7. Aerial sterile fly release

STEP V OF PROCESS IN FLOW CHART IN APPENDIX 2

Aerial release is more cost-effective than ground release for large-scale programmes and a more uniform sterile fly distribution is achieved compared to ground releases, which tend to clump sterile flies in localized sites or along release routes.

Sterile flies are released using fixwing aircrafts or helicopters. It has been shown that sterile medflies released by helicopter disperse throughout a narrower band than those released at higher altitudes by the standard airplane method. Helicopters appear to be well suited for sterile fly release in mountainous areas where terrain and unpredictable weather conditions are unsuitable for airplanes (Vargas *et al.* 1995).

Once the release area is selected, it is divided in polygons, where flight lines are depicted. The basic tools in this step are digitalized maps, follow-up GIS software and GPS (see Section 11).

For aerial release a flight plan should be formulated at least 24 hours in advance. Plans will depend on the following:

- General strategy of the programme (suppression, eradication, prevention, containment)
- Progress made on the weekly coverage of the release zone
- Amount of sterile flies available for release on that day
- Established release densities
- Results achieved in sterile fly distribution and density in the previous weeks
- Availability of transport units and number of sterile fly recharging points in the area

At the present time there are two (2) basic systems for aerial release. These are the bag release and chilled fly release systems.

7.1 AERIAL PAPER BAG RELEASE

The bag release is a relatively simple process where flies are emerged within sealed paper bags and released as the bags are ripped open once they come in contact with the hooks or knives located at the end of the chute upon exiting the aircraft (**Figure 7.1**).

FIGURE 7.1
Typical chute used in aircraft for paper bag aerial release.

The primary advantages of the bag release system are:

- That a minimal amount of accessory equipment is required for operation and a wide variety of facilities can be used to operate out of.
- Since the flies are never exposed to cold temperatures for immobilization prior to release, damage and reduced fly quality resulting from exposure to the cold is non-existent.

There are also some deficiencies in the bag release method. These include:

- Litter from bags throughout the release area is not environment-friendly in dry climates where they do not biodegrade rapidly.
- Space in aircraft is limited for bags and flies in bags are often damaged even with careful handling.
- Bags sometimes do not open, or only partially, allowing predators to enter bags before flies have found the exit.
- Flies are not watered prior to release and sometimes also not properly fed.
- Most importantly, sterile fly coverage within the target area is not as uniform compared with chilled adult release due to intermittent intervals (2 to 8 seconds) of release from the aircraft.
- In addition sterile flies may be subjected to higher predation rates because flies stick to the bags until they reach the ground.

7.1.1 Spacing and altitude of paper bag release

Usually, flight lanes range from 100 to 500 meters apart, according to the species dispersion capability and desired sterile fly coverage. Closer lanes are required in areas with high host density and species considered to be weak fliers, whereas more open lanes are possible in areas where hosts are scattered and for fruit fly species considered to be strong fliers. In the case of Medfly for temperate and semiarid environments, the most commonly used distance between lanes is 200 meters. Flight lanes should be straight or following altitudinal curves and lanes should always be kept parallel (Reyes *et al.* 1986, Diario Oficial de la Federación 1999).

Under conditions of calm winds no difference have been found between releasing sterile flies contained in paper bags from 200, 400 and 600 meters above ground level. However, lower release altitudes are preferred especially in areas subjected to strong dominant wind currents to prevent excess sterile fly or bag drift and in areas where predation due to birds is high and frequent (Reyes *et al.* 1986, Diario Oficial de la Federación 1999, SAG 1984). Releasing in the early morning is therefore preferable, when winds and temperature are moderate.

