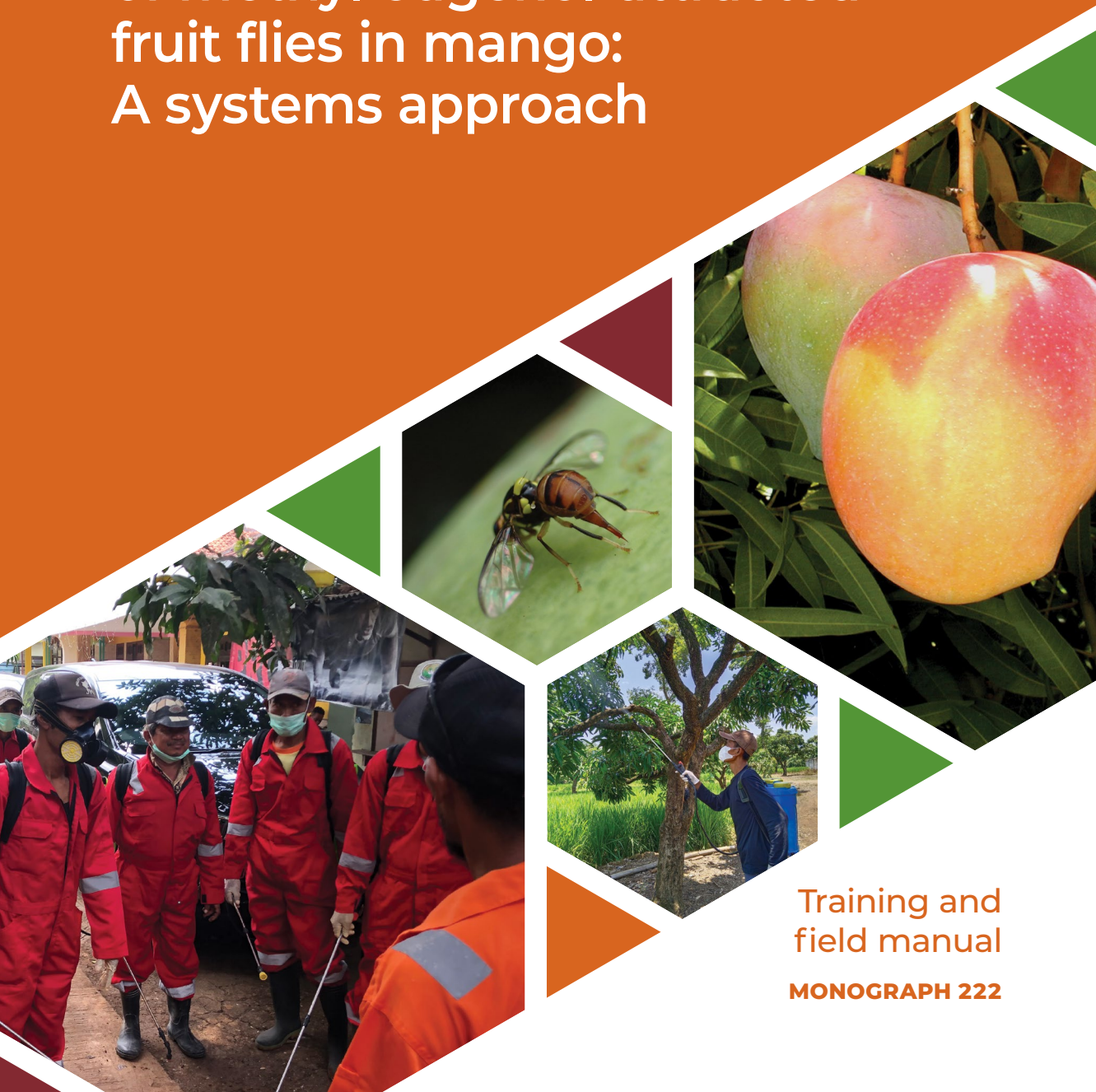
Australian Government
Australian Centre for
International Agricultural Research

Area-wide management of methyl eugenol-attracted fruit flies in mango: A systems approach



Training and field manual

MONOGRAPH 222

Area-wide management of methyl eugenol-attracted fruit flies in mango: A systems approach

Stefano De Faveri, S Vijaysegaran and Jodie Cheesman

2024

The Australian Centre for International Agricultural Research (ACIAR) was established in June 1982 by an Act of the Australian Parliament. ACIAR operates as part of Australia's international development assistance program, with a mission to achieve more productive and sustainable agricultural systems, for the benefit of developing countries and Australia. It commissions collaborative research between Australian and developing-country researchers in areas where Australia has special research competence. It also administers Australia's contribution to the International Agricultural Research Centres.

The Chief Executive Officer of ACIAR reports directly to the Australian Government Minister for Foreign Affairs. ACIAR operates solely on budget appropriation from Australia's Official Development Assistance (ODA).

The use of trade names constitutes neither endorsement of nor discrimination against any product by ACIAR.

ACIAR MONOGRAPH SERIES

This series contains the results of original research supported by ACIAR, or material deemed relevant to ACIAR research and development objectives. Publications in this series range from detailed scientific reports and analysis, written for researchers, extension agents and policymakers, to guides and manuals to support new or improved practices for smallholder farmers, fishers and foresters. Publications in the series are available as hard copy, in limited numbers, and online from the ACIAR website at **aciar.gov.au**

De Faveri S, Vijaysegaran S and Cheesman J (2024) *Area-wide management of methyl eugenol-attracted fruit flies in mango: A systems approach*, ACIAR Monograph No. 222, Australian Centre for International Agricultural Research, Canberra.

ACIAR Monograph Series No. 222 (MN222)

ISSN 1031-8194 (print)
ISSN 1447-090X (pdf)
ISBN 978-1-922983-95-4 (print)
ISBN 978-1-922983-96-1 (pdf)

Proofreading by Lorna Hendry
Design by Redtail Design
Printing by Elect Printing

Foreword

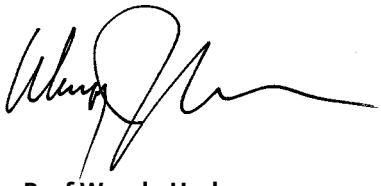
Fruit flies are one of the most serious horticultural pests globally, causing catastrophic damage to fruit and vegetable crops, and significant economic losses negatively affecting the livelihoods of millions of farmers. Fruit fly infestation is a major barrier to trade and market access, as many countries impose strict quarantine measures to prevent the introduction and spread of these pests.

Finding effective and sustainable ways to manage fruit fly infestation is a priority for many developing countries in the Asia-Pacific region. One of the most promising strategies is area-wide management, which involves the coordinated implementation of a range of control methods across a defined geographic area, targeting the entire fruit fly population rather than striving to achieve control on individual farms or orchards.

The Australian Centre for International Agricultural Research (ACIAR) is mandated under the *Australian Centre for International Agricultural Research Act 1982* to work with partners across the Indo-Pacific region to generate knowledge and technologies that underpin improvements in agricultural productivity, sustainability and food systems resilience. We do this by funding, brokering and managing research partnerships for the benefit of partner countries and Australia.

ACIAR has funded 3 major projects in Indonesia and the Philippines that have developed, tested and promoted area-wide management system (AWM system) programs for fruit fly. Drawing on knowledge and experience from these projects, this manual is a comprehensive and practical guide to the implementation of an AWM system, covering the key concepts, principles, steps and techniques involved. It is a useful tool that will help communities in tropical and subtropical regions manage fruit fly infestation.

I hope that this manual will inspire and assist many growers, practitioners and researchers to adopt and adapt an AWM system to improve the productivity, profitability and sustainability of horticultural production systems.



Prof Wendy Umberger
Chief Executive Officer, ACIAR

Contents

List of figures

List of tables

List of boxes

Authors

Stefano De Faveri

Department of Agriculture and Fisheries Queensland

Cleveland, Australia

S Vijaysegaran

Consultant entomologist

Kenmore, Queensland, Australia

Jodie Cheesman

Department of Agriculture and Fisheries Queensland

Mareeba, Australia

Contributors

Affandi

Badan Riset dan Inovasi Nasional (National Research and Innovation Agency of Indonesia), Pasuruan, Indonesia

Cecep

Balai Perlindungan Tanaman Pangan dan Hortikultura Provinsi Jawa Barat, (Centre for Food Crop Protection and Horticulture West Java Province), Cirebon, Indonesia

Deni Emilda

Badan Standardisasi Instrumen Pertanian (Indonesian Agency for Agricultural Instrument Standardization), Solok, Indonesia

Hendri

Badan Standardisasi Instrumen Pertanian (Indonesian Agency for Agricultural Instrument Standardization), Solok, Indonesia

Peter Johnson

Consultant horticulturist

Kununurra, Western Australia

Nelly Saptayanti

Direktorat Jenderal Hortikultura (Directorate General of Horticulture), Jakarta, Indonesia

Elvan Setyono

APMK – farmer group, Mekarjaya, Indonesia

Suputa

Universitas Gadjah Mada, Yogyakarta, Indonesia

Valentina E F Aryuwandari

Universitas Gadjah Mada, Yogyakarta, Indonesia

Waryana

Angling Darma - farmer group, Krasak, Indonesia

Y. Andi Trisyono

Universitas Gadjah Mada, Yogyakarta, Indonesia

Acknowledgements

This manual is a product of the research project 'Development of area-wide management approaches for fruit flies in mango for Indonesia, Philippines, Australia and the Asia-Pacific region' (HORT/2015/042), funded by the Australian Centre for International Agricultural Research (ACIAR). Predominantly, the manual is based on research outcomes from this project with partners in Indonesia. It also draws on fruit fly research from previous ACIAR-supported projects in the region.

The authors greatly appreciate the following institutions whose funding, facilities and collaboration has enabled the completion of research used in this manual:

- Queensland Department of Agriculture and Fisheries
- Badan Standardisasi Instrumen Pertanian (Indonesian Agency for Agricultural Instrument Standardization)
- Badan Riset dan Inovasi Nasional (National Research and Innovation Agency of Indonesia)
- Direktorat Jenderal Hortikultura, Direktorat Perlindungan Hortikultura (Directorate General Horticulture, Directorate of Horticulture Protection)
- University of Gadjah Mada – Indonesian Centre for Agriculture Socio Economic and Policy Studies.

We thank the following farmer groups/villages for allowing us to undertake the area-wide management system research on their properties.

