MANUAL FOR THE CONTROL OF THE CARAMBOLA FRUIT FLY IN SOUTH AMERICA

Operations Manual

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Paramaribo, Suriname
SECOND EDITION, SEPTEMBER 2013

CFF OPERATION MANUAL -

SECOND EDITION, SEPTEMBER 2013

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This manual was developed as a reference for use in the CFF programme in Suriname, Guyana, French Guyana and Brazil. It contains the basic information regarding *Bactrocera carambolae*, its biology, trapping and control. It can also be used as reference for trapping programmes in the region, aimed at detecting and controlling exotic species.

Material included here is original or compiled from similar manuals from the United States Department of Agriculture, APHIS - Animal and Plant Health Inspection Service and CDFA - California Department of Food and Agriculture; from the IAEA trapping manual; from FAO ISPM's and from publications.

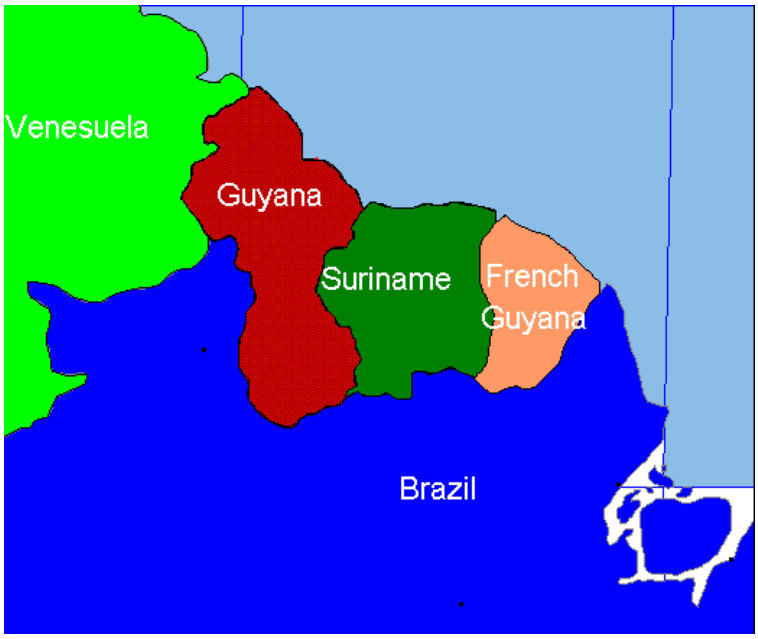
General Information

History of CFF in South America

Carambola fruit fly (CFF) is a pest new to the Americas due to improvements in transportation around the world in the 1960's and 70's. CFF was first collected in South America in 1975 from Paramaribo. CFF is native to Indonesia, Malaysia, and Thailand, and was first collected in South America in 1975 from Paramaribo, Suriname. Indonesia is also the origin of about 20% of Suriname's population. It is likely that CFF was introduced into the region by small-scale trade or family visits between Suriname and Indonesia in the 1960s or early 1970's.

The flies collected in 1975 were not identified and CFF was not found again until 1981. These specimens sent to the United States for identification and were identified as *Dacus dorsalis*, the Oriental fruit fly. Although Oriental fruit fly is one of the most serious pests in the world, no action was taken at that time. In 1986, the international community realized that the presence of Oriental Fruit Fly in Suriname represented an important threat to the production and marketing of fruit throughout tropical and subtropical America, including the Caribbean. The fly was later found to be a separate species from the Oriental fruit fly: *Bactrocera carambolae*, the Carambola fruit fly.

Lack of funding and coordination among the international community allowed the fly to expand its distribution. CFF was first found in French Guyana in 1989 and in Amapa, in Brazil in March, 1996. It was detected in Guyana in 1993; eradicated during the Regional project, after which Guyana was declared free in 2000, but due to the cessation of this project, the fly moved back to areas previously eradicated, and continued to move further westward into Guyana (2007), where now several regions are infested.



Economic Impact

Many countries in the region will lose large amounts of money if CFF becomes permanently established. A study carried out by USDA/APHIS in 1995 estimated the losses for the countries that are most at risk. The estimate for field losses ranges from 2.5% for cashew, breadfruit and Suriname cherry to as much as 50% for carambola.

Value of Production yearly loss in US$	
Suriname	849,041
Guyana	360,000
French Guyana	869,553
Brazil	57,681,569
Dominican Republic	44,294,970
Haiti	14,062,925
Trinidad and Tobago	284,160
Venezuela	526,662

Apart from the direct losses in the field, the establishment of CFF in some countries would prevent them from exporting fruit to countries that do not have CFF. The total export loss for the entire region is estimated to be US$ 25.3 million if banana is not a host and US$ 67,1 million, if banana were a host. An eradication program for CFF in South America was estimated to cost US$ 9 million in the late 90's. When compared to the potential loss to the region, the eradication program is very cost-effective.

Taxonomic Status

Bactrocera carambolae was described as a valid species in 1994 by the Australian taxonomist Richard Drew. He decided to split the large genus *Dacus* into two genera. He named the second genus *Bactrocera* and it includes most of the species that were in the genus *Dacus*.
The group of flies that was *Dacus dorsalis* and is now *Bactrocera dorsalis*, is found throughout Asia and the Pacific Islands. Drew first suggested that *B. dorsalis* was not 1 species, but several; however, he has now described 44 different species based on morphology, geographic distribution, and host range. CFF is very closely-related to the OFF and is usually found in Indonesia, Malaysia and Thailand. The Guyana's region of South America is the only area outside of Asia where CFF can be found.

Description of CFF

- **Egg:**

  Curved (banana-shaped), 1 mm long, shining white, milky when ready to hatch.

- **Larva:**

  Elongate and pointed at head. Length from 1 mm just after hatching to 7-8 mm just before pupation. The color is white or the same color as the fruit pulp. Older larvae jump repeatedly about 10 cm or more when removed from the fruit and placed on a flat, dry surface.

