Fruit Fly Management for Vegetable Growers

Horticulture Innovation Australia

contents

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All photographs and diagrams by AHR unless otherwise indicated

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01.

FRUIT FLIES CAN INFEST MANY FRUITING VEGETABLE CROPS. WHILE COVER SPRAY OPTIONS ARE DECREASING, THERE ARE MANY OTHER TOOLS GROWERS CAN USE. THIS PUBLICATION DESCRIBES THE OPTIONS AVAILABLE AND SUGGESTS BEST PRACTICE BASED ON CURRENT KNOWLEDGE.

Introduction

Fruit flies are a major pest of fruiting vegetable crops, not only because they damage production, but also because of their impact on market access.

Fruit fly management and control have two quite separate objectives

- Producing a marketable crop and
- Accessing fruit fly sensitive markets.

A pest free crop can be produced using a range of control measures to keep damage below an economic threshold. These can include exploitation of fruit fly biology and behaviour, chemical controls, food and para-pheromone lures, physical barriers and postharvest treatments. Systems approaches combine two or more of these strategies, and can be a form of integrated pest management for fruit flies.

In contrast, market access requires a much higher level of certainty that no pests are present. Either probit 9 (99.9968% mortality) or probit 8.7 (99.99% mortality) are likely to be used as a standard, with no consideration given to actual infestation levels in a given consignment, the probability of establishment, or other factors likely to limit risk to the importer. Market access usually requires a postharvest kill step, or at least an inspection, to ensure the product is pest free.

This publication is focused on the first objective – producing a marketable crop. Without this, there is little purpose to progressing towards objective two.

WHAT DO WE KNOW

Nearly all of the research on control measures for fruit flies has focused on tree fruits; a quick assessment suggests that at least 15 papers on tree fruits are published for every paper on vegetables. While research in orchards can provide some useful guidance, it is unclear how readily such strategies can be applied to vegetable crops.

For example, there has been considerable work on how Qfly (Queensland fruit fly, *Bactrocera tryoni*) and Medfly (Mediterranean fruit fly, *Ceratitis capitata)* move about within orchards, including flight distances and searching for hosts. However there is little or no information about how these pests behave in a vegetable crop such as capsicum or squash.

Cucumber fly (*Bactrocera cucumis*) is an important pest of cucurbits but has been barely studied, with little known about behaviour and biology. Other species including Jarvis fly (*Bactrocera jarvisi*), Island fly (*Dirioxa pornia*) and lesser Queensland fruit fly (*Bactrocera neohumeralis*) can also infest fruiting vegetables, but almost nothing is known about them.

THIS PUBLICATION

This publication aims to combine published literature, experimental data, and commercial practices to provide a “Best Bets” manual for fruit fly management on vegetable farms.

The guide is split into sections on:

- Species
- Lifecycle
- Monitoring
- Protein baits
- Male annihilation
- Female biased traps
- Physical protection
- Field hygiene

A number of cover sprays are currently allowed for fruit fly management. Regulations vary between states, and even between regions, with many products covered under temporary permits.

Due to the complexity of issues relating to chemical use, this aspect is not covered in the guide. Growers are advised to seek local professional advice on the use of cover sprays for control of fruit fly.

02.

THERE ARE MANY DIFFERENT FRUIT FLY SPECIES IN AUSTRALIA. IDENTIFYING WHICH ONES CREATE A PROBLEM IN THE CROP IS AN IMPORTANT STEP IN MANAGING THESE PESTS.

Fruit fly species

More than 78 species of fruit fly occur in Australia. While only a few are known to attack vegetable crops, many are of increasing quarantine concern with trading partners. Little is known of most species, including the effectiveness of current control strategies.

QUEENSLAND FRUIT FLY *(Bactrocera tryoni)*

Queensland fruit fly or Qfly is the species most people think about when discussing fruit fly control. Qfly can infest nearly all fruit and fruiting vegetables, including Solanaceae (capsicums, chillies) and cucurbits (zucchini, cucumber).

Qfly is found across the Northern Territory and throughout eastern Australia, stretching from Cape York to East Gippsland in Victoria.

The Fruit Fly Exclusion Zone (FFEZ) was developed to eliminate Qfly from the NSW Riverland and Sunraysia, including east to Shepparton and west to Waikerie. Government officers checked traps and took action if outbreaks occurred.

Over the last few years outbreaks have increased, with flies continuing to be trapped into late autumn. The FFEZ was withdrawn in 2003, leaving only Sunrasia as a designated pest free area. Qfly is now found throughout the eastern states of Australia.

Qfly adults are about 5–8mm long with reddish eyes. They are generally brown with yellow “shoulder pads” and other markings, including a yellow triangle at the base of the thorax (midsection).

MEDITERRANEAN FRUIT FLY *(Ceratitis capitata)*

Medfly is a native of Africa, but has spread widely throughout Europe, Central and South America and the Middle East. It is found in south-west WA, and north along the coast as far as Carnarvon.

Although introduced to eastern Australia, medfly has not been found in the NSW or Qld for more than 70 years, probably due to competition from Qfly.

Like Qfly, Medfly can infest a very wide range of fruit and fruiting vegetables. Medfly is somewhat smaller than Qfly, with adults around 3-5mm long. It is quite colourful, with black and silver patches on its thorax (middle) and a striped brown abdomen.

Female Qfly

Female Medfly (Photo by USDA)

Qfly (left) and lesser Qfly (right). Lesser Qfly lacks one set of yellow 'shoulder pads'. (Photo by UNSW Fruit Fly Lab)

LESSER QUEENSLAND FRUIT FLY *(Bactrocera neohumeralis)*

Lesser Qfly infests a similar range of crops as Qfly. It is thought to occur in large numbers, especially in northern areas, where populations may be similar to those of Qfly.

It is difficult to distinguish Lesser Qfly from Qfly, as they are closely related and look very similar. Lesser Qfly is slightly darker than Qfly, and lacks one set of yellow "shoulder pads". However the main difference between the two is that Lesser Qfly mates during the day, whereas Qfly mates at dusk.

Lesser Qfly has been raised as a quarantine pest by a number of trading partners.

CUCUMBER FLY *(Bactrocera cucumis)*

Until recently, cucumber fly was not considered of great economic importance. However, outbreaks are becoming more frequent in areas producing pumpkins, melons, squash, zucchini and other cucurbit crops. It can also occasionally infest capsicums and other Solanaceae. Cucumber fly is likely to present increasing problems in the future.

Cucumber fly does not respond to the lures used for other fly species. As a result its distribution is poorly understood, although it is known to occur in south-east Queensland and northern NSW.

Cucumber fly is lighter brown and more slender than Qfly. It also has a distinctive yellow keel in the centre of its back, so the two species are fairly easy to distinguish.

NB. Cucumber fly has recently been renamed *Zeugodacus cucumis*

JARVIS'S FLY *(Bactrocera jarvisi)*

Like cucumber fly, Jarvis fly is increasingly being recognized as a major pest. It attacks capsicums and chillies, and possibly other fruting vegetables. It is very common in north Queensland, where populations may be greater than Qfly. It is found from Broome through the Northern Territory, and south as far as Maryborough in Queensland. Jarvis fly has recently been discovered to respond to the lure zingerone, which should allow more information on distribution to be collected.

Jarvis fly looks somewhat similar to Qfly, which may be one reason it has only recently been recognized as an important pest. It can be distinguished by the more intense striping on its abdomen, which has a distinct, wide cream band with dark stripe either side and a dark keel to the tip of its tail (like a 'T'). The thorax is an even, red-brown colour and female flies have a longer ovipositor than Qfly.

Male cucumber fly (Photo by M Tattersall)

Female Jarvis fly (Photo by G Cocks)

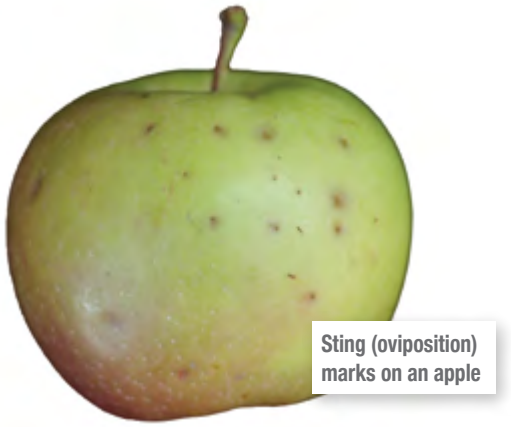
03.

UNDERSTANDING THE LIFECYCLE AND BEHAVIOUR OF FRUIT FLIES PROVIDES MANY CLUES AS TO THE BEST WAY TO PREVENT THEM INFESTING VEGETABLE CROPS.