- Angling Darma – Krasak Village, Indramayu
- Suka Mulya – Sedong Lor Village, Cirebon
- APMK – Mekerjaya Village, Majalengka
- Pawidean Village farmers, Indramayu
- Cilopang, Putat Village, Cirebon

Illustrations were produced by Studio Manga Rokyu, Kota Bogor, Indonesia.

Abbreviations

a.i.	active ingredient
AWM	Area-wide management
BAT	Bait application technique
FTD	Flies per trap per day
GIS	Geographic information system
GPS	Global positioning system
MAT	Male annihilation technique
MDF	Medium density fibreboard
ME	Methyl eugenol
PPE	Personal protective equipment

Introduction

Mango is an important commodity and is the most widely cultivated fruit in the Asia-Pacific region. It is grown mainly by resource-poor smallholders and farm families for whom mango cultivation is the main or an additional source of income.

Farmers generally sell produce to local collectors, who are the start of the wholesale part of the value chain. Produce moves through several levels of the value chain before reaching the consumer. Most of the produce is sold domestically, with some being exported. However, countries are aspiring to increase mango production for export markets.

Many pests and diseases affect mango production. The most serious is an insect pest called the fruit fly. The main species that infests mango crops in Asia and parts of the Pacific is the oriental fruit fly (*Bactrocera dorsalis*). The carambola fruit fly (*B. carambolae*) and the peach fruit fly (*B. zonata*) are major pests in Asia. The Pacific fruit fly (*B. xanthodes*), as it name suggests, is a major pest in the Pacific. These fruit fly belong to the order Diptera and family Tephritidae. Many other species of fruit fly also occur in the family Tephritidae.

Fruit flies are pests of international quarantine importance. The export and free trade of mangoes from countries where fruit fly infestations occur is severely restricted, impacting farmer incomes and access to international markets.

High fruit fly infestation rates of mango are common in the Asia-Pacific region and result in proportionally high rejection rates of produce. The profitability and viability of mango growers is threatened without the development of effective management systems for the pest.

This manual has been prepared for extension officers and technical staff who are interested in and plan to establish an area-wide management (AWM) system to manage fruit fly in mango trees and orchards.

The manual provides information about fruit fly biology, current control measures for the pest and the benefits of implementing an AWM system. It presents the steps for implementing and managing an AWM system. The steps include fruit fly identification, making and monitoring traps, and installing suppression technologies.

Safe handling of the insecticides and chemicals recommended in an AWM system is critical. This manual provides important information for all chemical users.

1. Fruit fly biology and behaviour

1. Fruit fly biology and behaviour

Four species of fruit fly commonly infest mango. These are:

- oriental fruit fly (*Bactrocera dorsalis*)
- carambola fruit fly (*B. carambolae*)
- peach fruit fly (*B. zonata*)
- Pacific fruit fly (*B. xanthodes*).

The information presented in this manual has been designed for, and tested on, the oriental fruit fly and carambola fruit fly (**Figure 1**).

FIGURE 1 Two species of fruit fly

Top: Adult oriental fruit fly. Bottom: Adult carambola fruit fly.

Correct species identification is critical to the successful management of the fruit flies that are infesting the crop.

Different species respond differently to different management techniques. For example, oriental fruit fly and carambola fruit fly males are attracted to the male lure, methyl eugenol, whereas the Queensland fruit fly (*B. tryoni*) males are attracted to cue lure, and some species do not respond to male lures at all.

The Fruit Fly Identification Australia website (**fruitflyidentification.org.au**) is a useful resource for identification of pest fruit fly species in the Asia-Pacific region.

1.1 Life cycle

Understanding the fruit fly life cycle (for example, knowing the time it takes to complete the life cycle and the required time for adult flies to mature and lay eggs) helps in the development and application of management techniques.

Adult female fruit flies pierce the skin of fruits with their needle-like ovipositor and lay their eggs under the skin.

The eggs hatch in 1–2 days into larvae which undergo 3 developmental stages (known as instars). The larvae burrow into and feed on the flesh of the fruit. The first instar larvae are small and difficult to see, but the second and third instar larvae are more visible to the naked eye.

The larvae reach maturity at about 9–10 days, after which they exit the fruit, fall to the ground, and pupate in the soil.

The pupal period is approximately 10 days. After this period the flies emerge as sexually immature adults. It is these immature adult flies that are most attracted to protein baits (**8.2 Bait application**).

The complete life cycle of a fruit fly takes approximately 3 weeks in warm tropical climates (**Figure 2**).

The length of the life cycle depends on the ambient temperature, so in cooler or dryer climates the life cycle may take a little longer to complete. The short life cycle means that fruit flies can multiply rapidly if not controlled.

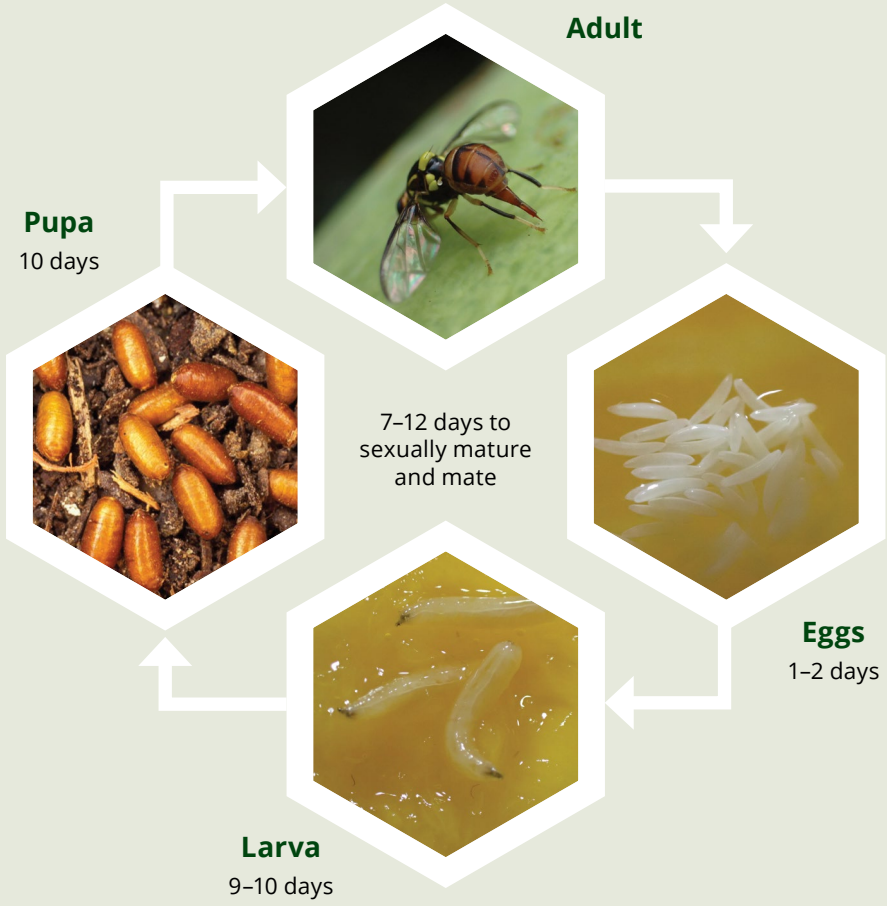


FIGURE 2 Life cycle of the fruit fly (*B. dorsalis*)

1.2 Biology and feeding

Adult fruit flies have mouthparts that are adapted to a fluid mode of feeding. They also have a filtering mechanism that prevents them from consuming solid particles larger than 0.5 microns in diameter. As part of their feeding behaviour, fruit flies ingest large amounts of fluids and store them in a sac-like structure in the abdomen. This structure, which forms part of their alimentary system, is called the crop (**Figure 3**).

Adult fruit flies actively regurgitate fluids from their crops to dissolve solid foods, such as carbohydrates and proteins from leaf and fruit surfaces then re-ingest the mixture as a liquid (**Figure 4**).

This feeding behaviour allows us to use protein baits to attract and kill adult fruit flies in the field (Vijaysegaran et al. 1997).

FIGURE 4 A Queensland fruit fly (*B. tryoni*) regurgitating blue liquid food dye from its crop

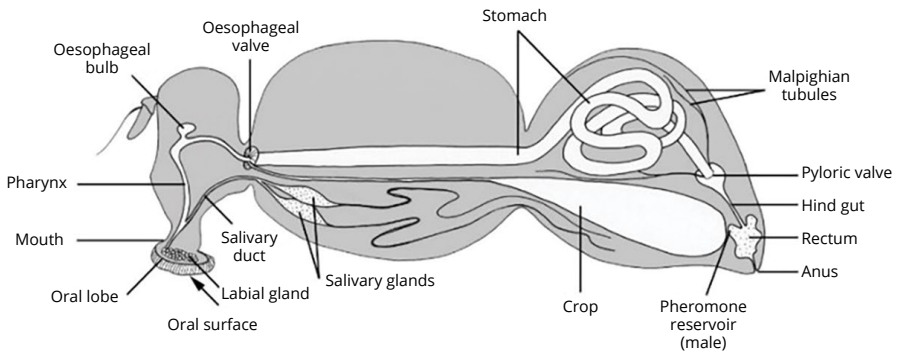


FIGURE 3 Longitudinal section of an adult fruit fly

1.3 Behaviour

Adult fruit flies are only active during the day; they rest under leaf surfaces at night. They start to become active at sunrise and begin to forage for food and water on the foliage and surfaces of fruit, most commonly of their larval host plants.

Most species of fruit fly mate at dusk, with the exception being *B. neohumeralis* in Australia, which mates at noon. Male flies gather under the surface of the leaves of the host plant and begin a mating ritual where they emit a sex pheromone to call or attract female flies. Female flies are attracted to the odour of this pheromone and fly to the spots where the males are calling. The males then mate with the females and remain coupled for several hours. After mating, female flies produce fertile eggs.

Adult fruit flies require water and carbohydrates for their survival and proteins to develop their testes and ovaries and become sexually mature. Upon reaching sexual maturity, adult fruit flies do not appear to fly or migrate long distances. They are resident mostly within the area of their host plants (Clarke 2019).

Both *B. dorsalis* and *B. carambolae* infest a very large variety of fruits in their native habitats other than mango. As a result, they can breed freely and very large populations of flies may occur in and around mango and other fruit orchards.

For more information on the range of fruits that can act as hosts for *B. dorsalis* and *B. carambolae*, and other major species of fruit fly, refer to Allwood et al. (1999), Hancock et al. (2000) and Fruit Fly Identification Australia (**fruitflyidentification.org.au**).