- **Pupa:**

  Cylindrical, about 4 mm long, dark reddish brown, resembling a swollen grain of unhusked rice.

- **Adult:**

  Length 3.5-5 mm. Black-yellowish with brown tinge, especially on abdomen, head, and legs. Thorax black. Black vein on front of the wings. Eyes can be one of many colors. Male: abdomen is rounded; female: ovipositor is knife shaped, 1.2 mm long. The femur of CFF has dark patches, especially the middle pair of legs, compared to *dorsalis*.

Biology

Life cycle. From egg to mature adult takes about 22 days under good conditions (26°C and 70% RH). Eggs take 1-2 days to hatch. The larval stage lasts 6-9 days, and pupation 8-9 days. Adults become sexually mature in more than 20 days after emergence. The minimum period of time for one generation is approximately 36 days.

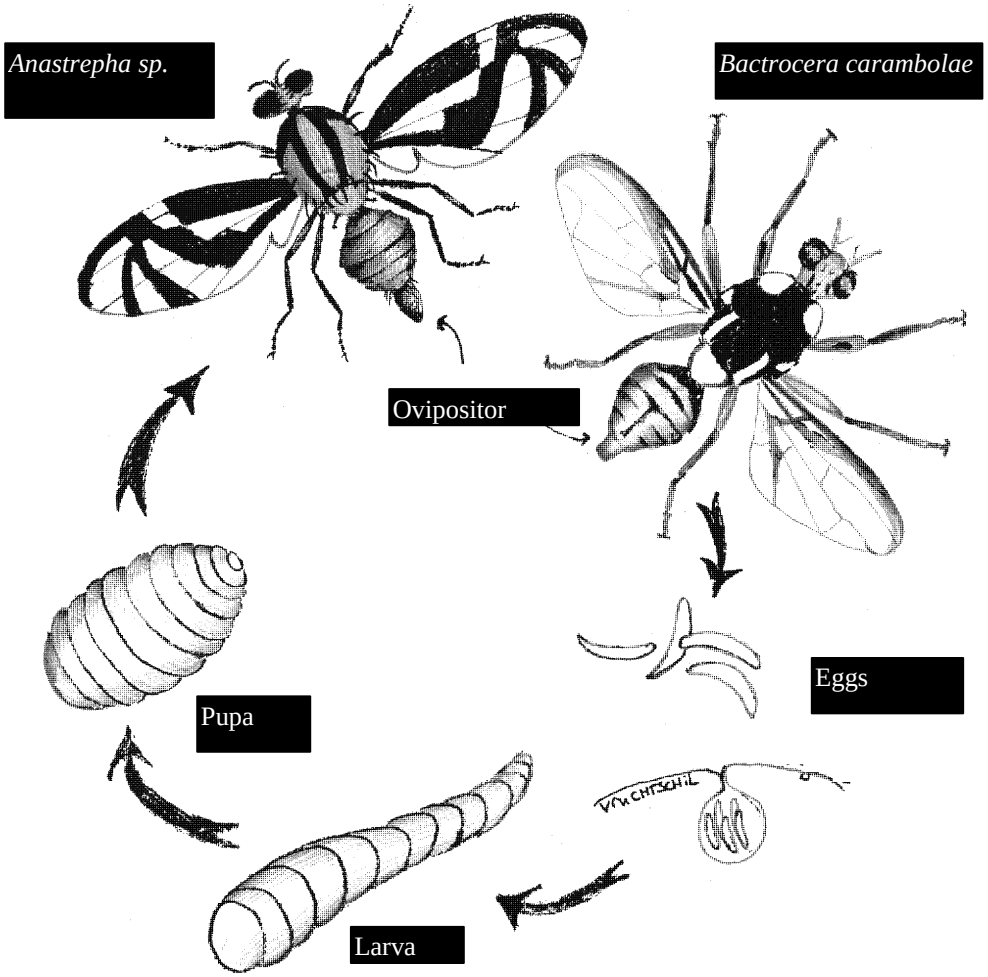
Females puncture the skin of green or mature fruit and lay eggs in groups of 3 to 5 just under the skin. Larvae have 3 instars (stages) inside the fruit where they feed on the pulp and make tunnels in the fruit. At the end of the third instar, the larvae leave the fruit. Usually the fruit has fallen on the ground by this time and the larvae leave the fruit and burrow 2-7 cm into the soil to pupate. The length of time the pupal stage lasts depends on the soils' temperature and humidity. The adults emerge from the puparium and wait for their wings to expand before flying away.

Larvae of Carambola fruit flies can be distinguished from *Anastrepha* larvae by their ability to jump. If full grown larvae are placed on a dry surface, they crawl up and jump several centimeters. *Anastrepha* larvae only crawl.

Both males and females begin to look actively for food once they reach maturity at 8-12 days of age. They need protein to produce eggs and sperm. Mature adults copulate after males perform a courtship dance in the early evening, just before the sun falls. The flies eat spoiled fruit, plant nectar, bird dung, honeydew and other substances. CFF starts their courtship later in the evening (around 300 lux) than Oriental fruit fly (2500 lux) (McInnis et al., 1999).

Adults usually live 30-60 days in nature but may live as long as 6 months. Females can lay more than 1,000 eggs over their lifetime.

Both, males and females are strong flyers and will fly long distances if they cannot find a good source of food or site to lay eggs. Data from *B. dorsalis* have shown that the adults can fly over 50 km from the emergence site. Likewise, they tend to remain in the place where they emerged if host trees with fruits are nearby.


