icipe

African Fruit Fly Programme
(Programme Africain de la Mouche de Fruit)

A Guide to the Management of Invasive and Native Fruit Flies attacking Mango

"More yield, more quality, secured livelihoods"

Training Manual

Project Partners

Department of Agricultural Research Services (Malawi)

Eduardo Mondlane University (Mozambique)

Zambia Agriculture Research Institute (Zambia)

Department of research and Specialist Services (Zimbabwe)

With the generous support of:

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***Ceratitis cosyra* female fruit fly laying eggs on ripe mango**

***Bactrocera dorsalis* female fruit fly laying eggs on ripe mango**

icipe – Working in Africa for Africa…

International Centre of Insect Physiology and Ecology (*icipe*) – was established in 1970 in direct response to the need for alternative and environmentally-friendly pest and vector management strategies. Headquartered in Nairobi, Kenya, *icipe* is mandated to conduct research and develop methods that are effective, selective, non-polluting, non-resistance inducing, and which are affordable to resource-limited rural and urban communities. *icipe's* mandate further extends to the conservation and utilisation of the rich insect biodiversity found in Africa.

icipe contributes to sustainable food security in Africa through the development of integrated pest management systems for major agricultural and horticultural crops. Such strategies include biological control and use of behaviour-modifying and arthropodactive botanicals. *icipe* emphasizes control approaches that have no detrimental impact on the environment. These options are always designed to fit the needs of the farmers and are developed on-farm and with farmers' participation. In addition to fruit flies, other key areas of *icipe's* research include pests of tomato, brassicas, beans, and staple food crops such as maize and sorghum.

African Fruit Fly Programme is an *icipe*-led fruit fly management program for income generation, poverty alleviation, and improving the food and nutritional security of growers across Africa.

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INTRODUCTION

Mango production plays an important role worldwide, in providing nutritious food, income, and employment opportunities along the mango value chain. In most parts of Africa, the mango orchards are owned by men but women and youths are often involved in the harvesting and sale of the fruits. Women and children usually sell mangoes along roadsides, at market places, and even at the farm level. There are touching stories of women who have managed to take care of their families through mango proceeds, for example by buying food, and clothes and even paying school fees for their children. Despite these benefits, mango trees are often neglected, with farmers rarely watering the trees, or providing various aspects of good agricultural practices. The neglect stems from the high losses experienced due to fruit fly infestation. Fruit flies can cause up to 80% loss depending on mango variety, season, and the locality where the mangoes are grown. Fruit flies lay their eggs in the fruits and upon hatching, maggots destroy the fruit from inside rendering them unsuitable for eating and selling. In countries that export mangoes, the fruits are then rejected by importing countries resulting in the farmer and the country losing income.

To address these challenges, the International Centre of Insect Physiology and Ecology (*icipe*), together with national and international partners, funded by various donors, have developed, tested, and disseminated a fruit fly (Integrated Pest Management) IPM package that is friendly to both human and environmental health. Consistent use of two or more components of this package results in a reduction of damage caused by fruit flies by more than 80%, and an increase in incomes from the selling of mangoes by 60%. *icipe* and partners have invested in training agricultural extension officers, farmers, policymakers, and postgraduate students in a bid to increase the knowledge base that will then spearhead fruit fly research and management. The ultimate goal is to contribute immensely to improved food security, nutrition, income, and poverty alleviation in sub-Saharan Africa and beyond. This guide has been prepared for use in training and also to serve as a quick reference point for farmers. It is a good tool for information dissemination and can be used at any level.

1.0 MANGO PRODUCTION

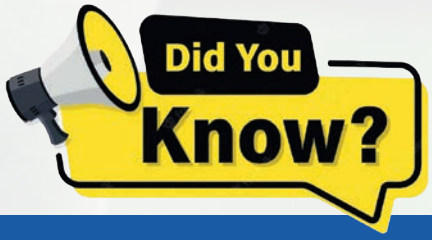
- Millions of smallholder farmers in Africa own between one and hundreds of mango trees in their homesteads, orchards, or farms.
- Mango farmers in Southern Africa particularly Malawi, Mozambique, Zambia, and Zimbabwe are still producing the traditional mango varieties with the production of improved mango varieties such as Apple, Kent, and Tommy Atkins still lagging.
- When mango trees are taken care of, mango production becomes a business that feeds nutritious food to nations, generates income, and creates employment for millions of people along the value chain.
- Mango is a source of food, nutrition, or income when fresh fruits are sold during the fruiting season.
- Mango processing and value addition are taking centre stage in most countries as farmers and value chain actors seek to ensure that mango is available during the offseason as mango flacks, juice, and other mango products. In this way, more income is realised.
- Therefore, mango is known as the "**Golden fruit**" or "**King of tropical fruits**" for its central role in providing food and nutrition to millions of people worldwide.

Plate 1: A farmer in East Africa shows off his good harvest of an improved mango variety called Tommy Atkins.

Mangoes were first grown in Asia (particularly India) about 5000 years ago, and spread to Middle East, East Africa and other parts of the world as people travelled from one continent to the next.

1.1 Constraints to mango production

- Insect pests such as fruit flies, and mango seed weevil
- Diseases such as anthracnose.
- Lack of knowledge. Most mango farmers do not have the information that can transform mango production into a profitable venture.
- Lack of well-defined markets for mangoes, hence farmers slacken on production.



Fruit flies spoil as much as 80% of mangoes (8 in every 10 mangoes) if left uncontrolled or control is inadequate.