1.4 Current control measures

Fruit flies infest a very wide range of cultivated and wild fruits, leading to large populations of adult flies being present in a wide range of habitats, which poses a constant threat to fruit cultivation. If not controlled, fruit fly infestation can cause mango yield losses of 40–100% at harvest.

In most countries in the Asia-Pacific region, farmers exercise uncoordinated, localised or orchard-by-orchard actions to control fruit flies. These are often heavily dependent on insecticide cover sprays, are highly variable and do not provide adequate protection, leading to high yield losses and poor fruit quality.

The traditional approach to controlling fruit flies has been the use of cover sprays of insecticides on individual farms. Cover spraying involves applying insecticides to the whole tree, across the entire mango crop (**Figure 5**). Spraying is done at weekly intervals from fruit set until 4–6 weeks before harvest.

An uncoordinated cover spraying approach uses a large volume of chemicals, which increases the individual farmer's costs. Although it can control fruit fly populations in a very small crop area, the population in the surrounding area is not effectively controlled and re-infestation is inevitable.

Additionally, the large-scale application of chemicals can lead to pollution of the surrounding environment, which can cause harm to other plants, animals and beneficial insects in the area. It also leaves residue on the fruit. For these reasons, cover spraying is becoming increasingly undesirable.

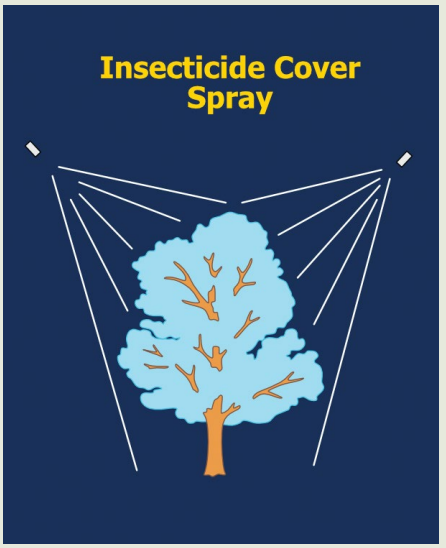


FIGURE 5 Traditional high-volume insecticide cover spraying

Consumers and markets want high-quality fruit that have little or no pesticide residues and that have been produced in a more environmentally friendly manner.

An effective fruit fly management system that enables growers to produce fruit that is free of fruit fly infestation is urgently needed in the Asia-Pacific region.

The area-wide management systems approach is a fruit fly management technique that has been proven to be effective and can be applied to the mango industry in the region.

2. Benefits of area-wide management

2. Benefits of area-wide management

Area-wide management of fruit fly aims to suppress the total population of fruit flies across a wider area of the mango crop than an individual farmer's land. This is in contrast to farmers in an area having individualised approaches to fruit fly management.

An area-wide management (AWM) system consists of a combination of fruit fly monitoring and suppression techniques that are applied in a coordinated manner across a large but defined area, usually containing the crop areas of more than one farmer.

It is important that the implementation of an AWM system includes farmer training (see **3. Implementing an area-wide management system**).

The benefits of a coordinated fruit fly control approach are shared by many farmers in the AWM system zone.

2.1 Benefits to growers

When growers collaborate and synchronise the application of control technology, fruit fly populations across the area are quickly suppressed, and the benefits are shared by all growers who are participating in the AWM system.

Compared with the current practices, an AWM system supresses fruit fly populations in a cost-effective and environmentally friendly manner. The AWM system uses very low volumes of pesticides, reducing chemical costs for participating farmers. Many international supermarkets increasingly require that imported fruit is cultivated using environmentally friendly methods, which includes minimal use of pesticides. An AWM system contributes towards meeting these requirements for fruit destined for export.

An established export market can be easily disrupted if fruit fly larvae are detected by the importing country. A properly initiated and managed AWM system ensures that harvested fruit are practically free of fruit fly infestation.

Following in-field control, some importing countries also require exporters to apply post-harvest treatments such as vapour heat treatment or irradiation. Farmers need to check the importing country requirements.

2.2 Benefits to industry and nations

Fruit flies are pests of international quarantine importance. Countries that do not have fruit flies, or in which they have been eradicated, are able to produce and export fruit without many of the restrictions currently imposed on countries in which fruit flies are endemic or have been introduced.

The global spread and impact of fruit flies is also increasing worldwide with new incursions of tropical species occurring in new areas, such as Europe. Unfortunately, fruit flies are endemic in almost all countries in the Asia-Pacific region and pose many obstacles to mango production and export.

Fruit flies have a very wide host range, in addition to mango, and breed in many other fruits of economic importance as well as in many wild hosts.

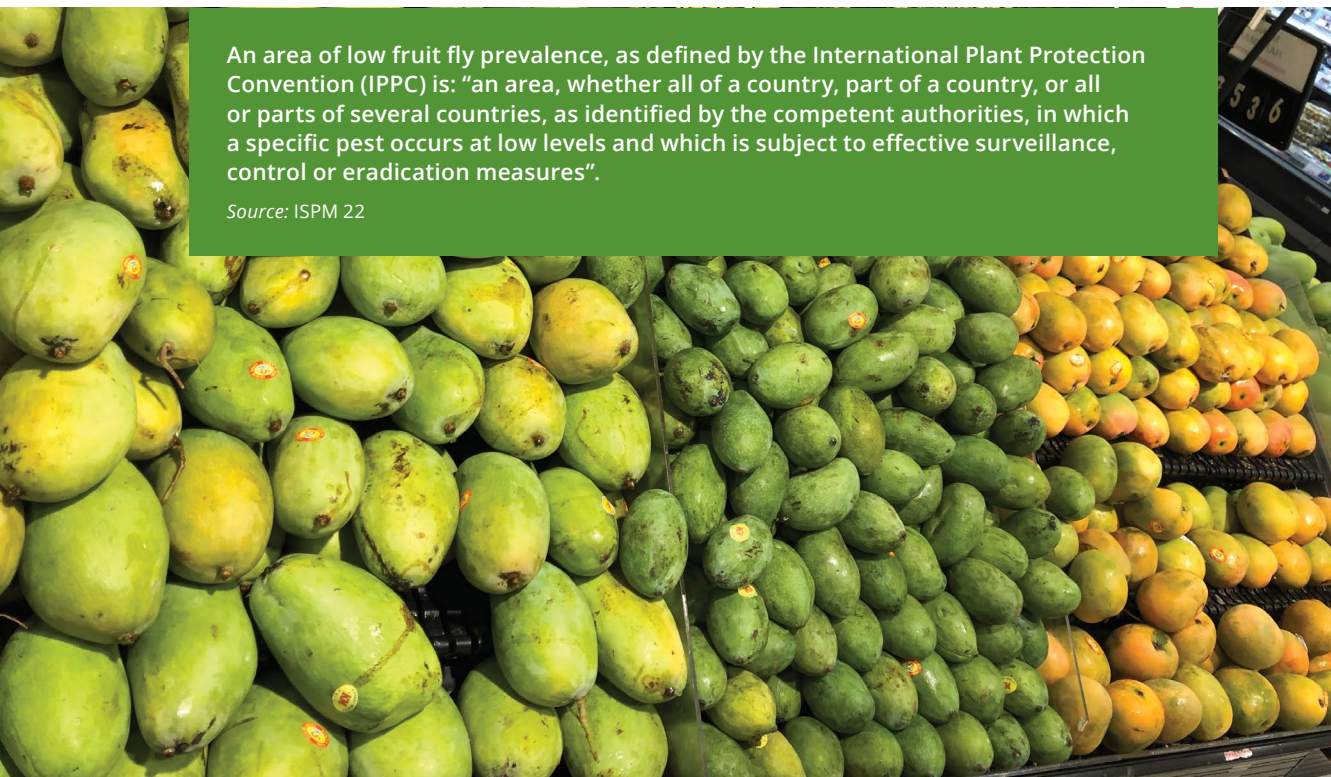
In a tropical climate such breeding results in very high populations of fruit flies being present all year round, posing a constant threat to the mango crop (Allwood et al. 1999 and Hancock et al. 2000).

Eradication is usually not feasible in countries where fruit flies are endemic. The alternative strategy is to establish areas where fruit flies are controlled to the extent that they occur in extremely low numbers. This is an internationally accepted concept and is described as an Area of Low Pest Prevalence.

The international standard for establishing an Area of Low Pest Prevalence can be found under ISPM 22, "Requirements for the establishment of areas of low pest prevalence for fruit flies (Tephritidae)" (FAO/IPPC 2016).

An area of low fruit fly prevalence, as defined by the International Plant Protection Convention (IPPC) is: "an area, whether all of a country, part of a country, or all or parts of several countries, as identified by the competent authorities, in which a specific pest occurs at low levels and which is subject to effective surveillance, control or eradication measures".

Source: ISPM 22



3. Implementing an area-wide management system

3. Implementing an area-wide management system

The area-wide management (AWM) system approach is a combination of different control techniques used together in a coordinated program to suppress adult fruit fly populations to extremely low levels over a wide area of the mango crop.

The list below provides the key steps involved in setting up and managing an AWM system. Information to support carrying out these steps is found in the following sections of the manual.

AWM system steps

1. **Identify** pest fruit fly species
2. **Identify** the area of mango production to which the AWM system will be applied
3. **Define** the border of the AWM system zone
4. **Identify** key stakeholders and hold a stakeholder meeting
5. **Create** a map of the area selected for the AWM system program
6. **Identify** all major alternate fruit fly host plants
7. **Conduct** training, field schools and coordination meetings
8. **Monitor** adult fruit fly populations
9. **Apply** male annihilation technique
10. **Set up** a protein baiting program
11. **Maintain** good sanitation
12. **Monitor** fruit damage after the program has commenced
13. **Manage** hotspots and population spikes
14. **Hold** regular grower meetings

Before you start the program

The AWM system includes the use of chemicals and exposure to other hazards. Personal protective equipment (PPE) must be worn when handling and using chemicals. Information about required PPE and safety procedures for each task in this manual is listed on pages **30**, **40** and **45**, and must be followed by all users.

Information about the health risks and first aid measures for commercially produced chemicals can be found in the Safety Data Sheet for each product, and is generally available from the chemical manufacturer's website and the reseller.

Throughout this manual, safety information is presented in boxes alongside the relevant topic.

◀ The safe use and disposal of chemicals, and the required PPE is a critical part of training for farmer groups and others involved in the implementation of an AWM system.

Engaging agencies, advisors and farmers

A core component of implementing an AWM system is training extension workers and farmers to implement various elements of the program. This is ideally achieved with the support of the local agriculture department or extension agency.