Anastrepha sp.
Bactrocera carambolae
Ovipositor
Eggs
Pupa
Larva

Host List

The Carambola fruit fly is known to attack more than 100 different fruits in Southeast Asia (Allwood, A.J. et al, 1999).
In Suriname, results of fruit collections from 1986-2002 were published (van Sauers-Muller, A.E. 2005). For French Guyana, a survey conducted from 1994-2003 is published (J.F. Vayssières et all, 2013). In Brazil several publications provide information on host status of CFF and in Guyana, the host list was published in a report from the ministry of Agriculture.
According to the ISPM standard (draft) specific definitions apply to indicate host status of fruit flies. All collected fruits were field collected, and can therefore be considered natural hosts. Whether a host is considered a good or poor host depends on the number of larvae/pupae per 100 gram of fruit and on the frequency of infestation of these hosts.

Host status: Brazil (B), French Guiana (FG), Guyana (G) and Suriname (S).

Scientific name	Common names	Family	Country	Host status
Averrhoa carambola L.	carambola caramboles fransmanbirambie five finger	Oxalidaceae	Brazil French Guiana Guyana Suriname	good host
Eugenia ligustrina (Sw.) Willd.	black cherry cerise noir	Myrtaceae	French Guiana	medium host
Eugenia cf. *patrisii*	forest cherry boskers	Myrtaceae	Suriname	medium host
Eugenia uniflora L.	Suriname cherry pitanga monki-monki kers cerise de Cayenne	Myrtaceae	French Guiana Suriname	medium host (FG, S)
Syzygium malaccensis (L.) Merr. & Perry	pommerak, malay apple pomme d'amour	Myrtaceae	French Guiana Suriname	medium (S) to good host (FG)
Syzygium samarangense (Blume) Merr. & Perry	Curacao apple, wax apple Curaçaose appel Malaka cashew	Myrtaceae	French Guiana Guyana Suriname	good host (FG, S)
Syzygium jambos (L.) Alston	pommeroos	Myrtaceae	Suriname	medium host
Psidium guajava L.	guava goyave goiaba guave	Myrtaceae	Brazil French Guiana Suriname	medium to good host (FG, S); varietal differences!
Malpighia punicifolia L. synonym *Malpighia emarginata* DC	West-Indian cherry acerola, cerise pays west-indische kers	Malpighiaceae	Brazil French Guiana Suriname	good host (FG, S)
Terminalia catappa L.	tropical almond amendoeira	Combretaceae	French Guiana Suriname	medium (FG, S) host

	amandel			
Anacardium occidentale L.	cashew caju kasjoe	Anacardiaceae	French Guiana Suriname	poor host (S, FG)
Mangifera indica L.	mango, manga manja	Anacardiaceae	French Guiana Guyana Suriname	medium host, good host; varietal differences!
Spondias cytherea Sonn. synonym *Spondias dulcis* Foster	golden apple pomme de cythere	Anacardiaceae	French Guiana Suriname	medium (S) to good (FG) host
Spondias mombin L.	hog plum, caja, mope, taperebá	Anacardiaceae	Brazil French Guiana Suriname	poor host (S) to good host (FG)
Spondias purpurea L.	purple mombin	Anacardiaceae	French Guiana	medium host
Chrysophyllum cainito L.	star-apple abio sterappel	Sapotaceae	French Guiana Suriname	poor (S) to medium (FG) host
Manilkara achras (Mill.) Fosberg	sapodilla sapotilles sapotille	Sapotaceae	French Guiana Suriname	medium (S) to poor (FG) host
Pouteria caimito	abiu	Sapotaceae	Brazil	Status unknown
Richardella macrophylla Lam.	Jaune d'oeuf Canistel	Sapotaceae	French Guiana	poor host
Citrus reticulata Blanco	mandarin mandarijn	Rutaceae	French Guiana Suriname	poor host
Citrus sinensis (L.) Osbeck	sweet orange laranja doce sinaasappel	Rutaceae	French Guiana Suriname	poor host
Citrus paradisi	grapefruit pomelo	Rutaceae	French Guiana Suriname	poor host
Garcinia dulcis (Roxb.) Kurz	moendoe	Clusiaceae	Suriname	poor host
Mammea americana L.	mamey apple	Clusiaceae	French Guiana	poor host
Ziziphus mauritiana syn.*Z. jujuba*	Jujube olijf	Rhamnaceae	French Guiana Suriname	medium host (S, FG)
Inga laurina (Sw) willd.	swiet bonki, whytee	Mimosaceae	Guyana Suriname	poor host
Inga sp.	pois sucre sweet bean	Mimosaceae	French Guiana	medium host
Annona muricata L.	soursop corossol	Annonaceae	French Guiana	poor host
Rollinia mucosa	biribá	Annonaceae	Brazil	Status unknown

SURVEY PROCEDURES

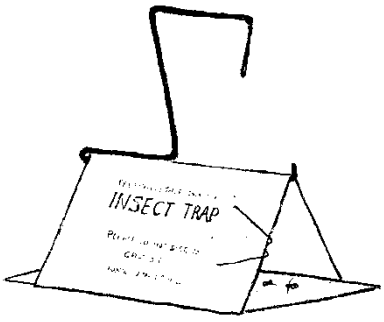
You can run but you can't hide. - - Mick Jagger

Trap types and baits

The types of traps that can be used for monitoring for Carambola fruit fly (CFF) are the Jackson trap, Multilure traps and the McPhail traps (see figures).

Jackson traps.

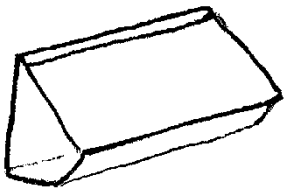
Jackson trap



The delta-shaped Jackson trap is made of plastic-coated cardboard. The lure + insecticide are placed on a cotton wick held inside the trap by a wire wick-holder. An insert with glue, placed on the bottom of the trap, holds the flies for later inspection.

The Jackson trap consists of 5 parts: trap body, insert, wick holder, wick and a metal hanger.