Plate 2: Poor management of mango trees in homesteads often leads to the production of few and small fruits in the tree, which are usually heavily infested by fruit flies.

1.2 Major constraints to mango production

- Fruit flies are the major constraints to mango production (Lux et al., 2003)
- They directly lay their eggs inside fruits, and the eggs hatch into maggots which feed on mango pulp/flesh thereby causing the fruits to rot.
- Fruit flies attack both small immature and mature fruits causing them to fall to the ground.
- In extreme cases, farmers can lose the entire harvest through fruit flies infestation.

2.0 Background information on fruit flies

- Of the over 4000 fruit fly species known worldwide, about 1400 species develop in fruits and only about 250 species are major pests. The rest are not much of a problem as they are not of economic importance (Van Houdt et al., 2010).
- About 915 fruit fly species are native to Africa and of these, slightly above 300 species develop on fruits.
- Various fruit flies species are native to specific regions of the world and are only found outside their native regions because of their invasive nature.

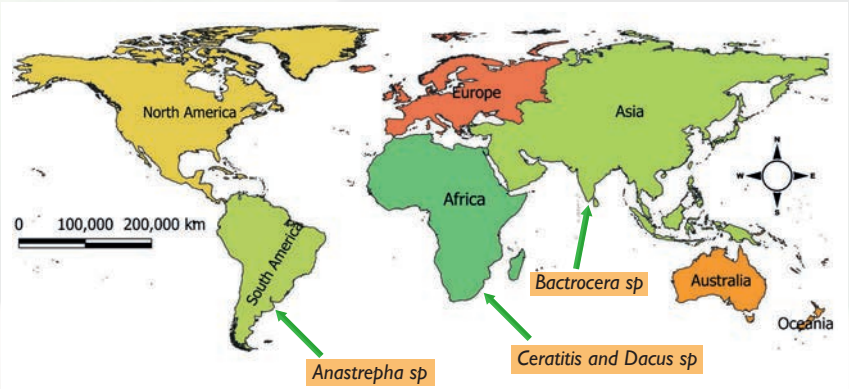


Figure 1: The origin of various fruit fly species

- *Bactrocera* species (*Bactrocera dorsalis, Bactrocera latifrons*) are native to Asia but are now widespread in the whole world. This is because they feed on a wide range of fruits and vegetables, reproduce faster, and adapt to new habitats easily. These are pests of various fruits and vegetables.
- *Anastrepha* species (*Anastrepha ludens, Anastrepha suspensa*) are indigenous to America, particularly Latin America. They attack fruits eg guava and mango among others
- *Ceratitis* (for example *Ceratitis cosyra, Ceratitis capitata, Ceratitis rosa, Ceratitis anonae and Ceratitis fasciventris*) and Dacus species (*Dacus ciliatus, Dacus bivittatus)* are native to Africa. *Ceratitis* are pests of mango, wild fruits eg marula, coffee, etc while *Dacus* species attack cucurbits e.g. cucumbers, watermelon and pumpkin.

2.1 Two major fruit flies that attack mango and lower yields

(1) The Mango fruit fly (*Ceratitis cosyra*)

(2) The Oriental fruit fly (*Bactrocera dorsalis* formerly known as *Bactrocera invadens*)

DID YOU KNOW?

The mango fruit fly Ceratitis capitata is not as aggressive as the invasive Bactrocera dorsalis. Natural enemies available in Africa can adequetly regulate populations of the mango fruit fly.

2.1.1 The Mango fruit fly (*Ceratitis cosyra*)

- The mango fruit fly occurs naturally in Africa hence it is referred to as native/indigenous to Africa.
- It also affects Amarula fruits (*Sclerocarya birrea*) in the wild.
- In mangoes, the Mango fruit fly can cause the loss of approximately 20 out of every 100 mangoes in the tree (20% damage).

Plate 3: Adult mango fruit fly *Ceratitis cosyra* on a mango fruit looking for sites to pierce the fruit using their ovipositor and lay eggs

2.1.2 The Oriental fruit fly (*Bactrocera dorsalis*)

- The Oriental fruit fly is formerly known as *Bactrocera invadens*.
- In Africa, it was reported for the first time in Kenya in 2003, hence it is called an invasive fruit fly species.
- It is a devastating pest affecting various fruits and vegetables either domesticated or in the wild.
- Since 2003, it has spread to many African countries causing huge losses.
- In mangoes, the Oriental fruit fly can destroy approximately 80 out of every 100 mangoes in a tree (80% damage).

Plate 4: Adult Oriental fruit flies on a mango fruit looking for sites to pierce the fruit using their ovipositor and lay eggs

2.2 The life cycle of fruit flies

- There are four stages in the life cycle of fruit flies namely the egg, the larvae/maggots, the pupa, and the adult.
- The male and female fruit flies mate usually at dusk for the eggs to be fertilised. When there is no mating, unfertilised eggs are laid by the female and they do not hatch.
- The female fruit fly has a needle-like structure at the end of the abdomen which has the egg-laying organ.
- It uses this structure to pierce fruits and insert its eggs just below the skin of the mango fruit.

- The eggs hatch into tiny maggots within 1-2 days depending on factors such as temperature.
- The maggots burrow into the fruit, feeding on fruit pulp. This destroys the mango, making it soft and causing it to start rotting.
- The maggots develop from the first to the third instar inside the fruit and the duration of a feeding is often dependent on temperature and food quality.
- The third instar maggot then pops out of the fruit into the soil and changes into a resting stage that does not feed called a puparium.
- The puparium then develops into adult fruit flies which when mature break the puparium cacoon and walk out as adult flies ready to mate and start the cycle again.

