PEST ADVISORY LEAFLET NO. 40

Plant Protection Service
Secretariat of the Pacific Community

2001

Fruit Fly Control Methods for Pacific Island Countries and Territories

Fruit flies (Family Tephritidae) are one of the most serious insect pests of horticultural produce throughout the tropical and sub-tropical world. They attack sound and damaged fruits and vegetables by laying eggs under the skin (Figure 1). The eggs (Figure 2) hatch into larvae that feed in the decaying flesh of the fruits and vegetables (Figure 3). At maturity, larvae drop to the ground and after burrowing in the ground, their skins harden to form hard shells called puparia, inside which the larvae transform themselves into adults (Figure 4). Infested fruits quickly become rotten and inedible or may drop to the ground prematurely, thus causing considerable losses in production. Feeding by fruit fly larvae may cause complete destruction of fruits, rather than cosmetic damage as is caused by many other insect pests. As well as these direct losses, other major losses result from quarantine restrictions that are imposed by importing countries to prevent the entry or establishment of unwanted fruit fly species. Considerable financial burdens are imposed on governments, farmers and exporters, who have no choice but to implement quarantine surveillance systems, quality assurance schemes and acceptable post-harvest quarantine treatments if they wish to export fruit fly host products.

Figure 1: Female of Pacific fruit fly (*Bactrocera xanthodes*) laying eggs in fruit.

Figure 2: Fruit fly eggs in host fruit flesh.

Strategies for the control of fruit flies include physical control, cultural control, biological control, behavioural control, genetic control, chemical control and combinations of some or all of these into an Integrated Pest Management (IPM) approach. Most of these techniques are appropriate for the Pacific Island countries and territories (PICTs); genetic control is probably too expensive or too sophisticated to use in the PICTs under normal conditions.

PHYSICAL CONTROL

The principle of physical control involves providing a barrier between the host fruits and the egg-laying female fruit fly. The most common method is to bag or wrap fruit before the fruits reach a stage of maturity at which they are susceptible to infestation. Bags made from double layers of newspaper or brown paper are used (Figure 5).

Fruit bagging has been widely used in tropical Asia for nearly a century. Bagging or wrapping is a common practice in Malaysia for the protection of crops of carambola or starfruit (*Averrhoa carambola*), particularly those grown

Figure 3: Fruit fly larva.

for export. In Malaysia, damage levels may be reduced from nearly 100% to 15-25% by bagging. Similarly, this technique is used in Thailand to protect mangoes from fruit fly attack and in Taiwan to protect melons from melon fly. Generally, this technique is applicable where relatively

Figure 4: Fruit fly puparia.

small areas of production are involved (e.g., village or subsistence production); where the costs of labour is cheap; where high quality, high value, unblemished produce is necessary; and where no alternative practical methods of control are available. This technique is appropriate for Pacific island production systems and should be encouraged especially for backyard and village production.

To prepare a bag (Figures 6-10): Use a double layer of newspaper. A single layer breaks easily. Fold and sew or staple the sides and bottom of the sheets to form a rectangular bag. To bag fruits (Figures 11-12), blow in the bag to inflate it. Place the fruit in the bag and firmly tie top end of bag with string or tie wire. Bag immature fruits not yet infested with larvae. Push the bottom of bag upwards to make it "v"-shaped. This prevents damage by rain and keeps the bag inflated, and keeps the fruit away from the sides of the bag. Near harvest time, the bag may be carefully opened to check if the fruit inside is ripe. Bagging produces very high quality fruits at harvest. It is best suited to protect guavas, mangoes and carambolas.

Plastic bags may be used but are not ideal, because the inside gets hot and moisture favors fungus growth. Alternatively, bags made of natural leaves may be used. Leaves of Pandanus, betel nut tree, sago palm or swamp taro are recommended. Leaves can be softened to increase pliability by heating them over a fire. To protect bananas, the whole bunch may be bagged inside banana leaves, as is frequently done in Papua New Guinea to protect bananas against banana fruit fly (*Bactrocera musae*) and to improve market appearance of bananas (Figure 13-14).

CULTURAL CONTROL

Cultural control includes practices, such as those below, that may be regarded as part of the normal production system and do not involve the application of insecticides.

Production during periods of relatively low fruit fly activity

Fruit fly activity and populations vary throughout the year. Trapping data in Tonga, Fiji Islands and Cook Islands show that the populations of fruit flies are low during May, June, July and August, i.e., during the cooler months. Damage caused by *Bactrocera facialis* to capsicums in Tonga at this time of the year, for example, is relatively low - less than 10%.

Therefore, the growing of capsicums in Tonga in May-August may be worthwhile, considering that New Zealand authorities may be prepared to accept seasonal abundance data and data on seasonal damage levels in low risk crops as part of a move to recognise a 'winter window' for importation of some commodities.

The combination of low fruit fly activity and effective field control in the exporting country during cooler months and the low risk of establishment of fruit flies in winter months in the importing country may open up new markets for low risk fruit fly host commodities. Also, growing crops a

Figure 5: Bagged carambola trees in Malaysia.

