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Biocontrol

Fruit Fly *Management*

Bactrocera flies: Major pests of fruit and vegetable crops

Fruit flies are one of the world's **most destructive horticultural pests and pose risks to most commercial fruit and vegetable crops**. Several hundreds of species are known, but only few have significant economic impact.

In Southeast Asia, major pests include *Bactrocera carambolae*, *B. correcta*, *B. cucurbitae*, *B. dorsalis* complex (including e.g., *B. occipitalis, B. papayae*), and *B. latifrons*.

About 90% of the dacine pest species can be identified accurately by microscopic examination of the adult (Plant Health Australia, 2011). The remaining species, mainly some *dorsalis* complex species, can be identified also morphologically, but may require additional supporting evidence such as molecular diagnosis or host association records.

This brochure provides information on major pest species in Southeast Asia, including biology, host (crop) ranges, and management focusing on application of mass trapping and attractant technology.

A case study on wide-area management in Indonesia illustrates some hands-on experiences within a smallholder setting.


Melon fly

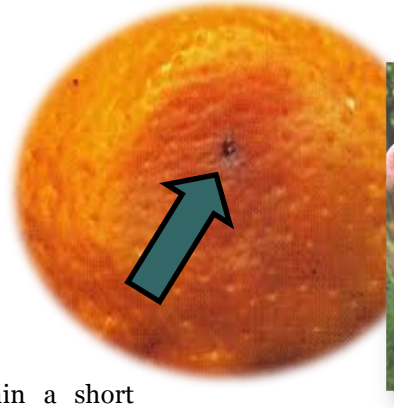
Area-wide Fruit Fly Management (more on pages 8-9):

The chapter on area-wide fruit fly management showcases results obtained by implementation of an area-wide program with citrus farmers in Karo district of North Sumatra, Indonesia. This is complemented with experiences of the Department of Agriculture of Indonesia with area-wide fruit fly management in mango orchards on Java.

Acknowledgement: This brochure uses valuable information published by others, in particular by references 1, 3, and 7. Some figures of fruit flies were taken from reference 1 (pages 1,2,6,7). The other images are courtesy of Dwi Iswari, Thomas Jäkel, or property of SAS Project, Bangkok.

Hands-on Guidance on implementing Biocontrol and IPM

Inside this issue:



Biology and Crops Affected

Fruit flies can attack and infest a wide range of commercial and native fruits and vegetables. Fruit is more likely to be attacked once is becomes more mature or when fruit fly populations increase during certain seasons. In or close to urban areas fruit fly populations are often higher than in outlying orchards.

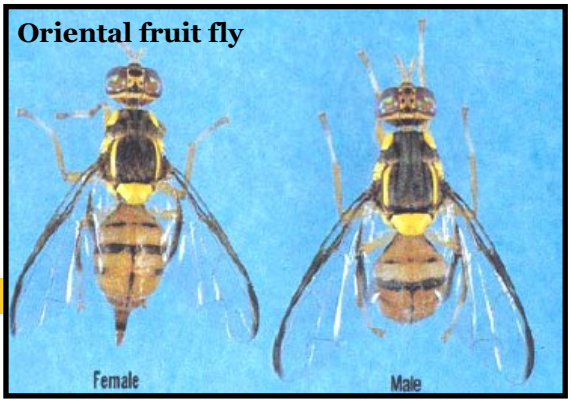
Adult fruit flies have a diet based on secretion of plants from leaves, fruits, but also nectar, pollen, bird feces, and honeydew. Protein helps fruit flies to reach normal fertility and stimulates egg production. Fruit flies can move long distances within a short time; exceptional observations showed a *Bactrocera* sp. moving up to 200 km.

A major route by which this pest may spread in trade or transport is through eggs and larvae hidden in fruiting bodies. Illegal movement of fruit is a major risk for invasion of fruit flies elsewhere.

Signs of Infestation

Infested fruits usually show a **'sting' mark** (see arrow above), but visibility largely depends on the species of fruit. A shallow cut through the fruit can identify the sting and the egg cavity containing eggs, larvae or the remains of hatched eggs. Fruit will fall from the tree due to larval infestation.

Larvae usually burrow towards the centre of the fruit. This causes decay and potential secondary infection with fungi responsible for **green mould** in citrus (see image above) and **brown rot** in stone fruit.