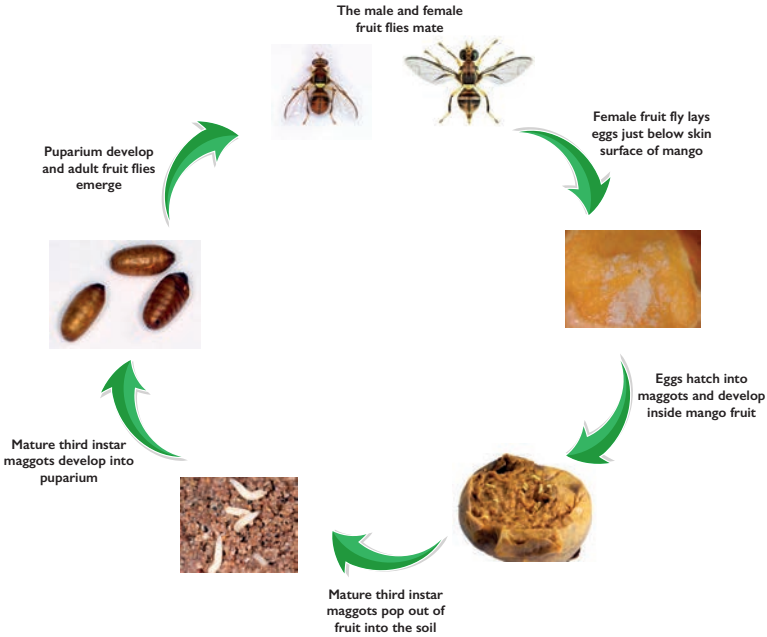


Figure 2: The life cycle of the invasive oriental fruit fly *Bactrocera dorsalis*. The duration of the life cycle depends on temperature, humidity, and food quality

Did You Know?

Not all fruit flies are pests of economic importance! Some are harmless to our fruits and vegetables.

2.3 Integrated Pest Management (IPM): Fruit Fly IPM

- Integrated Pest Management (IPM) is a practice of preventing or suppressing pests by using various tactics/methods that are friendly to the environment, the user, and the consumer to destroy the various stages of the pest so that the farmer can harvest more quality crops eg fruits and vegetables.
- IPM is ecosystem-based (it is cognisant of the health of humans and the environment) and focuses on long-term prevention of pests than immediate short-lived successes.
- To implement IPM more effectively, one must have full knowledge of the pests.
- IPM encourages the use of two or more methods such as biological control, cultural practices, resistant varieties, physical methods, and sanitation among others.

Integrated Pest Management (IPM)

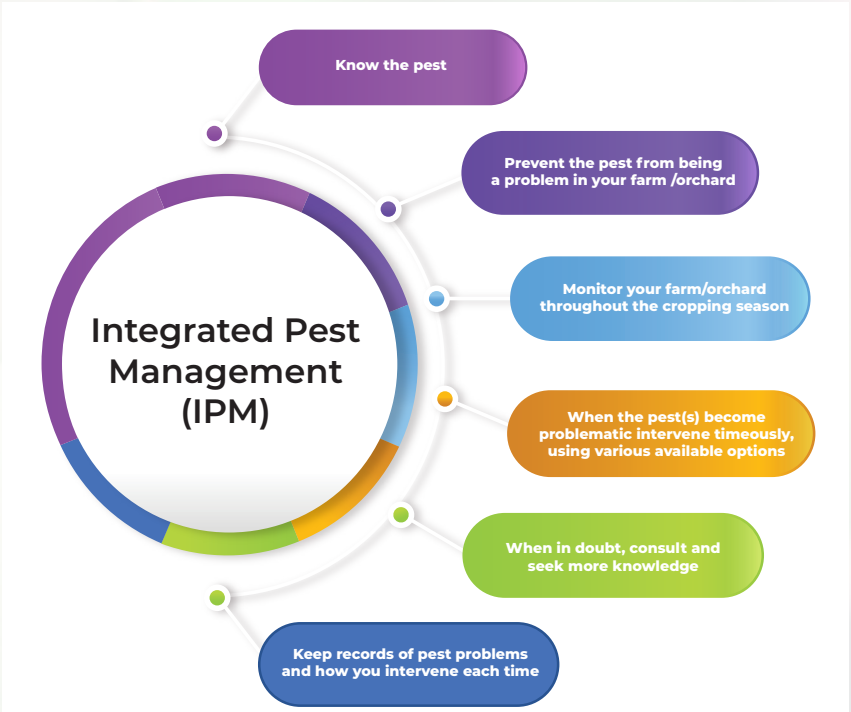


Figure 3: What Integrated Pest Management entails

DID YOU KNOW

IPM is not a silver bullet control method, but a holistic approach that involves specific evaluations, decisions and controls.

2.3.1 Managing/Controlling native and invasive fruit flies using IPM

- With native and invasive fruit flies species threatening the production of fruits and vegetables, various tactics/methods were developed through research by several *icipe* and institutions and funding from various donors.
- These continue to be perfected and adapted to different agricultural ecologies through the model farmer approach.
- In East Africa, consistent use of Fruit Fly IPM in mango orchards was shown to reduce the use of dangerous synthetic insecticides by 46%, reduce mango losses by 55% and increase incomes from mango sales by 48%.