7.1.2 Calibration of paper bag release rates

According to the aircraft speed, required sterile fly density per unit area (hectare, square kilometres, acres or square miles) and size of the release area, a frequency for releasing the bags must be established. The labourer inside the aircraft must tear the bags and release them through a chute according with the established frequency. To estimate the frequency of paper bag release (in seconds/bag the following procedure is used:

1. To determine **the size of the release area** to be covered by one full paper bag load

1.1 Full paper bag load = 300 bags

1.2 Number of emerged sterile adult flies per bag = 6,400 (8000 pupae 80% emergence)

1.3 Number of sterile flying adults per bag = 5,120 (6,400 adults × 80% fliers)

1.4 Total number of effective (flying) sterile adult flies per load = 1,536,000 (5,120 sterile flies × 300 bags)

1.5 Required sterile fly density = 2000 sterile flies per hectare

1.6 Total release area:

$$\frac{\textit{Total number of sterile flies}}{\textit{Sterile fly density per hectare}} = \frac{1{,}536{,}000}{2{,}000} = \boxed{768\ ha\ (7.7\ km^2)}$$

2. To determine **length of flight lanes** of release area
2.1 Total square area (from 1.5) = 7.7 km^2 (~ 2.77 km × 2.77 km)
2.2 Length of one flight lane = 2.77 km (2,770 m)

3. To determine **number of lanes in release area**
3.1 Distance between lanes = 200 m
3.2 Length of square area (from 2.1) = 2,770 m
3.3 Number of lanes:

$$\frac{\textit{Length of square area (m)}}{\textit{Distance between lanes (m)}} = \frac{2{,}770\,\cancel{m}}{200\,\cancel{m}} = \boxed{13.8\ lanes}$$

4. To determine **frequency (in seconds) of paper bag release**
4.1 Speed of aircraft = 45 m/s
4.2 Length of flight lane (from 2.2) = 2.77 km (2,770 m)
4.3 Total number of lanes (from 3.3) = 13.8
4.4 Frequency:

$$\frac{\textit{(Length of flight lane)(No. of flight lanes)}}{\textit{(Aircraft speed (m/s))(No. of bags)}} = \frac{(2{,}770\,\cancel{m})(13.8)}{(45\,\cancel{m}/s)(300\ bags)} = \boxed{2.8\ s/bag}$$

With a full load of 300 bags (1.5 million sterile flies), each bag needs to be released every 2.8 seconds in order to have a density of 2,000 sterile flies per hectare. Considering that the speed of the aircraft is constant and that the maximum load in this case is 300 bags with a total of 1,536,000 effective (flying) sterile flies, to increase the sterile fly density, the frequency of bag release should be increased.

GPS and appropriate software can be used to verify that the aircraft is following the flight lines, as well as the correct swath distance (See Section 11).

According with the longevity of the insect (measured as specified in the quality control manual, FAO/IAEA/USDA 2003) the release interval should be adjusted. In Medfly it should be carried out at least twice per week (See **Figure 9.1** in Section 9).

In order to evaluate the effect of the process on the quality of the sterile flies, samples are taken periodically before and after the release process in the aircraft (See Section 13).

7.2 CHILLED ADULT RELEASE

The chilled fly release is primarily utilized and designed for large scale programmes. It is a more complex system designed to handle large volumes of flies.

The primary advantage of the chilled adult release method is that large numbers of flies can be carried on each flight and uniformly dispensed into the environment. Other benefits include no litter from bags; proper feeding and watering of flies prior to release; reduced predation and reduced labour.

There are also disadvantages to this method that include: chilled release equipment is often specialized and limited thus can be expensive to purchase and maintain; facilities are specially designed to accommodate the processes involved in emergence and fly release, thus expensive. Nevertheless, this method continues to be the most cost-effective.

There is a degree of damage to the flies from exposure to the cold temperatures needed to immobilize the flies and this is directly proportional to the length of exposure. For this reason if the target release area is located at a great distance from the emergence facility it may reduce the quality to a point that another setup location would have to be considered. Other factors affecting quality include condensation, compaction and damage from moving mechanical parts (IAEA 2004).

In Mexico, a large-scale study was conducted with Medflies comparing these release methods: chilled adults, paper bags and small cardboard boxes (Villaseñor 1985). The release was made from a fix-wing aircraft using sterile flies marked with different colours for each system. The main parameters used to evaluate the methods were: a) field distribution assessed by % of traps with flies, b) density of recaptured flies assessed by FTD, with Jackson traps baited with trimedlure (male specific lure) and, c) cost of each release method. Results showed that the best sterile fly distribution and density was achieved with chilled adults followed by boxes and bags. On the other hand the most economic system was bags followed by boxes and chilled adults (Villaseñor 1985). Initially the main constraint of the chilled adult release system was the constant breakdown of the equipment, difficulty in acquiring spare parts and lack of specialized maintenance service. The new generation of chilled adult release machines use simpler mechanisms and are much more reliable, thus this constraint has been partially overcome as will be explained in the following Section.