The extension workers and farmers can subsequently be trained as coordinators who then carry out a similar process with the participating growers and other key stakeholders, further extending the AWM system program.

Use this manual to introduce AWM system coordinators to fruit fly biology and the concept of area-wide management, and then use the information in the following sections to implement the AWM system in the field.

◀ Extension worker and farmer training is a core component of the AWM system program.

4. Fruit fly identification

4. Fruit fly identification

The first step in the area-wide management (AWM) system is to identify the species of fruit fly that is infesting the fruit crop. Species identification is a critical step, as responses to management techniques will be different for different species.

Species identification will assist in determining which lure to use for monitoring and male annihilation techniques, if applicable.

Two common species that infest mango are oriental fruit fly (*B. dorsalis*) and carambola fruit fly (*B. carambolae*) (**Figure 6**).

The Fruit Fly Identification Australia website (**fruitflyidentification.org.au**) is a useful resource for identification of pest fruit fly species in the Asia-Pacific region. It also has a downloadable handbook.

▲ A useful guide to fruit fly identification for the Asia-Pacific region.

FIGURE 6 Common mango-infesting fruit fly species
Left: Adult oriental fruit fly. Right: Adult carambola fruit fly.

It is also important to know which sex of fruit fly is being observed, in order to understand the impact on fruit and to plan appropriate monitoring and management techniques.

Male and female fruit flies can be distinguished by the shape of and features on their abdomen.

Male fruit flies have a rounded abdomen and female fruit flies have a needle-like ovipositor on their abdomen (**Figure 7**).

Male fruit flies do not cause any damage to the fruit. Female fruit flies use their ovipositor to pierce the fruit and lay eggs within. The egg-laying process introduces bacteria to break down the fruit flesh so that it is more palatable to the larvae.

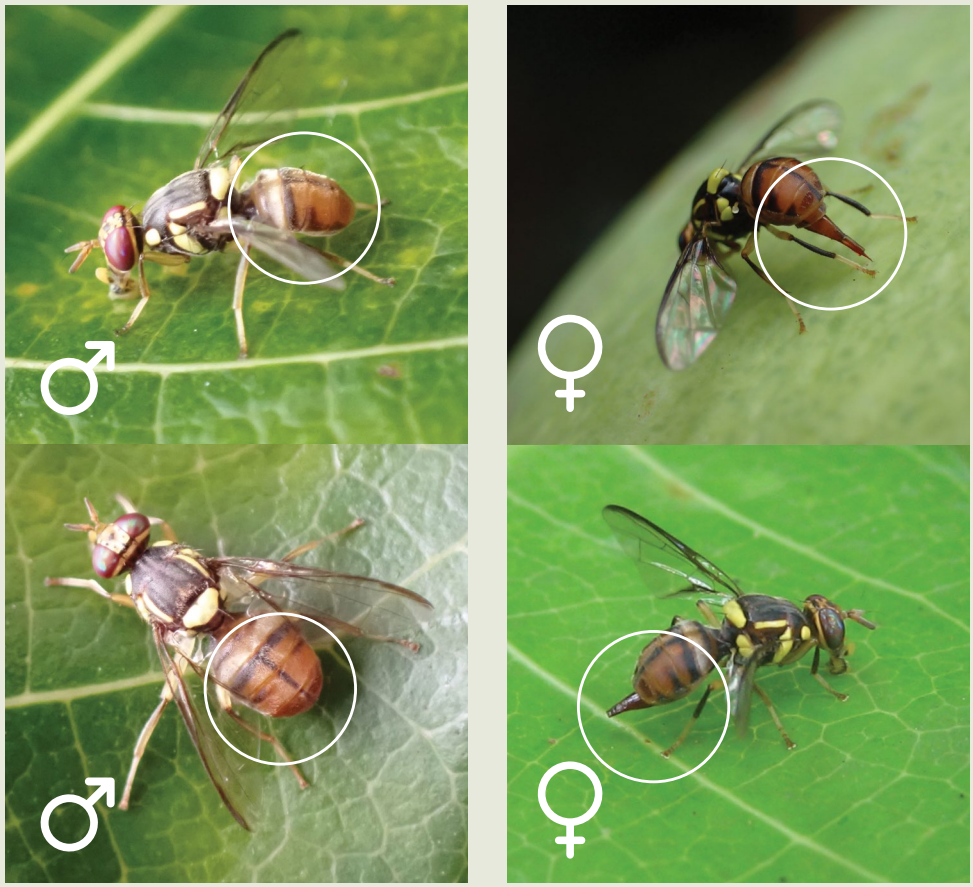


FIGURE 7 Distinguishing features of adult male and female fruit flies

Left: Male fruit flies have a rounded abdomen (circled). Right: Female fruit flies have a needle-like ovipositor on the abdomen (circled).

5. Site selection and mapping

5. Site selection and mapping

Once the local pest species has/have been identified, the next step is to identify and select an area of mango farms that will form the area-wide management (AWM) system zone.

The proposed zone should cover a continuous area of 25 ha or more. The larger the area, the more effective suppression will be. The suppression of fruit flies in areas smaller than 25 ha has not been tested and may not be as effective.

Google Earth (**earth.google.com**) is a useful tool that can provide good satellite photos of the selected area that can be used to map the AWM system zone. Satellite and aerial photos from other sources can be used, as long as they provide sufficient resolution to plan, document and record the activities that are part of the AWM system.

Data from global positioning systems (GPS) and/or geographic information systems (GIS) are used to mark and map the location of the borders and major features of the AWM system zone, such as the planted mango area, roads, rivers and other natural features, as well as the location of dwellings and other buildings.

These features can be geo-referenced with a handheld GPS device or by dropping pins on a Google Earth map using a mobile phone (**Figure 8**).

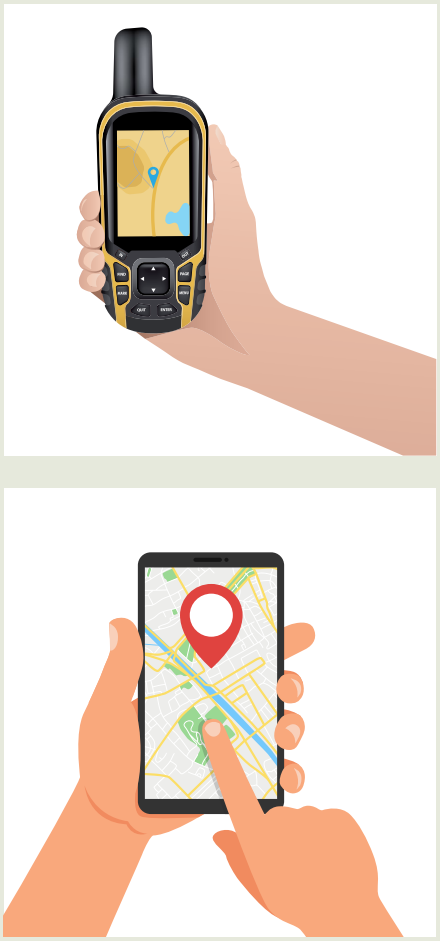


FIGURE 8 Examples of devices to use for geo-referencing
Source: Shutterstock

The map should show alternate fruit fly hosts, as well as the exact location of monitoring traps, male annihilation technique (MAT) blocks and other key features.

Figure 9 shows an example of a completed AWM system zone map. In this image the blue outer line marks the border of the AWM system zone, the traps are indicated by yellow flags and the MAT blocks (**8.1 Male annihilation**) are indicated as clear diamonds.

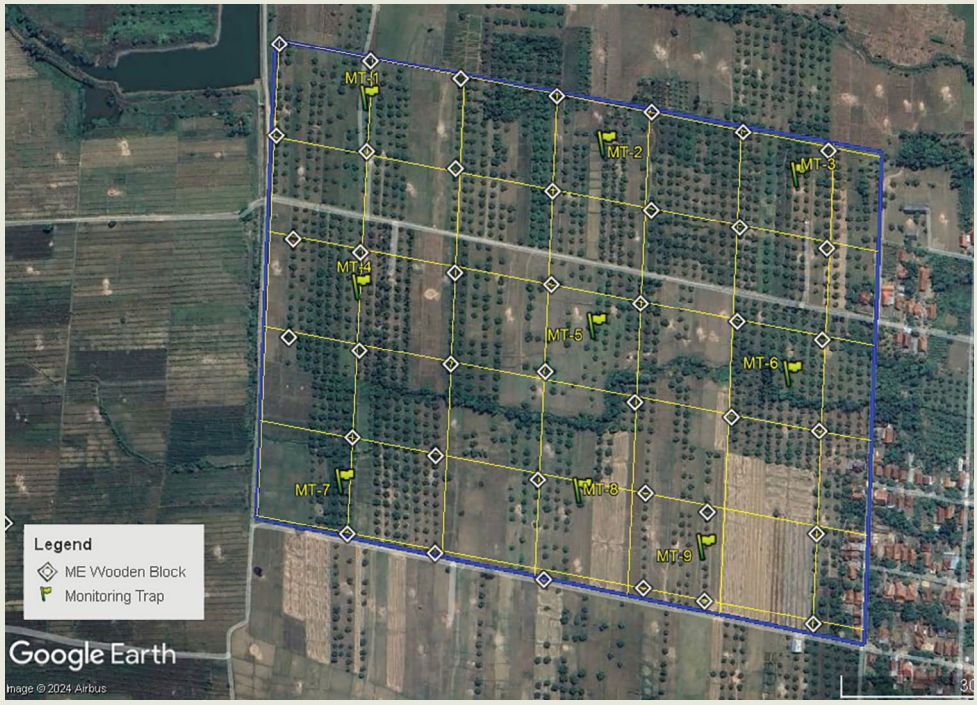


FIGURE 9 An example of a mapped AWM system zone

6. Stakeholder engagement

6. Stakeholder engagement

A good area-wide management (AWM) system includes a well-organised and well-developed coordination component.

The first step is to identify stakeholders who are motivated to participate and likely to benefit from the system. Key stakeholders will ensure greater cooperation and commitment to the system, and are likely to be:

- mango growers
- contractors
- extension agencies
- wholesale buyers
- retail outlets such as supermarkets.

The subsequent steps of stakeholder engagement, over the course of the program, are:

- present the concept and benefits of the fruit fly AWM system for the mango industry to the various stakeholders
- plan the coordination of the control and other activities to be implemented
- carry out training of trainers and farmers
- present, discuss and review the results with the farmers to inform ongoing activities and results.

The safe use and disposal of chemicals, and the required personal protective equipment, is a critical part of training for farmer groups and others involved in implementation of an AWM system.