TYPICAL LIFE CYCLE

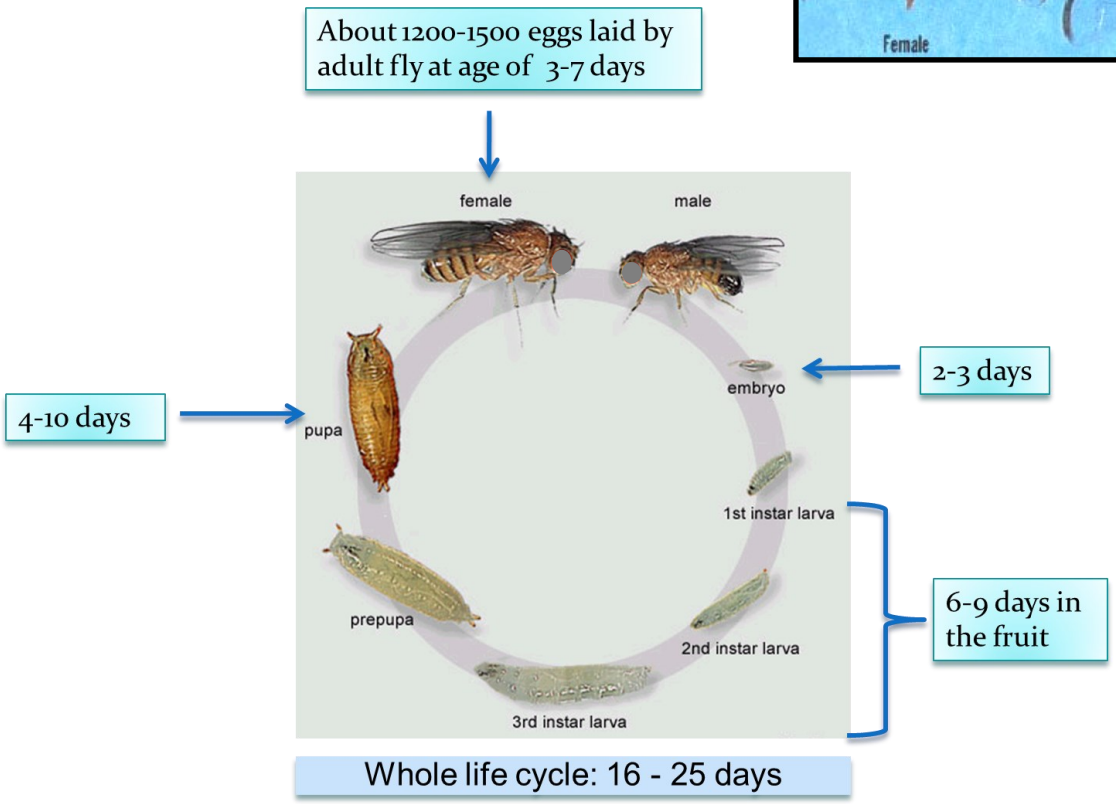


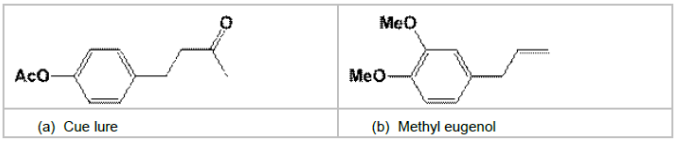
Table 1: Important Fruit Fly Species (Bactrocera spp.) of Southeast Asia