The life of fruit flies

From a freshly laid egg to an adult fly laying several hundred eggs, a fruit fly generation can be completed in less than a month. Understanding this lifecycle can help identify management practices that can control these pests. The information in this section is based primarily on Qfly. Other species are similar, but specific details will vary.

Female Qfly laying eggs



Sting (oviposition) marks on an apple

LAYING EGGS

A female Qfly can potentially lay more than 500 eggs during her lifetime, while a Medfly can lay over 700. All female fruit flies are equipped with a sharp ovipositor, which they use to deposit eggs just under the skin of the host fruit. Both Qfly and Medfly ovipositors are not very strong, so they often use a natural opening, like a split, wound or the fruit lenticels (breathing holes) to lay into.

Female Qfly find it difficult to lay eggs directly into smooth, firm fruit with no natural openings – such as a cherry tomato. Their ovipositor simply slides off the surface, unable to pierce the skin.

EGGS

It takes a female fruit fly only 2–5 minutes to lay a batch of at least six, and up to 20, eggs into the host fruit. Fruit fly eggs are white, slender and around 1mm long, so barely visible with the naked eye. They hatch after around 1-2 days at 26°C.

"Sting" marks, where flies have laid eggs, are easy to see on light coloured fruit such as apples and loquats. However, they are more difficult to detect on vegetable crops.

Eggs laid into a red capsicum

When larvae hatch they use bacteria to dissolve the fruit flesh so they can digest it (left). They can eat out a capsicum, leaving only the fruit skin (centre). In other fruit, they head to the centre and eat out the core (right)

LARVAE

Qfly larvae are less than 2mm long when they hatch, but grow quickly. They mature after only 6 days at 26°C, reaching 5-9mm long. Medfly larvae are a little slower, taking around two weeks to mature in summer, but up to 45 days in winter. When mature, their black feeding hook can be easily seen. Both Qfly and Medfly larvae are a creamy colour, with guts coloured by the food they are eating.

Fruit fly larvae are associated with a number of bacteria. The bacteria help break down the fruit flesh into a semi liquid, making it easy for the larvae to scoop up and digest. This is why they cause so much damage.

Larvae feed underneath the fruit skin, so damage may not be easily seen from the outside. Sunken or discoloured areas can indicate where the underlying flesh has been broken down, leaving the skin intact.

Breaking the fruit open reveals soft, cavity riddled flesh but without obvious fungal infection. In orchard fruit such as stonefruit and apples, the maggots burrow their way into the centre of the fruit, which can become quite brown and slimy.

Pupal cases. Note that some pupae are intact, but in others the cap has come off and the fly emerged, leaving behind just the empty shell.

Infested capsicum from the outside

PUPAE

Once larvae mature they hop from the fruit and bury themselves in the soil. Here they form a pupae. Pupae look like large grains of brown rice.

It takes around 10 days for the larva to re-assemble itself inside its pupal case, becoming a fly. When it is ready to emerge the young fly breaks the top off the pupal case (operculum) and scrambles to the soil surface. In the picture above, some of the flies have emerged, leaving behind the empty pupal cases.

Fly feeding on sugar syrup on a leaf (left) and males gathered together in a citrus tree at dusk (right)

ADULTS

Once the adult fruit fly emerges and expands its new wings, the first thing it needs is a drink of water. In warm conditions, flies will die in less than 48 hours without water.

As flies can't feed on solids, they need either liquid food or food they can dissolve in regurgitated gut liquid. It is unclear what fruit flies feed on in nature, but it is believed food sources include nectar, juice from damaged fruit, honeydew and exudates on leaves.

Both male and female flies need to feed on protein to become sexually mature. This is especially important for the female in order to produce viable eggs. The more protein the female can find, the more eggs she

At dusk, male Qflies gather together at "lekking points" in trees and emit a pheromone to attract female flies

Female (left) and male (right) Qflies

is able to lay. Natural sources of protein include bird droppings and bacteria on leaves.

Fruit flies can breed when daily maximum temperatures are at least 20°C. Under these conditions, and with adequate water and protein, flies become sexually mature 10–14 days after emergence. They then search for a mate.

Qflies only mate for around 30 minutes at dusk. At this time, male flies gather in groups in trees (lekking points) and emit a cloud of pheromone to attract female flies. Males are more likely to mate if they have fed on the para-pheromone cue-lure, as well as if they are able to "sing" (produce a buzzing noise).

Females may mate once or many times. They are more likely to re-mate if they sense their first mate lacked fitness. Female flies can store sperm from a single mating for weeks, using it to fertilise eggs throughout their life.

It is easy to tell male and female flies apart. Female flies have an ovipositor, which protrudes behind them, whereas males simply have a rounded abdomen.

Once the female fly has mated, she searches for a suitable host to lay her eggs. It is believed she mainly uses visual cues, but smell is also important. Her preferred hosts are soft fruit such as peaches, loquats and feijoas. However, potential hosts also include lemons, grapes and even passionfruit. Fruit usually has to be ripe, but flies will lay eggs in unripe fruit if no other hosts are available or populations are high.

Female fruit flies only lay into attached fruit; fruit that is already rotting or on the ground is not attractive. However, infested fruit that has started to decay sometimes detaches from the plant. Orchards with a lot of fallen fruit can prove to be population centres for fruit flies.

Female Qfly on a backyard loquat tree, looking for a good place to lay eggs.

It is not clear how long flies can live in the wild. Adult Qfly survival is poor if average yearly minimum temperatures are below 2.6°C. However, it is widely believed that flies overwinter as adults, not as pupae or larvae. This suggests flies can live for at least three months, possibly longer.

Queensland fruit fly

Bactrocera tryoni

mating and oviposition

14 days

Adult

fly emergence

10 days

life c

Pupae

2 days

larvae hop from fruit

26°C

Eggs

2 days

1st instar larvae

cycle

2 days

2nd instar larvae

2 days

3rd instar larvae

FRUIT FLIES VS VINEGAR FLIES

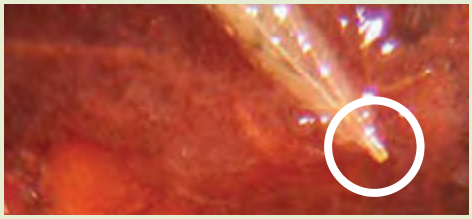
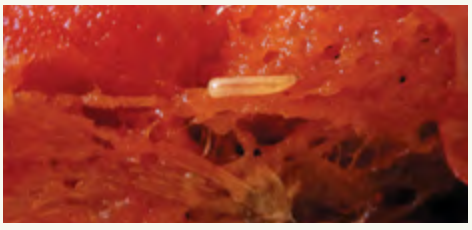
In general, if larvae are found in fruit already rotting on the ground, it has probably been infested by *Drosophila melanogaster* – vinegar fly. It is important to be able to tell the difference between these larvae and those of fruit flies; fruit fly damages intact fruit and can affect market access, whereas vinegar fly only attacks previously damaged fruit and is not a market access issue.

Another larvae sometimes found in rotting capsicums looks very like fruit fly, but has distinct black spiracles at its tail end and a large mouth hook. This is the larvae of *Atherigona* sp.. Like vinegar fly, *Atherigona* lays eggs in damaged or rotting fruit, so is not an economic pest.

Key differences between fruit fly and vinegar fly are shown below.

Atherigona larvae look similar to fruit fly but have black spiracles.

Key Differences Fruit Flies Vs Vinegar Flies:

	Qfly	Vinegar fly
	Generally intact fruit	Rotting fruit or vegetable
Larvae number	Usually 2 – 10 per fruit, but can be 20 or more.	Usually >30 per fruit, rarely <10 per fruit.
Larvae appearance	White to cream, black feeding hook visible in mature larvae, smooth bodied, 2–9mm long.	White with black feeding hook, slightly notched along body, 1–5mm long.
Larvae shape	Wedge shaped, plumper at tail than head.	Slender throughout.
Larvae breathing holes (spiracles)	Very slight bumps for breathing holes in tail end. 	Distinct, long breathing tubes coming out of tail end. 
Host material	Soft, spongy, starting to rot. May be fully eaten out with only skin left. 	Liquified and rotting. 
Pupae appearance	Like a large grain of brown rice, variable colour. 	Like a small, rather slender grain of brown rice, with two small prongs at one end. 

FRUIT FLY BEHAVIOUR

Natural habitat

The natural habitat of fruit flies is the forest, particularly the forest edges. They mate in trees, search for host fruit in trees, and generally feed, rest and shelter there as well.

Trees are sources of food and moisture. Bacteria on leaves and bird droppings on branches are also important foods for fruit flies. Food is therefore likely to be much easier to find in the forest than in vegetable crops, which represent a relatively barren environment for fruit flies.