7. Monitoring techniques

7. Monitoring techniques

A central part of an area-wide management (AWM) system is the initial and ongoing monitoring of adult fruit fly populations and inspection of damaged fruit for the presence of larvae. Monitoring activities are important in the early stages of an AWM system to demonstrate the uncontrolled population numbers, and to give a baseline for measuring the success of fruit fly suppression.

Once the AWM system is set up, it is critical that farmers in the zone maintain monitoring activities to determine the ongoing success of suppression techniques and to indicate hotspots and outbreaks that may need special attention (**9. Managing hotspots and outbreaks**).

Monitoring results should be shared with participating farms and stakeholders to inform them of the program's results.

7.1 Monitoring adult populations

Methyl eugenol is a naturally occurring organic compound found in many plants. Fruit flies have been observed feeding on leaves, blossoms and fruits that contain methyl eugenol (Tan and Nishida 2012).

Male fruit flies feed on methyl eugenol in nature and use it to produce pheromones (Nishida and Tan 2016). The review by Shelly (2010) states that for methyl eugenol-responsive species, females are more sexually attracted to males that have fed on methyl eugenol and those males have increased mating success.

Adult male oriental fruit fly (*B. dorsalis*) and carambola fruit fly (*B. carambolae*) are strongly attracted to methyl eugenol. Therefore, commercially produced methyl eugenol is used as a lure for male fruit flies.

Adjusting insecticide concentration

Insecticides are produced in various formulations and concentrations, depending on the manufacturer and a country's registration requirements.

To make the solutions recommended for AWM system techniques, it may be necessary to adjust the concentration of commercially available insecticides. The calculations required to do this are included in the guidelines on the green pages in this section.

Insecticide products change over time with new technologies and concentrations may change with new regulations. *Always* read the product label or consult an advisor before using the product.

How to make and use monitoring traps

Preparing the chemicals

Steiner-type traps baited with methyl eugenol and an insecticide are hung on trees in the orchard. The lure attracts male fruit flies, which die inside the trap after feeding on the insecticide-laced lure.

Traps for monitoring *B. dorsalis* and *B. carambolae* fruit flies use a dental wick (or roll) soaked with methyl eugenol (to attract male fruit flies) and insecticide (to kill the flies). The insecticides currently used are fipronil and malathion.

In this manual, the method for preparing the soaking solution is based on insecticides that have the active ingredient concentrations shown in **Table 1**.

If the insecticide available is the same concentration as shown in **Table 1**, it can be used undiluted to make the soaking solution.

If the insecticide available has a different concentration, it will need to be adjusted to the percentage active ingredient shown in **Table 2**. Use the formula in **Box 1** (page **30**) to calculate the volume of insecticide to be used. Do not dilute the insecticide.

Always check the product label to identify the concentration of the product being used.

▲ A fruit fly monitoring trap, which uses methyl eugenol as a lure for adult male flies.

Table 1 Concentration of insecticide (active ingredient) used to make the soaking solution

Insecticide	Concentration of a.i.	
Fipronil	50 mL/L	5%
Malathion	500 mL/L	50%

Table 2 Required concentration of insecticide (active ingredient) in the soaking solution of the dental wicks

Insecticide	Concentration of a.i.
Fipronil	1.25%
Malathion	12.5%

How to make and use monitoring traps

Box 1: Adjusting insecticide concentration for the dental wicks soaking solution

Use the following formula to calculate the volume of insecticide to add to methyl eugenol.

V1 = (V2 x N2) ÷ N1

V1 = volume of insecticide required

N1 = concentration of available insecticide, as % active ingredient (from the label)

V2 = volume of methyl eugenol in the soaking solution (in mL)

N2 = required concentration of insecticide in the soaking solution (**Table 2**)

Example:

Soaking solution is to be made using locally available fipronil and 100 mL of methyl eugenol (V2)

The required concentration of fipronil in the dental wicks is 1.25% a.i. (N2)

The concentration of the available fipronil is 200 mL/L active ingredient = 20% a.i. (N1)

Using the formula above, the volume of insecticide (V1) required is:

V1 = (100 x 1.25) ÷ 20 = 6.25 mL

Therefore, to make the soaking solution, add 6.25 mL of insecticide to 100 mL of methyl eugenol.

NOTE: A surfactant may need to be added if the insecticide does not mix well with the methyl eugenol. Check surfactant label for required rates.

Safety warning

Insecticides and methyl eugenol are hazardous chemicals to humans and the environment. These chemicals are:

- **harmful** if swallowed
- **harmful** in contact with skin
- **harmful** if inhaled
- **damaging** to organs through prolonged or repeated exposure
- **potentially toxic** to aquatic life.

Methyl eugenol has been reported as a probable cause of cancer in humans (Riboli et al. 2023) and is suspected of causing genetic disorders.

Insecticide and methyl eugenol exposure to users and the environment must be avoided. The following personal protective equipment **must** be worn when handling these chemicals:

- chemical resistant gloves (e.g. latex, nitrile and PVC) – select gloves that are flexible and comfortable
- full skin cover such as coveralls, hat, covered-in shoes
- full face respirator with the correct filter/cartridge
  - respirator cartridges should be multi-purpose combination (US) or type ABEK (EN 14387)
  - users should be trained in respirator use and maintenance.

How to make and use monitoring traps

Making the soaking solution

- Make the soaking solution by mixing 4 parts of 95–98% methyl eugenol with 1 part of insecticide (**Table 1**), or by adjusting the available insecticide according to **Box 1** to achieve the concentration in **Table 2**.

Making the traps

- Using a graduated syringe or disposable pipette, drip 5 mL of the soaking solution evenly onto dental wick/roll. Dental wicks/rolls can be purchased from dental supply companies and come in various sizes and thicknesses. Test how much dental wick is required to absorb the correct amount of solution (**Figure 10**).
- Hang the baited wick in the top of a standard Steiner-type trap (**Figure 11**).
- Aim to make up sufficient solution for the number of traps required. However, if excess solution is prepared, store it in a well-sealed chemical-resistant container, labelled correctly and in a cool, dry place away from direct sunlight. Keep out of reach of children and do not store in a residence.
- Label each trap with trap code, details of farmer group/organisation, including name and contact number, and a statement that states the trap contains chemicals.

Hanging the traps

- Hang the monitoring traps on mango trees throughout the AWM system zone at a density of 1 trap per 4–6 ha (**Figure 12**).
- Ensure hotspot areas such as boundaries adjacent to villages are covered.

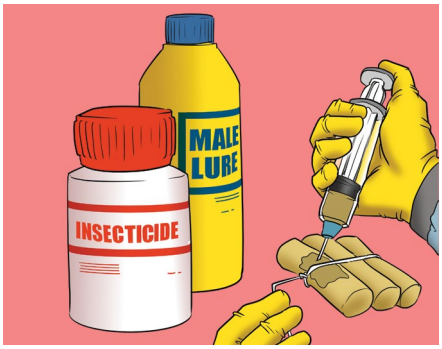


FIGURE 10 Soaking the dental wick lure

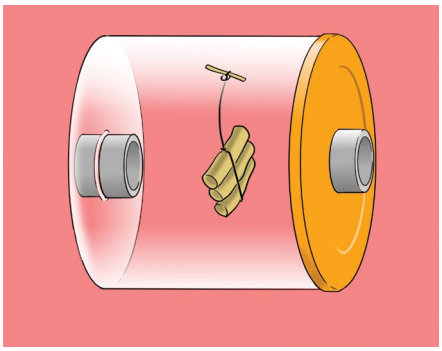


FIGURE 11 Steiner trap and wicks

FIGURE 12 Hanging the traps

How to make and use monitoring traps

Monitoring the traps

Population monitoring involves counting the trapped flies to determine the level of suppression. The target level of suppression is less than one fly per trap per day, or FTD 1 (FAO/IAEA 2018).

- Collect the trapped flies once a week, preferably on the same day each week.
- Count and record the number of flies caught in each trap (**Figure 13**).
- Calculate the number of flies per trap per day (FTD) as shown in **Box 2**.
- Enter the FTD data in the spreadsheet (**Figure 14**).
- Graph the FTD over time (**Figure 15**).

FIGURE 13 Counting collected fruit flies and recording the data

Box 2: Calculating flies per trap per day

The flies per trap per day (FTD) is the average of the total number of flies from all the traps in the monitoring area.

N = Number of flies captured from all traps

D = Trapping period (no. days)

T = Number of traps.

FTD = (N ÷ D) ÷ T

Example:

A farmer has collected a total of 650 flies from the 12 traps in the crop area after a 7-day trapping period.

In this case: N = 650, D = 7 and T = 12

FTD = (N ÷ D) ÷ T

= (650 ÷ 7) ÷ 12

= 7.74

Therefore FTD = 7.74

The target FTD = 1

*This calculation can easily be built into the data collection spreadsheet (***Figure 14***).*

Note: It may take up to 6 months for fruit fly populations to stabilise at low levels and this may not be achievable until after the protein baiting program has commenced.

How to make and use monitoring traps

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	Attachment 1. Monitoring sheet for recording data population of fruit flies																		
2																			
3	**Observation Data Capture Fruit Flies**																		
4																			
5	Location	: Krasak Village, Jati Barang Sub-District, Indramayu District																	
6	Attractant	: ME + Fipronil																	
7																			
8	**No. of Trap**	**2019**																	
9		01/08/19	08/08/19	15/08/19	19/08/19	26/08/19	02/09/19	09/09/19	16/09/19	23/09/19	30/09/19	07/10/19	15/10/19	21/10/19	28/10/19	04/11/19	11/11/09	18/11/19	25/11/19
10	ME 1	16	13	14	12	99	13	42	68	70	146	108	109	86	243	80	32	26	15
11	ME 2	18	16	19	27	18	2	1	2	3	9	10	12	8	53	83	22	5	4
12	ME 3	27	13	27	18	19	0	0	0	0	1	4	5	7	14	24	4	3	1
13	ME 4	11	9	11	19	9	0	0	0	1	0	2	3	4	48	80	35	1	0
14	ME 5	16	11	14	24	90	0	0	0	0	1	8	10	3	11	9	2	0	1
15	ME 6	131	102	88	91	22	0	1	1	1	2	4	3	2	21	42	7	6	4
16	ME 7	216	145	144	87	69	7	11	13	14	21	79	81	46	128	86	34	6	7
17	ME 8	81	69	77	85	91	4	6	9	8	23	34	40	72	96	141	58	16	13
18	ME 9	62	40	47	32	31	1	3	7	6	12	36	42	71	104	115	15	1	2
19	ME 10	118	96	99	84	36	0	1	7	7	9	68	73	38	141	62	30	3	4
20	ME 11	49	35	38															
21	Number of flies	745	549	578	479	484	27	65	107	110	224	353	378	337	859	722	239	67	51
22	Number of traps	11	11	11	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
23	Number of Days	7	7	7	4	7	7	7	7	7	7	7	8	6	7	7	7	7	7
24	FTD	9.68	7.13	7.51	11.98	6.91	0.39	0.93	1.53	1.57	3.20	5.04	4.73	5.62	12.27	10.31	3.41	0.96	0.73
25																			
26						After relocated the trap													

FIGURE 14 An example of weekly trapping data

The spreadsheet shows individual trap collection data and calculates an average flies per trap per day for the monitoring area.