HANGER



VAL (TRAP BODY)

CLIP MET WATJE (CLIP WITH COTTON WICK)

LIJMLAAG (INSERT)

The lure used for *B. carambolae* is methyl-eugenol (ME), a natural product derived from clove oil that is a powerful male attractant. An insecticide, Malathion, is added to the methyl-eugenol to kill the males that are attracted to the lure and they are then caught on the sticky insert. Although methyl-eugenol is a specific attractant for males of many *Bactrocera* species, the trap may occasionally also catch females of fruit flies in the genus *Anastrepha.*

If no insecticide is provided with the lure, there is, especially in areas with very low populations of CFF (or any other ME attracted *Bactrocera* species) the risk that the male fly will be attracted, feed on the ME, and leave the trap better equipped to mate due to feeding on ME.

Multilure traps.

The Multilure trap (MLT) is a version of the McPhail trap. The trap is 18 cm high and 15 cm wide at the base and can hold up to 750 ml of liquid (Figure 11). It consists of a two-piece plastic invaginated cylinder-shaped container. The top part is transparent and the base is yellow. The upper part and base of the trap separate, allowing the trap to be serviced and rebaited. The transparent upper part of the trap contrasts with the yellow base enhancing the trap's ability to catch fruit flies. A wire hanger, placed on top of the trap body, is used to hang the trap from tree branches.

Figure 11. Multilure trap.

McPhail Traps.

The bell-shaped McPhail trap was originally made of glass, but is now commercially available in plastic, with just one entrance in the bottom. The present designs have two parts in which the upper part and base of the trap can be separated allowing for easy service (rebaiting) and inspection of fruit fly captures. This trap is used for all kinds of fruit flies - males or females – and species and it is baited with a food lure. The fly enters the trap through the bottom entrance and it feeds on the liquid lure. When they try to fly toward the light at the top of the trap, the insects are not able to escape and fall into the liquid and die. For this trap to function properly it is essential that the body stays clean.

Usually the food attractants used are sources of protein such as protein hydrolysate or Torula yeast, but all kinds of fruit juices are attractive to fruit flies.

McPhail trap

McPhail traps with liquid protein attractant are labour intensive. Servicing and rebaiting take time, and the number of traps that can be serviced in a normal working day is half that of some other trap types. Due to the nature of the bait, traps need to be serviced every week to 14 days.

Servicing the traps

Jackson.

The wick is baited with a mixture of 4 parts methyl eugenol and 1 part Malathion®. Malathion 96% ULV mixes better with the methyl-eugenol than Malathion 57% EC, due to the formulation of the insecticide. ME and Malathion ULV are both oily substances that stay mixed well.

The insecticide is necessary, as male flies will be attracted by methyl-eugenol only, and might remain stuck in a trap, but -especially in the case of a low population, as in recent introductions- they could feed on the lure and leave the trap again, without the trappers ever being aware that the fly is present. The insecticide will keep the fly in the trap. Experiments are carried out in Suriname to find alternative insecticides that are less toxic.

Each wick holds about 6 ml of the lure, sufficient to saturate the wick without dripping. After loading the wick at the laboratory, it should be wrapped in aluminum foil that has to be removed before placing the wick in the trap body in the field. Another method is baiting the wick in the field in a bottle with the pre-mixed lure/insecticide. Care should be taken that dripping does not occur, as it will lure flies away from the trap.

The bait, under conditions in north of South America, should be changed monthly. The trap body should be changed when damaged or weakened - depending the rainfall. This can vary from 3 months to one year.

The sticky insert must be changed every time the trap is serviced and the trap number and date written on the underside. Trappers should write the dates they place and service the traps on the underside of the trap. They should also avoid contaminating the trap with the lure because it may distract the fly from entering the trap and thus not be captured. An accidental spill, even a few drops, will cause a decrease in the effectiveness of the trap or may make it totally ineffective.

If a suspicious fruit fly is found on the insert do not fold it tightly, as this hampers the identification of the flies. Just fold the insert slightly (it might help to place a small stick or a leaf of e.g. a mango tree in between) to preserve the specimen better and prevent it from getting under glue from both sides of the insert.

McPhail and Multilure traps

The traps should be filled to just below the lip, with 250 to 600 ml - depending on the size - of lure. If protein hydrolysate is used - Mazoferm®, NU-LURE® - a 10% solution has to be prepared in the lab; add 3% Borax to adjust the pH of the attractant. If using Torula yeast, 3-5 pellets per trap should be dissolved in the water by crushing the tablets and stirring the solution until the yeast mixture is dissolved completely. The preferred attractant is Torula yeast.

Try to avoid spilling the bait solution outside the trap in order not to decrease the number of captured flies. Spillage on the ground will attract them to the ground and not to the trap. The bait solution should be changed weekly for better results.

When servicing a trap, the solution must be sieved using a small strainer over a plastic bucket. The contents of the strainer should be placed in a plastic vial with 70% alcohol. A small label with the trap number and date written with a pencil must be put inside the vial to avoid misidentification. The labels should be written in the lab; however take extra labels and a pencil to the field. The upper part of the McPhail trap should be cleaned regularly, if this part prevents light from entering the trap, the captured flies will find the bottom opening and escape from the trap. The remaining liquid from the trap is taken to a location where it can be discarded without affecting trap catches.

Trap Placement

Selection of a trapping site:

In selecting a site, first consideration should be given to the availability of preferred hosts, with fruit, in which to place the trap. If there is a choice between two or more possible trap locations with hosts of equal status, preference should be given to the site that has more than one host tree. In many cases, host trees will be by themselves. Care should also be taken to select sites that are easily available and can be found again. Remember, the trap is placed to catch fruit flies that are present in the area; but if the tree is more attractive to the fly than your trap, you will not catch the fly. So be careful in selecting a site and rotate to other fruit bearing host trees if necessary.

In some cases, a very desirable host may not have mature fruit or enough shade (too few leaves) to place a trap. In such cases, a nearby honeydew source (fruit trees with sucking insects like aphids or scale insects) might be a desirable trap location. Traps should always be placed in host trees with fruits compared to host trees without fruits. This means that traps should be regularly rotated in a plot with different host trees.