This means that although flies will enter a crop to search for host fruit, they usually travel only a relatively short distance into it. Fruit near the crop edges is the most likely to become infested, especially if trees or other shelter is nearby. As the main reason for being in a vegetable crop is to lay eggs, it seems possible that more female flies enter crops than males.

Damp, tree lined areas along watercourses are good habitats for fruit flies.

Flight distance

Fruit flies are not strong fliers. They spend far more time walking around the tree canopy than flying. When they do fly, it tends to be relatively short distances (5–50cm) from branch to branch, or close to (~2m) the ground in between trees. However, flight is an essential skill. Without it, fruit flies are unable to find a mate or fruit in which to lay eggs.

Flight-ability is affected by factors such as temperature, humidity and nutrition. For example, Qfly is unable to fly at temperatures below 16°C, while Medfly is inactive below 12°C. Flight is also restricted by high winds or low humidity. Conversely, adult flies are able to fly better if they were well-fed as larvae.

As long as food and host fruit are available, 90% of Qflies will range only 600m from where they emerged. Medflies are similar, with 90% of flies travelling less than 700m. Both species rarely travel more than 1km during their lifetime.

One of the reasons flies rarely disperse widely is because it makes it difficult for them to find mates. In the case of Qfly, flies mate for only around 30 minutes at dusk. During this short period groups of males gather together, producing a plume of scented pheromone to attract female flies. It seems likely that the relatively small amount of pheromone produced by a single male makes it difficult to attract distant females. This may be why dispersal more than 1km from their origin results in 'non-viable density' of the population.

On the rare occasions flies do disperse long distances, it is probable this is by accidental "hitch-hiking" on vehicles, equipment or plant material. Reports of Qflies travelling tens of kilometers are likely to be human assisted journeys rather than ones taken by wing power alone! Most outbreaks of fruit flies in remote areas have been linked to infested fruit carried into the region, rather than incursions by travelling flies.

Likes and dislikes

There are conflicting reports about what colours attract or repel fruit flies. There is general agreement that yellow is attractive, which is why many monitoring traps are this colour. However the attractiveness of red, blue and other colours is unclear. This may be because flies see in shorter wavelengths than humans, so items that reflect a lot of ultraviolet (UV) might look quite different to flies than they do to us. It has been shown that reflected UV light can attract fruit flies, especially at dusk.

It is also clear that fruit flies prefer to gather in dark spaces rather than brightly lit ones, probably due to their origin in forests. Conversely, flies appear to be repelled by white. White plastic may be one of the reasons fruit flies almost never enter greenhouse environments.

Fruit flies can be attracted by certain fruit volatiles, as well as by ammonia. There is increasing interest in combining fruit aromas with fruit mimics – generally spheres – to attract female fruit flies.

As previously noted, fruit flies are also attracted to "tree shaped" objects. Damp, tree-lined areas around creeks and dams are good habitats for flies, and it has been suggested that creek-lines are the main route they use to move through the landscape; fruit flies rarely fly directly across open grassland or grain crops.

04.

MONITORING CAN HELP IDENTIFY WHERE FRUIT FLIES ARE COMING FROM, WHETHER POPULATIONS ARE INCREASING OR DECREASING, AND WHAT ACTIONS ARE NEEDED. TRAPS NEED TO BE PLACED IN HIGH-RISK AREAS AS WELL AS AROUND CROP PERIMETERS AND CHECKED REGULARLY.

Monitoring

The purpose of monitoring is to find out whether flies are present, and whether numbers are increasing or decreasing.

- *Monitoring DOES NOT indicate how many flies are in the crop, whether females are present, or fruit are infested. Depending on the crop, even significant numbers of flies in traps does not mean the product is infested.*
- *Monitoring DOES indicate whether control strategies are proving effective. It can also help focus extra control measures on fly hot spots, inside or outside the crop.*

GOVERNMENT MONITORING GRIDS

While there are clear differences between Government grids and monitoring on vegetable farms, these protocols do provide guidance as to trap spacing and actions to be taken.

Monitoring grids are maintained by Government authorities in certain growing regions. These are primarily areas where fruit fly is absent, or pest numbers are low enough to make claims in relation to market access. Monitoring grids may be targeted at detecting any fruit fly (in the case of a fruit fly free production zone) or for detecting incursions of species not present in that area (such as Qfly into WA).

Trapping grids are therefore maintained in areas around ports, in the north of Australia, and regions such as the Sunraysia Pest Free Area in Victoria / NSW. For example, the Tasmanian Government maintains a monitoring grid of over 900 traps for both Qfly and Medfly.

Urban monitoring grids have traps spaced at 400m intervals and are checked weekly, at least during summer. Grids in orchard areas more commonly use 1km spacing. Exotic fly incursions may be detected using grids spaced even more widely, on a 5km grid.

PARAPHEROMONE LURES

Monitoring usually involves traps baited with male attractants – 'parapheromones'. These are manufactured chemicals that have pheromone–like activity. Parapheromones improve mating performance in male flies that have been exposed to them. They do not usually attract female flies.

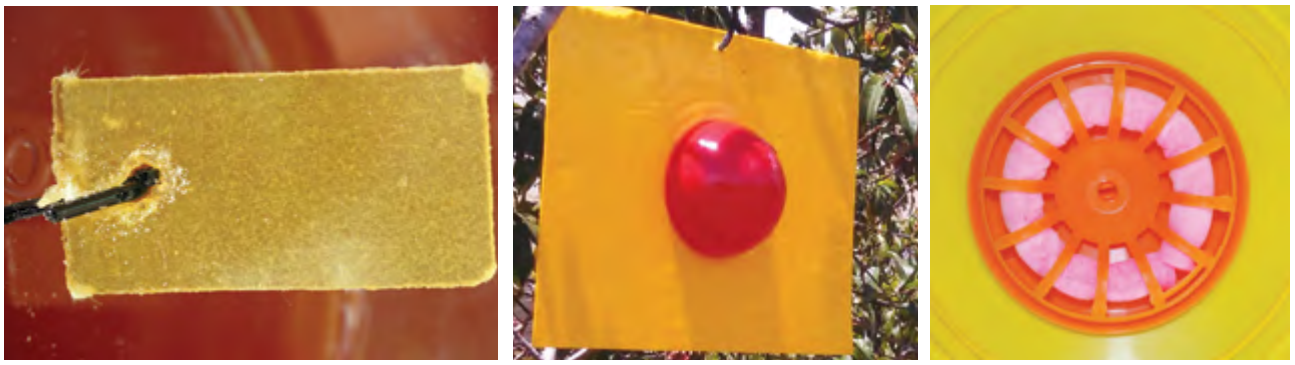
Attractiveness varies by lure and species;

- Cuelure attracts Qfly and lesser Qfly
- Trimedlure attracts Medfly.

Standard actions relating to detections on a 1km grid are:

Fruit Fly Code of Practice, 1993

Fly detection	Time interval	Action
One male	2 weeks	Do nothing
2-4 males	2 weeks	Supplementary trapping
5 males	2 weeks	Control program for >12 weeks within 1.5 km of trap
Gravid female	any	Control program
Larvae in fruit	any	Control program



Wafer type lure (left), Ladd trap (centre) and wick lure (right)

- Methyl eugenol mainly attracts exotic species such as Oriental fruit fly *(B. dorsalis).*
- Zingerone attracts Jarvis fly.

Approximately 40% of fruit fly species do not respond to any of the known para-pheromones. For example, Cucumber fly is an increasingly important pest of cucurbits. Unfortunately it does not respond to any of the existing parapheromones, so cannot be readily monitored. (note: a new lure using cucumber volatiles may provide a monitoring tool in the future).

In addition, monitoring traps have a limited zone of attractiveness. For example, the zone of attraction of cuelure to Qfly is unclear, but may be in the order of 10–20m. The attraction of Medfly to trimedlure is stronger, with flies drawn from 32–50m distance. However, even within this zone, only a percentage of the total population is likely to be captured by the lure. No lure will attract 100% of male flies.

OTHER TYPES OF LURE

If a parapheromone is being used as part of an attract and kill strategy (eg MAT) then monitoring using the same attractant becomes unreliable.

Although lures based on food or volatiles have a smaller zone of attraction than parapheromone lures, they can provide some information about fruit fly populations. Lures containing protein and/or volatiles can attract female as well as male flies. However liquid lures need to be topped up regularly and can become smelly and messy, especially when trying to count flies. They also attract by-catch, such as blowflies and other non-pest insects.

New gel lures are becoming available, but are relatively untested for monitoring purposes.

Fruit mimics can also be used to attract fruit flies. For example, the Ladd trap consists of a sticky yellow sheet and red ball in the centre. The sticky sheet has to be replaced regularly, with flies identified and counted.