7.2.1 Evolution of chilled adult release machines

Machines specifically designed to release chilled, sterile fruit flies have been in existence for more than 30 years.

There are four (4) basic components for these machines that are standard. These are:

- A means of cooling of flies during release (sterile flies are kept at a temperature of 3 to 4°C during release)
- A means of metering the flies
- A control system for the machines
- A release mechanisms

The first model was designed and fabricated by USDA in 1974 (**Figure 7.2**). It was first used for releasing sterile Medflies in southern California in 1975–1976. This machine used a stack of collapsible bottomed trays to hold the chilled, immobile flies. The stack of trays was positioned over a funnel that channeled the flies toward a moving belt. The belt conveyed the flies to the release chute positioned at a forty-five degree angle from the fuselage of the aircraft. In operation, a photocell was used to detect the presence of flies on the moving belt. When none were detected, a motorized screw drive mechanism was actuated to release the bottom door on the next individual tray of flies thus dropping them onto the belt, breaking the photocell light beam and stopping the screw drive. The fly release rate was controlled by adjusting the speed of the conveyor belt. The machine maintained the flies at temperatures of 2-4° C for the duration of the flight.

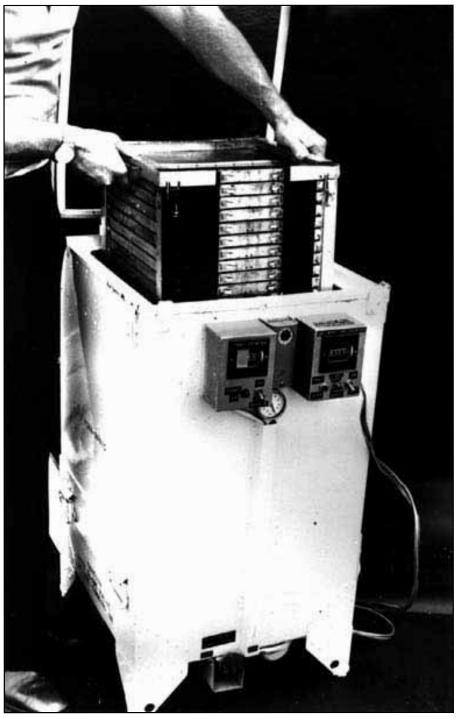

FIGURE 7.2
Release machine with capacity of 5 million sterile flies per load used for medfly release in Southern California in 1975.

FIGURE 7.3
Release machine with a capacity of 10 million sterile flies per load.

In the first release machine, problems were found that included difficulty in loading flies, limited load capacity, clumping of flies due to excess water condensation, and frequent breakdown of mechanical components. Work immediately began on the design of a less complicated, larger capacity design and, when Medfly outbreaks occurred in both northern and southern California in 1980, the improved model was put into service. In the new model, the stackable trays were replaced with a single box. The flies were supported within the box by collapsible wedge-shaped baffles. As in the earlier model, the photocell and conveyor belt were retained for metering and conveying flies to the release chute.

The first version of the new machine held two boxes of flies, each box having nearly three times the capacity of the 1974 model (**Figure 7.3**). Also, the refrigeration system consisted of standard automotive components and was much more trouble-free. The double box version was found to have more capacity than required for the release rates used at the time and was too large to fit into most single engine aircraft so later models were built with only one box. This model was used in all of the USDA fruit fly programs between 1980 and 1991.

The third generation of release machines replaced the mechanical baffles with fixed supports. Also, the conveyor belt was replaced with screw augers (**Figure 7.4**). The simplified design was found to be far more reliable. The release rate was controlled by adjusting the rotation rate of the three screw augers located beneath the box of chilled flies. Up to four speed settings could be programmed into each release and the pilot could change release rates with the push of a button.