3.0 Monitoring of pests

- Monitoring simply refers to the continuous checking of the farm to determine which pests are present, and in what numbers, and to appreciate the damage they are causing.
- Through monitoring for fruit flies, the farmer can tell which fruit fly species occur on his farm, their distribution, and their dynamics (increasing or decreasing) and decide on what action to be taken,
- If action is already being taken, monitoring informs the farmer on how effective applied control measures are.
- When monitoring data is shared among farmers, they can pinpoint local hot spots where fruit fly populations have reached high populations and require immediate control.
- Through monitoring, farmers can detect new fruit fly species and quickly alert authorities. This is how the devastating invasive fruit fly *Bactrocera dorsalis* was first noticed.

3.1 What to use in monitoring

- For fruit flies, the best monitoring is done using protein food bait. Protein is required in nature by both male and female fruit flies, although females have a higher requirement for egg maturation.
- Thus protein will attract both males and females and the farmer can obtain data on what fruit fly species occur on his farm or area.
- The protein bait will have to be placed in a trap so that flies are caught, identified, and counted.

- When the aim is to monitor a particular fruit fly species, male lures/ pheromones/attractants can be used. For example, methyl eugenol is a well-known lure for fruit flies belonging to the *Bactrocera* genus.
- Various traps are available for use with protein food bait or lures/ pheromones.
- In the absence of food baits and pheromones, the farmer can periodically collect fallen fruits and keep them in such a way that water drains freely from the fruits, and insects (if any) complete their development and emerge as adults and be identified. Sand is provided so that maggots exiting the fruit can pupariate.

4.0 Some of the methods which can be used to manage fruit flies

The following methods are used based on recommendations from data gathered during the monitoring phase.

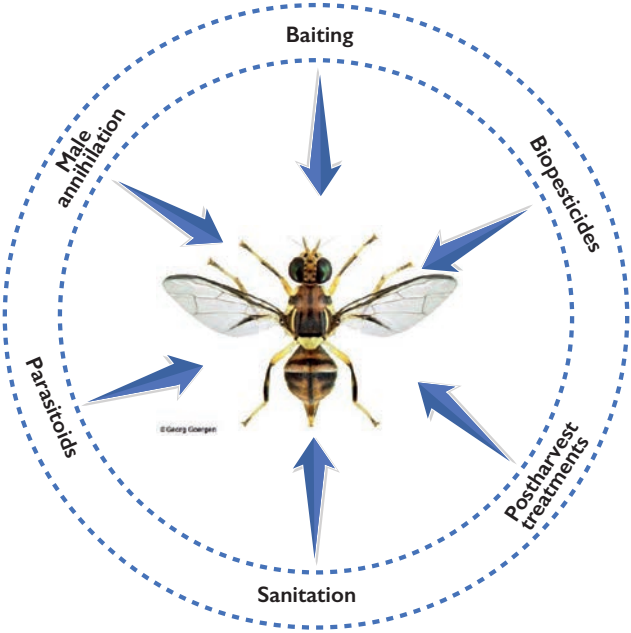


Figure 4: Technologies available for fruit fly management

4.1 Important points to note

- Fruit fly management methods are most effective when used in combination since they differ in application and the stages of fruit flies they target.
- Farmers are advised to start using the different methods well before fruit fly populations overwhelm the crop.
- Where synthetic pesticides are used for example in male annihilation and biopesticides, only small volumes are used and are not applied directly to the fruit. This ensures that no chemical residues are left on the fruits and that non-target organisms like parasitoids and pollinators are not harmed.

4.2 Pre-harvest management options

4.2.1 Male annihilation technology

- A very powerful attractant/lure called methyl eugenol is placed in a trap to attract male fruit flies and they are killed by a small dose of insecticide incorporated into the lure.
- Thus, females are deprived of males to mate with, thus they lay unfertilized eggs that do not hatch. In this manner, the fruit fly population reduces significantly, and mangoes are not damaged.
- The attractant used in traps is methyl eugenol (ME), which is a very powerful lure as it can attract the invasive fruit fly *Bactrocera dorsalis* from a distance of 1km.
- The attractant is usually effective for 4-6 weeks and requires replacement when the farmer notices that catches have reduced drastically with time.
- Traps are placed in the mango orchard/farm at a rate of 1 trap per 20 mango trees.
- This method of trapping fruit flies is common with mango farmers as they can see the trapped dead flies.
- It is advisable to start using traps soon after the fruitlets are formed until mangoes are harvested.
- Other lures are also available for *Dacus* and *Ceratitis* species.

Did You Know?

Male annihilation must start just before the first fruitlets form. When started late when fruits have already formed, it is not effective as female flies would have already mated and fertilised by males.

[A]

[B]

Plate 5: The lure for male fruit flies is packaged in various forms eg [A] as polymeric plugs [B] as blocks

Plate 6: A Research Officer from *icipe* (Peterson Nderitu) explained to a mango farmer how traps and attractants are used in male annihilation

Plate 7: Fruit flies inside a trap before emptying the trap

Plate 8: Heaps of fruit flies, emptied from traps in Ethiopia

4.2.2 Baiting technology

- Fruit flies naturally require protein to develop (Drew 1987). Though both males and females require protein, it is the females that need it most to mature their eggs.
- Various protein sources have been commercialized as bait for fruit flies but since most are manufactured outside Africa e.g GF-120, they rea relatively expensive and are beyond the reach of resource-poor smallholder farmers.
- A bait product called Fruitfly Mania™ was developed and is being produced in Kenya by a private sector company. It is currently being tested in Southern Africa to pave way for registration to ensure its availability to farmers.
- The protein is mixed with a small portion of environmentally friendly insecticide and sprayed on 1 square metre of the tree trunk or canopy away from fruits. This ensures that fruits are free from chemical residues).