Placement of the trap in host:

The trap should be placed high enough in the tree to be out of reach of children, pets (parrots, monkeys) or livestock. Take care to place it securely in the tree so that it will not be blown down by high winds

The trap must be placed in open shade, never in direct sunlight. The trap should not hang below or outside the foliage of the tree. Neither should the trap be placed in dense foliage, which would block the entrance of the trap.

CORRECT
PROPER HEIGHT

INCORRECT
PLACED TOO LOW

FIGURE 4

COMMON MISTAKES IN TRAP MAINTENANCE:

⇒ the Jackson trap body and insert do not have its proper trap identification number.
⇒ inserts and Jackson trap bodies are not replaced often enough.
⇒ failure to replace contaminated traps.
⇒ contamination of ground from overfilled McPhail traps.
⇒ Failure to clean McPhail and Multilure trap upper parts.
⇒ inadequately filling out vial label information when insect specimens are submitted.
⇒ failure to number the trap or to rewrite a number that has faded.
⇒ not indicating on trap body when previous rebaiting occurred.
⇒ failure to fill out trap record sheets.

WHAT TO TAKE IN THE FIELD WHEN TRAPPING:

* traps, inserts, hangers, wicks with lure + clips.
* McPhail traps
* trap record sheets on clipboard.
* marker, pencil and pen.
* plastic containers with lids and sawdust.
* sieve.
* water
* protein hydrolisate or Torula
* stick to place traps.
* machete.
* plastic bags.
* rain clothing.
* Labels
* GPS

You will not be the first, neither the last, to travel, sometimes far, to the flied, only to realize that you have forgotten essential trapping material at the office…..!

Trap density

Trapping is done:

- to detect the presence of CFF
  to determine the CFF distribution and population level after a first detection
- to control CFF where MAT is not being executed
- to determine absence after control activities (= detection in terms of density)

The density should be applied following the chart (number of traps per km^2):

TRAP	AREA	DETECTION	DISTRIBUTION	CONTROL
Jackson	rural	2 (or 1 each 5 km in a highway)	10 to 20	30-50
Jackson	urban	0.5	10 to 20	50-80
McPhail	rural	0 for detection, 2 to determine	4 to 8	10-20
McPhail	urban	zero	4 to 8	10-20

The action radius of a Jackson trap baited with methyl-eugenol is around 100m. So, only 1 Jackson should be installed in one hectare (100 x 100 m). McPhail traps attract flies in a radius of 20 m. So, each McPhail has to be at least 40 m away from the next one.

FRUIT COLLECTION

Objectives

Host fruit are collected in the field for the following reasons:

* to determine the host status of a given fruit species and/or varieties;
* to detect the presence of a fruit fly species in the area;
* to evaluate the effectiveness of control/eradication programs;
* to determine the population/infestation level of a fruit fly species in the area and the distribution of the fly species
* to determine the presence of parasitoids for the fruit fly species.

Collecting

Collectors should try to take samples of many stages of ripeness and include newly ripe, mature, and old injured fruit. The sample should be large enough to determine if the fruit have larvae. A reasonable sample is 20; for small fruits - like West Indian cherry - a sample could contain over a hundred fruits, while in the case of a large fruit like sour sop, 3-4 fruit would be enough.

Collect fruits in plastic containers in which you placed some dry sawdust, sand, or vermiculite. Be careful not to place too many fruits together or smash them as this will cause the larvae to smother and die. Do not use plastic bags to collect samples. You must label each collected sample with the location, date and fruit species and whether the fruit was collected from the tree or from the soil (fallen). If the fruit comes from a tree with a trap, write also the trap number or take a GPS point.

Bring the fruits into the lab in plastic containers with sawdust, sand, or vermiculite. These substances absorb the extra liquid coming out of the fruits. In case of travel over several days, they also provide a medium for the larvae to pupate. In this case, also cover the trays with cloth, to prevent larvae from jumping in other containers, and prevent *drosophila*'s from infesting the sample.

Fruit holding and fruit fly rearing:

In the lab the fruits are counted, weighed, recorded and transferred - if is the case - to smaller containers for rearing. If the juice coming out from the fruit leaves the sawdust too wet it kills the larvae or pupae. The sawdust should be sifted every week for pupae and for at least two weeks or until the fruit is complete dry or rotten. The container should be covered with screen or fine cloth. Aeration is essential for the survival of the larvae. Record all information on the samples in a logbook, and use that log number on the containers.

After the pupae have been found in the sawdust, remove them and place them in a separate jar (marked with the same sample number). Cover this jar with screen or fine cloth and a rubber band. The sawdust in the jar should stay moist, but not wet. If the sawdust is too dry, the pupae will die.

Emerging flies should be fed with water and sugar for 2-3 days to gain full color. If is the case, the flies should be killed and placed in a vial with a 70% ethanol for future identification. Inside the vial a pencil written label must be placed and also on the outside of the vial. Both labels bear the log number, date, collection site, and fruit species. The logbook should contain all information on the sample as fruit species (scientific name, local name and the variety), number of fruits, weight, location, any exceptional remarks, whether collected from the soil or picked from the tree, the date that pupae and their number were found, emergence of flies or parasitoids and their identity.

Pictures of containers, jars etc. to be added.

Infested carambola fruit.

FIRST DETECTION ACTION

If a CFF male is captured in an area considered free, the procedures to be followed are:

1. If one or more males are found in a Jackson trap, immediately:

a) Increase the number of Jackson traps with 10 to 20 (depending if the finding has few trees or if it is a nice environment for the flies) in a 300 meters radius from the point where the male was found. In Brazil, 10 Jacksons in 200 meter radius from the focus is used.

b) Set up 4 to 8 McPhail traps baited with protein; In Brazil, 10 McPhail traps are set up in a radius 200 meters from focus.

c) Check all traps: frequency in Brazil: daily for 15 days; when 0 flies are found: check traps 3 x per week for 30 days; when 0 flies are found: check traps 2 x per week for 60 days; when 0 flies are found: weekly for 90 days; when 0 flies are found, check every 14 days.