Species	*B. carambolae*	*B. correcta*	*B. cucurbitae*	*B. dorsalis* complex (incl. *B. occipitalis*, *B. papayae*),	*B. latifrons*
Common name	Carambola fly	Guava fruit fly	Melon fly	Oriental fruit fly	Solanum fruit fly
Host range	carambola, rose apple, sapodilla, malacca apple, guava, wax apple, watery rose-apple	cashew nut, guava, mango, water apple, sapodilla, Singapore almond, Spanish cherry, common jujube	ivy gourd, ornamental gourd, melon , snake gourd, giant pumpkin	cashew nut, spanish cherry, bullock's heart, Jamaican cherry, sugarapple, banana, carambola, apricot, bell pepper, sweet cherry, papaya, sour cherry, caimito, plum, mandarin, peach, persimmon, arabica coffee, guava, longan tree, European pear, watery rose-apple, acerola, black plum, apple, rose apple, bachang, malay-apple, mango, water apple, sapodilla	peppers, tomato, bell pepper, eggplant
Distribution	Southern Thailand, Peninsular Malaysia, East Malaysia, Kalimantan (Borneo), Singapore, Indonesian islands east to Sumbawa	Myanmar, Northern Thailand, Vietnam	Widely distributed over Southeast Asia, also from Papua New Guinea to the Solomon Islands	Myanmar, Northern Thailand, Vietnam, Cambodia, Laos *B. occipitalis*: Philippines, East Malaysia (Sabah), Brunei, Indonesia (Kalimantan) *B. papayae*: Irian Jaya, Papua New Guinea, Southern Thailand, Peninsular Malaysia, East Malaysia, Brunei, Singapore, Indonesia provinces	Thailand, Laos, Vietnam, Peninsular Malaysia, Indonesia
Pest status	High priority pest of fruit industry and throughout the region	Major pest, particularly in Vietnam	Very serious pest in all curcubit crops	*B. dorsalis*: Major economic pest, e.g. citrus; *B. occipitalis*: Musk lime, mango, guava *B. papayae*: Major pest species within the dorsalis complex in apple, pear, avocado, banana, citrus, mango	Pest of solanaceous crops throughout distribution range
Attractant	Methyl eugenol	Methyl eugenol	Cue lure or a mixture of methyl eugenol and cue lure	Methyl eugenol	Not known; Alphaionol, known as latilure is not a strong attractant.

Attractants

Attractants or lures are commonly used to trap fruit flies as they provide an easy way to collect large numbers of flies in a short period of time.

Males of many species respond to chemicals referred to as **parapheromones**. These lures attract flies from large distances. **Cue lure** (CUE) (Figure a below) and **methyl eugenol** (ME) (Figure b below) are two **male attractants** widely used in collecting *Bactrocera* spp. fruit flies. Most species appear to be attracted to one lure or the other, however other species are attracted to a combination of both lures (Dominiak et al., 2011). Trimedlure/capilure is used to trap *Ceratitis* spp. All three lures are used in Lynfield and Steiner traps. These attractants are generally highly volatile chemicals and need only to be used in small amounts to be effective.



(a) Cue lure (b) Methyl eugenol

ME is naturally present in many plants and can be extracted from e.g., basil. Extracts may contain as much as 80% ME, and concentrations of around 0.2 ml per bloc or cotton ball have been found useful.

Another effective attractant is so-called '**protein bait**', which consists of hydrolysed (wet) protein, commonly encountered for instance as a byproduct of the brewing industry (e.g., yeast autolysate concentrate with about 400g protein litre^{-1}). This attractant is very important in the control of **both female and male** fruit flies. However, protein bait may also attract non-target species and trapping efficacy is usually lower when compared to ME or CUE.

A typical working dilution of the above mentioned protein is 50 ml autolysate plus 950 ml water. Dilutions may vary depending on the type and concentration of protein bait.

Two useful recipes for fruit fly bait (*reference 7*)

1. Peel of oranges or cucumbers or their fruit pulp, 100 ml ammonia or cow urine, 0.5 litre of water; all mixed well and allowed to stand overnight. For ready-to-use bait, mixture is diluted with 15 litre of water.
2. 6 ml yeast extract, 0.5 g sodium sulphite (Na_2S), 1 litre of water.

Trapping

Steiner trap with ME-laced cotton ball

Trapping can be carried out either for purposes of **monitoring** or **mass-trapping/management** of fruit fly populations.

There exist **different types of traps** such as Lynfield, Steiner, Paton, and Mcphail. Especially with regard to providing cheap trapping devices , a Steiner or Lynfield trap can be easily created by using plastic water bottles (Steiner design, see figure above; Lynfield, see opposite page).

Attractants are commonly combined with insecticides (e.g., protein bait with spinosad or fipronil), following an 'attract-and-kill' approach, for instance by spot spraying on the crop. However, we recommend here to avoid insecticides and use traps for **mass trapping**, killing the flies in a water reservoir of the trap.

Commercial wood blocs impregnated with ME and hung inside a trap have been shown to be highly effective to lure fruit flies inside. Additionally, cotton wads can be laced with ME (in Indonesia, growers use basil oils, which contain ME). Cotton wads are renewed about every 2 weeks, ME blocs should be replaced every 1-2 months, depending on the product.

Traps are placed over the crop canopy, or at a height at which they can be serviced conveniently (e.g. 1.5—2.0 m).

Recommended **trap densities ha^{-1} vary between 15 (citrus) to 20 (mango), or more**, also depending on the level of pest infestation.