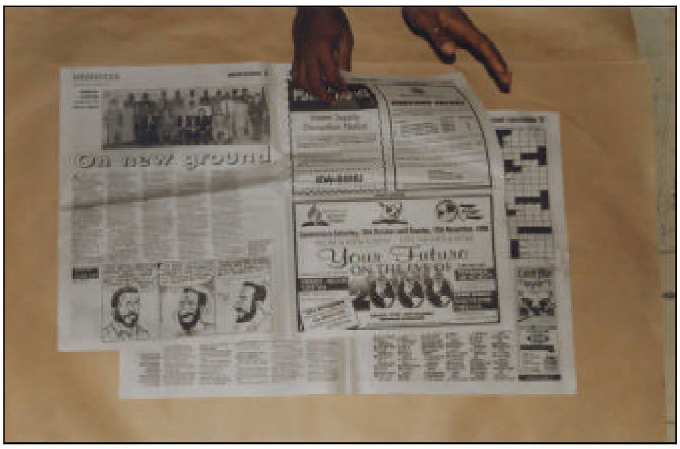
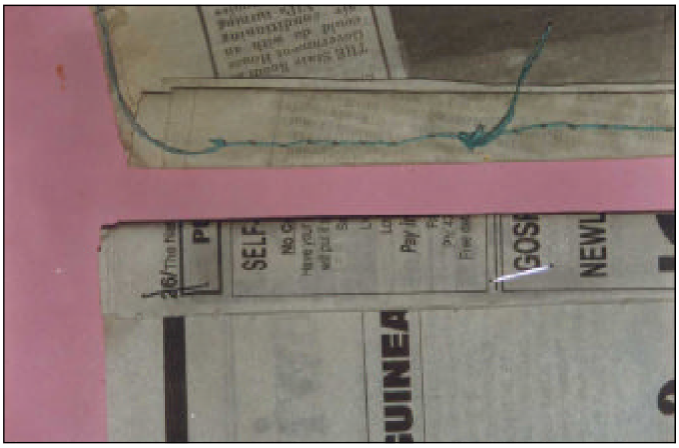


Figure 6: A double layer of newspaper is needed to make a newspaper bag.



Figures 7 to 10: Steps in preparation of bag for fruit bagging.

during the cooler months reduces pressure on the effectiveness of field control systems, such as protein bait sprays.

Growing less susceptible varieties

With the advent of a standard for testing the susceptibility of various fruits and vegetables to fruit flies, there is an option now to be able to grow varieties that may be less susceptible or not susceptible to fruit flies. Under the Regional Fruit Fly Project in the South Pacific (RFFP) in Fiji Islands, two varieties of chillies, 'Hot Rod' and 'Red Fire', have been cleared by New Zealand Ministry of Agriculture (Regulatory Authority) for export without additional post-harvest quarantine treatment. These varieties are classed as non-hosts for fruit flies in Fiji Islands.
Similarly, fruit crops such as lychee and rambutan are not infested by fruit flies in northern Thailand, provided the skin is intact. Pineapples are not hosts for fruit flies at any stage of maturity in Fiji Islands. Other crops that may be non-hosts or at least low risk in some PICTs are squash (pumpkin), zucchini, cucumber, some varieties of watermelon, rockmelon, limes and pawpaw at colour break.

PICTs that have conducted research into the non-host status include Cook Islands, Tonga, Samoa, Fiji Islands, Vanuatu, Solomon Islands, New Caledonia and FSM.

Sound crop sanitation

The collection and destruction of fallen, damaged and overripe fruits is strongly recommended to reduce the resident population of fruit flies. Evidence from Hawaii shows that

Figures 11-12: Steps in fruit bagging.

pawpaws left on the ground act as a major breeding site for oriental fruit fly (*B. dorsalis*) and melon fly (*B. cucurbitae*). To eliminate or reduce this reservoir of the resident population, crop sanitation should be an essential component of melon fly and oriental fruit fly programs in pawpaw orchards. Initial results from sampling kumquats (*Fortunella japonica*) in Fiji Islands indicate similar trends to those of pawpaw in Hawaii. Thirty-five percent of the fruits on the ground were infested with *B. passiflorae*, while about 7% of fruits on the tree at a similar stage of maturity were infested. In some areas of China, *B. minax*, a highly destructive pest of citrus, is successfully controlled by large-scale, area-wide practice of destruction of fallen fruits in orchards and villages.

Crop residues such as fallen, over-ripe or damaged fruits may be destroyed by deep-burying (>50cm) or by burning or by feeding them to pigs. Alternatively, they may be sealed inside plastic bags and exposed to direct sunlight for several hours. Putting fruit or vegetable residues into compost heaps or rubbish dumps is not recommended.

Not adopting sound crop sanitation places unnecessary pressure on other components of control systems, particularly protein bait sprays, whose effectiveness may be threatened under high fruit fly population pressures. Under quality assurance schemes being adopted for production of commodities for export, sound crop sanitation is essential and

Figures 13-14: Banana whole bunch bagging – a common practice in Papua New Guinea.

