More detailed and in-depth discussions, identification and species distribution in the world can be found in White and Elson-Harris (1992), De Meyer (1996, 1998, 2001a, b), De Meyer et al. (2002a, b) and De Meyer, M. & White, I.M. (2004). Names of veins, thoracic parts and setae are shown in White and Elson-Harris (1992) on pages 31–33.

Key to the common fruit fly species

1. Sub-costal vein Sc ends approximately 90° on 3rd break (sub-costal break). Dorsal side of radial vein R_1 with setulae. Wing cell with acute extension (i.e. cu*p*), wing usually patterned by coloured bands (See **Figures 18A** and **28**).....**(Tephritidae)** .....**2.**

   Sc vein bends gradually towards costal vein, not ending on 3rd break. Dorsal side of vein R without setulae and wing cell without any acute extension .....**Non-Tephritidae.**

2. Scutellum with yellow areas (i.e. 'wavy' yellow band across base as in **Figure 18B**). Presence of isolated preapical cross band (on dm-cu). Basal cells of wing (c, br, bm, cu*p*), usually with spot and fleck-shaped marks, giving the wing a reticulate appearance (see **Figure 18A**)..... .....***Ceratitis* species** ..... **A.**

   Scutellum with or without yellow areas, preapical crossband absent or not isolated. Basal cells of wing with consistent colour, no reticulate appearance.....**Non-*Ceratitis* species**..... **B.**

A. Ceratitis species

1. Wing with apex of veins M not covered by diagonal coloured band. Yellow 'wavy' band runs **only** across base of scutellum. Male anterior pair of orbital setae **black and 'kite-like'** (See **Figures 18A, B** and **D**)..... .....***C. capitata.***

   Males and females can be separated from most other species by the apical half of the scutellum being entirely black and the characteristic wing pattern. *Ceratitis capitata* attacks a vast variety of cultivated and wild hosts, making it the most devastating of all fruit pests. Originally indigenous to Africa, it has spread to many other parts of the world. It is attracted to Trimedlure and terpinyl acetate.

   Veins M may or may not be covered by diagonal coloured band. Yellow **'wavy'** band on scutellum not only across base **(Figure 18C).** Male anterior pair of orbital setae absent or present. If present, **not 'kite-like'** as in **Figure 18D** .....**2.**

2. Yellow 'wavy' band also runs down **to apical end of scutellum, thus dividing it into 3 dark spots** (see **Figures 18C, 19B, 20B** and **22C**). Wing banding brown to black, with a small break or gap in the costal band between the costal break and R_1 or across R_1 **(Figures 18A** and **21B**)... . .....**3.**

   Wing banding more yellowish, with **no break or gap in costal band.** Scutellum also with 3 dark spots (see **Figures 22B** and **C**).....**5.**

3. Male with thick feathering on **both mid femora and tibiae** along most of the inner edge of femur, with no gap in the feathering (see **Figures 19C** and **D**)..... ***C. anonae*** **(Figures 19 A–D).**

   This species is recognised by the three black areas on the apical half of the scutellum and by the male having broad feathering along the mid-tibia and on the mid-femur. Females are virtually impossible to distinguish from those of *C. rosa* and *C. fasciventris*.

   Male with thick feathering restricted **only to mid tibiae**.....**4.**

4. **Very thick mid tibial feathering,** covering **about two-thirds** total length of tibia from apical end, with **very dark** central area between rows of feathering. Central dark area with **oblique border marking (Figures 20C** and **D).** Mid tibia **tapers gradually** towards basal end. **Mid femur without stout ventral setae,** fore femur with a few strong setae but not as dense as in mid tibia and very few anterior setae **(Figure 20D)** .... ***C. rosa*** **(Figures 20 A–D).**

   This species is recognised by the three black areas in the apical half of the scutellum and by the male having feathering on the mid tibia, but not on the mid-femur. Females are virtually impossible to distinguish from those of *C. anonae* and *C. fasciventris*. *Ceratitis rosa* is attracted to Trimedlure and terpinyl acetate.

   Feathering covers **about one-third** total length of mid tibia, and restricted **only to apical part (Figure 21C).** Space between feathering of mid leg paler, with no oblique border marking (than in *C. rosa*), and tapers sharply to about half the thickness at middle or apical end **(Figures 21C** and **D)** ..... ***C. fasciventris*** **(Figures 21 A–D).**

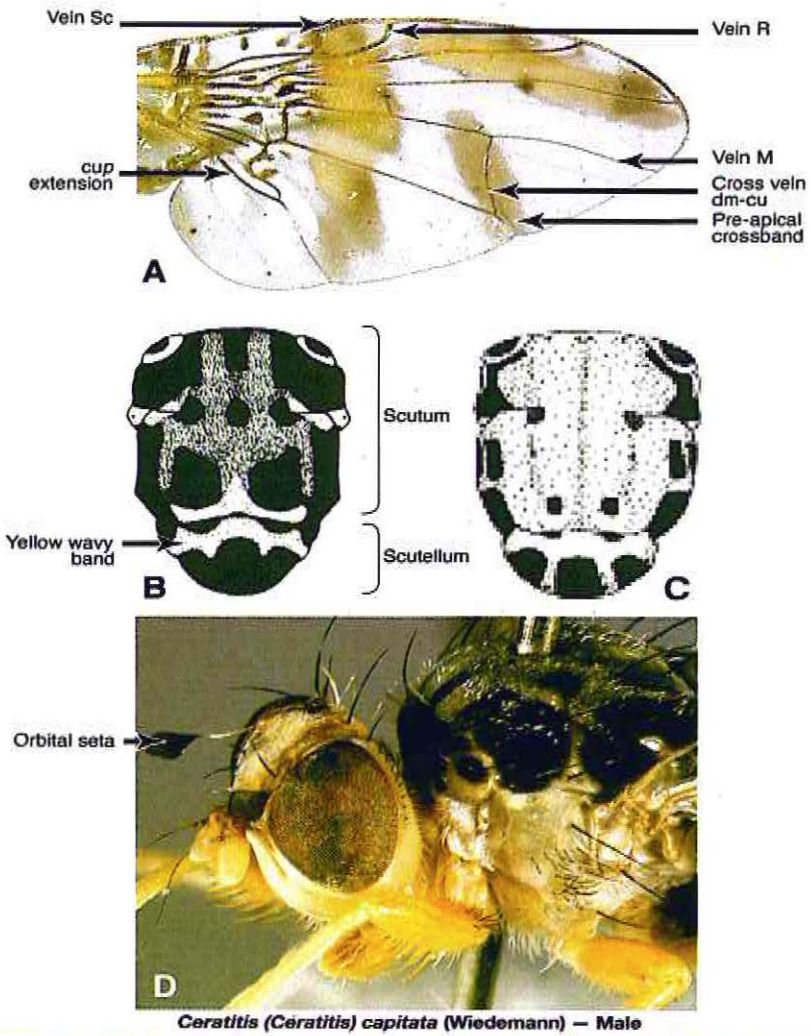
   This species is very similar to *Ceratitis rosa*, which it replaces in the western parts of Central Africa. The ranges of the two species apparently overlap, with *C. rosa* being confined mainly to the eastern coastal areas of Kenya. Only recently separated from *C. rosa*. Therefore host records likely to be within the same range as *C. rosa*. Females are virtually impossible to distinguish from those of *C. rosa* and *C. anonae*.

5. Scutum predominantly yellow or pale brown, with pattern of black spots **(Figure 22C). Fore femur yellow on both sides,** and in both sexes. Female with sharp and pointed aculeus. Post-pronotal spot **relatively big,** with seta sitting **anteriorly (Figure 22A).** Costal band continuous (no gap) **(Figure 22B)** ..... ***C. cosyra.***

   Ceratitis cosyra has three black areas on the apical half of the scutellum, the male orbital setae are not expanded at the apex and the tibiae are not feathered. It is also recognised by the four black spots on either side of the thorax and the four black spots on the dorsal surface of the thorax. *Ceratitis cosyra* is attracted to terpinyl acetate, but not Trimedlure or methyl eugenol.

Mesonotal supra-alar spots at least **partly or completely divided longitudinally.** Basal spots of scutellum with darker yellow colouration. **Females with aculeus tip bilobed.** Post-pronotal **spot small,** with seta sitting **almost in the centre** (non-mango pest)..... ***C. discussa.***

A casual glance at this species tells it is *C. cosyra*, until the post-pronotal lobe and the tip of the aculeus of females are closely observed.



***Ceratitis (Ceratitis) capitata* (Wiedemann) — Male**

Figure 18. (**A**) Forewing; (**B**) thoracic colour pattern and (**D**) head showing the male orbital setae of *Ceratitis capitata* (Wiedemann) (the Mediterranean fruit fly/med fly); **C**, thoracic colour pattern of *Ceratitis cosyra*