IF after 1 week:

1. NO MORE FLIES FOUND OR 1-2 MALES FOUND

a) Keep the same # of traps for 2 consecutive weeks

2. 1 OR MORE FEMALES OR 3 OR MORE MALES FOUND

Remove all Jackson traps

a) Increase the number to 20 McPhail traps

b) Release 500 impregnated fiber blocks in 250,000 m^2 (or 500 x 500 m)(20 blocks per ha) every 20 days; in case of one focus: 200 blocks in a radius of 500 meters around the focus, every 20 days

c) check the McPhail every 3 days

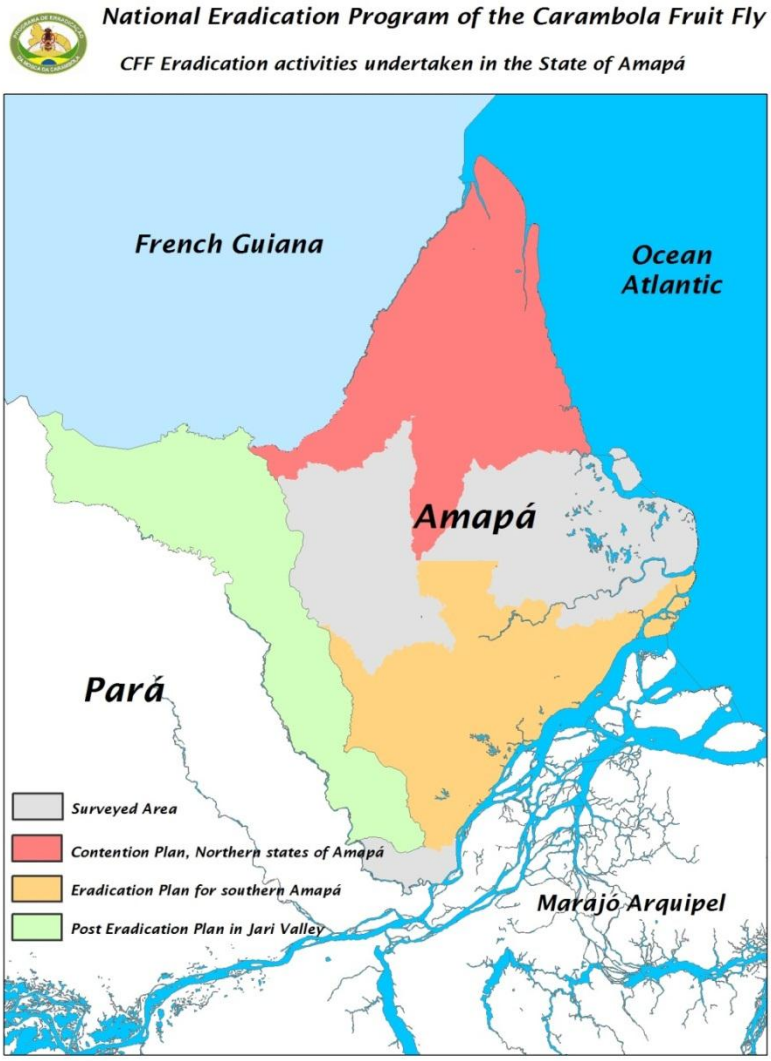
d) if more females are captured, bait spray with protein + malathion

e) after reaching zero catch again in 3 consecutive weeks, set up 10 Jackson and reduce McPhail to 2.

f) the outbreak would be considered eliminated if no flies are captured for 5 months.

IF more than 4 foci are found: treat as infested area (large area control)

Install 0.4 Jackson traps per hectare, and 0.2 McPhail traps per hectare (Brazil), (both higher than in trap density table, p. 19).



Introduction to Fruit Fly Control

To control Carambola fruit flies is the most difficult objective to accomplish. After we have used traps to determine that there are flies an area, we will use control methods to kill them. Insect biologists have been working for many years to develop methods to control fruit flies.

In general, fruit fly control can be divided into two types of techniques: **large area** and **small area** techniques. In our program we will use both of these types of control strategies.

Large area control

Large area control uses techniques that only work if they are done in the same way throughout the area where the fly is found, such as a city, district, or even an entire country. The most well-known example of this type of control is the Sterile Insect Technique (SIT). Male flies are sterilized with radiation and then released in very large numbers throughout the program area. These males mate with the females flies, but the females do not lay fertile eggs.

Small area control

Small area control is anything that a farmer or homeowner does to protect the trees on his own farm or property. Spraying insecticide on a single tree to kill the female flies that come to lay eggs in the fruit is one example of a small area control strategy. Other examples are placing paper or cloth bags over the fruit to protect it from egg laying females, collecting and destroying fruit, or even killing some of the most attractive kinds of trees to protect the rest of the orchard.

The strategy in Northern South-America

In the Carambola Fruit Fly Program the main control strategy which is used is the **Male Annihilation Technique** (MAT). This is a large area approach that uses the behavior of the fly against itself. Poisoned baits containing an attractant that lures the male flies are placed throughout the area under control. In some areas, small area methods of control can be used in addition to MAT.

Male Annihilation Technique

MAT is an effective way of controlling fruit fly populations that uses knowledge about the behavior of the fly to eliminate it. So MAT is similar to biological control methods, though it uses a small amount of insecticide. Very little insecticide is used in MAT because the flies are attracted by the methyl eugenol to ingest the insecticide, rather

than the insecticide applied directly to the fly or fruit. MAT is very environmentally friendly compared to many techniques used in small area control.