FIGURE 15 An example of a graph showing weekly FTDs

Maintaining the traps

Ongoing and continual monitoring of the adult fly population is crucial for the success of an AWM system, so traps must be regularly maintained to make sure they are working properly.

- Replace the lure wicks with fresh ones every 8 weeks.
- Dispose of used lures in a container ready to be collected by chemical waste collection companies. If this is not possible, wrap used lures in several layers of plastic and place in a container. Take the container to the chemical waste collection centre at the local rubbish dump.
- Plastic traps become brittle over time, so it is important to replace them annually.

7.2 Monitoring fruit damage

Monitoring fruit damage to determine fruit fly infestation rates will demonstrate the effectiveness of the AWM system program. The data can be used in negotiations with buyers or trading partners.

The sample fruit is visually inspected on the outside and then cut open to confirm the presence (or otherwise) of fruit fly larvae.

Monitoring can be conducted on mangoes, as the primary host fruit, or an alternate host fruit from within the AWM system zone.

Safety

Personal protective equipment must be worn when setting up, checking and sieving pupae. The following PPE items are required:

- **disposable gloves**
- **P2 mask**
- **safety glasses**
- **covered-in shoes.**

How to monitor fruit damage

Setting up monitoring containers

- Collect a minimum of 100 fruit per 25 ha. Larger samples will produce more accurate results.
- The samples should be typical of harvest maturity level within the AWM system zone.
- Additional sampling times may be required if the harvest period is long.
- Record the date collected, the location where the fruit was collected and the total number of fruit collected.
- Place fruit on vermiculite/untreated sawdust/fine sand in containers and cover the container with a material that allows ventilation but prevents flies moving in or out (**Figure 16**).
- Label each container with the date the samples were collected, location, sample number and fruit type.
- Record all data in a spreadsheet (**Figure 17**).
- Keep containers in shade at ambient temperatures for 5 days to allow any eggs to emerge as larvae.

Inspecting fruit damage

- After 5 days, inspect the fruit in the containers for damage.
- Cut all fruit and look for larvae.
- Categorise fruit as either infested (larvae present) or not infested (no larvae present).
- Record data in a spreadsheet.

FIGURE 16 A fruit monitoring container

Left: Mango fruit placed on sawdust. Right: A monitoring container covered with a fine woven cloth to prevent fruits flies escaping and smaller flies (such as vinegar flies) from entering.

Date collected	Location	Sample number	Fruit type	No. fruit collected (*N*)	No. fruit infested (*I*)	Infestation rate % (*I*/*N* x 100)
2/11/2023	Village 1	M001	Mango	100	5	5
17/12/2023	Village 1	M002	Mango	150	3	2
2/1/2024	Village 2	C001	Carambola	110	23	21

FIGURE 17 Fruit damage data spreadsheet

8. Suppression techniques

8. Suppression techniques

The next component of an area-wide management (AWM) system is to suppress the population of fruit flies within the AWM system zone, to bring the flies per trap per day down to the target level of less than 1.

Suppression is achieved using a combination of 3 techniques:

1. male annihilation technique
2. bait application technique
3. farm sanitation.

8.1 Male annihilation

As discussed in **7.1 Monitoring adult populations**, male fruit flies are attracted to methyl eugenol. The male annihilation technique (MAT) uses particle board blocks that have been soaked in a mixture of methyl eugenol and insecticide to suppress male fruit fly populations. The MAT blocks are placed in trees within the field.

Mature adult male flies are attracted to and feed on these blocks, and are rapidly killed by the insecticide, resulting in a drastic reduction in the population of male flies.

The safest way for farmers to use methyl eugenol for MAT blocks is to buy them from a commercial supplier. This avoids the need to handle concentrated chemicals and avoid spills which might cause environmental contamination.

If commercial blocks are not available, farmers can make their own blocks using the method on page **39**.

Adjusting insecticide concentration

Insecticides are produced in various formulations and concentrations, depending on the manufacturer and a country's registration requirements.

To make the solutions recommended for AWM system techniques, it may be necessary to adjust the concentration of commercially available insecticides. The calculations required to do this are included in the guidelines on the green pages in this section.

Insecticide products change over time with new technologies and concentrations may change with new regulations. *Always* read the product label or consult an advisor before using the product.

How to make and use MAT blocks

Preparing the blocks

- Obtain 1 cm thick medium density fibreboard (MDF) .
- Cut the MDF into 5 cm by 5 cm blocks.
- Drill a small hole through each block, at least 5 mm in from the edge (**Figure 18**). This hole is for inserting the wire that will be used to hang the blocks.

Preparing the chemicals

The insecticides currently recommended for making MAT blocks are fipronil and malathion, the same as those used in the dental wicks for making monitoring traps.

In this manual, the method for preparing the MAT block solution is based on insecticides that have the active ingredient concentrations shown in **Table 3**.

If the insecticide available is in the same concentration as shown in **Table 3**, it can be used undiluted to make the MAT blocks.

Always check the product label to identify the concentration of the product being used.

If the insecticide available has a different concentration, it will need to be adjusted to the percentages shown in **Table 4**. Use the formula in **Box 3** (page **40**) to calculate the volume of insecticide to be used. Do not dilute the insecticide.

FIGURE 18 Equipment for MAT and drilling the blocks

Table 3 Concentration of insecticide (active ingredient) used to make the MAT block solution

Insecticide	Concentration of a.i.	
Fipronil	50 mL / L	5%
Malathion	500 mL / L	50%

Table 4 Required insecticide concentration of the MAT block solution

Insecticide	Concentration of a.i.
Fipronil	1.25%
Malathion	12.5%

How to make and use MAT blocks

Box 3: Adjusting insecticide concentration for the MAT block solution

Use the following formula to calculate the volume of insecticide to add to methyl eugenol.

V1 = (V2 x N2) ÷ N1

V1 = Volume of insecticide required

N1 = Concentration of available insecticide, as % active ingredient (from the label)

V2 = Volume of methyl eugenol in the MAT block solution (in mL)

N2 = Required concentration of insecticide in the MAT block solution (**Table 3**)

Example:

MAT block solution is to be made using locally available fipronil and 5 L or 5000 mL of methyl eugenol (V2)

The required concentration of fipronil in the blocks is 1.25% a.i. (N2)

The concentration of the available fipronil is 200 mL/L active ingredient = 20% a.i. (N1)

Using the formula above, the volume of insecticide (V1) required is:

V1 = (5000 x 1.25) ÷ 20 = 312.5 mL

Therefore, to make the MAT block solution, add 312.5 mL of insecticide to 5 L of methyl eugenol.

NOTE: A surfactant may need to be added if the insecticide does not mix well with the methyl eugenol. Check surfactant label for required rates.

Safety warning

Insecticides and methyl eugenol are hazardous chemicals to humans and the environment. These chemicals are:

- **harmful** if swallowed
- **harmful** in contact with skin
- **harmful** if inhaled
- **damaging** to organs through prolonged or repeated exposure
- **potentially toxic** to aquatic life.

Methyl eugenol has been reported as a probable cause of cancer in humans (Riboli et al. 2023) and is suspected of causing genetic disorders.

Insecticide and methyl eugenol exposure to users and the environment must be avoided. The following personal protective equipment **must** be worn when handling these chemicals:

- chemical resistant gloves (e.g. latex, nitrile and PVC) – select gloves that are flexible and comfortable
- full skin cover such as coveralls, hat, covered-in shoes
- full face respirator with the correct filter/cartridge
  - respirator cartridges should be multi-purpose combination (US) or type ABEK (EN 14387)
  - users should be trained in respirator use and maintenance.

How to make and use MAT blocks

Making MAT blocks

- Make the soaking solution for the blocks by mixing 4 parts of 95–98% methyl eugenol with 1 part of insecticide (**Table 3**), or by adjusting the available insecticide according to **Box 3** to achieve the concentration in **Table 4**.
- Wrap the MDF blocks in fabric and soak in the chemical mixture for 24 hours (**Figure 19**).
- Drain the excess mixture by hanging the blocks over a container for another 24 hours to drip dry. Collect the residual chemical (**Figure 20**).
- The drip and excess mixture can be kept for the next round of block preparation. Keep the MAT block solution in a well-sealed, labelled chemical resistant container and store in a cool dry place away from direct sunlight for up to 2 months. Keep out of reach of children and do not store in a residence.

Transporting MAT blocks safely

- Wear the correct personal protective equipment (page **40**).
- Pack the blocks into a chemical resistant plastic container for transport and use in the field.
- Place container of blocks securely in the tray of pick-up or truck when being transported. Do not carry the blocks inside the driver or passenger cabin.

FIGURE 19 Soaking MAT blocks

FIGURE 20 Draining MAT blocks

How to make and use MAT blocks

Hanging MAT blocks

The placement of MAT blocks throughout the crop ensures that the mature male fruit fly population is reduced which therefore helps to reduce mating.

The density of blocks, if hung following these instructions, will be about 2 blocks per hectare across the AWM system zone. This is the optimal coverage for supressing fruit fly populations in mango crops without using excess resources.

Extra MAT blocks may be necessary at the perimeter of the AWM system zone where many alternate host plants may be present.

- Insert a piece of wire through the hole in each MAT block, leaving about 20 cm for hanging and fastening to the mango trees (**Figure 21**).
- Hang the block on a mango tree, or other vegetation, at 150–180 cm above the ground (**Figure 22**).
- Place blocks in trees at 100 m intervals in a grid pattern across the entire AWM system area.
- Record the position of the block on the AWM map (**5. Site selection and mapping**).
- Maintain MAT blocking continuously in the AWM system zone all year round.