- When the fruit flies eat the poisoned protein bait, they die thus their population is reduced.
- Protein baits are also available as baiting stations. (These are plastic devices with protein, some plant extracts, and chemicals that can be hung in a mango tree).
- As a rule of thumb, one metre can be estimated as the distance from one shoulder to the tip of the other stretched hand (see illustration below).

Figure 3: [A] Measuring 1 square metre on tree trunk or canopy, which is then sprayed with a mixture of protein and a small portion of insecticide [B] Fruitfly Mania™ being promoted as protein bait in East Africa. [C] How to estimate 1m using outstreched arms

4.2.3 Use of Biopesticides

- Biopesticides are naturally occurring substances processed from fungus, plants, animals, bacteria, and viruses among others for use in the control of pests.
- *icip*e has isolated from the soil several biopesticides based on the fungus *Metarhizium anisopliae* and these have been commercialized in collaboration with private sector partners and the products are availed to farmers through retail channels.
- These fungus-based biopesticides can be used in various ways to control different stages of development for fruit flies.

Plate 9: Fungus-based biopesticide in liquid form (container) and dry spores (in sachet)

a) Spraying under the tree canopy

- When fruit flies lay their eggs in mangoes on the tree, this causes the fruits to fall to the ground. Fruit fly maggots developing in the fruit, often pop out when they are old enough and change into a resting stage called the puparia.
- The biopesticides (which are formulated in the liquid form either as water or oil formulation) can be mixed with water in a knapsack sprayer and sprayed under the canopy area to target the maggots as they pop out from the fruit or the puparia.
- When the fungus spores get in contact with the maggots or puparia, they begin growing, entering the maggot body or puparia thus causing death.

Plate 10: A mango farmer spraying a fungus-based biopesticide under the tree canopy to kill fruit fly maggots and puparia

b) Use of autodissemination trap/device

- An autodissemination trap/device used in fruit fly control consists of two plastic containers with the top inverted and its sides having velvet material. The bottom part has a compartment into which a fruit fly lure like methyl eugenol is placed.
- The fungus mentioned above which is used in spraying is used here in a different formulation as dry spores. The spores are smeared on the velvet material and the autodissemination trap/device hung in the mango orchard 1.5m from the ground.
- Fruit flies are attracted to the trap by the lure (methyl eugenol or any other lure) and enter the trap through some small holes in the top inverted plastic container.
- Fruit flies walk on the velvet material as they look for the lure but are unable to locate it because it will be in the bottom compartment. In this manner, flies pick spores that contaminate their bodies. Disappointed by the failure to reach the lure, they leave the trap and fly away.

- When they fly away they spread the spores to other fruit flies during the process of mating.
- Fruit flies often participate in "lekking". At dusk, male fruit flies congregate in swarms and males engage in elaborate displays as they impress female flies to mate with them. It is in such groups that hundreds or thousands of fruit flies are contaminated with fungus spores and die after a few days.
- Thus the autodissemination trap/device targets adult fruit flies.

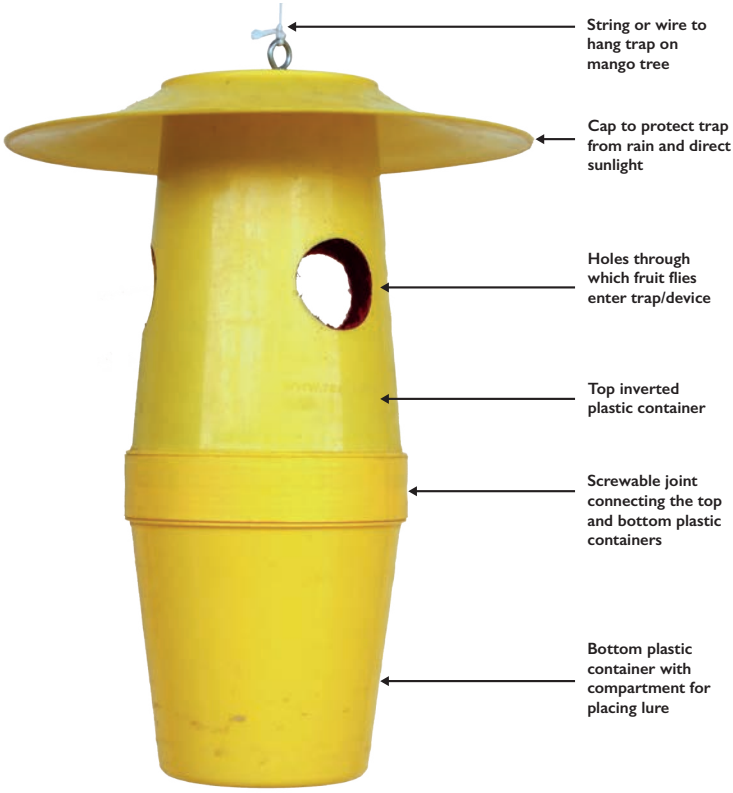


Plate 11: The autodissemination trap/device for use with dry spores of fungal biopesticide