FIGURE 7.4
Screw auger system for chilled adult release.

FIGURE 7.5
Release system installed inside a Cessna 206 aircraft.

The most current design was developed by the USDA, APHIS in Guatemala for the large scale Moscamed Program in Guatemala and southern Mexico. This design replaces the release box with a cylindrical container to hold and convey the chilled flies toward the release chute. Mechanical refrigeration is replaced with frozen carbon dioxide (CO_2) through the use of ducts and heat exchangers. Some of the advantages of this design include much larger load capacity, less electric wiring required in aircraft, reduced ferrying time between flights, better moisture removal from the flies and programmable fly release rates directly linked to GPS-GIS system (**Figure 7.5**) (Tween 2007).

7.2.2 Aircrafts and chilled fly release machines

Aircraft and chilled fly release machines used for the different programmes often vary. Both single and twin engine aircraft, gas and turbine are utilized (**Tables 7.1 and 7.2**). All release systems use 32 amp/24 volt electrical systems. Aircraft that operate with 12 volts will need to be converted to 24 volts.

7.2.3 Quality control of chilled adult release process

There is a new quality control system called MACX, used in Mexico for assessing the release process of *Anastrepha* spp. The MACX system is designed to help in the follow-up of the chilled adult releases. It allows transmission to the base station during release in real time, of data on the quality of the release process. The data is recognized, analyzed, translated and re-transmitted to a web-site where it is available to supervisors and programme managers.

This system has been developed to work together with the Mubarqui release machines. The Mubarqui chilled adult release machine is equipped with sensor devices to recognize the internal conditions inside the release machine and its biological material. Main sensors are: a) sensor that measures the loaded volume and how it is being released during the flight, and b) humidity and temperature sensors. Since temperature and humidity are determining factors to maintain the quality of the release insects during the aerial release process, with the sensors these factors are checked in real time. From the ground, the required humidity and temperature conditions are adjusted if needed and kept at the recommended levels (Leal Mubarqui 2005).

The aircraft(s) equipped with the MACX system include(s) a transmitter linked to the sensor devices of the Mubarqui chilled adult release machine and a GPS. The GPS recognizes second by second the position of the aircraft with high accuracy. The system also allows the base station to know the speed, the flight course in magnetic degrees, departure and landing time, as well as the flight duration in just a fraction of time.

TABLE 7.1
Machines for chilled adult release.

Frut fly species	Type of Machine[1]	Type of Aircraft	Capacity (million sterile flies/load)
Medfly (*C. capitata*)	USDA chilled release machine	Cessna Grand Caravan	40 million
Medfly	Cylindrical box with frozen carbon dioxide	Cessna Grand Caravan	15 million
Medfly	USDA chilled release machine	Cessna 2007	2.5–3.5 million
Medfly	USDA chilled release machine	Beechcraft King Air 90 Norman Islander	5 million
Mexfly (*A. ludens*), West Indian fruit fly (*A. obliqua*)	Mubarqui, MACX SYSTEM	Cessna 206 Maule Cherokee	5 million
Mexfly, West Indian fruit fly	USDA chilled release machine	Cessna 205 Cessna 207	5 million

[1]For suppliers of chilled adult release machines see **Appendix 7**.

TABLE 7.2
Common aircraft and release systems used.

Fruit fly species	Type of release system	Aircraft	Programme location
Medfly (*C. capitata*)	Paper bags Chilled adult	Cessna 172	Chile
Medfly	Paper bags	Pipper PA-28	Chile
Medfly	Chilled adult	Cessna Grand Caravan 310	Guatemala, Mexico, USA
Medfly	Chilled adult	Beechcraft King Air 90	Guatemala, Mexico, Madeira, Portugal, USA
Medfly	Paper bags	Helicopter Bell 206 Helicopter Bell 212	Mexico
Medfly	Paper bags Chilled adult	Cessna 206 Aerocommander	USA, Mexico
Medfly	Chilled adult	Cessna 207	South Africa
Medfly	Chilled adult	Norman Islander	Israel
Medfly West Indian fruit fly (*A. obliqua*)	Paper bags Chilled adult	Cessna 207	Guatemala, Mexico
Medfly Mexfly *A. ludens*) West Indian fruit fly	Paper bags Chilled adult	Cessna 208	Guatemala, Mexico
Mexfly	Chilled adult	Maule	Mexico
Mexfly	Chilled adult	Cessna 205	Mexico
West Indian fruit fly	Chilled adult	Cherokee	Mexico

The web-site to view the data of the MACX system in real time is: www.macxd.org.mx. This page not only has the real time report but also keeps historical data from the different release areas.