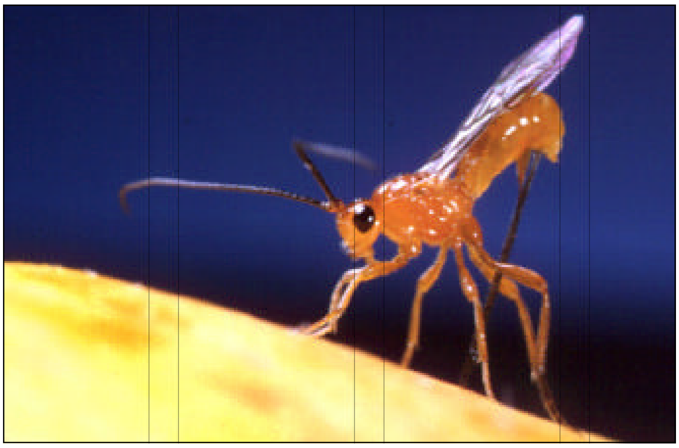


Figure 15: *Diachasmimorpha kraussi* – a common fruit fly parasitoid in Australia, Papua New Guinea and Solomon Islands.

Figure 16: Caneite block for fruit fly male annihilation.

a prerequisite for any farm that is registered for export production.

Early harvesting

Avoidance of fruit fly infestation is possible by harvesting crops at a stage of maturity when the fruit or vegetable is not susceptible to fruit fly attack. Bananas, for example, have been exported around the world because they are not susceptible to fruit flies at the mature green stage, except in countries where banana fruit fly (*B. musae*) and Asian papaya fruit fly (*B. papayae*) occur. On that basis, Samoa exports large amounts of green bananas to New Zealand. Banana fruit flies may lay eggs in banana fruits when the fruits are very small. The eggs do not hatch until the fruit commences to ripen. Asian papaya fruit fly may also infest green bananas. Pawpaws, harvested at colour break, are less likely to be infested by fruit flies than if harvested at later stages of maturity. Harvesting at colour break has become one of the conditions for export of pawpaws from Cook Islands and Fiji Islands to New Zealand.

BIOLOGICAL CONTROL

Despite a large amount of effort being devoted to the use of biological control agents (predators and parasitoids) to control fruit flies, there have been relatively few instances that may be regarded as sustainable successes.

Generally, predators have little effect on the populations of fruit flies in an orchard or vegetable production situation. Invertebrate predators may include spiders, ants, carabid beetles, assassin bugs, staphylinid beetles and probably others. In Crete, the numbers of olive flies (*B. oleae*) are reduced by birds that eat 81% of infested fruits. In consuming the fruits, predators, unfortunately, also consume parasitoids so there is an indirect adverse effect. In the endemic forest habitat, however, predation by fruit-eating vertebrates, such as birds and primates, results in marked reductions in fruit fly numbers.

The use of parasitoids (Figure 15) to control fruit flies biologically has always had wide appeal, but tropical fruit flies have not, in general, proved to be good targets for biological control. The most documented research on using parasitoids to reduce fruit fly populations has been in Hawaii, where a large number of species have been introduced and released to control oriental fruit fly, Mediterranean fruit fly (*Ceratitis capitata*), and melon fly. The parasitoids belong to the families Braconidae, Chalcididae and Eulophidae. Releases of a suite of parasitoids resulted in reductions in populations of Mediterranean and orien-

Table 1: Fruit fly parasitoids recorded in Pacific Island countries and territories. N = Native; I = introduced at an unknown date; 1951 = introduced at a known date.

	Cook Islands	Fiji Islands	Guam	Micronesia (FSM)	New Caledonia	Northern Marianas	Palau	Papua New Guinea	Samoa	Solomon Islands	Tonga	Vanuatu
Braconidae: *Biosteres* sp												N
Braconidae: *Diachasmimorpha hageni*		N										
Braconidae: *Diachasmimorpha kraussi*								N		N		
Braconidae: *Diachasmimorpha longicaudata*		1951	N	1997	N	N		N				
Braconidae: *Fopius arisanus*	I	1951		1997			N		I		I	
Braconidae: *Fopius deeralensis*								N				
Braconidae: *Opius frogatti*					N							
Braconidae: *Opius* sp								N				
Braconidae: *Psyttalia fijiensis*		N			N			N			N?	
Braconidae: *Psyttalia fletcheri*			1950							1997		
Eulophidae: *Aceratoneuromyia indica*		1938	1952						1935			
Eulophidae: *Tetrastichus giffardianus*		1935										
Pteromalidae: *Pachycrepoideus vindemiae*		N										
Pteromalidae: *Spalangia cameroni*		1927										
Pteromalidae: *Spalangia endius*		N			N							
Pteromalidae: *Spalangia* sp											?	

tal fruit flies of up to 95%. Also, in normally heavily infested commercial fruits, the levels of damage caused by fruit flies were reduced to a point where the fruits were virtually free from infestation. These results were due mainly to the establishment of the wasp *Fopius arisanus* and, to a lesser extent, the establishment of *Fopius vandenboschii* and *Diachasmimorpha longicaudata*. It was claimed that oriental fruit fly, by 1968, was no longer a major pest of many kinds of fruits, except guava. This level of control, however, has not been sustained. Oriental fruit fly and Mediterranean fruit fly are still very serious pests of a wide range of fruits and vegetables. Inundative releases of laboratory-reared parasitoids may be an appropriate option and is being researched in Hawaii.