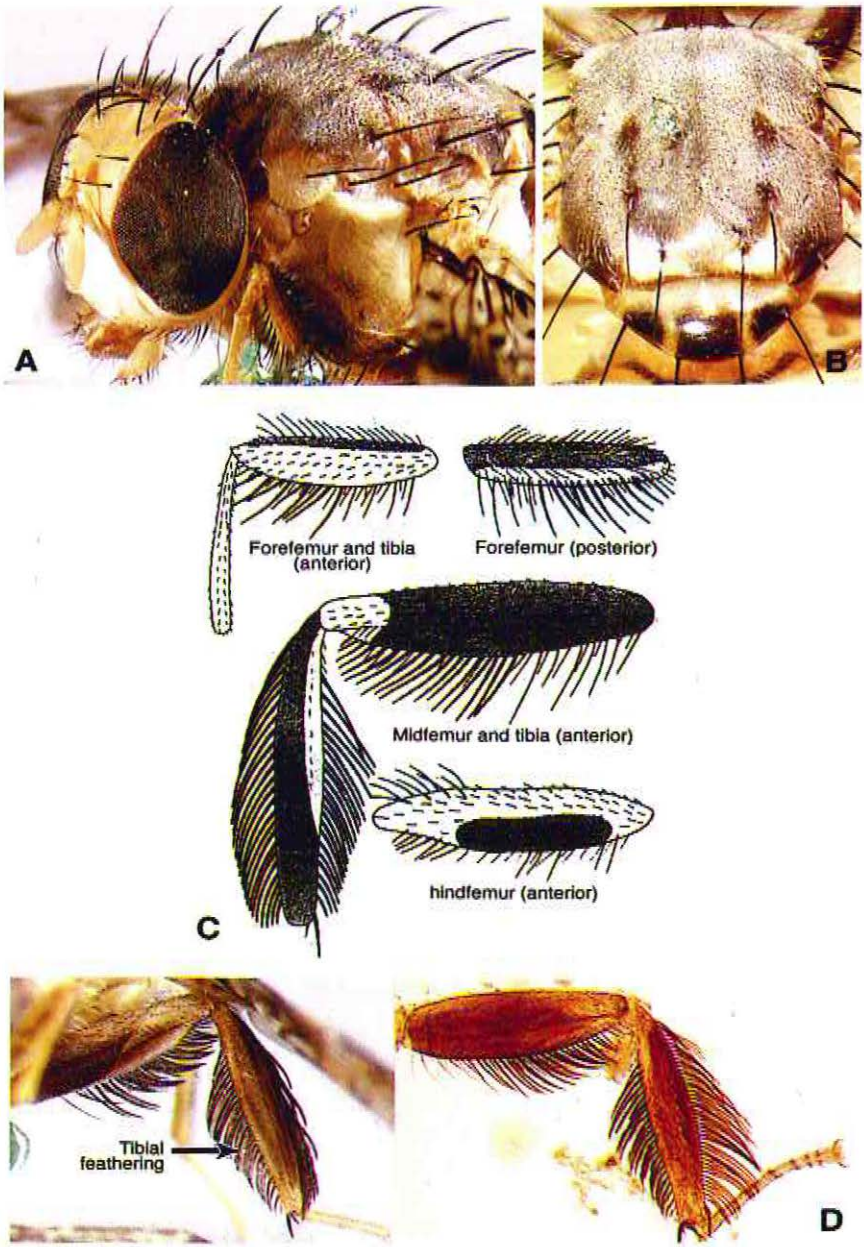


Figure 19. (A) Head, (B) thorax and (C, D) mid leg feathering of *Ceratitis anonae* Graham

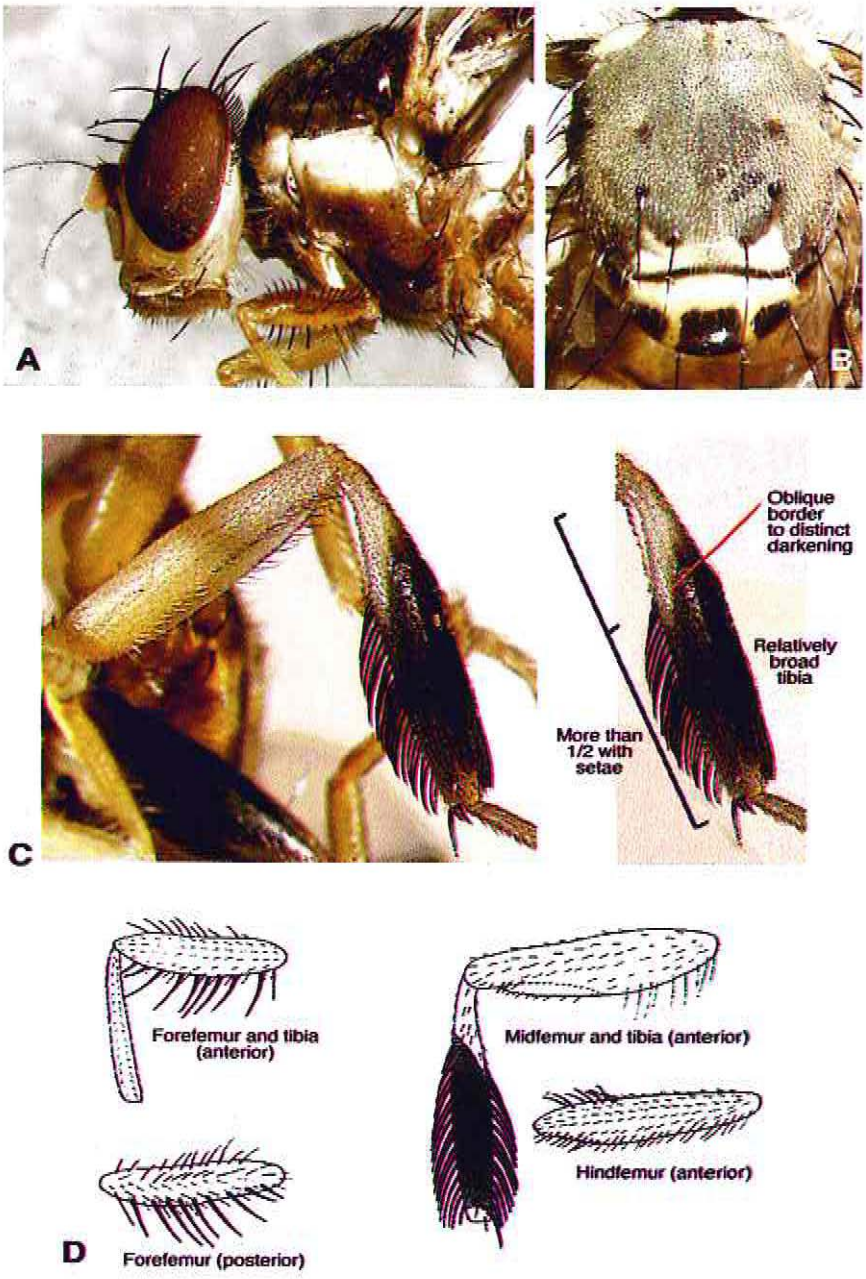


Figure 20. (A) Head, (B) thorax and (C, D) mid leg feathering of *Ceratitis rosa* Karsch (Natal fruit fly/Natal fly)

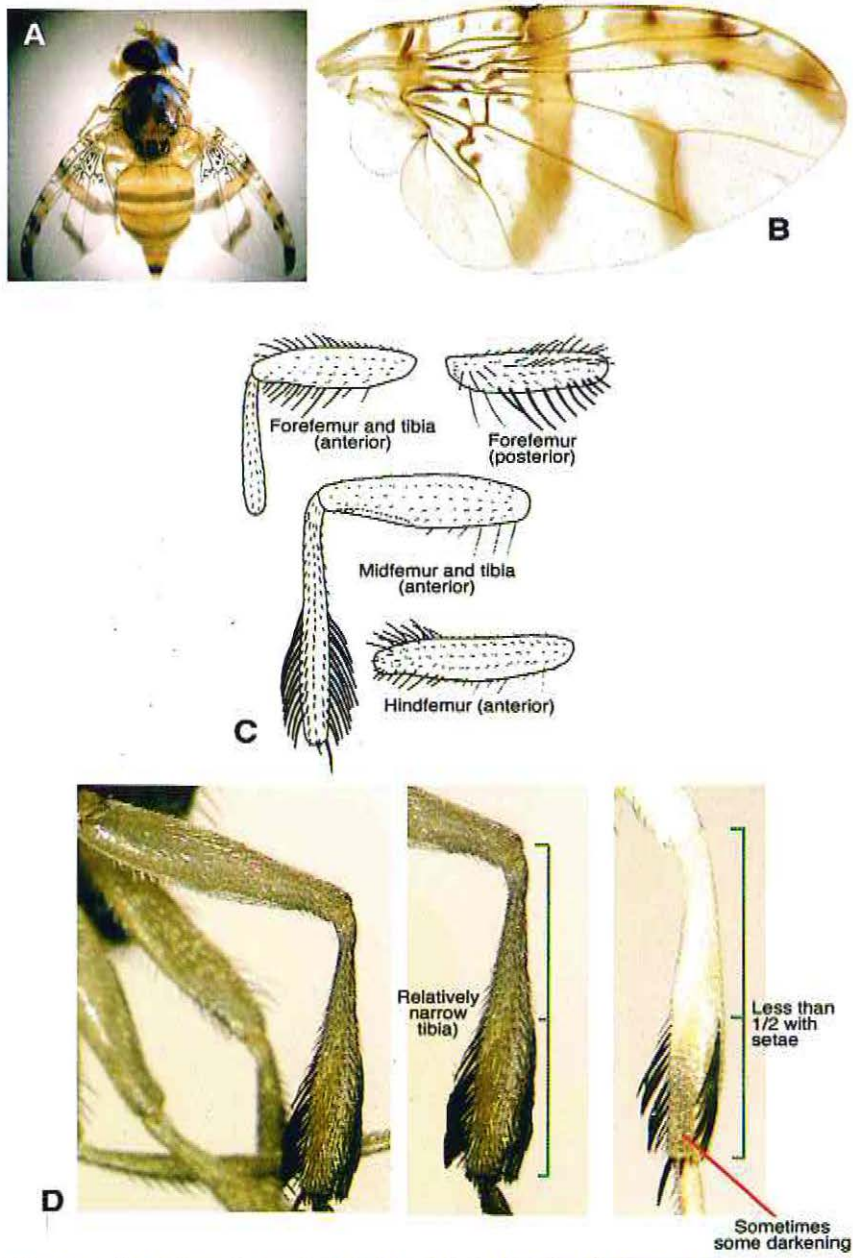


Figure 21. **(A)** Thorax, **(B)** wing of female and **(C, D)** mid leg feathering of male *Ceratitis fasciventris* (Bezzi)