All equipment must be subjected to quality assurance protocols before use.

7.2.4 Spacing and altitude of chilled release

There are differences between programmes in the lane spacing and altitude of releases. For example, in the USA, in most chilled fruit fly releases the lane spacing used is normally

268 meters (880 feet). In preventive release programmes covering flat terrain, 536 meters (1,760 feet) is used between lanes. For *Anastrepha spp* in Mexico, there is a tendency to use a 100 meter (320 feet) distance between lanes to ensure total coverage of the area.

There are many factors that need to be considered to assess the altitude of releases. Some of these are; environmental conditions such as wind, temperature, cloud cover, fog, smog, and time of day of releases; geographical conditions including terrain, urban or rural, vegetation; other conditions to include the flight dispersal of the insect being released, influence from other agencies to include governmental regulations on aviation, flight restrictions (no fly areas) also require the releases to vary in altitude.

For example, in most fruit fly release programmes in the USA, the altitude used for release is 610 – 762 m (2000 – 2500 feet) above ground level (AGL). Chilled flies should preferably not be released lower than 150 m to avoid some chilled flies reaching the ground before warming up. However, other programmes in warmer climates use lower altitudes such as the *Anastrepha spp* release programme in Mexico, which in flat terrain releases sterile flies at an altitude of 100 m above the ground and where flies are already active when reaching the foliage of the vegetation. On the other hand, releases carried out at altitudes above 762 m (2500 feet) AGL will result in excessive drift of chilled sterile flies.

7.2.5 Calibration of chilled adult release rates

Operational programmes use different methodologies to calculate chilled adult release rates. The following is one way of determining these rates.

To determine **the number of chilled sterile flies released per second** the following formula is used:

Adults flies released per second = $M \times A \times V \times Z$

Where:

M = Number of adults per hectare
A = Width of lane spacing
V = Speed of the aircraft in km/h
Z = 0.0000278 Constant for determining adults per second

Example: To release 5,000 flies per hectare, the machine should release at a rate of 5,364 flies per second, if the speed of the aircraft is 144 km/h with 268 m (880 feet) width of lane spacing.

$$\text{Flies per second} = M \times A \times V \times Z;\ 5{,}000 \times 268 \times 144 \times 0.0000278$$

$$5{,}000 \times 268 = 1{,}340{,}000 \times 144 = 192{,}960{,}000 \times 0.0000278$$
$$= 5{,}364 \text{ flies per second}$$

The auger or band speed should be adjusted up or down based on **actual distance for release** of sterile flies (see procedure below). Since airspeed and load size are usually constant, a very accurate release rate should be obtained by fine-tuning the release machine speed over several flights. The release machine should be subjected to a regular maintenance protocol. A backup release machine should always be available to assure continuity of the sterile release programme.

The **actual distance for** release is estimated as follows:

1. To determine **total linear kilometres** the number of square kilometres and lane spacing must be determined for the release area:

1(km^2) divided by 268 m (lane spacing) = 0.373 linear km/km^2 times total area in square kilometres = total linear kilometres.

2. To determine **release rate**:

Total flies per release area divided by total linear kilometres (step 1) in the release area = flies per linear kilometre released.

3. To determine **number of flies per kilogram**:

Hand count and average 1 to 5 gram samples to determine the number of flies per gram and multiply this by 1000 to get the number of flies per kilogram.

4. To determine **number of flies per load**:

Number of flies per load = number of flies per kilogram (step 3) times the number of kilograms per load

5. **Set actual distance for release** of load:

The release machine auger (band) speed should be set to deliver the entire load over a set distance determined by the formula:

Total flies per load (step 4) divided by the flies per linear kilometre (step 2) equals the expected distance covered in kilometres, per load.