4.2.4 Use of natural enemies or parasitoids/wasps (farmer's friends)

- Some insects (beneficial insects) are known to control other insects which cause loss to the farmer.
- Parasitoids are beneficial insects also known as the farmers' friends because they control the eggs, the maggots, or even the adult insect pests.
- *icipe* has released in Africa, two types of parasitoids. One is called *Fopius arisanus* which controls the fruit flies at the egg stage and another is called *Diachasmimorpha longicaudata* which controls fruit flies at the maggot stage.
- Both of these farmers' friends specialised in finding the eggs and maggots of fruit flies inside fruits and then use their injection-like structures at the end of the abdomen to pierce the skin of the fruit thereby inserting their eggs inside the egg or maggot of the fruit fly.
- In this manner, fruit flies are controlled and their populations decline in mango orchards.
- *icipe* has released the fruit fly parasitoids in various countries in East, West, and Southern Africa and continues to do so to complement fruit fly management measures.
- These parasitoids were imported from other countries where the major fruit flies such as *Bactrocera dorsalis* came from because the native or indigenous parasitoids were unable to control the invasive fruit flies.
- The indigenous fruit flies such as *Ceratitis cosyra,* have their parasitoids which occur naturally in Africa and can control them.
- The release of imported parasitoids has significantly improved the control of both invasive and native fruit flies.

Excessive use of synthetic insecticides kills natural enemies! Farmers are encouraged to reduce the use of such insecticides. Say NO to calender sprays of broad spectrum insecticides!

Plate 12: Parasitoids (farmers' friends) [A] *Fopius arisanus* which controls the fruit flies at the egg stage and [B] *Diachasmimorpha longicaudata* which controls fruit flies at the maggot stage.

a) Advantages of using parasitoids

- Parasitoids are very specific and will not attack crops, animals, people, or any beneficial insects such as bees. They only attack fruit flies.
- Once parasitoids are released in mango farms, they spread to other areas thus their effect is long term.
- Their survival on the farms can be enhanced by reducing the number of synthetic pesticides applied on farms by farmers.

Plate 13: Farmers release parasitoids in their mango orchards. Once released they disperse on their own.

4.2.5 Field/Orchard sanitation/Cleanliness

- Field/orchard sanitation refers to the practice of picking, collecting, and destroying fallen fruits to remove possible sites where fruit flies can complete their life cycle.
- When infested fruits are left on the ground, fruit flies continue to have food substrate where they continue developing and eventually emerge as adults and reinfest fruits.
- When used with other control measures, field/orchard sanitation can reduce fruit fly populations significantly.

a) Handling fruits picked from the ground
b) Use of Augmentorium

- Fruits picked from the ground can be placed in a tent-like structure called an Augmentorium. If fruits are infested, the flies continue to develop and emerge as adults. However, they are unable to escape because the Augmentorium has small holes through which flies cannot escape.
- If parasitoids also emerge from the infested fruits, they escape through the small holes on the yellow top of most of the structure and go back into the farm or orchard.
- The fruit flies die inside the Augmentorium and the decomposing fruits can be used as organic manure.

Plate 14: A farmer placing infested fallen fruit into the augmentorium

DID YOU KNOW?

Even without the Augmentorium, a farmer can still practice sanitation! Just pick all infested fruits and bury them underground.

Plate 15: An augmentorium showing the yellow top most part through which parasitoids escape back into the farm

c) Burying fruits underground

- In the absence of augmentoria, farmers can dig holes with a depth of at least 50cm and place all infested fruits inside and cover them. Emerging fruit flies will be unable to reach the surface thus they will die underground.
- The drawback of this method is that it also kills beneficial insects such as parasitoids.

d) Feeding infested fruits to animals

- Infested fruits can be fed to pigs and cows since the maggots are a source of protein.

e) Solarization

- Infested fruits can be placed in black plastic/polythene bags which are then tied and left in the sun.
- The heat of the sun kills all stages of the development of fruit flies.
- The fruits can then be decomposed and used as organic manure.

f) Used in the rearing of insects for feed

- The rearing of insects such as the Black Soldier Fly for use in animal feeds is slowly gaining momentum in Africa.
- Farmers can use fruits picked from the ground as feed material for the insects which thrive in rotting organic matter.
- The resulting organic matter can then be formulated into organic fertilizers.

5.0 Post-harvest management options

- There are various post-harvest treatments for mangoes such as vapour treatment, irradiation, and hot water treatment among many others.
- Postharvest management of fruits is mostly important for ensuring that fruits are not lost to fruit fly infestation after they have been harvested.
- Postharvest treatments ensure that fruits are available beyond the fruiting/harvesting season and can be exported satisfactorily to markets that are sensitive to quarantine insects such as *Bactrocera dorsalis*.
- Postharvest treatments are not a stand-alone management measure but complement pre-harvest management measures.
- Hot Water Treatment (HWT) is considered as one of the most effective and environmentally friendly treatments, relatively affordable to set up compared to other treatments and easy to maintain (Ndlela et al., 2021).

5.1 Hot water treatment (HWT) of mangoes

- Fruits are harvested at the green physiologically mature stage and placed in a special tank that has temperature-controlled circulating water for a specified period at a predetermined temperature.
- This method of disinfesting mango fruits has been studied extensively at *icipe* and protocols for disinfesting various mango varieties have been developed.
- Mangoes subjected to hot water treatment were shipped to Europe (Italy) and the consignment passed all phytosanitary requirements, thus opening up export markets in Europe that have not been accepting mangoes from Africa for years now.
- A common user facility for hot water treatment is currently being constructed by the Kenyan government near the Jomo Kenyatta International Airport in Nairobi and will be open to all users.