TRAP TYPES

There are many different types and styles of traps sold for monitoring Qfly and Medfly. With the exception of visual / aroma based traps such as the Ladd trap, all contain a dispenser for the parapheromone. This is usually a fabric wick or a waxy 'wafer'. The new FT Mallett-CL wafer provides more controlled release of cuelure than fabric wicks, and is very attractive to Qfly.

Traps also contain a contact insecticide, which may be added by the operator or already included in the wick / wafer. Malathion (maldison) and DDVP (dichlorvos) are two insecticides commonly used.

The McPhail trap is the original fruit fly trap once widely used in Government trapping grids. It has a yellow base and clear lid. The lure can be suspended from the lid, or (more often) a liquid protein lure added. Flies enter through a hole in the base. Originally constructed of hard plastic, newer models are more lightweight and less expensive.

The Biotrap also has a clear lid with yellow base. Either a para-pheromone lure or a liquid can be added. When baited with a wax wafer impregnated with cuelure + maldison, the Biotrap has been demonstrated to be a very effective tool for monitoring Qfly.

The Probodelt Conetrap comes flat packed, and is easily clipped together. As the inside of the lid is pre-coated with an insecticide, it can be safely assembled even without gloves. The cuelure is contained inside a tyvec sachet, which is placed inside. Flies enter through inverted side holes but then move towards the light, and are killed on contact with the lid.

Other traps include the Lynfield trap, and similar, modified versions sold by companies such as Organic Crop Protectants (OCP) and Bugs for Bugs. The Lynfield trap is usually baited with dental wicks that have been soaked in cuelure, or other parapheromone, plus maldison. The OCP trap avoids handling risks by using a fabric wick already impregnated with cuelure plus maldison. The wick is secured inside a plastic protector, which is then safely installed under the lid.

Traps (clockwise from top left) – McPhail trap, Biotrap, Conetrap, Lynfield trap and modified Lynfield trap (Organic Crop Protectants, Bugs for Bugs)

TRAP PLACEMENT

The natural habitat of fruit flies is the forest. Flies tend to feed and rest in trees, preferring those near moist areas such as creek lines or dam edges. Trees are also where they go to mate. Fields of vegetables are not the natural habitat of fruit flies, although females will enter them to lay eggs.

The best place for traps is therefore in tree lines around the edges of the crop.

Extra traps can be placed around areas where infestation may come from, such as neighbouring orchards, town areas with backyard fruit trees, or creek lines. Areas with abandoned or unmanaged fruit crops are a particular risk, so well worth monitoring.

Under cold conditions, flies are likely to be attracted to warm spots, such the northern side of trees. However, if conditions are hot and dry, then the flies are more likely to be found on the eastern or southern side of trees.

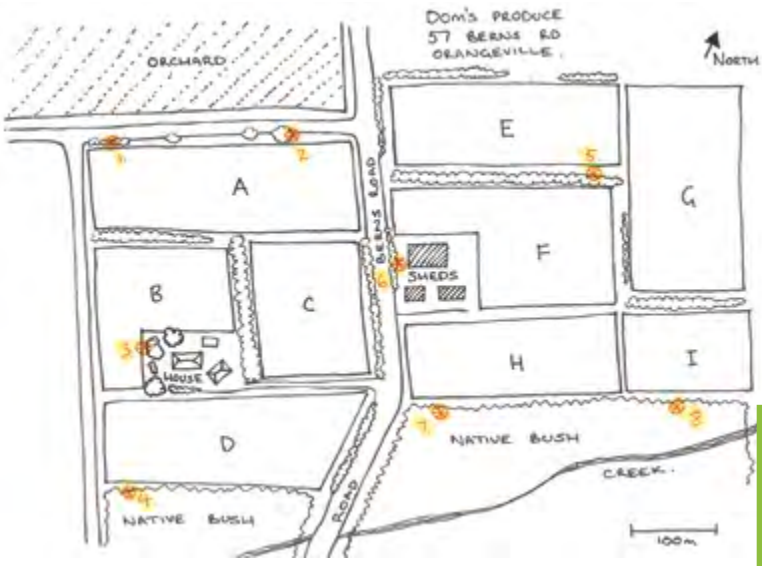
In large cropping areas, or where there are no alternatives, it may be necessary to place traps within the crop itself. However traps attract male flies, whereas it is the female flies that are searching for host fruit. Trap catches of male flies within a crop may therefore provide only limited information on the local population.

CHECKING TRAPS

Traps should be numbered and listed on a farm map, so that anyone can check them. They need to be checked weekly when populations are expected to be increasing or high. For Qfly, this is when daily maximums exceed 22°C. Traps may be checked every 2–4 weeks at other times. The operator needs to record the number of flies found using a record sheet. The trap should then be emptied and reset.

If possible, the operator should also record whether any female flies are found inside the trap – finding a female fly inside a para-pheromone baited can indicate that populations are high, and action needs to be taken.

Checking and maintaining traps takes time. However, the more traps there are, the better the warning of



Farm map showing placement of fruit fly traps

Fruit fly monitoring

Date	Trap no.	Fruit flies	Other

Example of fruit fly record sheet

incursions into the crop. Standard trap spacing is 400m, but it can be useful to include more traps in high-risk areas.

The purpose of monitoring is to detect incursions of fruit flies into the area, and determine whether populations are increasing or decreasing. How this information is used will depend on risk of crop infestation. The actions taken for Government trapping grids shown in Table on page 14 may be useful for areas with low pest populations. However, for areas where fruit flies are present throughout the year, higher action thresholds may be appropriate.

Abandoned citrus orchards are a major potential source of fruit flies, so well worth monitoring with an extra trap.

BEST PRACTICE

- ✔ Monitoring usually involves a para-pheromone lure. Lures need to be appropriate to the target species.
  - The FT Mallett-CL wafer is very effective for Qfly and lesser Qfly.
  - Trimedlure is used for Medfly.
  - There are currently no commercial lures for Cucumber fly or Jarvis fly.
- ✔ Suitable traps include the Biotrap, Conetrap and versions of the Lynfield trap.
- ✔ Monitoring traps should be located at least every 400m around the cropping area.
- ✔ It is recommended to install additional traps in high-risk areas, such as adjacent to orchards, near urban areas and along treed watercourses.
- ✔ During cool periods, traps are best located in warm spots, such as the northern side of trees. In hot conditions traps are best in cooler, sheltered areas.
- ✔ Traps need to be numbered and recorded on a farm map.
- ✔ Check traps weekly when populations are increasing or high and every 2–4 weeks at other times. Record the number of flies, noting if any are female, and re-set the trap.
- ✔ For Government run fruit fly monitoring programs, catching 5 male flies or 1 female fly in a single trap within a fortnight triggers a control program. Higher or lower thresholds may be appropriate for vegetable farms depending on the crop and farm circumstances.

05.

PROTEIN BAITS ARE AN IMPORTANT PART OF ANY FRUIT FLY MANAGEMENT PLAN AS THEY TARGET IMMATURE FEMALE FLIES. THEY SHOULD BE APPLIED WEEKLY ONCE FLIES START TO EMERGE.

Protein Baits

Protein baits can attract both male and female flies. They are especially attractive to newly emerged female flies, which need to feed on protein to mature and develop their eggs. The ingredients used, and how and when baits are applied, greatly influences their effectiveness in the field.

Sprayable baits can contain:

Protein + Insecticide + Carbohydrate + Thickeners

PROTEIN

Protein needs to be partially broken down (hydrolysed) to make it attractive to the flies. Yeast autolysate is the usual protein source used. Commercial products include;

Protein product	Formulation	Protein content	Bait consistency
Fruit Fly Lure™	Thick liquid	420 g/L	Suspension
Natflav 500™	Thick liquid	420 g/L	Suspension
CERABAIT™	Liquid	360 g/L	Suspension
Flavex® FL622	Liquid	140 g/L	Liquid
HYM-LURE™	Liquid	425 g/L	Liquid
ANAMED™ SPLAT (protein)	Paste		Paste
Flavex SPA400	Powder	420 g/L	Liquid
DacGEL™	Powder		Gel

While all of these products provide protein, they have different attractiveness to flies.

Trials conducted by QDAF suggest that Hym-Lure is highly attractive to both Qfly and Jarvis Fly. The bait was applied at 0.84% concentration (2L per 100L water), slightly more concentrated than the suggested label rate of 1.5L per 100L water. Qfly is also strongly attracted to Flavex SPA400, followed closely by Flavex FL622.

Cucumber fly was also strongly attracted to Flavex SPA400, as well as to Fruit Fly Lure.

Note that some growers have found that mixing bait the night before application helps to avoid any potential lumps in solution, especially if a powdered protein source is used.