In Australia, there are several native parasitoids of Queensland fruit fly (*B. tryoni*), but they exert very little control on populations of fruit flies. CSIRO introduced several species of parasitoids into Australia in the 1950s. *F. arisanus* apparently bred in seven dacine and trypetine hosts, but by 1966, neither *F. arisanus* nor *D. longicaudata* affected the incidence of Queensland fruit fly. Now, only F. *arisanus* is established.

In the PICTs, there are only a few native parasitoids of fruit flies. For example, *Diachasmimorpha hageni* and *Psyttalia fijiensis* were recorded in Fiji as early as 1916. Parasitism levels of 5-10% were recorded in 1935. These promising results, together with results from Hawaii, saw a major effort to introduce parasitoids to Fiji and Cook Islands between 1927 and 1935 and in the 1950s. Parasitoids such as *F. arisanus*, *D. longicaudata*, *Aceratoneuromyia indica*, *Tetrastichus giffardianus* and *Psyttalia concolor* were introduced into Fiji.

Recent surveys in the PICTs during the Regional Fruit Fly Project since 1991 show that parasitism levels are still relatively low, generally at less than 10%. This level of parasitism is consistent with parasitism levels throughout northern Australia and Southeast Asia. There are occasions when levels of parasitism exceed 60%, but this is usually towards the end of a major fruiting season, e.g. guava. Based on these results, no special effort is being made in the PICTs to encourage augmentative releases of existing parasitoids. However, field control systems based on protein bait sprays take cognisance of the need to conserve the parasitism levels that now occur naturally.

With respect to melon fly in Solomon Islands, the parasitoid *Psyttalia fletcheri* was introduced from Hawaii in 1997, with the aim of reducing its populations to a level that may reduce the pressure on the efficacy of protein bait sprays. As the populations of mango fly (*B. frauenfeldi*) are extremely high throughout the year in the Federated States of Micronesia, *F. arisanus* and *D. longicaudata* were introduced in 1997 on Pohnpei and Kosrae Islands, respectively, to reduce the populations. *F. arisanus* has become quickly established on Pohnpei, but it is too early to assess its long term impact on mango fly populations. The establishment of *D. longicaudata* on Kosrae has not been confirmed.

BEHAVIOURAL CONTROL

Use of colours, shapes and odours

Behavioural control covers an array of techniques that involve manipulation of some aspects of behaviour of fruit flies such that populations are reduced. Red spheres coated with a non-drying adhesive combined with attractants with odours resembling ripening apples result in excellent control of the apple maggot (*Rhagoletis pomonela*) in United States. The need for cover sprays has been virtually eliminated. Unfortunately, though tropical dacine fruit flies are attracted to various colours (eg. Queensland fruit fly to blue, oriental fruit fly and melon fly to yellow, and *B. xanthodes* to grey), there does not seem to be any immediate prospects for using this technique for control in the PICTs.

Male Annihilation Technique (MAT)

MAT involves the use of a high density of bait stations consisting of a male lure combined with an insecticide (usually technical malathion, and more recently fipronil), to reduce the male population of fruit flies to such a low level that mating does not occur. This is achieved by distributing cordelitos (lengths of 6-ply cotton string about 30-45 cm) or caneite (compressed fibreboard) blocks (Figure 16) (50 mm x 50 mm x 12.7 mm), or coconut husk blocks (50 mm x 50 mm x 10 mm) (Figure 17) impregnated with the lure/insecticide mixture. These are distributed from the ground or air at the rate of at least 400 per km^2. This treat-

Figure 17: Cononut husk block for fruit fly male annihilation.

Figure 18: BactroMAT C-L station for fruit fly male annihilation.

Figure 19: Treated piece of cardboard inside a plastic bottle for male annihilation.

ment is repeated every 8 weeks. There are several examples of the successful use of methyl eugenol in the technique. Oriental fruit fly (*B. dorsalis*) was eradicated from Guam and the Commonwealth of Northern Mariana Islands in the 1960's by Steiner and his colleagues. The insecticide used during the eradication was naled. Outstanding successes have been recorded using this method for eradication of Oriental fruit fly from California and from the Amami Islands of Japan.

More recently, this method, using lengths of string or cord soaked in methyl eugenol and malathion, was successful in eradicating Asian papaya fruit fly from several Torres Strait Islands, in an effort to keep this species out of Cape York in Queensland. A similar method, using caneite blocks nailed to trees instead of string, was used to successfully eradicate Asian papaya fruit fly from the Cairns area, in northern Queensland, during the mid 1990s.