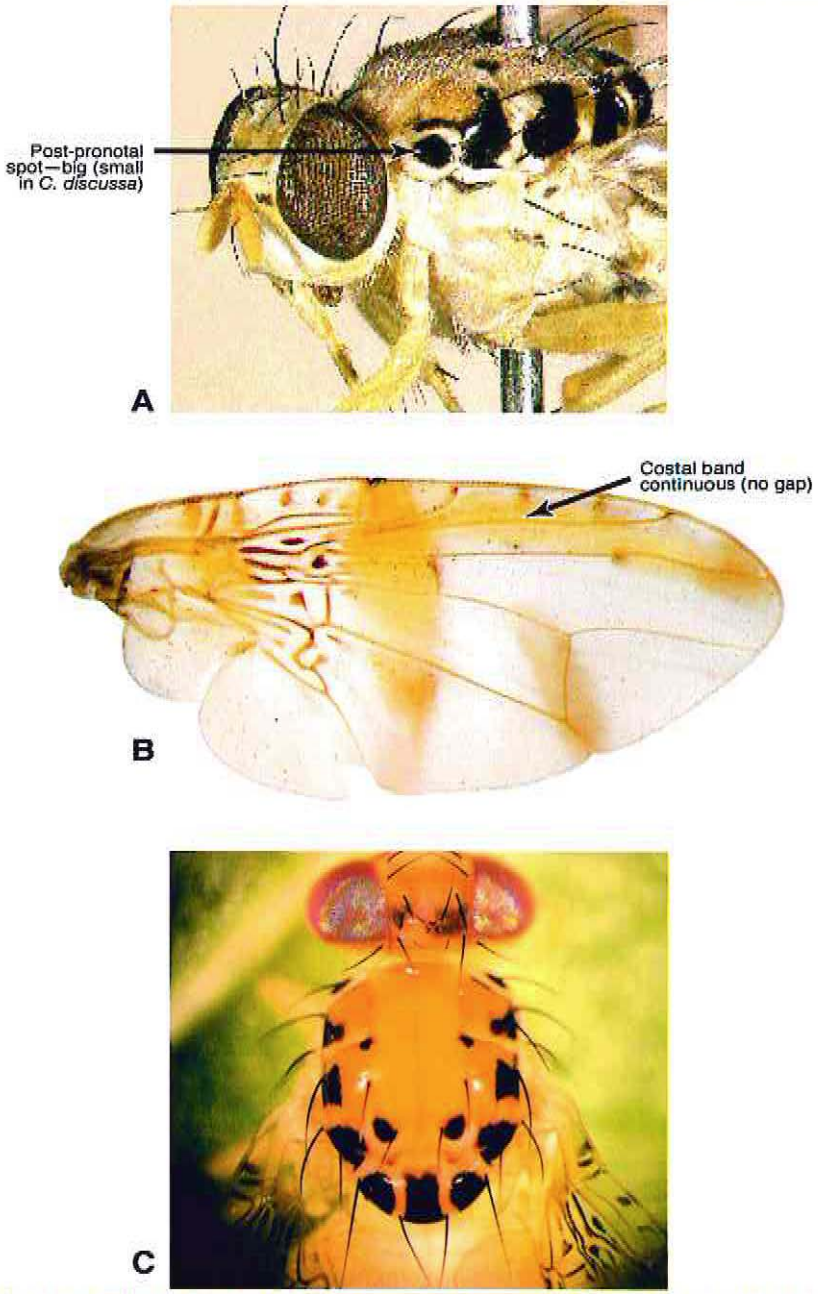


Figure 22. **(A)** Post-pronotal spot on thorax, **(B)** costal band on wing and **(C)** thoracic colour pattern of *Ceratitis cosyra* (Walker) (mango fruit fly/marula fly)

B. Non-*Ceratitis* species

1. Smallish-looking flies (like *Ceratitis*). Scutellum almost entirely dark brown to black, at most with yellow spots to the scutellar setae. If wing has pre-apical cross bands, they join the rest of the wing pattern. Basal cells not reticulate. Species mostly sexually dimorphic .....***Trirhithrum* species. (Figure 23)** ..... **C.**

   Flies are wasp-like and bigger (cf. *Ceratitis* species). Scutellum yellowish or brownish. Wings with simple patterns, except for costal band and a few with cross bands.....***Dacus* and *Bactrocera* species** .....**D.**

C. *Trirhithrum* species

1. *Trirhithrum coffeae* Bezzi—Coffee fly

Wing with very dark/black mark on costal vein just before subcostal break and **a small spot** between veins R_{2+3} and R_{4+5}, about 1/3 way from base. Post-pronotal lobe dark. Side of thorax with white patches. **Male wings paler with diffuse patterning, but dark near base of cell cua_1 (above cu*p* extension).** Costal band and posterior apical cross bands in males almost fused and extend beyond M. **Tibiae paler apically and dark basally.** Abdomen all dark (in both sexes). **Pre-apical cross band smaller and more curved and touches discal crossband at a very small point (at base of cross vein r-m).** In *T. nigerrimum* it is almost straight and joins whole length of r-m. Cell c with little patterning (in both sexes) as compared to *T. nigerrimum*.

Females, much darker than males. Small, black spot between veins R_{2+3} and R_{4+5}. Not distinct in females. Post-pronotal lobe darker. **All femora and tibiae dark.** Wing with black mark on costal vein (just before sub costal break), with a smaller one in-between R_{2+3} and R_{4+5}. **Wing banding pattern darker and very sharp.**

Attacks a variety of coffee species, including arabica (*Coffea arabica*).

2. *Trirhithrum nigerrimum* (Bezzi)

Thorax, abdomen and halteres black (Figure 23). Post-pronotal lobe dark/brown. **Has white patches on the face, but not on side of thorax.** Wing pattern with broad costal band and slight hyaline patches between R_1 and R_{2+3} and R_{2+3} and R_{4+5}. Costal hyaline-indentations very small, almost non-existent. Posterior apical cross band reduced to **small mark from costal band (not extending beyond middle of cell r_{4+5}. In males,** this is fused with tip of costal band, forming a big diffused spot that extends beyond vein M. **Costal band does not end in an expanded**

apical spot, but ends halfway between veins R_{4+5} and M. Basal part of wing with little hyaline spots. No bulla. (Small isolated black spot in middle of cell c.) **Cell sc filled with very dark spot between sub costal break and end of R_1. All femora dark, tibiae light brown/pale.**

Wing patterns and marks generally sharper and darker in females (male patterns infuscate or diffuse). **In females, pre-apical cross band is sharper, slightly curved and joins discal cross band at entire length of cross vein r-m.** (Male bands **not** distinguishable cf. *T. coffeae*) **(Figure 23).**

Attacks arabica and robusta coffee (*Coffea arabica* and *C. canephora*).

Figure 23. Thorax, abdomen and wings of *Trirhithrum nigerrimum* (Bezzi)

D. *Dacus* and *Bactrocera* species

1. Abdomen with **all tergites FUSED** into a single plate (with smooth transverse lines along boundaries). No overlapping sclerites (This is seen from the side) **(Figure 24A)**.....***Dacus* species** .....**E.**

   Abdomen with **all tergites SEPARATED.** Overlapping sclerites clearly observed from side (see **Figure 24B**).....***Bactrocera* species** .....**F.**

E. *Dacus* species

1. Scutum **with lateral and/or medial yellow or orange stripes/vittae** (see **Figure 25A**).....**2.**

   Scutum **without any yellow or orange stripes/vittae**.....**4.**

2. Wing with **very broad** costal band .....**3.**
   Costal band not broad. Presence of a small apical spot just at the end

of vein R_{4+5} and restricted to < 1/2 distance between veins R_{4+5} and M. Crossvein r-m sometimes covered by infuscate dark mark. Scutum with broad dark background in which the medial yellow stripe lies. Post-pronotal lobe and scutellum yellow/orange. Anatergite, katatergite yellow. All tibiae dark. Fore, mid and hind femora yellow/orange at base and dark apically—hind femur with more yellow (~2/3) than dark. No pre-scutellar acrostichal setae ..... ***Dacus punctatifrons.***

3. Broad costal band **very dark and continuous** from base to apex, expands apically over vein R_{4+5}, almost reaching vein M. **Band forms an infuscate dark mark over crossvein r-m.** Combined depth of r_1 and r_{2+3} at r-m crossvein, about equal to length of r-m crossvein. Post-pronotal lobe, 1/2 pale at top and brown down. Anatergite, katatergite yellow. All tibiae dark. Fore and mid femora 2/3 dark from apical end, basal 1/3 yellow, while hind femur has more yellow at base than apex. Scutellum yellow. Anterior supra-alar setae present, but without pre-scutellar acrostichal setae ..... ***.Dacus bivittatus.***

Dacus bivittatus is recognised by the dark orange to red-brown species, with lateral and median yellow stripes on the thorax. The scutellum is entirely yellow. The wings have a broad costal band from the base to the apex and a black mark overlying the sharp-pointed cubital cell. It is a pest of Cucurbitaceae, including a number of wild cucurbit plants. *Dacus bivittatus* is attracted to Cuelure, but not methyl eugenol.

Broad costal band slightly lighter than in *D. bivittatus*, expands apically over vein R_{4+5}, fills cell r_{4+5} apically and extends over vein M. **No infuscate mark over crossvein r-m.** Post-pronotal lobe all dark/brown. Anatergite orange/brown, katatergite with 1 or 2 small irregular yellow spots in centre. All tibiae dark. **Fore and mid femora completely dark/brown.** Hind femur 2/3 yellow at base and dark apically. **Scutellum dark, with yellow marks apically. Without anterior supra-alar setae** and pre-scutellar acrostichal setae..... ***Dacus lounsburyii.***

4. **Both** anatergite and katatergite **(Figure 26A)** with some yellow marking.. .....**5.**

Yellow marking confined to **either anatergite or katatergite** (the other brown) .....**6.**

5. Yellow spot in postero-lateral area not confined to katatergite, but extends across **both katatergite and anatergite,** forming a stripe. Yellow stripe separated from scutellum only by **one-third its length.** Post-pronotal lobe and scutellum yellow. Mid femur markedly darker in apical half than basal half. **All femora** yellow in basal half and brown/dark in apical half. Costal band with **rounded apical spot ending just at tip of vein R_{4+5}.** General body colour orange-brown..... ***D. vertebratus.***

This species has no stripes on the thorax, but has a stripe that covers most of the anatergite and katatergite on the sides of the thorax. Wing has a narrow costal band that is expanded apically to form an apical spot. It is a pest of Cucurbitaceae, especially watermelon (*Citrullus lanatus*), but also from cucumber, squash, cantaloupe and many wild species of cucurbits. Males are attracted to Vertlure.

A predominantly orange species. Basal part of scutum with 2 black rounded spots. Presence of 2 black rounded spots on either side of abdominal tergite 3. Most part of anatergite and katatergite covered by a yellow stripe. Apical half of mid femur darkened; no darkening in fore and hind femora. **Apical spot extends > 1/2 way between veins R_{4+5} and M.** Anterior supra-alar and prescutellar acrostichal setae present..... ..... ***D. frontalis.***

No longitudinal stripes on thorax, but a stripe covering most of the anatergite and katatergite. Differs from *D. vertebratus* and *D. ciliatus* by the darkened apex of the mid-femur. Wing with apical spot. Pest of Cucurbitaceae, including cucumber, watermelon, sweet melon, pumpkin and gourds. Attracted to Cuelure.