Female fly feeding on protein bait

INSECTICIDE

Insecticide needs to be mixed with the protein source.

The main two insecticides currently used in protein bait sprays are Maldison and Spinosad. Trichlorfon (Dipterex™ 500) is also registered but considered to be less effective.

Fipronil (Regent® 200SC) and Abamectin (CroPro STEALTH©) have both been shown in trials to be effective against Qfly, while Fipronil and Spinetoram (Success™ Neo) were highly effective against cucumber fly. Unlike Maldison, these insecticides do not have a repellent effect on fruit fly feeding. However, none of these insecticides are currently registered for use in fruit fly baits.

Maldison

Maldison is a highly effective, contact insecticide. This means the fly is killed simply by landing on the bait. It is relatively stable, so remains active for weeks or even months after application. Registered commercial products include HyMal®, Maldison 500™, Amgrow Malathon® and Fyfanon 440 EW®.

Maldison is an anti-cholinesterase compound; it works as a nerve poison. As a result, it is hazardous to humans and other mammals, highly toxic to insects including bees and deadly to fish. Protective equipment must be worn when mixing or applying maldison based baits. Extreme care is needed if applying maldison baits in areas near water-courses or residential areas.

Applying maldison baits in the early morning while conditions are cool will help limit any effect on bees as well as maximise its effectiveness.

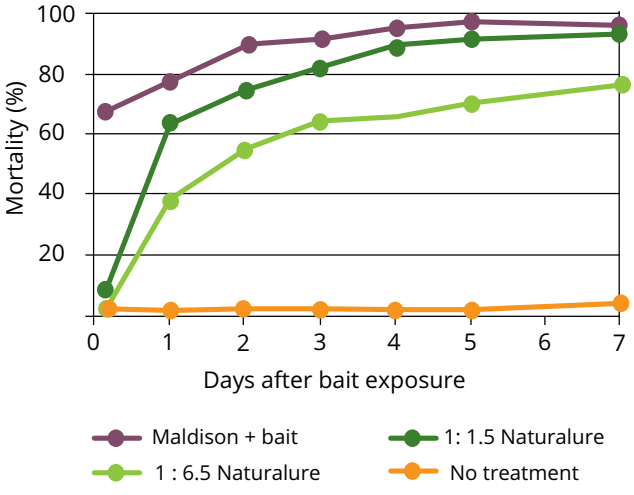
Spinosad

Spinosad kills by ingestion, making it safer for bees and other beneficial insects. It is applied as part of the pre-mixed bait Naturalure™; other formulations of spinosad (eg Success Naturalyte™) are not registered for use in fruit fly baits. Spinosad is derived from a naturally occurring soil bacterium. It is classified as organic (under some schemes) and has very low toxicity to humans. It can therefore be used in sensitive areas and poses minimal risk to worker health and safety.

Spinosad is degraded by UV light. Depending on weather conditions, it remains toxic for 3 to 7 days after application. Baits need to be applied at approximately weekly intervals anyway, and this is particularly important if using Naturalure.

Another factor to consider is that the fly has to eat enough Spinosad to get a toxic dose – if it only eats a little it will not be killed. Sub-lethal doses can increase development of resistance. If flies have already fed on protein they will be less attracted, and eat less of the bait if they do respond. Naturalure is therefore less effective against female flies that have already fed on protein.

The Naturalure label specifies two dilution rates; 1:1.5 and 1:6.5. Different volumes are applied for each rate, so as to deliver the same total amount of Naturalure per hectare. The more concentrated solution is a thick liquid, so difficult to apply through normal spray equipment. However, trials have found that the 1:1.5 dilution rate is more effective at controlling flies. It is also longer lasting in the environment, still killing flies for up to 7 days whereas the 1:6.5 solution loses effectiveness more quickly.



Mortality of Qfly exposed to two different label rates of Naturalure over a seven day period. Results are compared to a standard Maldison + protein bait and no treatment.

Windbreak plants such as sorghum are very suitable for applying baits. Baits for Qfly and Medfly should be applied 1.5-2m above the ground, whereas baits for cucumber fly are best at 1m above the ground, as that is where the flies are likely to be foraging (DeFaveri, 2016).

OTHER INGREDIENTS

Carbohydrate sources – sugars – can be added to baits to increase attractiveness. However, this may also attract non-target insects such as ants and even bees.

Thickeners can increase the time the bait remains effective. Thickened bait is more resistant to washing off during rain or irrigation. Thickeners can also help stop the bait from drying out, which is likely to extend the time it stays attractive.

WHERE TO PUT BAITS

In orchards, baits are usually sprayed on the bases of trees along every second row. However in vegetable crops it is not possible to spray within the crop itself.

Bait must therefore be applied to the perimeter vegetation. This is appropriate, as perimeter vegetation is where flies are most likely to feed, rest and search for mates. Baits have only a very small zone of attractiveness, so they need to be applied where flies are most likely to be.

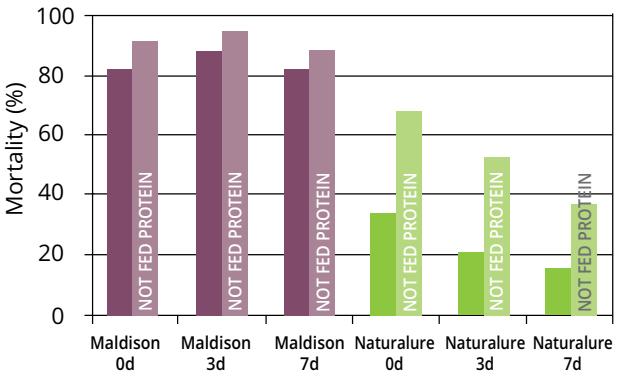
Baits perform better when sprayed onto vegetation than inert surfaces (such as posts, boards etc.). This is thought to be because baits stimulate bacteria already on the plant leaves, and it is volatiles from the bacteria that help attract hungry fruit flies.

The type of plants growing around the perimeter also affects baiting effectiveness. Research by Queensland DAF has found that windbreaks of sorghum, cassava and sweet corn were more suitable for baiting than vegetable crops or permanent hedging plants such as orange jessamine and lilly pilly. This may be due to the density of leaves, which provides sites for roosting and a larger surface for the bait itself.

One of the other criteria for plant suitability is height. Qfly tends to roost high in trees, so baits should be applied 1.5m to 2m above the ground. Cucumber fly, in contrast, tends to stay closer to the ground. In this case baits should be applied at approximately 1m height.

WHEN TO APPLY

After emerging from the pupae, it takes female flies around two weeks to reach full maturity. This is when they most actively search for protein to mature their eggs; once they have fed on protein they are less interested in finding more, although they will feed if it is there in front of them.



Effect of insecticide type and bait age on protein fed (dark bars) and protein deprived (light bars) female Qflies. The trial was conducted in small cages; even accidental contact with the Maldison bait killed flies. Naturalure kills by ingestion so mortality depends on how much the flies eat. Flies fed protein before the trial did not eat the bait, especially if it was a few days old. Flies that had NOT fed on protein before the trial were more likely to eat the bait but still ate less if the bait was old.

Baits need to be where flies will find them, right when they most need a protein meal.

Like bread from the bakery, baits are most attractive when they are fresh. Even though Maldison-based baits can remain active for several weeks, once they have dried out and aged they are not nearly so attractive to flies.

Bait applications therefore need to start when young, female flies are starting to emerge. They should be applied weekly for best effect, or at least every 10 days. Some growers apply every five days, just in case they are forced to miss a date.

Bait applications should use a coarse spray, resulting in droplets of 2mm across. If more than 5mm rain occurs it may be necessary to re-apply the bait.

Fruit flies most actively forage for food in the morning. Spraying early in the day not only reduces risk to bees, it ensures fresh bait is there when flies want it.

As with any other chemical, bait applications need to be recorded.

BEST PRACTICE

- ✔ **Baits need to combine an attractive protein source with an effective insecticide.**
  - **Protein sources Hym-Lure and Flavex are both very attractive to Qfly and Jarvis fly Natflav 500 is also appropriate.**
  - **Flavex and Fruit Fly Lure are very attractive to Cucumber fly.**
  - **Maldison is an effective and long lasting insecticide.**
  - **Adding a thickener helps to preserve bait in the environment**
- ✔ **Naturalure is a less toxic alternative to maldison-based baits, so may be used in sensitive areas. Apply heavy droplets at the 1:1.5 dilution rate for best results.**
- ✔ **Newly emerged female flies are most strongly attracted to protein baits. Bait applications should start when flies are just starting to appear, before fruit matures.**
- ✔ **Baits should be applied in the early morning, when flies are actively searching for food.**
- ✔ **Apply baits weekly when fly populations are high. If >5mm rain falls bait may need to be re-applied.**
- ✔ **Spray baits on windbreak plants around the crop perimeter.**
  - **Dense foliaged plants such as sorghum, cassava or sweet corn are very suitable.**
  - **Permanent hedging and vegetable crop plants are less attractive.**
  - **Baits should be applied at least 1.5m from the ground to target Qfly and Medfly, but 1m from the ground for Cucumber fly.**
- ✔ **Like any other chemical, bait applications must be recorded.**

Protein bait application record

Date	Start time	Finish time	Location treated	Product	Rate	Equipment	Wind	Operator signature

Sample form for recording sprays of protein bait.