In the PICTs, eradication programmes have been carried out against oriental fruit fly in Tahiti and Moorea, and four species [oriental fruit fly, Pacific fruit fly (*B. xanthodes*), melon fly (*B. cucurbitae*), and mango fly (*B. frauenfeldi*)] on Nauru. Impregnated coconut husk blocks treated with methyl eugenol and malathion were distributed by ground teams and from the air by helicopter in Tahiti and Moorea six times in 1997, in an attempt to eradicate oriental fruit

Figure 20: Bactrogel sticking on tree leaves.

fly. Hot spots of breeding fly populations were not completely eradicated, and from these, fly populations spread again over the two islands. MAT to eradicate the species was resumed in 1999. In Nauru, oriental fruit fly and Pacific fruit fly (*B. xanthodes*) were eradicated in early 1999 and early 2000, respectively, with caneite blocks (50 mm x 50 mm x 12.7 mm) treated with methyl eugenol and using fipronil instead of malathion.

The effectiveness of using Cue-lure as the lure for the male annihilation of species attracted to it is not as great as that using methyl eugenol. Therefore, attempts to use Cue-lure to eradicate melon fly populations have been in the past unsuccessful. During 1998-1999, though, melon fly was eradicated from Nauru, using caneite blocks treated with Cue-lure and fipronil. The prolonged drought and the resultant reduction in cucurbit host availability were favourable conditions that facilitated its eradication. Mango fly is the only species remaining in Nauru, and the application on Cue-lure treated blocks, in combination with protein bait spraying, has reduced populations to very low numbers.

A new male annihilation technology has recently been developed by Aventis CropScience in Australia. The bait stations are made of 'papier mâché' (same recycled cardboard material as egg cartons) soaked in a solution of Cue-lure or methyl eugenol and fipronil (Figure 18). The Cue-lure and methyl eugenol bait stations are called BactroMAT C-L? and BactroMAT M-E? , respectively. They may be imported by PICTs that have registered fipronil. In late 2000, the use of BactroMAT bait stations replaced the use of malathion-treated blocks in the eradication programmes in French Polynesia and Nauru.

Fipronil is a new insecticide in fruit fly control. It is highly toxic to fruit flies, hence a very small amount is needed to kill fruit flies. Because it takes 1-5 hours before the flies die, indirect evidence suggest that male flies that come in contact with fipronil may transmit a lethal dose to females during mating. Fipronil, in the amounts used for fruit fly control, is of very low toxicity to users.

Although MAT has been used primarily for fruit fly eradication, it may also be used for area suppression of fruit fly populations to reduce levels of damage. The rate of application of BactroMAT stations recommended by Aventis CropScience for area-wide fruit fly suppression is 4 to 7 stations per hectare (400-700 per km²) (grid pattern at 50-38m intervals) for BactroMAT M-E and 8 to 14 stations per hectare (800-1400 per km²) (grid pattern at 25-19m intervals) for BactroMAT C-L. The entire orchard (or village) should be covered, plus a 50m buffer zone around the perimeter. BactroMAT stations must be tied to trees in a shaded canopy area, because fipronil degrades if directly exposed to sunlight. New stations are distributed every 8 weeks.

Alternatively, caneite or coconut husk blocks, or even pieces of cardboard hung inside plastic bottles (Figure 19) treated with a malathion-based lure mixture may be used instead of BactroMAT, especially in countries that have not registered fipronil. For methyl eugenol, blocks are soaked in a solution containing 3 parts of methyl eugenol and 1 part of malathion 50% emulsifiable concentrate.10-12ml of solution are applied to each block. With Cue-lure, the Cue-lure is diluted with ethanol or methylated spirits at a rate of 9 parts alcohol to 1 part Cue-lure, then mixed with malathion in a ratio of 3:1. Blocks are soaked in the solution (10-12ml per block). The reason for diluting Cue-lure is that concentrated Cue-lure is not easily absorbed by the blocks and is a very expensive chemical. Blocks are nailed to trees at the same density and frequency as for BactroMAT. MAT for population suppression works best when combined with protein bait spray application.

Protein bait sprays

The use of bait sprays comprising an attractant and a toxicant date from 1889 in Australia. The bait or attractant was usually molasses or sugar solution and the toxicant was usually a stomach poison such as lead arsenate or Paris green. Subsequent developments tended to focus on the insecticide component of bait sprays and the bait component was nearly always sugar and molasses. This approach changed with Steiner's work on the use of protein hydrolysate as an attractant for bait sprays in Hawaii in the early 1950s. These bait sprays were based on acid hydrolysates of a plant protein (usually derived from maize). They were used in Australia in this basic form for about 15 years, until the past 15 years, when the acid hydrolysate component of bait sprays was replaced with a yeast autolysate.

The protein bait acts as a food attractant and its effectiveness relies on the fact that immature females need a protein meal to be able to develop mature eggs. When the flies feed on the bait spray residue on the foliage, they ingest the insecticide and die. Because the bait spray relies on its attractant properties for its mode of action, overall coverage of the tree canopy is unnecessary and a 'spot spraying technique' is adequate.