Trapping (contd)

However, **mass trapping** is a technique best applied at **low pest levels** and continued over long periods of time. Thus, it is a **preventative approach** to which the concept of threshold levels and re-active insect control does not apply.

Furthermore, fruit fly management is most effective if **implemented over a wide area** and under participation of as many growers and farmers as possible.

Mass trapping of males reduces their proportion in a population to a low level and therefore mating does not occur. Experience in field demonstrated that the level of infestation in mango for instance could be reduced to 5% by using ME blocs, from levels of infestation between 17% and 66%.

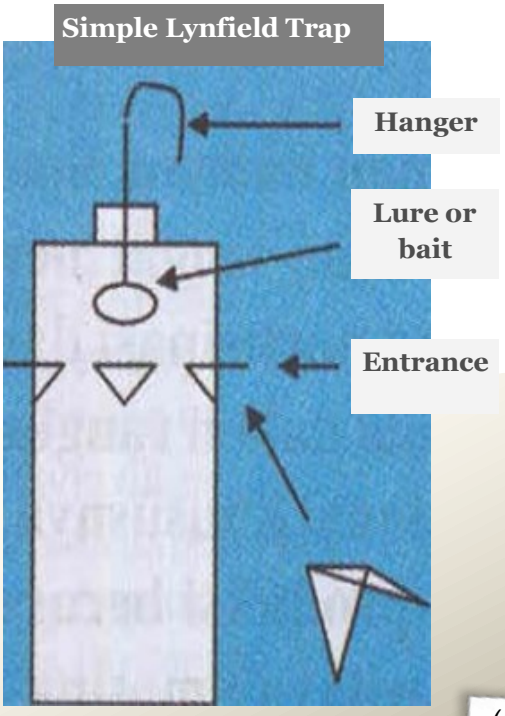


Figure 1: Tools for trapping (a) Mcphail trap in orange plantation; (b) water reservoir of Mcphail trap with fruit flies; (c) ME bloc (5x5x1 cm) ; (d) ME bloc sealed into aluminum foil for storage

Integrated Management

Fruit fly management can be divided in **3 main categories**: chemical, cultural, and biological.

Chemical control is widely used among farmers. The first synthetic chemical insecticide used to control fruit flies was DDT, which was later replaced by organophosphates. Currently, various active ingredients are used (see **Table 2**), whereby application of insecticides is done by spray cover on the entire crop or trees. Overuse of insecticides is rampant, for instance in citrus, which contributes to the regular emergence of **insecticide resistance**. Table 2 provides a useful overview over the potential negative impacts of common insecticides on humans (farm workers, based on time of exposure), on human health via consumption and leaching (e.g. contamination of groundwater), and non-target effects in the environment (e.g., on fish, bees, birds, beneficial arthropods). The **significant impact of insecticides on natural enemies** is often underestimated , but also the influence on organisms that contribute to soil´s fertility.

MAT: Insecticides can also be used in a mix with attractants like cuelure and methyl eugenol. This is a technique called **Male Annihilation Technique** (MAT) and consists of many bait stations throughout the field. The mixture can be applied in Steiner traps or other devices. Insecticides can also be mixed with protein bait, which controls both, male and female fruit flies. A hydrolysed protein-insecticide mix is applied on spots (spot technique) on the crop canopy. Of course, **mass- trapping of fruit flies can be also conducted without insecticides**, just using the attractants, the preferred approach in this guidance.

A mainstay of **cultural control** is **sanitation**: Infested fruit have to be removed **before they fall to the ground** (where larvae usually have left when picked up). Furthermore, **early harvesting** of fruit, where possible, greatly reduces infestation levels. **Bagging** of single fruits or clusters helps preventing infestation. Bags can be made out of paper, plastic, cloth, or even banana leaves. Using **resistant crops** is another way to reduce fruit fly attack; certain resistant varieties of fruit crop are available in Southeast Asia.