06.

MAT USES A PARA-PHEROMONE LURE PLUS INSECTICIDE TO LURE AND KILL A PERCENTAGE OF MALE FLIES IN THE POPULATION. AS MALES CAN MATE MANY TIMES, MAT NEEDS TO BE COMBINED WITH OTHER CONTROL STRATEGIES TO BE EFFECTIVE.

Male annihilation

The Male Annihilation Technique (MAT) involves the same lures and insecticides that are used for monitoring, just without the trap to retain dead flies.

MAT block made from caneite soaked in a mixture of cuelure and maldison (left), the OCP MAT cup (centre) and Amulet MAT containing cuelure plus fipronil insecticide (right, Photo by Daleys Nursery)

TYPES OF MAT

MAT combines a parapheromone such as cuelure with an insecticide, such as Maldison.

This mixture can be soaked into an absorbent material such as caneite blocks or compressed cardboard and simply hung out in the field. The wick lure used in the OCP / Bugs for Bugs trap can also be used separately as an MAT device. This unit has the advantage that the plastic cap protects the wick from rain and UV, extending its useful life.

Similarly, the Magnet MED trap contains trimedlure inside a protective, laminated shell. The outside of the device is coated with insecticide, and remains able to kill Medfly for approximately 6 months.

Flies which are not attracted to a known parapheromone, such as Cucumber fly, cannot be managed with MAT.

As no trap is involved, MAT blocks are cheap. They can remain both attractive and insecticidal for 3– 6 months depending on weather conditions.

Magnet MED trap for Medfly

Matching Fruit Fly to MAT

Species	Device
Qfly	Cuelure MAT
Lesser Qfly	Cuelure MAT
Medfly	Magnet MED
Jarvis fly	Zingerone lure
Cucumber fly	Unknown

HOW TO USE MAT

Just as with traps, not every male will be attracted to a lure. Parapheromones are attractive to male flies because feeding on them increases their mating success. Just as with protein in baits, they will be less responsive once they have been exposed to cuelure or a similar natural product. MAT is therefore most likely to be effective with newly matured male flies.

As previously noted, para-pheromones have a limited zone of attraction. For example, cuelure can attract Qfly from 10–20m distance. However even within this distance not all flies will respond.

For best results, MAT units need to be spaced regularly around the crop edges and other areas where flies are likely to gather, such as trees near watercourses. Spacing every 20m, or more frequently, will maximise the effects.

The other issue with MAT is that males can mate many times. Even eliminating a large number of males from the population will not prevent female flies from mating and laying eggs.

Finally, if the same lure and kill system is being used for MAT and in traps, this can affect the outcomes of the monitoring program. Reducing the number of male flies caught in traps can suggest that the population is low, when the number of female flies in the crop may actually be increasing in the crop.

MAT needs to be used in combination with other strategies, particularly protein baiting. MAT will be ineffective if used alone.

BEST PRACTICE

- ✔ **MAT devices should be installed no more than 20m apart around the crop perimeter and other places that flies may gather such as trees along watercourses.**
- ✔ **Units need to be replaced every 3–6 months to ensure the insecticide remains effective.**
- ✔ **As MAT uses the same lures and insecticides that are used in monitoring traps, trap data should be interpreted cautiously if MAT is in place.**
- ✔ **MAT is ineffective used alone, but can be combined with other control strategies, particularly protein baiting.**

07.

THERE ARE A NUMBER OF COMMERCIAL DEVICES AVAILABLE THAT LURE AND KILL FEMALE FRUIT FLIES. IT IS NOT CLEAR WHAT PERCENTAGE OF THE POPULATION IS REMOVED, AND SO FAR NONE HAVE BEEN DEMONSTRATED AS EFFECTIVE FOR VEGETABLE CROPS.

Female biased traps

Female biased traps aim to lure and kill a large percentage of the fly population. They can be based on food, fruit volatiles or fruit mimics. Despite many years of searching, there are no pheromone based lures for female fruit flies.

Cera Trap (left) and dead flies inside a trap (right)

CERA TRAP

The Cera Trap is food based, containing a liquid protein mixture with a mild ammonia smell. No insecticide is needed as flies simply drown. The liquid needs to be kept well topped up, so units need to be serviced regularly in hot weather.

Also, the trap can attract significant by-catch – blowflies, ants, etc – especially once captured insects start to rot. If large numbers are caught, the trap contents need to be strained to remove dead insects then replaced into the trap. This is a rather unpleasant and time consuming task.

Cera Traps attract both male and female fruit flies, with a bias to females. While Cera Traps can certainly kill Qfly, Jarvis fly and other fly species, it is unclear what percentage of the local population is trapped by this device.

Liquid protein does not have a strong smell, so the zone of attraction of the Cera Trap appears to be quite limited. Even placing traps at 15m intervals around the perimeter of a cropping area may only kill a relatively small percentage of the population. While it is satisfying to see dead flies in traps, this has not been demonstrated to significantly reduce the number of infested fruit in Australian vegetable crops.

Fruition trap (Photo by Griffith University)

Biotrap with gel attractant and DDVP cube

FRUITION TRAP

This new device (launched November 2016) combines a slow release sachet of fruit volatile aromas with a large, sticky, cobalt blue sphere. Flies attracted by visual and olfactory cues become stuck on the sphere. The developers claim that their synthetic ripe fruit aroma remains highly attractive to Qfly for up to eight weeks, as well as potentially other species. As this is a new device, its effectiveness for vegetable crops has not been tested.

BIOTRAP WITH GEL ATTRACTANT

The Biotrap Fruit Fly Attractant Gel is an ammonia and fruit volatile based gel which is stated to last up to three months. It is combined with a DDVP cube which kills flies entering the trap.

Suggested spacing is 15m intervals around the perimeter of the crop. As this is a new system, its effectiveness for vegetable crops has not been tested.

BEST PRACTICE

- ✔ **Female biased traps can kill a percentage of the fly population.**
- ✔ **They need to be installed at intervals of 15m or less around the crop perimeter then checked and re-set regularly.**
- ✔ **There is no published evidence that they are effective in vegetable crops. However, they may be useful in combination with other control strategies.**

08.

GREENHOUSE WALLS, NETTING AND EVEN PLANT COATINGS CAN PREVENT OR REDUCE FLIES ENTERING THE CROP AND INFESTING FRUIT. AS WELL AS BEING PHYSICAL BARRIERS, THESE DEFENSES CAN PREVENT FLIES FROM SEEING AND/OR SMELLING POTENTIAL HOSTS.

Physical protection

Physical protection can be expensive and is not suitable for all crops and field situations. However, it is a highly effective way to protect vegetables from fruit fly. It can also provide additional benefits in terms of productivity, quality, reduced irrigation requirements and control of other pests.

Greenhouses offer a major barrier to fruit flies, whether glass (left) or plastic (right). Even though the house shown at right has a retractable roof, flies rarely – if ever – enter this environment.

GREENHOUSES

Fruit flies rarely, if ever, enter greenhouses.

Greenhouse walls are clearly a physical barrier to fruit flies. They usually present a flat, white exterior, the crop inside being obscured.

In contrast, fruit flies are known to orient towards dark, tree shaped objects. They tend to avoid white or reflective areas. This suggests that greenhouses in general are likely to be relatively unattractive.

Although fruit flies could still enter through un-meshed roof vents or opened doors, they generally do not do so. This may be due to their habit of flying low to the ground or darting from tree to tree. Fruit flies rarely fly high across open spaces, such as pastures. They are only likely to enter roof vents if strongly attracted by fruit aroma or pheromone, or if they are blown there accidentally.

NET HOUSES

Net houses can be used to protect crops from weather, sunburn and pests ranging from wallabies to thrips.

The traditional view of netting against fruit fly was that the crop had to be fully enclosed in insect proof netting, with “air-locks” for entry of people and equipment.

However, most of the benefits of netting can be obtained with much lower levels of security.

Net houses, such as this one in Carnarvon WA, can greatly reduce the number of flies entering a crop. Even though flies can physically fit through or go under the mesh, the combination of a visual and a physical barrier greatly reduces incursions.