Experiments and experience indicate that bait spraying is most effective in 'area' treatment programs. It is ideal for medium to large orchards or where adjacent properties use the technique. The method has been used to control fruit fly in the major citrus growing areas in Queensland for over 25 years and has proved very successful. This technique is now being used as one component of quality assurance schemes for export produce. For example, it is being used as a field control method for mangoes grown in Fiji for the Japanese markets. Similarly, protein bait sprays have been included in quarantine protocols developed between Fiji, Tonga and Cook Islands and New Zealand for export of eggplant, some chillies, watermelons and breadfruit.

Most bait sprays used in other parts of the world still rely on acid hydrolysates for their protein source, but in the PICTs, Australia and South-East Asia, a different protein formulation has been produced in recent years. The most commonly used protein now is a yeast autolysate produced by enzymatic autolysis. The protein hydrolysate used previously was manufactured by hydrolyzing a plant protein with hydrochloric acid. This resulted in a protein bait with a low pH. Excess acid was neutralised with sodium hydroxide leaving a salt residue in the bait. Application of this type of bait spray often caused burning of fruit and foliage. There is minimal salt in the yeast autolysate used now so problems of phytotoxicity do not normally arise.

The yeast autolysate produced in Queensland is a light

Table 2: Results from fruit fly control trials using protein bait spraying in the Pacific.

Crop	Country	Pest fruit fly species	% damage without control	% damage with control
Capscium	Tonga	*B. facialis*	97-100%	< 7%
Guava	Vanuatu	*B. trilineola*	90%	15%
Mango	Fiji Islands	*B. passiflorae*	25%	1-2%
Guava	Fiji Islands	*B. passiflorae*	40-45%	< 4%
Surinam Cherry	FSM	*B. frauenfeldi*	68%	12.2%
Chilli	Tonga	*B. facialis*	93%	1-2%
Guava	PNG	*B. frauenfeldi, B. obliqua*	96%	20%
Carambola	PNG	*B. frauenfeldi*	70-100%	< 7%

Figures 21 to 24: Steps in preparation of Bactrogel-based protein bait solution.

brown liquid, containing 420 g per litre protein. It is marketed under the name Mauri's Pinnacle Protein Insect Lure (MPPIL). It may be stored at ambient temperature provided it is kept in a cool dark place. Refrigeration or air-conditioning will extend storage life and is recommended if possible. In Malaysia, the protein source used in bait sprays is a yeast autolysate produced as a by-product of the brewing process in the production of stout. It is marketed under the name of 'Promar'. It has proved to be an excellent attractant for the local species of fruit flies. The implementation of a bait spraying program for fruit fly control in carambola using the new protein formulation has been very successful, resulting in a doubling of carambola production in Malaysia.

A plant to convert waste yeast from the Royal Brewery in Tonga into yeast autolysate was established. This plant converts waste yeast into protein autolysate through a process of heating and addition of the enzyme papain and the food preservative potassium sorbate. The product, known as 'Royal Tongalure', was officially launched in early 1998 and is available to Tongan farmers at a much lower price than imported MPPIL. A similar plant was established in early 2001 in Vanuatu, run by Vanuatu Tusker Brewery.

Protein bait spraying has been extensively tested and demonstrated to farmers in the PICTs. Table 2 summarizes some of the trials carried out. The major disadvantage of protein bait sprays is that control may not be totally adequate at times of extreme pest pressure, especially if re-invasion of the treated area is continuous, and where the treated area is small in relation to untreated, surrounding areas. Control may also be less effective as the season progresses and populations with females at all stages of sexual maturity develop. Studies have shown that gravid females of the Queensland fruit fly are less interested in food than in finding suitable egg-laying sites. Additionally, in areas or during periods of high rainfall, heavy rain may wash a significant amount of bait solution tree off leaves.

On the other hand, the advantages of protein bait sprays far outweigh the disadvantages. Protein bait sprays are less harmful to beneficial insects, making them suitable for use in IPM programs. Because of the spot spraying technique, there is less insecticide applied to the crop or tree and non-target species have more refuges. Costs are considerably lower as less material is used per tree or per hectare. In addition, spot spraying is less time consuming than cover spraying and therefore less demanding of labour. Farmers may also be able to use simpler, inexpensive spraying equipment. Bait sprays are more environmentally sound because of reduced pesticide usage and less risk of spray drift. Spray applications can be directed on to foliage and away from fruit to minimize fruit residue problems. Reduced pesticide usage and use of coarse sprays at low pressure result in less hazard to the spray operator.

The following formulation is recommended if malathion and MPPIL are used: mix 50 ml of MPPIL concentrate, 4 ml of malathion 50% emulsifiable concentrate, and water (946ml) to make up one litre of solution. If Royal Tongalure is used, it is recommended to use 100 ml of Royal Tongalure per litre, because protein is less concentrated than MPPIL. The bait solution is sprayed at a rate of 50 ml on the undersurface of one square metre of leaves on each tree. Every trees in and surrounding the orchard or village is sprayed. In vegetable gardens, such as capsicum and chillies, or cucurbit crops, 20-25 litres per hectare are sprayed as a band of coarse spray to the foliage every third row. Sprays are repeated every 7 days, starting one month before fruits mature. In some situations, protein bait spraying should commence soon after fruit set (e.g. capsicums and chillies in Tonga) or as soon as fruits become susceptible (e.g. carambola in Palau or PNG). In very rainy areas, the spray interval should be decreased to every five days.