6. Yellow spot in katatergite separated from scutellum **by its own diameter.** Mid femur yellow/orange, but may be slightly brownish at apical end. Fore and hind femora yellow/orange. Narrow costal band, with a small apical spot extending halfway between veins R_{4+5} and M. Two small dark spots on lower scutum and a 3rd one on upper end, which extends almost to a line, or at times fading away completely. Post-pronotal lobe and scutellum yellow/pale. Abdominal tergite 3 with 2 dark spots on either side ..... ***D. ciliatus.***

This is a predominantly orange fly without longitudinal stripes, but with two yellow areas on the lateral surfaces of the thorax. Wings with brown costal band and an apical spot. Pest of Cucurbitaceae, including cucumber, squash, watermelon, cantaloupe, melon, various gourds and pumpkins.

F. *Bactrocera* species

1. Scutum **with** at least two yellow or orange **stripes/vittae (Figure 25A)**.. .....**2.**

   Scutum **without** any yellow or orange **stripes/vittae** .....**7.**

2. Presence of **only lateral yellow stripes** on scutum.....**3.**

   Presence of **both lateral and medial yellow** stripes on scutum .....**6.**

3. No medial yellow stripes or vittae. **Costal band continuous** and **runs to apical end of wing** .....**4.**

No medial yellow stripes/vittae. **Costal band not continuous;** ends with an **isolated apical band** ..... **5.**

4. Scutum predominantly black. **Only lateral yellow stripes present,** no medial stripes. Fore femur (in both sexes) without black spot. **All femora yellow** and all tibiae dark, with hind tibiae conspicuously darker (see **Figure 27A**). Abdominal tergites 3–5 **with black T-shaped mark (Figure 26B).** Costal band of wing not overlapping vein R_{2+3}, no sharp broadening or apical spot at end of R_{2+3} (**Figures 25B** L and **25C** U). Apical tip usually fills anterior half of cell r_{2+3} between end of veins R_{2+3} and R_{4+5}. Anatergite and katatergite both yellow **(Figure 26A).** Males with pecten ..... ***B. dorsalis.***

Scutum brown to black, but with high degree of variations from dark brown to complete black (see **Figure 25A**). Post-pronotal lobe yellow. Scutellum yellow, except for a narrow black band at the base. Mediotergite laterally black and red-brown centrally. Only lateral yellow stripes present. No medial stripes. Fore femur (in both sexes) without any black spot. Aggregation of microtrichia in cell br almost complete except for a small portion (< 1/2) which is bare. All femora yellow and all tibiae dark with hind tibiae conspicuously darker **(Figure 27A).** Abdominal tergites 3–5 with black T-shaped mark **(Figure 26B).** T-shaped mark with broader transverse band across anterior margin of tergite 3, which at times extends to the lateral sides of tergite 4. Anatergite and katatergite both yellow **(Figure 26A).** Males with pecten ..... ***B. invadens.***

B. invadens was only recently described by Drew et al. (2005). The thorax manifests variable colour patterns. It is apparently native to Sri Lanka, but recently invaded Africa and rapidly spread across the continent up to the Comoros Islands. It is known from Benin, Cameroon, Democratic Republic of Congo, Ghana, Kenya, Nigeria, Senegal, Sudan, Togo, Tanzania, Uganda and Zanzibar. The potential wide host range makes it an extremely dangerous invasive species. Males attracted to methyl eugenol.

5. Body predominantly **pale-brown to red-brown** (see **Figure 27B** 3). Scutum with **only lateral yellow stripes/vittae.** Presence of anterior supra-alar setae, prescutellar acrostichal setae and 2 scutellar setae (apical pair). Leg colourations as in *B. dorsalis*, but **hind tibiae with lighter middle part. No conspicuous black T-shaped mark** on abdomen (cf. **Figure 26B**). **Highly reduced wing pattern,** with an **almost isolated apical band** (see **Figure 25C,** D). Anatergite and katatergite both yellow (as in **Figure 26A**). Males with pecten ..... ***B. zonata*** **(see adult: Figure 27B** 3**).**

A predominantly pale orange-brown to red-brown species with lateral yellow stripes on the thorax. Has reduced wing pattern with narrow black costal band not extending to the wing apex and a brown marginal stripe at the wing

apex. No preapical crossband. *Bactrocera zonata* has extended its range from Asia and is currently known from Egypt and Mauritius in the Afrotropical region. The wide host range and the danger of it spreading southwards from Egypt make it a very serious invasive species in Africa. Males are attracted to methyl eugenol.

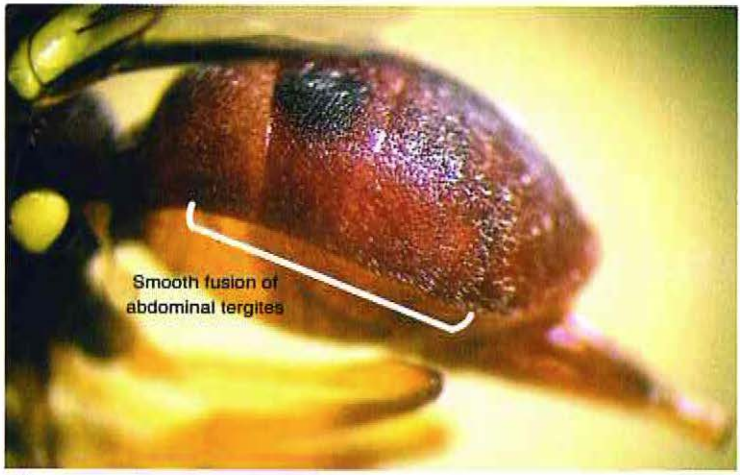
6. Scutum with anterior supra-alar setae and prescutellar acrostichal setae present in males. Males also have 2 scutellar setae (apical pair). **Wing with preapical crossband and broad apical spot** (see **Figure 25B** R) Anatergite and katatergite both yellow (as in **Figure 26A**). Lateral thoracic yellow mark with 2 dark marks on either side. Fore femur yellow. Mid and hind femora yellow at base, but dark at apical ends. Fore and hind tibiae dark, mid tibia only dark at basal end (non-mango pest, but commonly encountered in other fruits and vegetables) .... ***B. cucurbitae* (see adult: Figure 27B 2).**

This is a predominantly orange-brown species with lateral and median yellow stripes on the thorax. Wings characteristically marked—a costal band, an apical spot, a mark over the cubital cell and a preapical crossband. It is native to Asia, but has been introduced into Africa and is currently known from Egypt, Ghana, Kenya, Tanzania and also Mauritius and Réunion. It is a serious pest of Cucurbitaceae, but has been reared from over 125 species of plants, including non-cucurbits. The potentially wide host range makes it an extremely dangerous invasive species. Males are attracted to Cuelure.

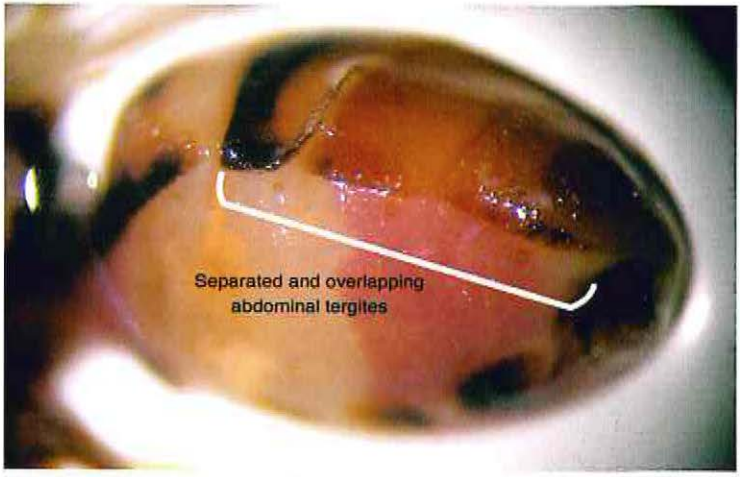
Medial stripe very prominent ('arrowhead-like' facing downwards). Wing with costal band expanded into apical spot. Scutellum with 4 marginal setae (2 apical scutellar and 2 basal scutellar). Face with a black line across mouth opening (From Oriental Asia and may be a potential pest of Cucurbitaceae; could also be confused with *B. cucurbitae*.) .... ***B. caudata.***

7. Scutum with a distinct black area and red-brown in the lateral area **(giving the appearance of lateral stripes).** Scutum without anterior supra-alar setae or prescutellar acrostichal setae. Scutellum with only 2 marginal setae (apical pair). Wing hyaline, except for a small mark at apex of vein R_{4+5} and sometimes a slight darkening of cell sc. Area of wing close to apex of vein A_1+CuA_2 with a dense patch of microtrichia (i.e. along *cup* extension). Segment 1 of abdomen (basal part of syntergite 1+2) about twice as broad at apex as at base and with segment 2 being part of the **general rounded shape** formed by segments 2–5. Oviscape slightly flattened in cross section, giving distinct lateral margins..... ..... ***B. oleae.***

B. oleae is a small reddish-brown species with no longitudinal yellow stripes on the thorax. The abdomen is orange medially and black laterally. Wings with reduced pattern and a distinct spot in the apex. Attacks only olives (*Olea europaea* and *O. africana*).