5.1.1 Advantages of hot water treatment

- The treatment kills all stages of development of fruit flies and ensures that mangoes are free of fruit flies of quarantine importance should they be exported.
- The same facility for treating mangoes can be used for disinfesting vegetables such as French beans and bell pepper.
- Hot water treatment does not affect the physical, chemical, and biological properties of treated fruits.

Plate 16: A miniature Hot water treatment tank with temperature controls/sensors, a water pump for water circulation, and cladded walls to guard against heat loss during treatment

Did You Know?

Hot Water Treatment is the future of postharvest treatments! It is relatively cheaper than other treatments and once the facility is set up, it can be used to treat other commodities such as bell pepper and French beans.

5.2 Mango drying

- Mangoes often ripen simultaneously and are in the market for a very short period during which the market for fresh mangoes is overwhelmed, with prices dropping drastically and some mangoes rotting.
- Mangoes can be dried at a small scale level (household) or large scale (commercial scale).
- Smallholder farmers can be trained on how to dry mangoes using the natural heat of the sun (green energy).
- Special net baskets are currently being used in Southern Africa and women are drying mangoes for food in the dry season and for sale at the household level.
- Women have been trained in the hygienic processing of mango fruits and storage of dried fruit.

Plate 17: Mango farmers drying mangoes in southern Africa as individuals [A] and as groups [B].

- Mango drying can be done in special greenhouses that retain heat and dry the mango flakes uniformly
- The greenhouse driers are relatively expensive compared to the net driers.

Plate 18: The greenhouse drier is made of special polythene material

Plate 19: Men and women pose outside a newly completed greenhouse drier in East Africa, Kitui, Kenya

Plate 20: Inside the greenhouse drier showing shelves

5.2.1 Other forms of driers

- The farmer can fashion his/her drier depending on the materials available. However, the source of energy remains solar, though some use electricity green energy is preferred.

Plate 21: A different type of solar-powered drier in Southern Africa, Zimbabwe

6.0 Area-wide Management of fruit Flies

- Area Wide Fruit Fly management is required to control the pests over large geographical areas so that fruit fly populations decline and the benefits are felt over large areas and enjoyed by a huge number of farmers (Jessup et al., 2007).
- Africa is characterised by a highly fragmented cropping system that provides diverse host plants to fruit flies and in some parts of the continent, throughout the year.
- Mango trees are found growing as wild plants and abandoned homesteads are also very common.
- Effective control of fruit flies requires farmers to unite and use available management options widely and consistently.
- Information and adoption of fruit fly management technologies must be cross cutting to leave no gaps where reservoir populations of fruit flies are preserved and form sources of infestation.
- Whole villages and districts must be sensitised so that large areas are using two or more components of fruit fly IPM.

Area Wide Management of fruit flies has been implemented in various countries with so much success. It requires consistency for it to be successful.

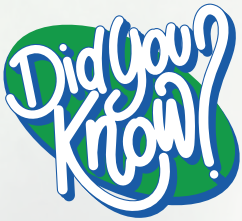
DID YOU KNOW?

Plate 22: Villagers being trained on fruit fly management by an Agricultural Extension Officer.

Plate 23: Villagers pose for a photo after attending a meeting on fruit fly management at a fellow villagers' homestead.

7.0 Training of Trainers (ToTs)

- The Trainer of trainers model involves identifying a few individuals within an area, and training them on fruit management so that together they constitute a pool of competent personnel who are knowledgeable and can then teach other people (colleagues, fellows, groups of farmers) Gerster-Bentaya et al., 2022).
- In most cases, Agricultural Extension personnel are often targeted for such training by virtue of their role in disseminating agricultural information and technologies.
- The role of Agricultural Extension Officers is evolving, thus they need to be equipped with new skill sets that they did not learn in college/ university.
- Agricultural Extension Officers understand their communities (where they work) and interact with farmers in different fora.
- Once trained, officers are expected to pass the message to farmers whenever they have the opportunity to do so. In this way training can happen over a long period, both theoretically and practically.
- In today's world the role of Agricultural Extension Officers has transitioned from merely that of being a conduit through which researchers pass raw information to the farmer, into active roles in which researchers, extension, and farmers work together as partners or stakeholders.



Effective trainer of trainers must possess adequate knowledge and skill in participatory education because training is more valuable and effective when trainees partake in both theory and practice.

Plate 24: Agricultural Extension Officers (and some key mango farmers) in Zambia displaying certificates after attending a two day ToT training on fruit fly management organised by *icipe*, with funds from IDRC and ACIAR.

Plate 25: A trained Agricultural Extension Officer, explaining to mango farmers how the male annihilation technique works.