To overcome the problem of bait being washed off leaves and to improve the effectiveness of bait sprays, Aventis CropScience (Australia) developed a new formulation, known as Bactrogel? , with fipronil instead of malathion as the active ingredient. Bactrogel is a powder that contains fipronil and forms a liquid gel when dissolved in water. The gel, which is sprayed in combination with natural protein autolysate, adheres to leaf surface and resists rainfall (Figure 20). When applied to well shaded leaf undersurface, the gel remains moist most of the day and will rehydrate with dew next morning. A much smaller amount of bait solution is necessary to achieve successful control when using Bactrogel than when using a protein autolysate source such as Mauri Pinnacle Protein Insect Lure (MPPIL) and malathion. Bactrogel has been extensively tested in Australia and used during the Nauru eradication programme since late 1998. It is commercially available to PICTs that have registered fipronil.

Steps in Bactrogel preparation are as follows: 1. Slowly sprinkle 50 grams of Bactrogel gel powder on the surface of 9.7 litres of water in a bucket, while vigorously stirring constantly (Figure 21). Continue stirring for several minutes until all lumps disperse and the mixture forms a liquid gel (Figure 22). Add 300 ml of protein bait concentrate and continue stirring to dissolve the protein (Figures 23-24). In orchards and villages, the protein bait is applied as spots of 10 ml of solution to each tree on lower surface of leaves. For row crops in vegetable gardens (such as capsicum and chillies), Aventis Crop Science recommends spraying 2.5-5 litres per hectare as spots of 5-10ml at 4 metres intervals, applied to the foliage at intervals 2-3 rows apart, depending on row spacing. The bait is sprayed at low pressure (1.5 Bar) as a coarse linear jet to form a 30-40cm wide spot on the leaves.

Almost any sprayer may be used to apply the bait, as long as a low pressure linear jet is applied (Figure 25). Inexpensive hand-held sprayers, affordable to farmers, may be used. If available, 'Rega' single-action sprayers are the most convenient, because they are sturdy and the amount of bait applied can be controlled, to ensure that small amounts are applied.

GENETIC CONTROL

The Sterile Insect Technique (SIT) aims at eradicating a species by flooding the population with sterilised males so that the chance of sterile males mating with wild females is greatly increased. The females generally mate once only under field conditions. The best example of success of this method is in eradication of melon fly from various Japanese islands and from the Commonwealth of Northern Mariana Islands in the 1960's.

Prerequisites for this method are appropriate mass culture diets and facilities, capacity to produce hundreds of millions of flies per week and to monitor their fitness to compete with wild flies, appropriate techniques for sterilising flies using Cobalt-60 or Cesium-137, effective transport and release techniques, and methods to evaluate the progress of the eradication program. These requirements mean a very expensive, sophisticated programme and one that is appropriate for ecologically or geographically isolated areas into which wild flies are not likely to migrate and so dilute the effect of flooding the wild population with sterilised males. It is a technique that is not likely to be used in the PICTs, without significant financial justification.

CHEMICAL CONTROL – INSECTICIDE COVER SPRAYS

The history of insecticide sprays to control fruit fly commenced with the use of inorganic insecticides such as lead arsenate and sodium fluorsilicate in the early 1900s. With the development of synthetic chemical insecticides after World War II, DDT became the standard insecticide for fruit fly control. The great advantage of DDT was that it repelled female fruit flies, which enhanced its effectiveness. Complete coverage of the tree was needed and sprays had to be applied regularly, usually every 5-7 days from early in the season. DDT was eventually replaced by the organophosphorous insecticides, dimethoate and fenthion, which have been in use for more than 40 years. As well as killing adult flies on contact, both of these insecticides penetrate the fruits and kill eggs and young larvae.

Consequently, they have an advantage in keeping fruit infestation to a minimum. However, to be most effective, they have to be sprayed on the fruit surface and thorough coverage of the crop or tree is essential. Advantages of insecticide cover sprays are that they normally provide a high level of protection against infestation and, provided the spray application is sound, the level of protection is usually consistent.

There are several disadvantages of insecticide cover sprays. Dimethoate and fenthion have comparatively long withholding periods, so the crop is not protected for periods of seven days or more just before harvest, when the fruits are most attractive to female fruit flies. Application of cover sprays may be expensive in terms of labour and materials because the entire crop or tree has to be treated. Achiev

Figure 25: Protein bait spraying.

ing adequate spray coverage of large, dense plantation trees may be difficult and may require sophisticated spray equipment. The insecticides used adversely affect beneficial organisms, including biological control agents and pollinating agents. Blind stings or stings where eggs do not develop are common and these may result in fruit being rejected for export or rotting due to the introduction of bacteria during oviposition. As cover sprays do not fit into Integrated Pest Management programs, they are not recommended for fruit fly control in PICTs.