MAT is based on the attraction of male flies to methyl eugenol, a naturally occurring oil that is found in many plants. Once the male flies become sexually mature they search their surroundings for methyl eugenol. They will fly hundreds of meters searching for it and once they find the methyl eugenol, eat as much as they can. With a body full of Methyl eugenol, the males are able to attract many other males around them. These groups of males, in a "leck", work together in a kind of dance to call females for mating. Males that have eaten methyl eugenol are preferred by the females.

In MAT, a small amount of the attractant, methyl eugenol, and insecticide, such as Malathion, is used to lure all the male flies in an area to a spot and kill them. Each spot is called a bait station or "bait".

In our program we use two kinds of baits. One is a wooden fiber block that is soaked in the mixture and the other is a 5-10 ml spot sprayed onto a tree or electric pole. In the spray, the methyl eugenol and insecticide are mixed together with Min-U-Gel. Min-U-Gel is a powder that, when mixed in the right proportion, makes a sort of jelly or grease. This gel lasts longer after being sprayed than the liquid by itself.

There are two situations in which we use MAT treatment. The first is the initial treatment to eradicate the fly from an area that is heavily infested; the second is to control the fly in a small area within the project where flies have been found for the first time, or months after the last capture.

Small area control methods

The MAT technique is very effective and will kill most of the flies in a large area within 6 months. After this time, however, some areas will still contain many flies. Most likely these are areas that have many different kinds of host trees. It will usually take longer to kill all of the flies in place with many different kinds of fruit trees (for example, cherry, mango, carambola and apple) than in an area with few kinds of fruit trees (only mangos or only apple trees). In some of these areas ("hot spots") we will use small area control methods to help the MAT kill the flies.

MAT only controls adult male flies that are sexually mature, these other control strategies target other stages (eggs or larvae) or adult male and female flies.

Protein bait sprays

Protein is a very attractive food for both male and female flies. Females especially need to eat a lot of protein to produce eggs. In protein bait sprays, insecticide is mixed with protein to kill flies which come to eat it. In this way it is like the bait we use in MAT. The difference is that females as well as males are attracted to it. The other main difference is that protein is not as attractive as methyl eugenol. This means that the protein bait stations must be placed closer to each other.

There are two versions of protein bait sprays available:

- hydrolyzed protein 500 ml + Malathion 50 ml + water 9.5 liter = 10 liter; borax should be added to the mixture to raise the pH and thus attract more flies.

- Spinosad. In Brazil, Success 0.02 CB is used. 1 liter Success + 4.5 liter water

In the second version, the insecticide that is used is not a poison at all for mammals, fish or the environment. In fact it is an artificial dye that is used in many of our packaged foods and drinks. A few years ago, someone discovered that many small insects that eat this dye are killed. How the dye kills them is not well-known, but it has to do with a reaction between light entering the stomach and the dye.

The mixture of dye, protein and a few other chemicals to make the mixture even more attractive are put together in a spray. And applied about every 15 meters in areas where we have found fruit infested with larvae. It is applied every 5 days in case of a focus, every three days during rainy season; but after 2 months without flies, the frequency changes to every 2 weeks.

Fruit Stripping

One reason that fruit fly populations become so high in some areas is because the fruit are left under the trees and not used or eaten. This allows the larvae to leave the fruit and go underground to complete their life cycle and become an adult fly. If the fruit are picked before or just after they fall to the ground and eaten or destroyed, there would be fewer flies in the area. Fruit can be destroyed by placing them water, such as canals, or swampy areas that are always wet. This drowns the larvae when they leave the fruit.

In areas where fly populations are high, we will ask residence to keep fruit from piling under their trees. Some of these people will be unable or unwilling to pick up their fruit and they will have to be assisted by one of our teams.

Fruit collected in Amapa

Fruit bagged in Suriname

Fruit should be picked up from the ground, and the tree shaken to cause as much of the ripe fruit as possible to fall to the ground. The fruit should be collected and taken nearby for destruction (placement in water, in plastic bags or buried). Don't bring the fruit more than a few meters away if possible. Don't bring infested fruit into non-infested areas.

The fruit in the plastic bags can be used for composting after being exposed to a week of sunshine.

Treatment Protocol

Treatment should begin when more than one fly has been trapped within the pilot project area within one month. If the captures are made in an isolated area, far from habitation or known host tree, then MAT should be conducted within 500 m of the capture area. If it is on a single road, Min-U-Gel should be sprayed 1km along the road and blocks placed or thrown as far into the forest possible. If the captures are within an inhabited area with many host trees, then treatments should be placed within 3 km of the capture sites in all directions.

MAT treatment should begin as soon as possible after the flies are caught. The decision to treat will be based on when and where the flies were trapped. A single fly trapped within less than one life cycle (1 month) of the original find may trigger intensive trapping only. More than one single find may trigger immediate treatment.

In California, four applications of baits (2-3 months) have been able to control the fly. In South America, it should be about the same, unless the infestation is very large, or when beginning control in a new area that is heavily infested.

Applying controls

Fiber Blocks

Fiber blocks soaked in the mixture of methyl eugenol (3 parts) and Malathion (1 part) are the longest lasting bait station available up to now. Fiber blocks must be placed 20 per hectare throughout the area under control. Blocks should be placed SECURELY in a shady place, protected from direct rainfall. They can be put in a tree, old building, fence, or other structure where they will not fall to the ground. The blocks either have wires attached to it, or are connected with another block with a rope, in which case they are thrown into a tree, around branches.

The most important part about applying MAT using blocks is to make sure they are evenly distributed throughout the area. Twenty blocks per hectare means that you should place a block about every 20 meters. No block should be more than 20 meters from the nearest. Leaving areas that are not under control can allow the flies a refuge where they can survive to maturity and mate without being exposed to the baits. Along a very narrow area, such as a road, or single row of houses, this is easy to do. However, in wider areas with many houses and trees in next to each other (like many villages) you must take care to place the blocks evenly.