A. *Dacus* species



B. *Bactrocera* species

Figure 24. The main distinguishing features of the abdominal tergites between **(A)** *Dacus* Fabricius and **(B)** *Bactrocera* Macquart

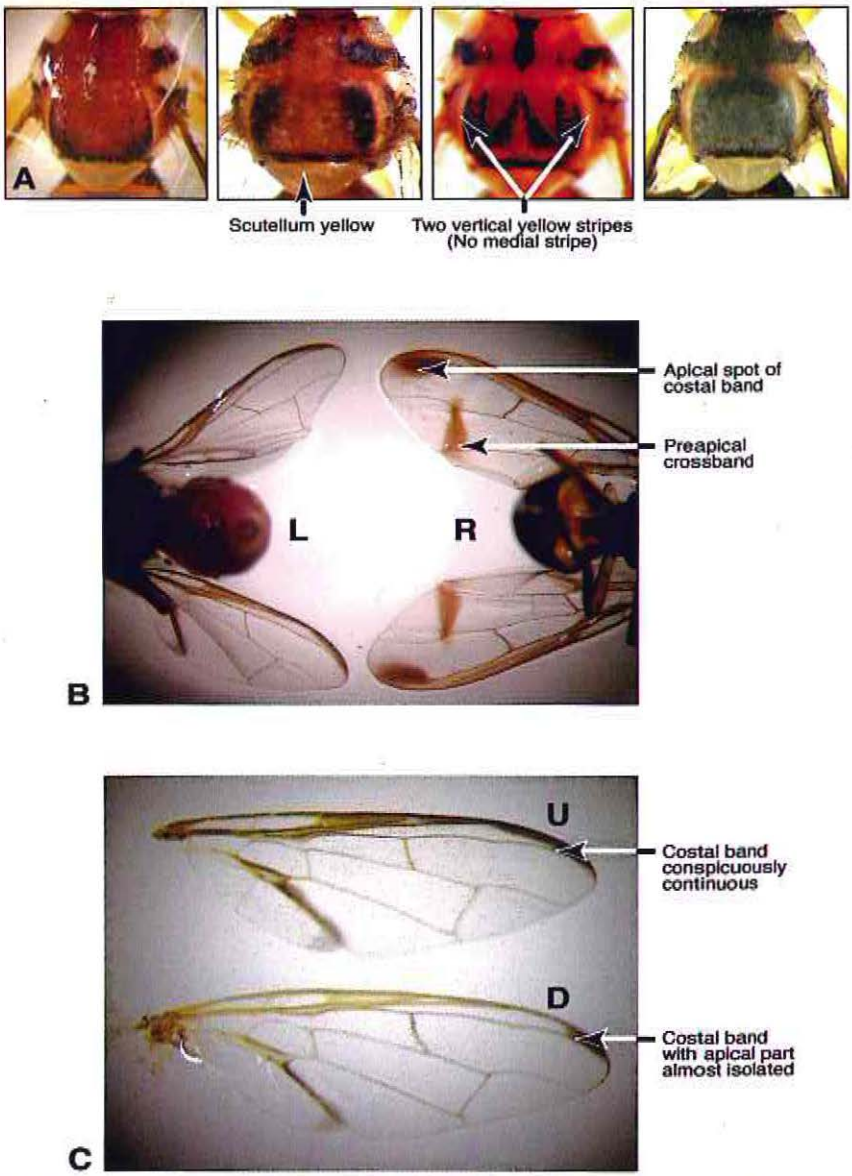


Figure 25. Thoracic and wing pattern variations in three *Bactrocera* species: **(A)** Variable thoracic colour patterns of *B. invadens*, **(B)** wing patterns of *B. invadens* (L) and *B. cucurbitae* (R) and **(C)** wing patterns of *B. invadens* (U) and *B. zonata* (D)

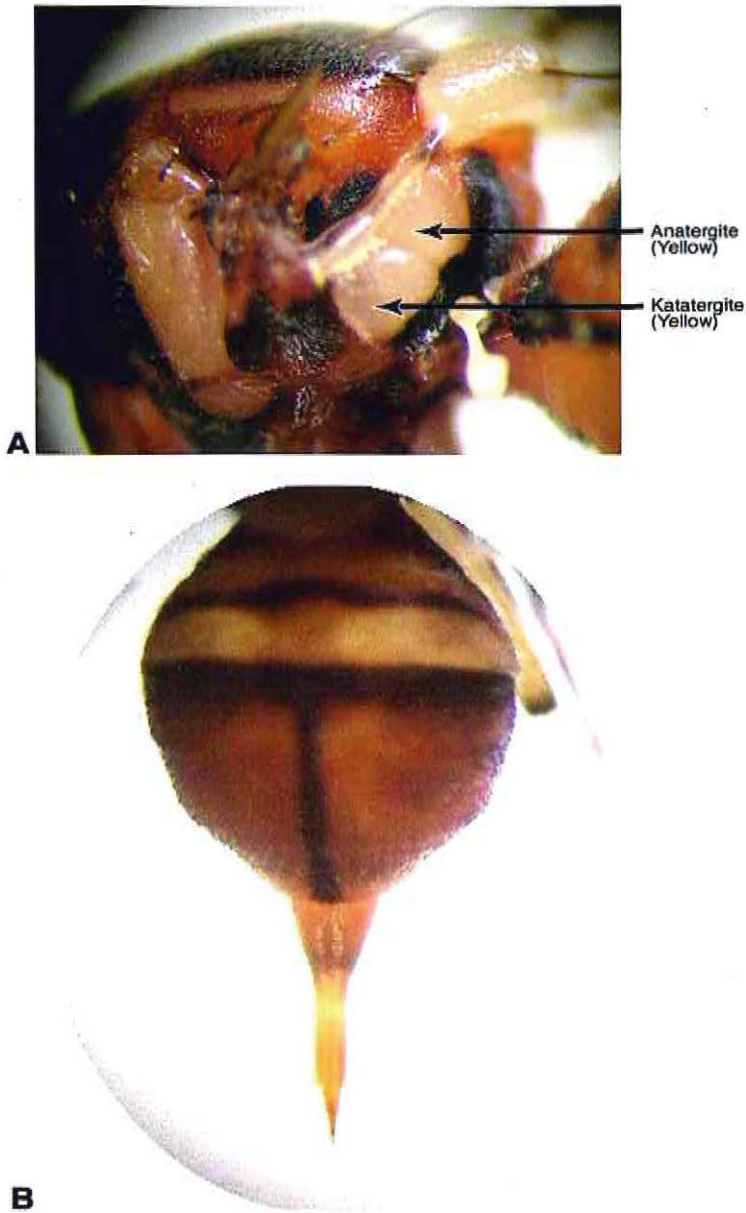


Figure 26. Thoracic and abdominal features of *Bactrocera invadens* female: **(A)** Thorax (side view) and **(B)** abdomen (dorsal view)

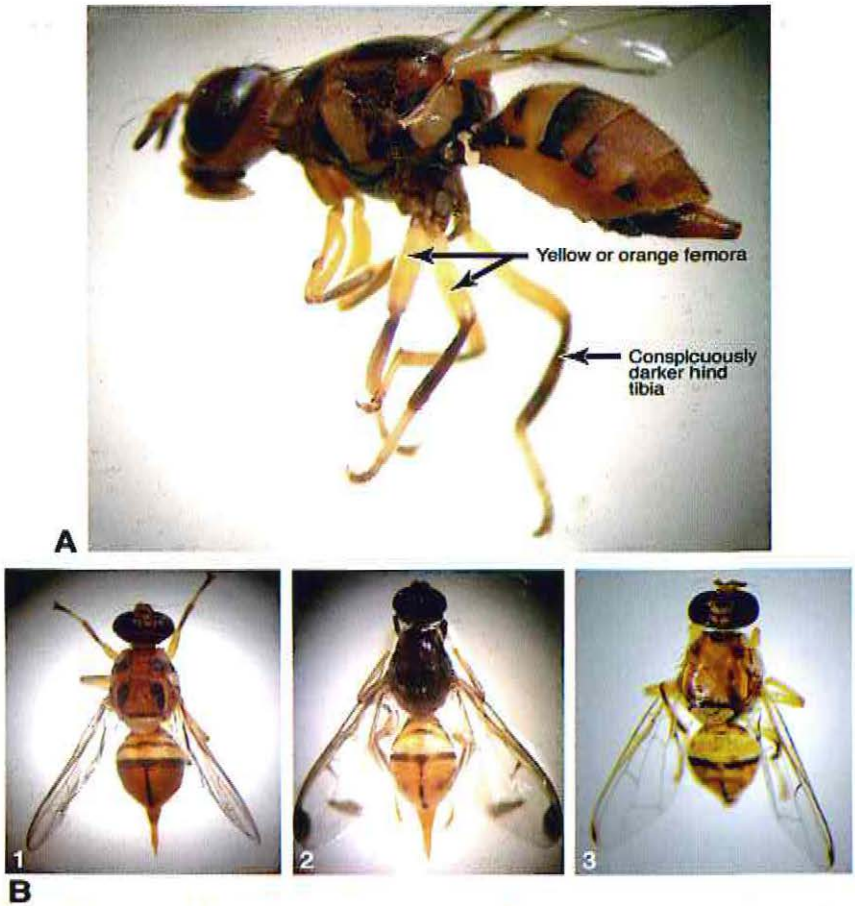


Figure 27. General physical appearance of some *Bactrocera* species: **(A)** *B. invadens* showing some femur and tibia features and **(B)** comparison of *B. invadens* (1), *B. cucurbitae* (2) and *B. zonata* (3)

References

Agnew A. D. Q. and Agnew S. (1994) *Upland Kenya Wild Flowers*. East African Natural History Society, Nairobi. 374 pp.

Beentje H. J. (1994) *Kenya Trees, Shrubs and Lianas*. National Museums of Kenya. 722 pp.

Blundell M. (1994) *Wild flowers of East Africa*. HarperCollins, Hong Kong. 160 pp.

Cunningham R. T. (1989) Parapheromones, pp. 221–229. In *Fruit Flies, Their Biology, Natural Enemies and Control* (Vol. 3A) (Edited by A. S. Robinson and G. Hooper). Elsevier, Amsterdam.

De Meyer M. (1996) Revision of the subgenus *Ceratitis (Pardalaspis)* Bezzi, 1918 (Diptera, Tephritidae, Ceratitini). *Systematic Entomology* 21, 15–26.

De Meyer M. (1998) Revision of the subgenus *Ceratitis (Ceratalaspis)* Hancock (Diptera: Tephritidae). *Bulletin of Entomological Research* 88, 257–290.

De Meyer M. (2001a) Distribution patterns and host-plant relationships within the genus *Capitata* MacLeay (Diptera: Tephritidae) in Africa. *Cimbebasia* 17, 219–228.

De Meyer M. (2001b) On the identity of the Natal fruit fly, *Ceratitis rosa* Karsch (Diptera: Tephritidae). *Entomologie* 71, 55–62.

De Meyer M. and White I. M. (2004) True fruit flies (Diptera, Tephritidae) of Africa. A queryable website on taxon and specimen information for afrotropical Ceratitidine fruit flies. Available at: http://projects.bebif.be/enbi/fruitfly/. Royal Museum for Central Africa, Tervuren. Access date: 13/06/2006.

De Meyer M., Copeland R. S., Wharton R. A. and McPheron B. A. (2002a) On the geographical origin of the medfly, *Ceratitis capitata* (Wiedemann). (Abstract: 6th Int'l Symposium on Fruit Flies of Economic Importance. Stellenbosch, S. Africa).

De Meyer M., Copeland R. S., Lux S. A., Mansell M., Quilici S., Wharton R., White I. M. and Zenz N. J. (2002b) Annotated checklist of host plants for Afrotropical fruit flies (Diptera: Tephritidae) of the genus *Ceratitis*. *Musée Royal de l'Afrique Centrale Tervuren, Belgique* 27, 1–91.