INTEGRATED PEST MANAGEMENT (IPM) APPROACH

The approach being fostered in the PICTs and elsewhere in the world is to use as little insecticide as possible by adopting an IPM strategy. Promoting a combination of bagging or wrapping of fruits, production during periods of low fruit fly activity, growing less susceptible varieties, adopting sound crop sanitation procedures, harvesting at times when the fruits or vegetables are least susceptible, and using protein bait sprays that will conserve existing parasitoids, fits into the concepts of IPM and reduced pesticide use in the PICTs. Adding to these techniques MAT for area-wide suppression provides a very good arsenal for effective fruit fly management in the PICTs. Most of these techniques are appropriate for the control of fruit flies in subsistence or commercial fruit and vegetable production.

FURTHER READING

1. Allwood, A.J., and R.A.I. Drew. 1997. Management of fruit flies in the Pacific. Proceedings of a Regional Symposium held in Nadi, Fiji, 28-31 October 1996. ACIAR Proceedings No. 76. 267 pages.

2. Drew, R.A.I. 1987. Reduction of fruit fly (Tephritidae: Dacinae) populations in their endemic rainforest habitat by frugivorous vertebrates. Australian Journal of Zoology. 35: 283-288.

3. Leblanc, L., Mararuai, A., Kalamen, M. 1999. Fruit bagging to control fruit flies. SPC Pest Advisory Leaflet (No. 36). 4pp.

4. Smith, D., and L. Nanan. 1988. Yeast autolysate bait sprays for control of Queensland fruit fly on passionfruit in Queensland. Queensland Journal of Agricultural and Animal Sciences, 45 (2): 169-177.

5. Waterhouse, D.F. 1993. Pest fruit flies in the Oceanic Pacific. Biological control - Pacific prospects. Supplement 2. Pp.9-47. Australian Centre for International Agricultural Reserach.

This leaflet was compiled under the fruit fly projects in the Pacific. The FAO/AusAID/UNDP/SPC Project on Regional Management of Fruit Flies in the Pacific (RMFFP) commenced in 1990 and Phase 1 initially operated in Fiji Islands, Cook Islands, Tonga and Samoa. Phase 2 (1994-1997) included, besides the four original countries, Federated States of Micronesia (FSM), Solomon Islands and Vanuatu. The third phase (1997-2000) included all 22 Pacific Island countries and territories (PICTs). The RMFFP was funded by AusAID, UNDP and New Zealand Government (NZODA), implemented by FAO and executed by the Secretariat of the Pacific Community (SPC). The Australian Centre for International Agricultural Research (ACIAR) has also run a parallel fruit fly project in the seven countries during Phases 1 and 2, and in Papua New Guinea since 1998. Since January 2001, fruit fly activities have become Component 2, "Fruit Fly Management", of the Project on "Pest Management in the Pacific", executed by SPC and funded by the Australian (AusAID) and New Zealand (NZODA) governments. For more information on the Fruit Fly Project, consult the Web site: **http://www.pacifly.org**.

NZODA

This leaflet was prepared by Allan J. Allwood, Agricultural Consultant; Luc Leblanc, Entomologist (Fruit Flies), Project on Pest Management in the Pacific - Fruit Fly Management (PMP-FFM); Ema Tora Vueti, Coordinator, PMP-FFM; and Richard Bull, Aventis CropScience (Australia). Further information can be obtained from Fruit Fly Project, Secretariat of the Pacific Community, Private Mail Bag, Suva, Fiji Islands. Photographs taken by Steve Wilson (1, 3, 21 to 25), Gerald McCormak (2, 4), Allan Allwood (5, 16, 17, 20), Luc Leblanc (6 to 12, 14, 19), Richard Bull (18) and Russell Messing (15).

Printed with financial assistance from UNDP, AusAID and NZODA.

Published by the Secretariat of the Pacific Community and printed by Quality Print, Suva, Fiji. Further copies of this leaflet may be obtained from the **Secretariat of the Pacific Community, Plant Protection Service, Private Mail Bag, Suva, Fiji Islands**; or from **Secretariat of the Pacific Community, BP D5, 98848 Nouméa Cedex, New Caledonia.**

Secretariat of the Pacific Community Cataloguing-in-publication data

Allwood, Allan J., Leblanc, Luc, Tora Vueti, Ema, Bull, Richard
Fruit fly control methods for the Pacific / by Allan J. Allwood, Luc Leblanc, Ema Tora Vueti, Richard Bull.

(Pest Advisory Leaflet / Secretariat of the Pacific Community. Plant Protection Service; 40)

1. Fruit-flies 2. Diptera - Pacific, Oceania 3. Tephritidae - Pacific, Oceania
I. Title II. Secretariat of the Pacific Community III. Series

634.049774 AACR2

Agdex 203 / 622

ISBN 982-203-816-X
ISSN 1017-6276