7.2.6 Pre-and post-release control of fly quality

The degree of damage to the flies caused by the release machine can be assessed by collecting samples of the flies and determining flight ability at three points in the release process:

- Control: The first sample is collected before release from the top of the release container full of flies and serves as the test control.
- Pre-release: The second sample is collected before release from the bottom beneath the release chute and serves as a measure of damage done by compaction of flies in the release container and damage done by the auger mechanism.
- Post-release: The third sample is collected from the runway and is a measure of damage caused by the release chute and wind shear as the flies exit the release aircraft. This is typically performed by the aircraft making several low passes over the runway with the machine dispensing flies at a high rate of release. The immobile flies are carefully aspirated into containers. A minimum of three samples of 100 flies each should be collected at each of the three points.

This last test should only be conducted when ambient temperatures are low enough (12°C) that the released flies do not become active before being collected. Otherwise, a disproportionate number of damaged flies will be collected, thus biasing the results.

For flight ability tests the flight tubes used should contain 100 flies each, be properly label as "control", "pre-release" and "post-release" and then placed in an area with a controlled environment. The percent flight ability for each sample is determined by counting the number of flies remaining in each tube at the end of a 24 hour period. This number is subtracted from 100 to determine percent fliers (FAO/IAEA/USDA 2003).

A difference of more than five percentage points between each step is an indication that excessive damage is being done to the flies. If this is found to occur, the aircraft and release machine should be immediately taken out of service and the source of the problem corrected.

7.3 REFERENCES CITED

Diario Oficial de la Federación. 1999. Norma Oficial Mexicana NOM-023-FITO-1995, por la que se establece la Campaña Nacional Contra Moscas de la Fruta. 11 de febrero 1999, México, D.F.

IAEA. 2004. Improving sterile male performance in fruit fly sit programmes. Report of the first research coordination meeting of an FAO/IAEA Coordinated Research Project, held in Antigua, Guatemala, from 25 to 29 October 2004. IAEA-314-D4.10.20-947.1. Vienna, Austria.

FAO/IAEA/USDA. 2003. Manual for product quality control and shipping procedures for sterile mass-reared tephritid fruit flies, Version 5.0. International Atomic Energy Agency. Vienna, Austria. 85 pp.

Leal Mubarqui, R. 2005. Manual de operación del método "MUBARQUI". Servicios Aéreos Biológicos y Forestales Mubarqui. 1ª edición. México.

Reyes J., A. Villaseñor, G. Ortiz, and P. Liedo. 1986. Manual de las operaciones de campo en una campaña de erradicación de la mosca del Mediterráneo en regiones tropicales y subtropicales, utilizando la técnica del insecto estéril. Moscamed Programme SAGARPA–USDA.

(SAG) Servicio Agrícola y Ganadero. 1984. Manual práctico de dispersión de moscas estériles del Mediterráneo TIE. SAG proyecto 335 moscas de da fruta, I región. Editado por: Rafael Mata Pereira Programa Moscamed, Guatemala y Jaime Godoy M., SAG, Chile. Arica, Chile.

Tween G., and P. Rendón. 2007. Current advances in the use of cryogenics and aerial navigation technologies for sterile insect delivery systems. pp. 229–238. *In* Area-Wide Control of Insect Pests: From Research to Field Implementation. 2007. M.J.B. Vreysen, A.S. Robinson and J. Hendrichs (eds.). Springer, Dordrecht, The Netherlands.

Vargas R., L. Whitehand, W. A. Walsh, J. P. Spencer, and C. Hsu. 1995. Aerial release of sterile Mediterranean fruit fly (Diptera: Tephritidae) by helicopter: Dispersal, recovery, and population suppression. Journal of Economic Entomology 88: 1279–1287.

Villaseñor, A. 1985. Comparación de tres sistemas de liberación aérea para mosca del mediterráneo estéril *Ceratitis capitata* Wied. Tesis de licenciatura, Ingeniero Agrónomo en especialidad de parasitología. Universidad Autónoma de Chiapas, Campus IV, Ciencias Agrícolas.