When applying the blocks, all workers should wear chemically resistant rubber gloves to reduce the amount of contact with the skin. The mixture of Methyl eugenol and Malathion, though not very toxic, can be irritating to skin and eyes.

Min-U-Gel Spray

The poisoned lure is applied to objects along the road and in backyards. It is sprayed using a pressurized Panama pump. The mixture of methyl eugenol and insecticide (Malathion) is applied at a rate of 20 spots per hectare, at about 5-10 ml (a quick "on-and-off" of the applicator gun). The spots should be applied on wooden objects such as utility poles, tree trunks, tree stumps and other unpainted surfaces such as fences. The spots can also be applied to concrete objects, but metal or painted objects should be avoided if possible. The mixture will burn leaves, so try to avoid application on leaves because they will fall off in less than two weeks.

Each spot should be applied about 2 meters above the ground. When making applications along the road, it is not usually necessary to stop at each area; however, the vehicle's speed should be slow enough to allow an accurate placement of material in one spot without splatter, drift, or a miss. Watch for drift when applying. Every street and house/farm more than 100m from the road must be treated.

If material accidentally gets on a vehicle, stop and wash it off immediately. Notify the owner.

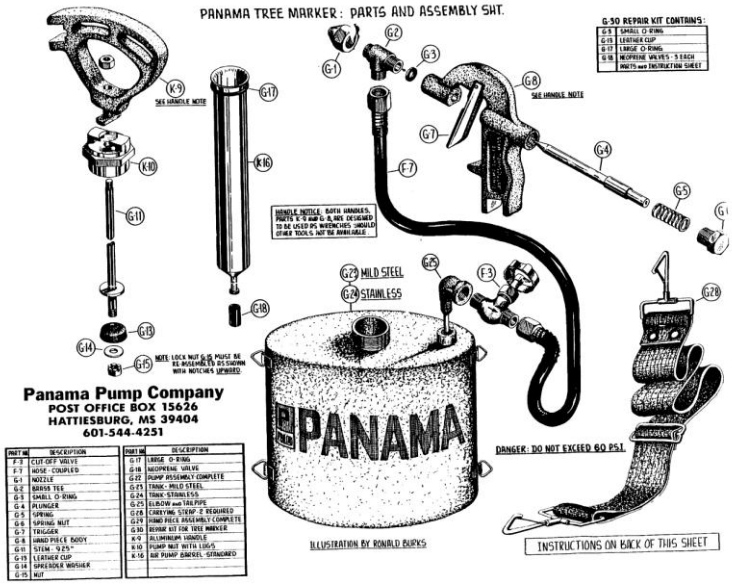
Mixing instructions

1. Safety equipment should be worn when mixing - - long pants, boots, gloves, face shield, and helmet.

2. Place 3 liters of Methyl eugenol/Malathion in a plastic bucket. Slowly add 1 kg (2 small white buckets) of Min-U-Gel while stirring. Stir until completely mixed.

3. Pour into Panama Pump Canister through a strainer and funnel.

4. Remove and wash protective clothing.



Assembly sheet of the Panama pump.

Cleanup after treatment

1. After finishing treatment for the day, remove all pressure from Panama pump by depressing the trigger and holding the pump on its side with the intake tube up until all air and excess material has been removed.

2. After arriving from the field, pour all extra material from the pump into the storage containers. Pour 0.5 liters of the liquid lure/insecticide mixture into the Panama Pump Canister. Pressurize to low pressure (10-15 psi) and spray into the appropriately labeled containers (making sure to tilt the canister to keep the intake tube on the lowest level).

3. Reassemble and store.

References:

- Allwood, A.J., A. Chinajariyawong, S. Kritsaneepaiboon, R.A.I. Drew, E.L. Hamacek, D.L. Hancock, C. Hengsawad, J.C. Jipanin, M. Jirusat, C.Kong Krong, C.T.S Leong & S. Vijaysegaran. 1999. Host plant records for fruit flies (Diptera: Tephritidae) in Southeast Asia. Raffles Bull. Zool., supplement n. 7:1-92.
- Kellman, V. CFF host list for Guyana, 1997-2006, Ministry of Agriculture.
- McInnis, D.O., P.Rendon, E. Jang, A. van Sauers-Muller, R. Sugayama and A. Malavasi. 1999. Interspecific Mating of introduced, sterile *Bactrocera dorsalis* with wild *B. carambolae* (Diptera: Tephritidae) in Suriname: A potential case for cross-species Sterile Insect Technique. Ann. Entomol. Soc.Amer. Vol 92: (5) 758-765.
- Silva, R.A., E. G. Deus, J.D.B. Pereira, C.R. Jesus, M.F. Souza-Filho, R.A. Zucchi. 2011. Conhecimento sobre moscas-das-frutas no Estado do Amapá. Capitulo 15. In: Moscas-das-frutas na Amazonia brasileira: diversidade, hospedeiros e inimigos naturais. (R.A. Silva, W.P. Lemos &R.A. Zucchi, ed.) Embrapa Amapá, Macapá, p 223-236
- Vayssières, J.F., J.P. Cayol, Ph. Caplong, J. Seguret, D. Midgarden, A. van Sauers-Muller, R. Zucchii, K. Uramoto, A. Malavasi. 2013. Diversity of fruit fly (Diptera Tephritidae) species in French Guiana: their main host plants and associated parasitoids during the period 1994-2003 and prospects for management. Fruits, vol. 68, p. 219-243.
- Van Sauers-Muller, A.E. 2005. Host plants of the Carambola fruit fly, *Bactrocera carambolae* Drew & Hancock (Diptera: Tephritidae), in Suriname, South America. Neotropical Entomology 34(2): 203-214.
- Van Sauers-Muller, A.E. 2009. Jaarverslag Carambola fruit vlieg onderzoek 2009 (Annual report). Ministry of Agriculture, Animal Husbandry and Fisheries, Directorate Research.