8.0 The model farmer -Demonstration farm approach (peer-to-peer learning)

- Model farmers are champion farmers chosen for training and their farms are used as learning sites where technologies are demonstrated and other farmers come and learn by seeing and participating.
- Model farmers must be jointly chosen by farmers, social workers, agricultural extension officers, and where possible, traditional or political leaders in given localities.
- This participatory approach ensures inclusivity and fairness, and selection is often based on acceptability, credibility, and the willingness of the prospective demonstration farm owner to host other farmers.
- Demonstration learning sites are an effective bottom-up tool for self-directed information gathering and perception molding based on the shared general understanding among farmers, researchers, the private sector, policymakers, or various entities (Marchand et al., 2021).
- The basis of demonstration learning sites stems from the notion that farmers learn and accept knowledge from their peers than from strangers (scientists) prescribing solutions that have not been proven in their context (Hamunen et al., 2015).
- Demonstration farms offer farmers an opportunity to co-create valuable people and location-specific information. When farmers see innovation in action, and approval from their peers, they are likely to consider adopting the technology.
- Since neighbors form the core of people learning from the nearest demonstration farm, issues of group dynamics such as leadership, trust, communication, intra-hostilities, and personalities are minimized as communities often choose individuals already with demonstrated leadership qualities.

Peer to peer learning is one of the best learning methods as it enables colleagues ausually at the same level to voluntarily share knowledge and experiences.

Plate 25: Signage for demonstration learning site outside the homestead of a mango farmer in Zimbabwe.

Plate 26: Learning under a mango tree: farmers sharing knowledge at a Demonstration farm in Zambia.

- *icipe* together with other entities normally provide support for norming and ensures that the model farmers and demonstration farms are taken into the performing stage.
- The adoption of technologies requires that potential candidates be provided with support to generate perceived benefits and realize productivity. Thus demonstration farm owners are often provided with IPM starter packs.

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Alien Invasive Fruit Flies in Southern Africa
Implementation of a Sustainable IPM Programme to Combat their Menaces

Fruit Fly IPM saved 7/10 mangoes from fruit fly damage hence farmers sold more quality fruits



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Alien Invasive Fruit Flies in Southern Africa
Implementation of a Sustainable IPM Programme to Combat their Menaces

END OF PROJECT MEETING

Project proposal funded 2019

Project inception in Zambia June 2019

Project implementation July 2019 – March 2022

Participatory monitoring and Evaluation -Throughout implementation

End of Official funding from **IDRC** and **ACIAR**

Thousands of Mango farmers in **Malawi**, **Mozambique**, **Zambia** and **Zimbabwe** adopt resilient fruit **fly IPM technologies** and **mango drying** for sustained livelihoods

icipe · ZARI · African Fruit Fly Programme

Alien Invasive Fruit Flies in Southern Africa
Implementation of a Sustainable IPM Programme to Combat their Menaces

IDRC · CRDI
Canada
Australian Government
Australian Centre for International Agricultural Research

- Environmentally friendly Integrated fruit fly management
- Gender inclusivity
- Value addition (Mango drying)
- Poverty reduction (incomes)
- Food and nutritional security
- Capacity building

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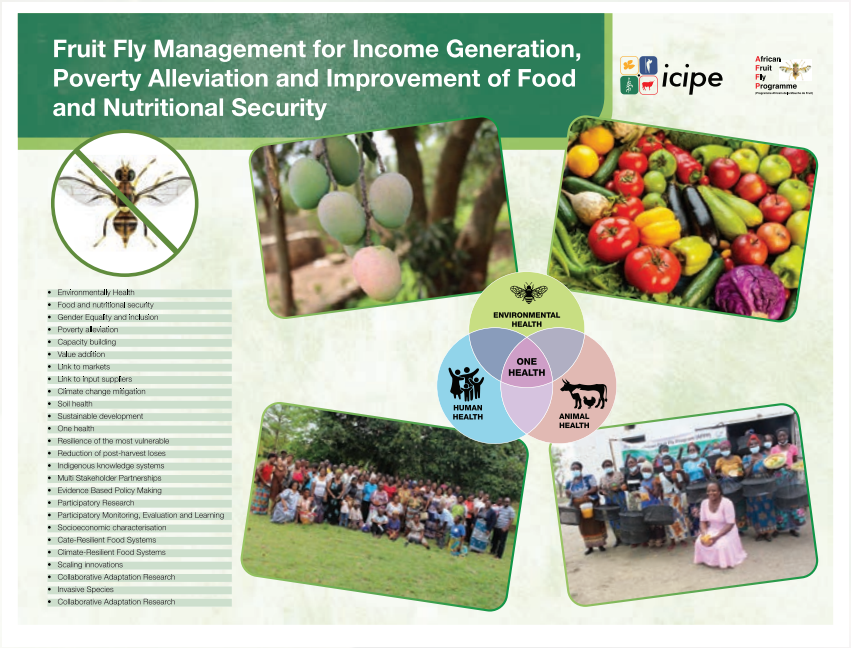
Fruit Fly Management for Income Generation, Poverty Alleviation and Improvement of Food and Nutritional Security
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African Fruit Fly Programme
Environmentally Health
Food and nutritional security
Gender Equality and Inclusion
Poverty alleviation
Capacity building
Value addition
Link to markets
Link to Input suppliers
Climate change mitigation
Soil health
Sustainable development
One health
Resilience of the most vulnerable
Reduction of post-harvest loses
Indigenous knowledge systems
Multi Stakeholder Partnerships
Evidence Based Policy Making
Participatory Research
Participatory Monitoring, Evaluation and Learning
Socioeconomic characterisation
Cate-Resilient Food Systems
Climate-Resilient Food Systems
Scaling innovations
Collaborative Adaptation Research
Invasive Species
Collaborative Adaptation Research
ENVIRONMENTAL HEALTH
ONE HEALTH
HUMAN HEALTH
ANIMAL HEALTH


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