Drew R. A. I., Tsuruta K. and White I. M. (2005) A new species of pest fruit fly (Diptera: Tephritidae: Dacinae) from Sri Lanka and Africa. *African Entomology* 13, 149–154.

Economopoulos A. P. and Haniotakis G. E. (1994) Advances in attractant and trapping technologies for tephritids, pp. 57–66. In *Fruit Flies and the Sterile Insect Technique* (Edited by C. O. Calkins, W. Klassen and P. Liedo). CRC Press, Boca Raton.

Ekesi S., Nderitu P. W. and Rwomushana I. (2006) Field infestation, life history and demographic parameters of the fruit fly *Bactrocera invadens* (Diptera: Tephritidae) in Africa. *Bulletin of Entomological Research* (In Press).

Heath R. R., Epsky N. D., Dueben B. D., Rizzo J. and Jeronimo F. (1997) Adding methyl-substituted ammonia derivatives to a food-based synthetic attractant on capture of Mediterranean and Mexican fruit flies (Diptera: Tephritidae). *Journal of Economic Entomology* 90, 1584–1589.

IAEA [International Atomic Energy Agency] (2003) *Trapping Guidelines for Area-Wide Fruit Fly Programmes*. IAEA, Vienna, Austria. 47 pp.

Lux S. A., Ekesi S., Dimbi S., Mohamed S. A. and Billah M. K. (2003) Mango-infesting fruit flies in Africa: Perspectives and limitations of biological approaches to their management, pp. 277–293. In *Biological Control in IPM Systems in Africa* (Edited by P. Neuenschwander, C. Borgemeister and J. Langewald). CAB International, Wallingford, UK.

Mazor M., Gothilf S. and Galun R. (1987) The role of ammonia in the attraction of females of the Mediterranean fruit fly to protein hydrolysate baits. *Entomologia Experimentalis et Applicata* 43, 25–29.

Verdcourt B. (1971) Annonaceae, 1–132. In *Flora of Tropical East Africa* (Edited by B. Verdcourt, E. Milne-Redhead and R. M. Polhill). Crown Agents for Overseas Governments and Administrations, London.

Victor J. E, Koekemoer M., Fish L., Smíthies S. J. and Mössmer M. (2004) Herbarium Essentials: The Southern African Herbarium User Manual. Southern African Botanical Diversity Network Report No. 25. SABONET, Pretoria. 93 pp.

White I. M. and Elson-Harris M. M. (1992) *Fruit Flies of Economic Significance: Their Identification and Bionomics*. CAB International, Wallingford, UK. 602 pp.

Suggested Further Reading

Barnes B. N. (Ed.) (2004) *Proceedings of the 6th International Symposium on Fruit Flies of Economic Importance*. 6–10 May 2002. Stellenbosch, South Africa. Isteg Scientific Publications, South Africa. 510 pp.

McNutt D. N. (1976) *Insect Collecting in the Tropics*. Centre for Overseas Pest Research. College House, Wrights Lane, London. 67 pp.

Neuenschwander P., Borgemeister C. and Langewald J. (Eds) (2003) *Biological Control in IPM Systems in Africa*. CAB International, Wallingford, UK. 414 pp.

Robinson A. S. and Hooper G. (Eds) (1989a) *Fruit Flies: Their Biology, Natural Enemies and Control. World Crop Pests 3* (B). Elsevier Science, Amsterdam. 353 pp.

Robinson A. S. and Hooper G. (Eds) (1989b) *Fruit Flies: Their Biology, Natural Enemies and Control. World Crop Pests 3 (A)*. Elsevier Science, Amsterdam. 372 pp.

Walker A. K. and Crosby T. K. (1979) *The Preparation and Curation of Insects*. N. Z. Department of Scientific and Industrial Research, Information Series No. 130. Auckland. 55 pp.

Checklist of Host Plants of Some Major Tephritid Fruit Flies in Africa

Host plant		Fruit fly species*																											
Botanical name	Family name	C. cosyra		C. fasciventris		C. rosa		C. anonae		C. capitata		B. zonata		B. cucurbitae		B. invadens		D. ciliatus		D. punctatifrons		D. vertebratus	
Burceracea sp.	Burceraceae							■	■														
Guttiferae sp.	Clusiaceae							■	■														
Acca sellowiana	Myrtaceae					■	■																
Acokanthera cf oppositifolia	Apocynaceae									■	■												
Acokanthera oppositifolia	Apocynaceae									■	■												
Acokanthera schimperi	Apocynaceae			■	■					■	■												
Acokanthera sp.	Apocynaceae									■	■												
Adenia lobata	Passifloraceae	■	■																				
Aegle marmelos	Rutaceae																						
Allium cepa	Rutaceae																						
Abelmoschus esculentus	Malvaceae																	■	■				
Allophylus pervillei	Sapindaceae					■	■																
Anacardium occidentale	Anacardiaceae					■	■			■	■												
Ananas comosus	Bromeliaceae																						
Angylocalyx braunii	Fabaceae					■	■																
Anisophyllea laurina	Anisophylleaceae	■	■	■	■																		
Annona cherimola	Annonaceae	■	■							■	■												
Annona muricata	Annonaceae	■	■			■	■	■	■	■	■			■	■	■	■						
Annona reticulata	Annonaceae	■	■			■	■			■	■			■	■								
Annona senegalensis	Annonaceae	■	■			■	■							■	■								
Annona sp.	Annonaceae	■	■																				
Annona squamosa	Annonaceae					■	■			■	■	■	■	■	■								
Antidesma venosum	Euphorbiaceae									■	■												
Antiaris africana	Moraceae							■	■														
Antiaris toxicaria	Moraceae							■	■														
Arbustus unedo	Ericaceae									■	■												
Argania spinosa	Sapotaceae									■	■												
Artabotrys monteiroae	Annonaceae			■	■			■	■	■	■												
Artocarpus altilis	Moraceae																						
Artocarpus heterophyllus	Moraceae													■	■								
Artocarpus sp.	Moraceae							■	■														
Asparagus offinalis	Liliaceae																						
Asparagus sp.	Liliaceae									■	■												
Averrhoa bilimbi	Oxalidaceae					■	■			■	■												

Host plant		Fruit fly species*																											
Botanical name	Family name	*C. cosyra*		*C. fasciventris*		*C. rosa*		*C. anonae*		*C. capitata*		*B. zonata*		*B. cucurbitae*		*B. invadens*		*D. ciliatus*		*D. punctatifrons*		*D. vertebratus*	
Averrhoa carambola	Oxalidaceae					■	■			■	■														
Azima tetracantha	Salvadoraceae									■	■														
Benincasa hispida	Cucurbitaceae											■	■												
Berberis holstii	Berberidaceae									■	■														
Blighia sapida	Sapindaceae																								
Bourreria petiolaris	Boraginaceae									■	■														
Brassica juncea	Brassicaceae													■	■										
Brassica oleracea	Brassicaceae													■	■										
Brucea antidysenterica	Simaroubaceae									■	■														
Cajanus cajan	Fabaceae																								
Calophyllum inophyllum	Clusiaceae									■	■			■	■										
Calophyllum lanaharca	Clusiaceae					■	■			■	■														
Calotropsis procera	Asclepiadaceae																								
Cananga odorata	Annonaceae					■	■			■	■														
Capparis sepiaria	Capparaceae									■	■														
Capparis sepiaria var. citrifolia	Capparaceae									■	■														
Capparis sp.	Capparaceae									■	■														
Capsicum annuum	Solanaceae									■	■			■	■										
Capsicum frutescens	Solanaceae					■	■			■	■			■	■										
Capsicum sp.	Solanaceae																	■	■						
Carica cauliflora	Caricaceae					■	■																		
Carica papaya	Caricaceae					■	■			■	■	■	■	■	■			■	■						
Carissa carandas	Apocynaceae					■	■			■	■														
Carissa edulis	Apocynaceae									■	■														
Carissa grandiflora	Apocynaceae					■	■			■	■														
Carissa longiflora	Apocynaceae			■	■					■	■														
Carissa sp.	Apocynaceae									■	■														
Carissa tetramera	Apocynaceae									■	■														
Casimiroa edulis	Rutaceae									■	■			■	■										
Cereus peruvianus	Cactaceae					■	■																		
Chrysobalanus ellipticus	Chrysobalanaceae	■	■																						
Chrysobalanus icaco	Chrysobalanaceae									■	■														
Chrysobalanus sp.	Chrysobalanaceae	■	■																						
Chrysophyllum albidum	Sapotaceae																								
Chrysophyllum argyrophyllum	Sapotaceae									■	■														
Chrysophyllum cainito	Sapotaceae					■	■			■	■			■	■										
Chrysophyllum	Sapotaceae					■	■			■	■														

*Fruit fly species: ■ = Host

Host plant		Fruit fly species*																					
Botanical name	Family name	C. cosyra		C. fasciventris		C. rosa		C. anonae		C. capitata		B. zonata		B. cucurbitae		B. invadens		D. ciliatus		D. punctatifrons		D. vertebratus	
Chrysophyllum magalismontanum	Sapotaceae																						
Chrysophyllum natalense	Sapotaceae																						
Chrysophyllum oliviform	Sapotaceae																						
Chrysophyllum viridifolium	Sapotaceae																						
Chysophyllum sp.	Sapotaceae																						
Cinnamomum verum	Lauraceae																						
Citroncirus webberi	Rutaceae																						
Citrullus colocynthis	Cucurbitaceae																						
Citrullus lanatus	Cucurbitaceae																						
Citrus aurantiifolia	Rutaceae																						
Citrus aurantium	Rutaceae																						
Citrus japonica	Rutaceae																						
Citrus limetta	Rutaceae																						
Citrus limon	Rutaceae																						
Citrus maxima	Rutaceae																						
Citrus medica	Rutaceae																						
Citrus nobilis	Rutaceae																						
Citrus reticulata	Rutaceae																						
Citrus sinensis	Rutaceae																						
Citrus sp.	Rutaceae																						
Citrus x paradisi	Rutaceae																						
Citrus x tangelo	Rutaceae																						
Clausena anisata	Rutaceae																						
Clausena lansium	Rutaceae																						
Coccinia grandis	Cucurbitaceae																						
Coccinia microphylla	Cucurbitaceae																						
Coccoloba uvifera	Polygonaceae																						
Coffea arabica	Rubiaceae																						
Coffea canephora	Rubiaceae																						
Coffea liberica	Rubiaceae																						
Coffea sp.	Rubiaceae																						
Cola natalensis	Sterculiaceae																						
Corallocarpus ellipticus	Cucurbitaceae																						
Cordyla africana	Fabaceae																						
Cucumeropsis mannii	Cucurbitaceae																						
Cucumis dipsaceus	Cucurbitaceae																						
Cucumis melo	Cucurbitaceae																						
Cucumis metuliferus	Cucurbitaceae																						
Cucumis sativus	Cucurbitaceae																						