FIGURE 21 Preparing for hanging

FIGURE 22 Hanging MAT blocks

Maintaining MAT blocks

- New blocks must be installed every 8 weeks – the methyl eugenol in the blocks wears out after about 2 months.
- Place new blocks next to the old ones.
- Old blocks will eventually degrade and fall to the ground.
- Collect and dispose of the old wire.

8.2 Bait application

Adult fruit flies require protein in their diet to attain sexual maturity and mate. This is especially important for female flies to produce and lay viable eggs in fruit.

Protein is not an abundant resource in the field and adult flies must forage extensively on leaf and fruit surfaces to meet their protein requirements. Hydrolysed vegetable protein and autolysed yeast – that also contains protein – has been found to be highly attractive to adult fruit flies, particularly to sexually immature adults. These proteins can be mixed with water and a small amount of insecticide to form a bait that will very effectively attract and kill both male and female flies. Importantly, it will attract and kill immature female flies before they are able to oviposit in fruit and cause damage.

The attraction of fruit flies to protein baits is at short distances of about 10–15 m. To achieve the greatest reduction of a fruit fly population the minimum volume of bait spray that needs to be applied to one hectare of mango is 10 L. The effectiveness of the bait is greatly reduced if the volume of bait spray applied is less than this.

These protein baits can be applied as a low volume spot spray on the foliage, typically 25 mL per spot, rather than as a traditional high volume cover spray (**Figure 23**).

This technique greatly reduces the volume of chemicals that are used, making it a more cost-effective technique for farmers. It also reduces the potential for chemical residues on the fruit or run off that could contaminate the wider environment.

This technique can rapidly reduce a large fruit fly population within a single fruiting season and provide fruit that is virtually free of fruit fly larvae.

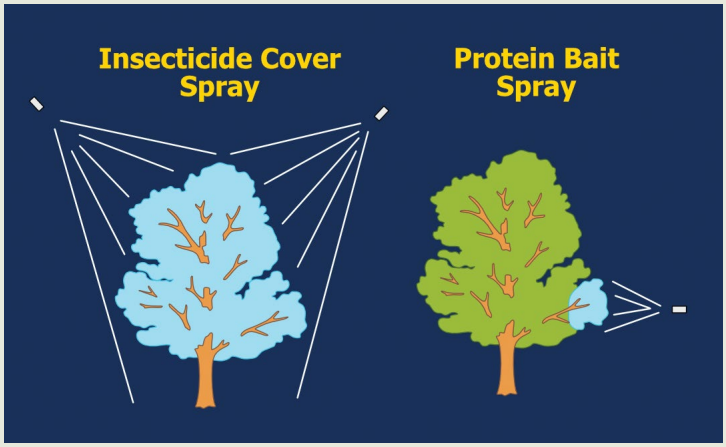


FIGURE 23 Bait application techniques

Left: Insecticide cover spray. Right: Low-volume protein bait spray.

How to make and use bait

Preparing the chemicals

To effectively attract and then kill fruit flies, it is important to prepare protein bait spray carefully, and ensure the concentration of protein and insecticide in the bait spray is correct.

Always check the product label to identify the concentration of the product being used, and ensure the product used is currently registered for use in your country.

Calculating volume of bait spray

The amount of bait spray needed is based on a minimum application rate of 10 L/ha, which is applied on a weekly basis. The volume of spray required can be calculated using the formula in **Box 4**.

Box 4: Calculating the volume of bait spray

Tree density will affect the volume of bait spray required. The volume is based on the number of trees per hectare, and using 4 baiting spots of 25 mL on each tree.

Example:

For a tree density of 100 trees/ha, the volume of bait spray required

= 100 trees/ha x 4 spots x 25 mL

= 10,000 mL or 10 L

If the tree density is 150 trees/ha, volume required

= 150 trees/ha x 4 spots x 25 mL

= 15,000 mL or 15 L

The recommended dilution for Prima® Fruit Fly Bait is 1 part Prima added to 20 parts clean water.

Other bait products are available, as listed on page **57**. The dilution rates for these baits is different to Prima. Check the label for recommended rates and instructions.

Calculating volume of insecticide

The required concentration of the selected insecticide in the bait spray is shown in **Table 5**.

The formulation and concentration of insecticide that is available locally may vary and it is important to check the label of the container you are using each time.

Before performing any calculations, convert the concentration of active ingredient in the insecticide from g/L into %. For example, 1.8 g/L = 1.8%.

The volume of insecticide required for the bait spray can be calculated using the formula in **Box 5**.

Table 5 Required concentration of insecticide (active ingredient) in bait spray

Insecticide	Concentration of a.i.
Abamectin	0.0045%
Malathion	0.2%
Spinetoram	0.0025%

How to make and use bait

Box 5: Adjusting insecticide concentration for bait spray

Use the following formula to calculate the volume of insecticide to add to protein bait spray.

V1 = (V2 x N2) ÷ N1

V1 = Volume of insecticide required

N1 = Concentration of available insecticide, as % active ingredient (from the label)

V2 = Volume of protein bait (in mL)

N2 = Required concentration of insecticide in the bait spray solution (**Table 5**)

Example:

30 ha of trees to spray, using 10 L/ha of protein bait and locally available Abamectin.

The total volume of bait required is 300 L or 300,000 mL (V2)

The required concentration of Abamectin in the blocks is 0.0045% a.i. (N2)

The concentration of the available Abamectin is 18 g/L or 1.8% a.i. (N1)

Using the formula above, the volume of insecticide (V1) required is:

V1 = (300,000 x 0.0045) ÷ 1.8 = 750 mL

Therefore, to make the bait spray solution, add 750 mL of insecticide to 300 L of protein bait.

Safety warning

Insecticides are hazardous chemicals to humans and the environment. These chemicals are:

- **harmful** if swallowed
- **harmful** in contact with skin
- **harmful** if inhaled
- **damaging** to organs through prolonged or repeated exposure
- **potentially toxic** to aquatic life.

Insecticide exposure to users and the environment must be avoided. The following personal protective equipment **must** be worn when handling insecticides:

- chemical resistant gloves (e.g. latex, nitrile and PVC) – select gloves that are flexible and comfortable
- full skin cover such as coveralls, hat, covered-in shoes
- full face respirator with the correct filter/cartridge
  - respirator cartridges should be multi-purpose combination (US) or type ABEK (EN 14387)
  - users should be trained in respirator use and maintenance.

How to make and use bait

Making the bait

- Calculate the volume of bait required (**Box 4**).
- Dilute the bait according to label instructions.
- Add the insecticide volume, calculated according to the formula in **Box 5**.
- Mix the bait solution and the insecticide thoroughly (**Figure 24**).

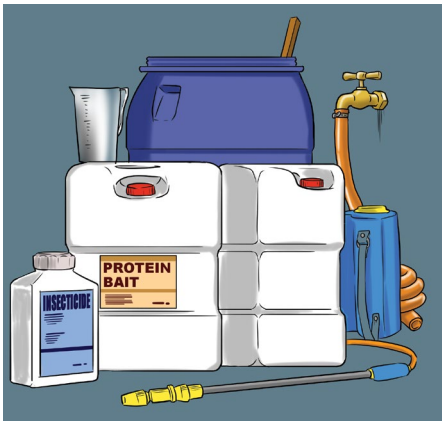


FIGURE 24 Preparing the protein bait plus insecticide mixture

Calibrating the sprayer

Before spraying can start it is important to calibrate the sprayer that is going to be used to apply the bait. This is to make sure that the correct amount of bait is applied to the tree at each spot, ensuring enough bait has been applied for it to be effective and that no excess bait is used.

- Adjust the nozzle so that the bait is applied as medium to coarse droplets instead of a fine spray.
- Spray the bait into a graduated measuring cylinder or jug and time how long it takes to collect 25 mL of liquid (**Figure 25**).

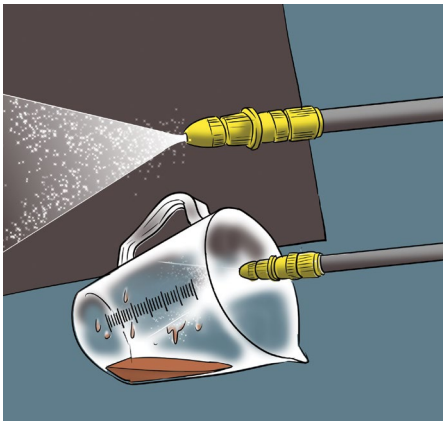


FIGURE 25 Calibrating the sprayer

How to make and use bait

Applying the bait

Begin bait spraying when the mango fruits are about golf ball size and continue at weekly intervals until harvest is completed and all residual fruits are removed from the orchard.

Usually, 10–12 applications of bait spray are required every mango fruiting season to provide protection from fruit fly infestation.

The best time to apply the bait spray is early in the morning, ideally between 7 and 9 am. This is when adult flies are actively foraging for food. Avoid spraying if it is raining as this will wash the bait away.

- Using the calibrated knapsack sprayer, apply 4 x 25 mL spots of bait spray to each mango tree.
- Apply the spots to foliage at evenly spaced intervals around the tree (**Figure 26** and **Figure 27**).
- Avoid applying bait spray on to fruit.
- Surplus bait can be applied to alternate hosts that are in the neighbouring area such as villages.

FIGURE 26 Applying the protein bait to the foliage

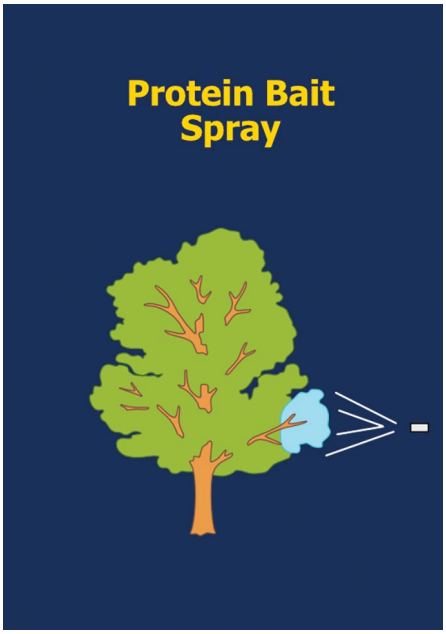


FIGURE 27 Protein bait spray applied to foliage on tree

Safety warning

Personal protective equipment must be worn when setting up, checking and applying bait. The following items are required:

- **disposable gloves**
- **P2 mask**
- **safety glasses**
- **covered-in shoes.**

8.3 Farm sanitation

Unwanted, diseased and fallen ripe mangoes may contain large numbers of fruit fly larvae. If left in the orchard, waste fruit will contribute to high populations of adult flies.