Hail netting is not fruit fly proof, as holes are large enough for flies to crawl through. Despite this, experience with orchard fruit has shown that installing white hail netting on both top and sidewalls greatly reduces entry of flies into the orchard. Note that white mesh is likely to be better at excluding flies than green or black, as white is repellent to fruit flies.

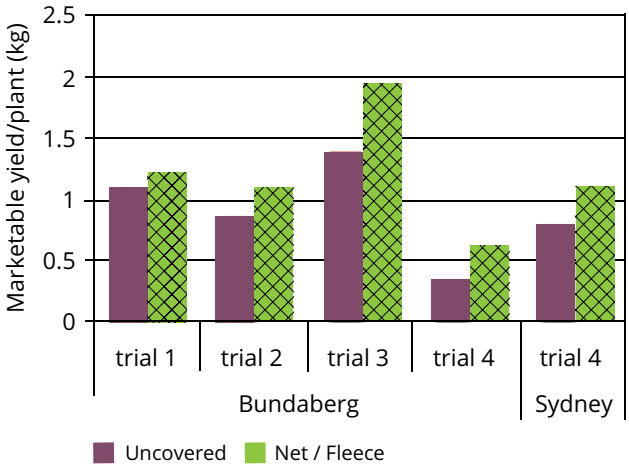
Flies use both visual and scent cues to find host fruit. Hail netting and windbreak materials hide the crop from flies, and may even reduce drifting of fruit aromas. If flies cannot see or smell the fruit, there is no reason for them to try to go inside.

FLOATING ROW COVERS

Unlike the permanent structures required to construct net houses, floating row covers involve simply draping netting over plants and securing the edges with shovelfuls of soil.

Various grades of netting can be used, ranging from coarse windbreak materials to extra fine nets designed to exclude all pests. The weight of materials can be an issue if they are not supported, but upright plants such as capsicums and eggplant can easily support lighter grade nets as they grow.

As with net houses, floating covers can give plants protection from wind, heavy rain and sunburn. They also reduce water requirements and exclude various pests. Light is diffused and evaporation is reduced, resulting in larger and healthier plants. For example, floating covers have been shown to increase marketable yield of capsicums, mainly through improved fruit set and reduced damage from wind and sun.



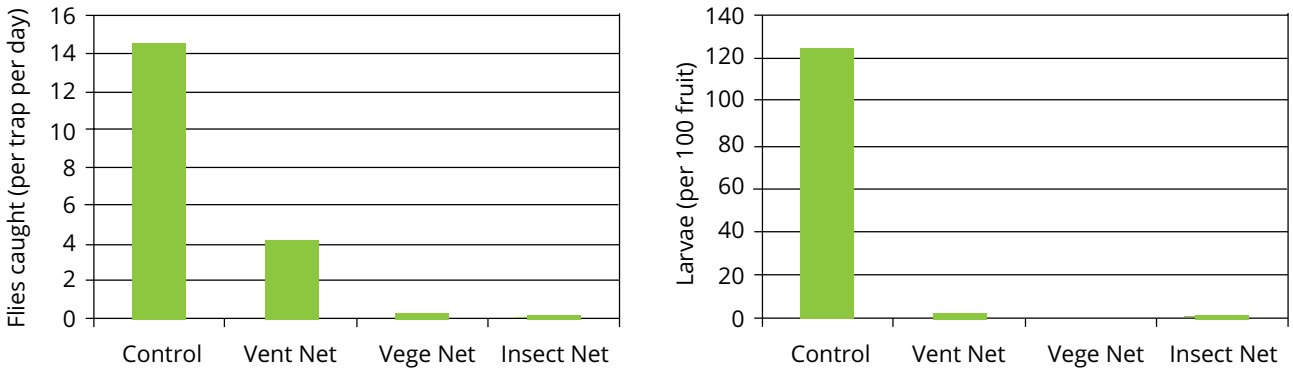
Marketable yield of capsicums (kg/plant) assessed at initial commercial maturity from four separate trials conducted in Bundaberg and southwest Sydney. Capsicums were grown under VegeNet or left uncovered (controls).

Like net houses, floating covers also provide a visual barrier to fruit flies. Even if a few flies do penetrate the netting, the number of infested fruit can be reduced to almost zero.

Lightweight materials such as VegeNet (NetPro) are very suitable for excluding fruit flies from vegetable crops. This material weighs 45g/m² and has mesh size approximately 1 x 3mm.

Trials in Bundaberg and Sydney testing various netting types found that;

- VegeNet was an effective visual barrier and did not exclude natural predators from the crop. No infested fruit were found under this material while it remained intact.



Number of flies caught (left) and number of larvae found per 100 fruit sampled (right) in a cayenne chilli crop where plants were left uncovered (control) or covered with VentNet (windbreak material), VegeNet (lightweight net) or Insect Net (fine net).

- Insect Net with mesh size 0.8mm was relatively transparent. No insecticides were used in the trial and the net excluded beneficial insects, with the result aphids infested the covered plants.
- Although flies could get into crops covered with Vent-Net screening material, oviposition was almost zero. It seems likely male flies were strongly attracted by cuelure in traps under the material, motivating them to find their way through the mesh, whereas female flies were less intent.

Placing netting over the crop while the plants are still small, even before fruit set, gave the best improvements in plant health.

Netting adds cost, both in materials and labour. Accessing the crop is more difficult, which is especially an issue if there are multiple harvests. While netting can be used for several years, cleaning the material between uses (to ensure disease is not spread) also creates challenges.

Single use frost protection fleece materials such as Daltex Groshield or Agryl can make effective insect barriers. While these materials are inexpensive, they tear easily if wind gets beneath the covers. These materials are therefore not suitable for application to upright plants such as capsicums and eggplant, but may be used for low growing crops such as pumpkin.

Male Qfly on the outside of VegeNet, unable to reach the cuelure baited trap inside.

In Europe, mechanical systems are used for installing and recovering floating covers. Such systems could potentially reduce costs and enable use of netting on large scale vegetable farms.

VegeNet (left) and Insect Net (centre) on capsicum plants. VegeNet is 1 x 3mm mesh size and 45g/m^2 whereas Insect Net is 0.8mm mesh and 70g/m^2. Vent-Net (right) on capsicum plants, with plague soldier beetle on the outside.

Kaolin on chilli plants (left), showing the effect after two kaolin applications followed by several rain events. Although some of the material has been washed from the plants, they still appear white from a distance. Kaolin on a potted chili plant (right).

KAOLIN CLAY

Kaolin – aluminium silicate – comes from kaolinite, a natural mineral. It is allowed under organic systems, and has a wide range of both industrial and agricultural uses.

Commercial sprayable kaolin products (eg Surround WP) are most commonly applied to tree crops such as apples and pears to prevent sunburn. The suspension is sprayed on using an agitated tank, coating the plants with fine, white powder. The crystalline structure of the clay reflects red light wavelengths and diffuses sunlight, so photosynthesis is actually increased. Kaolin lowers temperatures on the leaf surface and reduces water loss.

Plants sprayed with kaolin look white – which is repellent to fruit flies. The material also disguises the fruit, which are hard to distinguish from the foliage. Additionally, the fine clay particles are believed to irritate flies that land on the material, discouraging them from settling.

Trials using kaolin clay have found that it can reduce the number of larvae in fruit by 90 to 100% compared to untreated controls.

Kaolin is not without drawbacks. The material is relatively expensive, and has to be applied several times to get a good coating. Kaolin will likely need re-application if it rains or overhead irrigation is used. After harvest fruit needs to be thoroughly washed to remove the material, which usually requires water jets and brushes. It is likely to be difficult to remove all kaolin residues from irregularly shaped products such as capsicums.

BEST PRACTICE

- ✔ **Physical barriers are highly effective against fruit fly.**
- ✔ **Fruit flies rarely enter greenhouses, even if the roof is open.**
- ✔ **Floating covers are an effective way to reduce the number of flies entering a crop and can also improve plant health.**
  - **Net with 1 x 3mm diameter mesh is very suitable for excluding fruit flies.**
  - **Nets that are not insect-proof can still be effective if they provide a visual barrier.**
  - **Secure nets well around the edges using shovelfuls of soil.**
  - **Clean nets between uses to avoid transferring disease to new crops.**
  - **Disposable fleece materials could potentially be used to exclude fruit flies from low growing plants.**
- ✔ **Coating plants with kaolin may be a useful management tool, but cost and issues with removal must be considered.**

09.

REMOVING POTENTIAL SOURCES OF INFESTATION CAN STOP FRUIT FLY POPULATIONS BUILDING UP ON FARMS AND HELP PREVENT INCURSIONS FROM NEIGHBOURING AREAS.