Host plant		Fruit fly species*																					
Botanical name	Family name	C. cosyra		C. fasciventris		C. rosa		C. anonae		C. capitata		B. zonata		B. cucurbitae		B. invadens		D. ciliatus		D. punctatifrons		D. vertebratus	
Cucurbita maxima	Cucurbitaceae													■	■			■	■			■	■
Cucurbita moschata	Cucurbitaceae													■	■								
Cucurbita pepo	Cucurbitaceae													■	■			■	■	■	■		
Cucurbita sp.	Cucurbitaceae					■	■			■	■												
Cydonia oblonga	Rosaceae					■	■			■	■	■	■	■	■								
Cydonia vulgaris	Rosaceae					■	■																
Cynometra sp.	Fabaceae							■	■														
Cyphomandra crassicaulis	Solanaceae													■	■								
Dichapetalum bangii	Dichapetalaceae							■	■														
Dimocarpus longan	Sapindaceae					■	■			■	■			■	■								
Diospyros digyna	Ebenaceae																						
Diospyros abyssinica	Ebenaceae									■	■												
Diospyros kaki	Ebenaceae					■	■			■	■												
Diospyros mespiliformis	Ebenaceae	■	■							■	■												
Diospyros pallens	Ebenaceae									■	■												
Diospyros pubescens	Ebenaceae									■	■												
Dorstenia virginiana	Moraceae																						
Dorstenia sp.	Moraceae							■	■														
Dovyalis caffra	Flacourtiaceae	■	■			■	■			■	■												
Dovyalis sp.	Flacourtiaceae			■	■			■	■														
Dovyalis hebecarpa	Flacourtiaceae					■	■			■	■												
Dracontomelon dao	Anacardiaceae																						
Dracontomelon sp.	Anacardiaceae					■	■			■	■			■	■								
Drypetes battiscombei	Euphorbiaceae					■	■																
Drypetes cf spinosodentata var. longipedonculata	Euphorbiaceae							■	■														
Drypetes gerrardii	Euphorbiaceae			■	■					■	■												
Drypetes gossweileri	Euphorbiaceae	■	■					■	■														
Drypetes natalensis	Euphorbiaceae					■	■			■	■												
Drypetes sp.	Euphorbiaceae			■	■			■	■	■	■												
Ehretia cymosa	Boraginaceae					■	■			■	■												
Ekebergia capensis	Meliaceae			■	■	■	■			■	■												
Elaeodendron schweinfurthianum	Celastraceae									■	■												
Englerophytum oblanceolatum	Sapotaceae			■	■			■	■														
Eriobotrya japonica	Rosaceae			■	■	■	■			■	■			■	■								
Euclea divinorum	Ebenaceae			■	■					■	■												
Euclea sp.	Ebenaceae									■	■												
Eugenia paniculata	Myrtaceae									■	■												
		■	■			■	■	■	■	■	■												

Host plant		Fruit fly species*																											
Botanical name	Family name	*C. cosyra*		*C. fasciventris*		*C. rosa*		*C. anonae*		*C. capitata*		*B. zonata*		*B. cucurbitae*		*B. invadens*		*D. ciliatus*		*D. punctatifrons*		*D. vertebratus*	
Feijoa sellowiana	Myrtaceae																						
Ficus carica	Moraceae																						
Ficus sp.	Moraceae																						
Filicium decipiens	Sapindaceae																						
Flacourtia indica	Flacourtiaceae																						
Flacourtia sp.	Flacourtiaceae																						
Flagellaria guineensis	Flagellariaceae																						
Flueggea virosa	Euphorbiaceae																						
Fortunella japonica	Rutaceae																						
Fragaria chiloensis	Rosaceae																						
Garcinia livingstonei	Clusiaceae																						
Garcinia mangostana	Clusiaceae																						
Gloriosa sp.	Liliaceae																						
Gossypium sp.	Malvaceae																						
Grewia asiatica	Tiliaceae																						
Grewia trichocarpa	Tiliaceae																						
Guettarda speciosa	Rubiaceae																						
Harpephyllum caffrum	Anacardiaceae																						
Harrisonia abyssinica	Simaroubaceae																						
Hylocereus undatus	Cactaceae																						
Inga laurina	Fabaceae																						
Juglans hindsii	Juglandaceae																						
Lablab purpureus	Fabaceae																						
Lagenaria siceraria	Cucurbitaceae																						
Lamprothamnus zanguebaricus	Rubiaceae																						
Landolphia florida	Apocynaceae																						
Landolphia kirkii	Apocynaceae																						
Landolphia sp.	Apocynaceae																						
Leptactina platyphylla	Rubiaceae																						
Lettowianthus stellatus	Annonaceae																						
Litchi chinensis	Sapindaceae																						
Ludia mauritiana	Flacourtiaceae																						
Luffa acutangula	Cucurbitaceae																						
Luffa aegyptiaca	Cucurbitaceae																						
Lycium campanulatum	Solanaceae																						
Lycium sp.	Solanaceae																						
Lycopersicum esculentum	Solanaceae																						
Malpighia glabra	Malpighiaceae																						

Host plant		Fruit fly species*																					
Botanical name	Family name	C. cosyra		C. fasciventris		C. rosa		C. anonae		C. capitata		B. zonata		B. cucurbitae		B. invadens		D. ciliatus		D. punctatifrons		D. vertebratus	
Malus domestica	Rosaceae					■	■			■	■	■	■	■	■								
Malus pumila	Rosaceae									■	■	■	■	■	■								
Mammea americana	Clusiaceae																						
Mangifera indica	Anacardiaceae	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				
Manilkara butugi	Sapotaceae									■	■												
Manilkara sansibarensis	Sapotaceae									■	■												
Manilkara sulcata	Sapotaceae									■	■												
Manilkara zapota	Sapotaceae					■	■			■	■	■	■										
Mimusops bagshawei	Sapotaceae									■	■												
Mimusops caffra	Sapotaceae									■	■												
Mimusops elengi	Sapotaceae					■	■			■	■												
Mimusops kirkii	Sapotaceae									■	■												
Mimusops kummel	Sapotaceae									■	■												
Mimusops obtusifolia	Sapotaceae									■	■												
Mimusops sp.	Sapotaceae							■	■	■	■												
Mimusops zeyheri	Sapotaceae									■	■												
Momordica balsamina	Cucurbitaceae													■	■			■	■				
Momordica calantha	Cucurbitaceae			■	■							■	■	■	■			■	■	■	■		
Momordica cochinchinensis	Cucurbitaceae													■	■								
Monanthotaxis fornicata	Annonaceae					■	■																
Monodora grandidieri	Annonaceae					■	■			■	■												
Muntingia calabura	Elaeocarpaceae																						
Morus alba	Moraceae																						
Morus mesozygia	Moraceae							■	■														
Murraya paniculata	Rutaceae					■	■			■	■												
Musa nana	Musaceae					■	■																
Musa x paradisiaca	Musaceae					■	■							■	■								
Musa sp.	Musaceae															■	■						
Myrciaria cauliflora	Myrtaceae																						
Myrianthus arboreus	Cecropiaceae			■	■	■	■	■	■	■	■												
Myrianthus sp.	Cecropiaceae							■	■														
Nephelium lappaceum	Sapindaceae							■	■														
Olea europaea	Oleaceae																						
Olea europaea ssp africana	Oleaceae									■	■												
Olea woodiana	Oleaceae									■	■												
Omaralia calycina	Rubiaceae							■	■														
Opilia amentacea	Opiliaceae									■	■												

Host plant		Fruit fly species*																					
Botanical name	Family name	C. cosyra		C. fasciventris		C. rosa		C. anonae		C. capitata		B. zonata		B. cucurbitae		B. invadens		D. ciliatus		D. punctatifrons		D. vertebratus	
Opuntia tuna	Cactaceae																						
Opuntia vulgaris	Cactaceae																						
Opuntia sp.	Cactaceae																						
Oxyanthus zanguebaricus	Rubiaceae																						
Pachystela excelsa	Sapotaceae																						
Pancovia laurentii	Sapindaceae																						
Pancovia turbinata	Sapindaceae																						
Panda oleosa	Pandaceae																						
Parmentiera aculeata	Bignoniaceae																						
Passiflora caerulea	Passifloraceae																						
Passiflora cf subpeltata	Passifloraceae																						
Passiflora edulis	Passifloraceae																						
Passiflora foetida	Passifloraceae																						
Passiflora laurifolia	Passifloraceae																						
Passiflora sp.	Passifloraceae																						
Passiflora suberosa	Passifloraceae																						
Passiflora quadrangularis	Passifloraceae																						
Pentarhopalopilia umbellulata	Opiliaceae																						
Peponium mackenii	Cucurbitaceae																						
Pereskia aculeata	Cactaceae																						
Persea americana	Lauraceae																						
Persea gratissima	Lauraceae																						
Phaseolus sp.	Fabaceae																						
Phaseolus lanatus	Fabaceae																						
Phaseolus vulgaris	Fabaceae																						
Phoenix dactylifera	Arecaceae																						
Phyllanthus acidus	Euphorbiaceae																						
Physalis peruviana	Solanaceae																						
Physalis dioica	Solanaceae																						
Pithecellobium dulce	Fabaceae																						
Podocarpus elongatus	Podocarpaceae																						
Polysphaeria parvifolia	Rubiaceae																						
Pouteria altissima	Sapotaceae																						
Pouteria campechiana	Sapotaceae																						
Pouteria sapota	Sapotaceae																						
Pouteria usambarensis	Sapotaceae																						
Pouteria viridis	Sapotaceae																						
Prunus africana	Rosaceae																						