All farmers participating in the AWM system zone need to collect and destroy residual and fallen fruits on their farm to stop the fruit fly breeding cycle continuing in those fruits. This needs to be done for mangoes and all other host fruits in the AWM system zone.

▲ The fruit fly breeding cycle can be disrupted by collecting and disposing of fallen fruit.

How to sanitise your farm

Collect all fallen fruits and residual fruits on the mango trees where possible (**Figure 28**).

Destroy fruits so that the fruit fly breeding cycle is stopped.

Suggested methods of destruction include:

- burying the fruits at least 30 cm under the ground (**Figure 29**)
- placing fruit in fully sealed plastic bags and leaving the bags in full sun for one week before disposal (**Figure 30**).

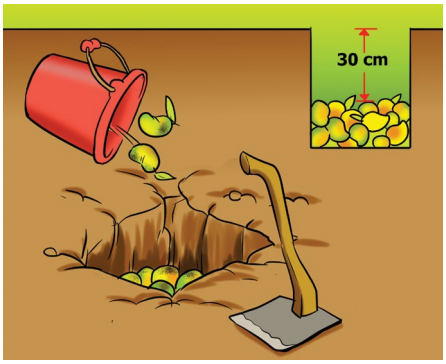


FIGURE 29 Bury fruit at least 30 cm deep

FIGURE 28 Collect all fallen fruit

FIGURE 30 Leave fruit in a bag in the sun for one week

9. Managing hotspots and outbreaks

9. Managing hotspots and outbreaks

An area-wide management (AWM) system zone covers a large area of land that may include a number of fruit fly host plants, other than mango, which flies can breed in. Alternate hosts may include other varieties of mangoes that mature at different periods to the main crop and other fruits. Alternate host plants may also be present along the edges of the AWM system zone, particularly if there are villages or housing areas within or bordering the AWM system zone.

The presence of alternate host plants can result in sudden spikes in the fruit fly population leading to a sudden increase in catches of male flies in the monitoring traps and the flies per trap per day rapidly rising to more than one. Such events are referred to as outbreaks and the location where it occurs is called a hotspot.

Other causes of sudden spikes in populations are residual or fallen fruits that have not been collected and disposed of correctly after protein baiting has ceased.

Check monitoring data regularly, inspect hotspot areas to determine the source of the problem and take remedial action. For example, if out-of-season fruit or alternate hosts are in the hotspot area, follow the procedures described in **8.2 Bait application** for those trees and remove and dispose of all residual and fallen fruits.

9.1 Treatment measures

To maintain the integrity of the AWM system zone, treat the outbreak area or hotspot immediately. This is necessary to arrest the outbreak and bring the flies per trap per day down to the target level of less than 1.

Treatment involves the following measures:

- If the hotspot is adjacent or near to the AWM zone, place additional MAT blocks at the recommended rate of 1 block at 100 metre intervals in the outbreak zone.
- Initiate weekly application of protein baits to the alternate host trees.
- Continue and maintain male annihilation techniques.
- Continue bait application until all fruit are removed and the flies per trap per day drops below 1.
- Continue to assess the fruiting status of key alternate hosts in the immediate surrounds. If heavy fruiting is observed, remove and destroy this excess fruit and continue with male annihilation technique and bait applications.

10. Other commodities and fruit fly species

10. Other commodities and fruit fly species

The area-wide management (AWM) system outlined in this manual has been tested primarily on the oriental fruit fly (*B. dorsalis*) and the carambola fruit fly (*B. carambolae*), which were infesting mango in Java, Indonesia. However, the basic principles and procedures described should enable the AWM system to be successfully implemented in most other fruit tree crops where *B. dorsalis* and *B. carambolae* are the primary pests.

In addition, the AWM system should also be able to be applied to manage other important fruit fly pest species that occur in the Asia-Pacific region, such as *B. occipitalis, B. correcta*, *B. zonata* and *B. xanthodes*. The system should also be able to treat any other pest fruit fly species that are attracted to the male lure methyl eugenol.

To manage fruit fly species that are not attracted to methyl eugenol, the relevant male lure must be used in the monitoring and male annihilation techniques. *B. tryoni* and *B. neohumeralis* are attracted to cue-lure and the Jarvis' fruit fly (*B. jarvisi*) is attracted to zingerone. For more information on management of Australian species refer to De Faveri et al. (2016) and Lloyd et al. (2010).

Several other fruit fly pest species are not attracted to any of the potent male lures. These species can be effectively controlled with low-volume protein bait spot sprays alone.

Protein baits attract and kill both male and female fruit flies, effectively breaking the breeding cycle of the flies within a single fruit season. This technique, when applied over a wide area, should be able to reduce fruit fly damage in harvested fruits to about 4% on average (Vijaysegaran 2016).

IMPORTANT NOTE: The authors have tested this management system on the oriental fruit fly and the carambola fruit fly, which were infesting mango in Indonesia. Programs in other crops and for other fruit fly species should be tested before implementing the system.

11. Further sources of information

11. Further sources of information

This section outlines valuable sources of information on fruit fly identification and management programs. Please note that this is only a selection of the available resources.

Identification

Fruit Fly Identification Australia (**fruitflyidentification.org.au**)

Plant Health Australia (2018) *The Australian handbook for the identification of fruit flies*, version 3.1, Plant Health Australia, ACT, Australia (available from **fruitflyidentification.org.au**).

Fruit fly traps

Enkerlin WR and Reyes-Flores J (eds) (2018) *Trapping guidelines for area-wide fruit fly programmes*, 2nd edition, FAO/IAEA, Rome, Italy.

Management systems

Clarke A (2019) *Biology and management of Bactrocera related fruit flies*, CABI, Oxfordshire, UK.

De Faveri S, Subramanium S, Chambers D, O'Farrell P, Robertson J, Lowe G and Senior L (2016) *Farm-wide fruit fly management systems for the east coast of Australia*, Final Report Project MT12050, Horticulture Innovation Australia.

Lloyd AC, Hamacek EL, Kopittke RA, Peek T, Wyatt PM, Neale CJ, Eelkema M and Gu H (2010) 'Area-wide management of fruit flies (Diptera: Tephritidae) in Central Burnett district of Queensland, Australia', *Crop Protection* 29(5):462–469.

Product suppliers

The AWM system uses male lures and protein baits. Available male lures can vary in purity and several types of protein bait are sold around the globe. Below is a selection of reputable sources of these products in the Asia-Pacific region.

Male lures

Methyl eugenol

Indesso
www.indesso.com

Merck
www.sigmaaldrich.com

Cue-lure

Bio Trap Australia
biotrap.com.au

Bugs for bugs
bugsforbugs.com.au

Merck
www.sigmaaldrich.com

MAT devices

Bugs for bugs
bugsforbugs.com.au

Nufarm
nufarm.com/au

Protein bait

BNJ Resources Sdn Bhd (Malaysia)
Tel: +6012 2226989
Email: **khoo.francis@yahoo.com**

Bugs for bugs
bugsforbugs.com.au

Bio Trap Australia
biotrap.com.au

References

Allwood AJ, Chinajariyawong A, Drew RAI, Hamacek EL, Hancock DL, Hengsawad C, Jipanin JC, Jirasurat M, Krong Krong C, Kristaneepaiboon S, Leong CTS and Vijaysegaran S (1999) 'Host plant records for fruit flies (Diptera: Tephritidae) in South East Asia', *Raffles Bulletin of Zoology* Supplement 7, 1–92.

Clarke A (2019) *Biology and management of Bactrocera related fruit flies*, CABI, Oxfordshire, UK.

De Faveri S, Subramanium S, Chambers D, O'Farrell P, Robertson J, Lowe G and Senior L (2016) *Farm-wide fruit fly management systems for the east coast of Australia*, Final Report Project MT12050, Horticulture Innovation Australia.

Enkerlin WR and Reyes-Flores J (eds) (2018) *Trapping guidelines for area-wide fruit fly programmes*, 2nd edition, FAO/IAEA, Rome, Italy.

FAO/IPPC (2016) *Requirements for the establishment of areas of low pest prevalence*, Secretariat of the International Plant Protection Convention (IPPC).

Hancock DL, Hamacek EL, Lloyd AC and Elson-Harris MM (2000) *The distribution and host plants of fruit flies (Diptera: Tephritidae) in Australia*, Information Series Q199067, Department of Primary Industries, Queensland, Australia.

Lloyd AC, Hamacek EL, Kopittke RA, Peek T, Wyatt PM, Neale CJ, Eelkema M and Gu H (2010) 'Area-wide management of fruit flies (Diptera: Tephritidae) in Central Burnett district of Queensland, Australia', *Crop Protection* 29(5):462–469.

Nishida R and Tan KH (2016) 'Search for new fruit fly attractants from plants: A review' in Sabater-Munoz B, Vera T, Cardoso-Periera R and Orankanok W (eds) *Proceedings of the Ninth International Symposium on Fruit Flies of Economic Importance*, 12–16 May 2014, Bangkok, Thailand.

Plant Health Australia (2018) *The Australian handbook for the identification of fruit flies*, version 3.1, Plant Health Australia, ACT, Australia.

Riboli E, Beland FA, Lachenmeier DW, Marques MMSD, Phillips D, Schernhammer E et al. (2023) Carcinogenicity of aspartame, isoeugenol, and methyleugenol, *The Lancet Oncology* 28(4):848–850. doi. org/10.1016/S1470-2045(23)00341-8.

Shelly TE (2010) 'Effects of methyl eugenol and raspberry ketone/cue lure on the sexual behavior of *Bactrocera* species (Diptera: Tephritidae)', *Applied Entomology and Zoology* 45(3):349–361.

Tan KH and Nishida R (2012) 'Methyl eugenol: Its occurrence, distribution, and role in nature, especially in relation to insect behavior and pollination', *Journal of Insect Science* 12:56. doi:10.1673/031.012.5601.

Vijaysegaran S, Walter GH and Drew RAI (1997) 'Mouthpart structure, feeding mechanisms, and natural food sources of adult *Bactrocera* (Diptera: Tephritidae)', *Annals of the Entomology Society of America*, 90(2):184–201. doi: 10.1093/aesa/90.2.184.

Vijaysegaran S (2016) 'Bait manufactured from beer yeast waste and its use for fruit fly management' in Sabater-Munoz B, Vera T, Cardoso-Periera R and Orankanok W (eds) *Proceedings of the Ninth International Symposium on Fruit Flies of Economic Importance*, 12–16 May 2014, Bangkok, Thailand.


ACIAR
Australian
Aid