Hygiene

On-farm hygiene and biosecurity are good practice in terms of managing ALL pests and diseases, not just fruit flies. Fruit flies can move, which creates additional challenges. However, limiting incursions into a crop can both reduce infestation of fruit and increase the effectiveness of other control measures.

ISOLATING THE CROP

As previously described, fruit flies are tree dwellers, at home in vegetation. They are not strong flyers, generally travelling less than 1km, and usually less than 600m, during their lifetime.

Grassy fields and vacant paddocks offer no food, shelter or potential hosts. Traps located in cereal crops or pastures consistently fail to trap any flies. Fruit flies just don't go there.

Crops that are located well away from orchards, town areas, and natural bushland are likely to be less susceptible to incursions by flies. While flies do move, a 200–400m wide "no-mans-land" around cropping areas still presents a significant barrier to infestation from the surrounding countryside.

Of course, it is not always possible to maintain such a large distance between a fruiting vegetable crop and potential hosts and roosting sites. However, it is worthwhile considering how and where flies can move into the crop from other areas.

This hydroponic tomato farm is located in an area endemic to fruit fly. However the farm is isolated, with more than 1km dry grassland in all directions. Combined with low pest pressure and the high walls of the greenhouse itself, fruit flies are effectively prevented from entering the crop.

Once harvesting has finished, potential fruit fly host crops need to be destroyed as soon as possible.

Cucurbit fruit such as melons or pumpkins can persist for a long time in the field, even after the plants have died (left). This can allow large populations of Cucumber fly to build up (right), then potentially transfer to neighbouring crops.

REDUCING INCURSIONS

Removing feral fruit trees is key to managing fruit flies; a single feijoa tree can produce up to 30,000 flies in a season if left unmanaged.

Backyard trees and urban areas in general are common breeding grounds for fruit flies. Tree owners may be unwilling or unable to control fruit flies themselves.

In addition, urban areas provide overwintering refuges. This is particularly important in regions with cold climates, which are only marginal for fruit fly survival. Microclimates around houses and shops are often significantly warmer than the surrounding countryside, and allow adult flies to survive temperatures that would normally kill them. The flies then disperse to neighbouring crops when the weather is warm enough to fly (>16°C for Qfly, >12°C for Medfly).

Physical barriers, or bare zones, can help prevent incursions from such areas.

Fruit fly outbreaks have also been associated with holidaymakers and workers, who unknowingly bring infested fruit into production areas. Ensuring that staff and contractors do not bring suspect fruit on-site can also reduce the chance of an outbreak.

A biosecurity sign on the front gate reminding visitors not to bring fruit onto the property is a simple but useful inclusion.

FARM HYGIENE

Standard recommendations for fruit fly management in orchards state that all fruit needs to be removed to prevent further infestation.

For vegetables this is not feasible, as picking and removing every single chilli, capsicum or squash is uneconomic. Moreover, flies do not usually lay eggs in fruit already on the ground and rotting. Unmarketable fruit noticed during harvest should therefore be pulled from the plant, dropped into the inter-row and crushed. Stomping with a boot or driving through with the tractor will help ensure waste fruit decays quickly.

In addition, host crops should be destroyed as soon as possible once harvesting is complete. This could just involve turning off the irrigation to kill the plants. Preferably, plants should be mulched into the ground.

If infested fruit is found, it is essential it should be destroyed to make sure the larvae do not survive. To do this either:

- Freeze the infested product overnight.
- Place inside black plastic garbage bags and leave in the sun (solarise).
- Bury at least 50cm deep.

BEST PRACTICE

- ✔ **Remove unmanaged fruit trees within 600m of the crop.**
- ✔ **Fruit trees within 600m of the crop that can't be removed need to be treated with insecticide during fruiting, or fruit picked before maturity.**
- ✔ **Ensure workers and contractors do not bring infested fruit onsite.**
- ✔ **Instruct harvesting staff to pull unmarketable fruit from the plant and crush them to speed decay.**
- ✔ **Destroy fruit fly host crops as soon as possible once harvesting is complete.**
- ✔ **If infested fruit is found, it must be destroyed by freezing, solarisation or burial.**

KEY REFERENCES

Balagawi S. *et al*. 2012. Spatial and temporal foraging patterns of Queensland fruit fly *Bactrocera tryoni* for protein and implications for managmeent. Aust. J. Ent. 51:279-288.

Balagawi S. Jackson K. Clarke AR. 2013. Resting sites, edge effects and dispersion of a polyphagous *Bactrocera* fruit fly within crops of different architecture. J. App. Ent. 138:510-515.

Broughton S, DeLima CPF. Field evaluation of female attractants for monitoring *Ceratitis capitata* under a range of climatic conditions and population levels in Western Australia. J. Econ. Entomol. 95:507-512.

Clarke AR *et al.* 2010. The ecology of *Bactrocera tryoni:* What do we know to assist pest management? Ann. App. Biol. 158:26-54.

D'Aquino S *et al.* 2011. Effects of kaolin based particle film to control *Ceratitis capitata* infestations and postharvest decay in citrus and stone fruit. Crop Prot. 30:1079-1086.

DeFaveri S *et al*. 2016. Farm-wide fruit fly management systems for the east coast of Australia. HIA Final Report MT12050.

Dominiak BC, Daniels D, Mapson R. 2011. Review of the outbreak threshold for Queensland fruit fly (*Bactrocera tryoni*). Plant Prot. Quart. 26:141-147.

Dominiak BC, Daniels D. 2012. Review of the past and present distribution of Mediterranean fruit fly (*Ceratitis capitata*) and Queensland fruit fly (*Bactrocera tryoni*) in Australia. Aust. J. Ent. 51:104-115.

Dominiak BC, Ekman JH. 2013. The rise and demise of control options for fruit fly in Australia. Crop Prot. 51:57-67.

Dominiak BC, Mavi HS, Nicol HI. 2006. Effect of town microclimate on the Queensland fruit fly *Bactrocera tryoni*. Aust. J. Exp. Ag. 46:1239-1249.

Dominiak BC. 2012. Review of dispersal, survival and establishment of *Bactrocera tryoni* for quarantine purposes. Ann. Ent. Soc. Am. 105:434-446.

Ekman JH. 2015. Fruit fly research gap analysis. HIA Final Report VG13040.

Fay HA. 2012. A highly effective and selective male lure for *Bactrocera jarvisi.* Aust. J. Entomol. 51:189-197.

Mazor M, Erez A. 2004. Processed kaolin protects fruits from Mediterranean fruit fly infestations. Crop Prot. 23:47-51.

Meats A, Edgerton JE. 2008. Short and long range dispersal of the Queensland fruit fly *Bactrocera tryoni* and its relevance to invasive potential, sterile insect technique and surveillance trapping. Aust. J. Exp. Ag. 48:1237-1245.

Meats A, Hartland CL. 1999. Upwind anemotaxis in response to cuelure by the Queensland fruit fly *Bactrocera tryoni*. Phys. Ent. 24:90-97.

Meats A, Smallridge CJ. 2007. Short and long-range dispersal of medfly *Ceratitis capitata* and its invasive potential. J. Appl. Ent. 131:518-523.

Mo J *et al.* 2014. Pest behaviour insights from quarantine surveillance of male Queensland fruit fly *Bactrocera tryoni*. Crop Prot. 62:55-63.

Pinerao JC, Mau RFL, Vargas RI. 2011. A comparative assessment of the response of three fruit fly species to a spinosad-based bait: effect of ammonium acetate, female age and protein hunger. Bull. Ent. Res. 101:373-381.

Royer JE *et al*. 2014. Cucumber volatile blend, a promising female-biased lure for *Bactrocera cucumis*, a pest fruit fly that does not respond to male attractants. Aust. Ent. 53:347-352.

Schutze MK *et al*. 2016. 'Ladd traps' as a visual trap for male and female Queensland fruit fly *Bactrocera tryoni.* Aust. Ent. 55:324-329.

Senior LJ *et al.* 2016. Protein feeding of Queensland fruit fly Bactrocera tryoni and cucumber fly Zeugodacus cucumis on non-host vegetation: effect of plant species and bait height. Austral. Entomol. *In Press.*

Subramaniam S. 2011. Alternative fruit fly control and market access for capsicums and tomatoes. HIA Final Report VG06028.

Vijaysegaran S, Walter GH, Drew RAI. 1997. Mouthpart structure, feeding mechanisms and natural food sources of adult *Bactrocera*. Ann. Ent. Soc. Am. 90:184-201.

Weldon C, Meats A. 2007. Short-range dispersal of recently emerged males and females of *Bactrocera tryoni* monitored by sticky sphere traps baited with protein and Lynfield traps baited with cuelure. Aust. Ent. 46:160-166.

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