Host plant		Fruit fly species*																											
Botanical name	Family name	C. cosyra		C. fasciventris		C. rosa		C. anonae		C. capitata		B. zonata		B. cucurbitae		B. invadens		D. ciliatus		D. punctatifrons		D. vertebratus	
Prunus armeniaca	Rosaceae																						
Prunus cerasus	Rosaceae																						
Prunus cf capuli	Rosaceae																						
Prunus domestica	Rosaceae																						
Prunus persica	Rosaceae																						
Prunus sp. cf capuli	Rosaceae																						
Psidium cattleyanum	Myrtaceae																						
Psidium friedrichsthalianum	Myrtaceae																						
Psidium granatum	Myrtaceae																						
Psidium guajava	Myrtaceae																						
Psidium guineense	Myrtaceae																						
Psidium japonicum	Myrtaceae																						
Psidium littorale	Myrtaceae																						
Psidium sp.	Myrtaceae																						
Punica granatum	Punicaceae																						
Pyrus communis	Rosaceae																						
Rawsonia lucida	Flacourtiaceae																						
Rawsonia sp.	Flacourtiaceae																						
Rawsonia usambarensis	Flacourtiaceae																						
Richardella campechiana	Sapotaceae																						
Rollinia mucosa	Annonaceae																						
Rubus flagelaris	Rosaceae																						
Rubus fruticosa	Rosaceae																						
Saba senegalensis	Apocynaceae																						
Salacia elegans	Hippocrateaceae																						
Sandoricum koetjape	Meliaceae																						
Santalum album	Santalaceae																						
Sarcocephalus exculentus	Rubiaceae																						
Sarcocephalus latifolius	Rubiaceae																						
Scaevola plumieri	Goodeniaceae																						
Scaevola sericea	Goodeniaceae																						
Scaevola taccada	Goodeniaceae																						
Schefflera volkensii	Araliaceae																						
Sclerocarya birrea	Anacardiaceae																						
Sclerocarya sp.	Anacardiaceae																						
Sechium edule	Cucurbitaceae																						
Sesbania grandiflora	Fabaceae																						
Sideroxylon inerme	Sapotaceae																						

Host plant		Fruit fly species*																							
Botanical name	Family name	C. cosyra		C. fasciventris		C. rosa		C. anonae		C. capitata		B. zonata		B. cucurbitae		B. invadens		D. ciliatus		D. punctatifrons		D. vertebratus	
Solanum cf. monotanthum	Solanaceae																						
Solanum giganteum	Solanaceae																						
Solanum incanum	Solanaceae																						
Solanum macrocarpon	Solanaceae																						
Solanum mauritianum	Solanaceae																						
Solanum melongena	Solanaceae																						
Solanum nigrum	Solanaceae																						
Solanum pseudocapsicum	Solanaceae																						
Solanum sealorthianum	Solanaceae																						
Solanum sp.	Solanaceae																						
Sorindea sp.	Solanaceae																						
Sphaerocoryne gracilis	Annonaceae																						
Spondias cytherea	Anacardiaceae																						
Spondias mombin	Anacardiaceae																						
Spondias purpurea	Anacardiaceae																						
Spondias sp.	Anacardiaceae																						
Strombosia scheffleri	Olacaceae																						
Strychnos decussata	Loganiaceae																						
Strychnos henningsii	Loganiaceae																						
Strychnos nux-vomica	Loganiaceae																						
Strychnos potatorum	Loganiaceae																						
Strychnos pungens	Loganiaceae																						
Strychnos sp.	Loganiaceae																						
Strychnos spinosa	Loganiaceae																						
Synsepalum brevipes	Sapotaceae																						
Synsepalum dulcificum	Sapotaceae																						
Synsepalum subverticillatum	Sapotaceae																						
Syzygium aqueum	Myrtaceae																						
Syzygium cumini	Myrtaceae																						
Syzygium jambos	Myrtaceae																						
Syzygium malaccense	Myrtaceae																						
Syzygium samarangense	Myrtaceae																						
Tabernaemontana penduliflora	Apocynaceae																						
Terminalia catappa	Combretaceae																						
Terminalia chebula	Combretaceae																						
Theobroma cacao	Sterculiaceae																						

Host plant		Fruit fly species*																											
Botanical name	Family name	C. cosyra		C. fasciventris		C. rosa		C. anonae		C. capitata		B. zonata		B. cucurbitae		B. invadens		D. ciliatus		D. punctatifrons		D. vertebratus	
Thevetia peruviana	Araliaceae																						
Tiliacora funifera	Menispermaceae																						
Toddalia asiatica	Rutaceae																						
Tricalysia pallens	Rubiaceae																						
Trichosanthes cucumerina	Cucurbitaceae																						
Trichosanthes cloica	Cucurbitaceae																						
Triphasia sp.	Rutaceae																						
Triphasia trifolia	Rutaceae																						
Uapaca kirkiana	Euphorbiaceae																						
Uvaria acuminata	Annonaceae																						
Uvaria lucida	Annonaceae																						
Vangueria infausta	Rubiaceae																						
Vangueria sp.	Rubiaceae																						
Vepris lanceolata	Rutaceae																						
Vepris nobilis	Rutaceae																						
Vepris simplicifolia	Rutaceae																						
Vepris trichocarpa	Rutaceae																						
Vigna radiata	Orchidaceae																						
Vigna unguiculata	Orchidaceae																						
Vitis vinifera	Vitaceae																						
Warburgia salutaris	Canellaceae																						
Warburgia sp.	Canellaceae																						
Ximenia americana	Olacaceae																						
Ximenia americana var. caffra	Olacaceae																						
Ziziphus abyssinica	Rhamnaceae																						
Ziziphus jujuba	Rhamnaceae																						
Ziziphus mauritiania	Rhamnaceae																						

References: De Meyer et al. (2002b), White and Elson-Harris (1992), Rwomushana and Seguni - unpublished data.

C., Ceratitis; B., Bactrocera; D, Dacus.

Fruit Fly Monitoring Datasheet

Country:..... Collector: .....

Trap ID No.	Location	Trap station	Habitat	Trap type	Lure type	Date of placement	Date of collection	GPS reading			Fruit fly species	Males	Females	Total	Non target species	No. of non target species	F/T/D*	Remarks
								Alt	Long.	Lat.								

*F/T/D = Flies per trap per day.

Sample Spreadsheet for Managing Fruit Fly Host Fruit Processing Data

Lab rearing number	Sampling date	Province	Location	Latitude	Longitude	Altitude (metres)	Plant species	Plant family	Plant identifier	Notes on collection	Detailed field note reference no.	Wild/cultivated	Number of fruits	Weight (grams)	Tephritid species 1	Tephritid species 2	Tephritid species 3	Tephritid species 4	Other insect species 1	Other insect species 2	Other insect species 3	Other insect species 4	Other insect species 5
3	6-Jun-01	Western	Kakamega Forest	0° 14.13′ N	34° 51.87′ E	1550	*Antiaris toxicaria*	Moraceae	RSC		1	w	34	52	*C. flexuosa*	*C. anonae*							
1	7-Jun-01	Western	Kakamega Forest	0° 12.732′ N	34° 55.430′ E	1570	*Manilkara butugi*	Sapotaceae	RSC	Ikuywa River	1	w	258	505									
2	7-Jun-01	Nyanza	Koru	0° 08.196′ S	35° 16.861′ E	1565	*Momordica foetida*	Cucurbitaceae	RSC	CRF	2	w	28	610	*D. sphaeristicus*	*D. limbipennis*							
4	11-Jun-01	Nairobi	Nairobi	1° 16.44′ S	36° 48.83′ E	1674	*Psychotria kirkii*	Rubiaceae	RSC	NMK	1	w	795	192									
5	11-Jun-01	Nairobi	Nairobi	1° 16.44′ S	36° 48.83′ E	1674	*Diplocyclos palmatus*	Cucurbitaceae	RSC	NMK	2	w	52	80	*D. punctatifrons*	*B. cucurbitae*							
6	11-Jun-01	Nairobi	Nairobi	1° 16.44′ S	36° 48.83′ E	1674	*Rothmannia urcelliformis*	Rubiaceae	RSC	NMK	3	w	7	338									
7	18-Jun-01	Nairobi	Nairobi	1° 14.45′ S	36° 47.24′ E	1774	*Zehneria scabra*	Cucurbitaceae	RSC	Kitisuru Rd.	1	w	425	56	*D. triater*								
8	18-Jun-01	Nairobi	Nairobi	1° 13.27′ S	36° 53.78′ E	1627	*Ziziphus* sp	Rhamnaceae	RSC	Kasarani, nr ICIPE	2	w	124	488									
9	18-Jun-01	Nairobi	Nairobi	1° 15.61′ S	36° 49.76′ E	1697	*Strychnos mitis*	Loganiaceae	RSC	City Park forest	3	w	119	127	*C. querita*								
10	18-Jun-01	Nairobi	Nairobi	1° 15.61′ S	36° 49.76′ E	1697	*Ekebergia capensis*	Meliaceae	RSC	City Park forest	4	w	148	340									

RSC, R. S. Copeland; NMK, National Museums of Kenya ; CRF, Coffee Research Foundation.

The development of horticultural industries to meet both domestic consumption and export to lucrative markets abroad is an important component of the economic development of African countries. However, tephritid fruit flies constitute a major constraint to increased production of fruits and vegetables in Africa. They cause enormous losses through direct feeding damage and loss of market opportunities through imposition of strict quarantine by importing countries to prevent entry and establishment of fruit flies.

At the concluding meeting of the first phase of an FAO TCP project on surveillance and management of the invasive fruit fly species *Bactrocera invadens* in East Africa, and the Dutch Programme for Cooperation with International Institutions (Netherlands-SII) and IFAD-sponsored International Group Training Course on Fruit fly Management in October 2005, representatives of National Plant Protection Organisations (NPPOs) of participating countries expressed the need for development of a field manual for management of economically important tephritid fruit flies in Africa in view of the fruit fly-related trans-boundary invasions arising from increased travel and trade in fruits and vegetables.

The manual provides information on the life cycle, damage symptoms, species composition, distribution and host plants of major fruit flies attacking fruits and vegetables in Africa. The purpose, tools and methodology for fruit fly monitoring, suppression and host fruit processing and handling are also comprehensively covered. Additionally, brief sections on safety precautions during monitoring and suppression, and packaging, handling and shipment of specimens to facilitate identification are provided. The field guide also provides a simple, user-friendly taxonomic key to all the common fruit flies to allow for rapid identification of the major species found on fruits and vegetables in Africa.

This is an indispensable reference book for agricultural scientists, extension workers and quarantine specialists involved in fruit fly monitoring, detection and management.

ISBN: 92 9064 179 7