Table 2: Environmental quotient of insecticides:
the lower the value the lower the negative impact on health and environment (Kovach et al. 2009)

Insecticide	Farm Worker	Consumer + Leaching	Ecology	Farm work + Consumer + Ecology / 3
Abamectin	13.8	3.9	86.4	34.7
Acetamiprid	6.9	7.4	72.0	28.7
Carbosulfan	6.9	8.4	126.7	47.3
Cypermethrin	13.8	4.9	89.4	36.4
Dichlorvos	41.4	17.6	100.8	53.3
Emamectin	9.0	4.0	65.0	26.3
Fipronil	60.0	9.0	203.8	90.9
Malathion	9.0	4.5	58.0	23.8
Rotenone	6.9	2.1	78.3	29.4
Triazophos	62.1	7.4	37.3	35.6

Biological control such as the introduction of **parasitoids** to infested fields has given good results in management of fruit flies (e.g. in Hawaii). However, parasitoids appear to have little impact on populations of most fruit flies, with 0-30% levels of parasitism typical (CABI 2007). In Thailand, parasitation rates of *B. dorsalis* by the wasps *Fopius arisanus* and *Diachasmimorpha longicaudata* were only 2%-9% in rose apple orchards. As residues of synthetic pesticides in the environment may hamper this approach, it might be possible that biological control was more effective under a zero-spray approach.

Field protocol for fruit fly management using Methyl-Eugenol (ME), protein bait, and other measures

ME blocs

1) Use about 16 traps equipped with ME blocs on each ha of orchard. Trap density may be even higher, depending on the level of infestation.
2) ME blocs are fitted into Steiner or Lynfield traps (e.g., made out of plastic water bottles; see page 5), and hung on a tree branch about 1.5 to 2.0 meters above the ground. Fill bottom of trap with water.
3) Dispose of trapped fruit flies once density in the trap becomes high. Rinse trap with sufficient water and re-fill bottom of trap with fresh water. Re-install trap and ME bloc in its original position if trapping was satisfactory.
4) Replace ME blocs every 1-3 months, depending on the emission period of the product in use (according to instruction of manufacturer). Cotton balls laced with ME can be also used, but emission my last only about 2 weeks, so requires more frequent replacements. This is also a question of cost of ME (or alternatives, e.g. basil oil) under the given conditions and the availability and cost of labor for servicing traps.
5) Do mass-trapping throughout the entire growing period, and also during the fallow period if that can maintain low fruit fly populations. The smaller the orchard or plot, the higher the need to arrange joint management with neighboring farmers or growers.

Food lure (protein bait)

6) Protein bait can also be applied as mass trapping tool, in combination with ME blocs. Because protein bait attracts females and males while ME attracts males only, the number of ME blocs can be reduced to 7-9 units per ha while the rest is made up by traps using protein bait (e.g., total of 16 traps per ha: 9 ME traps and 7 protein bait traps).

Other measures:

7) **Field sanitation**: Collect and destroy in regular intervals all infested fruit on the tree, and all fruit that has fallen. Infested fruit is best buried 3 feet under soil with addition of lime to kill larvae. Alternatively, infested fruit is cooked and used as animal feed or for composting.
8) Spraying the soil under trees or crops with *Metharhizium anisopliae* or other **entomopathogenic fungi** may be helpful in reducing fruit fly larvae in the soil. However, this activity is no replacement for proper sanitation as outlined under 7). It also requires that the fungal product used exhibits high effectiveness against fruit fly.
9) **Bagging**: This technique works well with melon, bitter gourd, mango, guava, star fruit, and banana. As density of fruit fly often increases towards ripening of the fruit or crop, bagging of fruit is most appropriate before infestation sets in. The right point of time depends on the type of fruit. For instance, mango is bagged 55-60 days from flower bloom, or when fruits are about the size of a chicken egg. Bagging of rose apple is recommended 14 days after stamen fell off; bitter gourd when the fruit is about 2-3 cm long.

Monitoring of management success

1) Use the same traps and installment as outlined above. Monitoring traps may contain a water reservoir laced with insecticide. If one attempts management of fruit flies in a larger area (e.g., several hundreds to thousands of ha), a monitoring trap can be placed every 5 ha or up to every 20 ha. On a smaller plot, one may start monitoring with one trap before the growing period, and select one trap in the middle of the plot once mass trapping sets in during the growing period.
2) For each monitoring trap, the number of fruit flies caught is assessed on the same week day once a week. Note trapping date and the number of fruit flies on each occasion.
3) The population size is determined as the **number of fruit flies per trap per day** (**FTD**), which requires the total number of flies recovered over a period (usually 7 days) divided by the number of serviced traps and the average days trap(s) were exposed in the field (FTD = F/[TxD]).
4) The development of FTD is plotted over time to indicate population trends. Roughly, an FTG between 0.1 and 1 means that the population is suppressed, while an FTD larger than 1 warrants for continued control efforts.

Area-wide management

The General Directorate of Horticulture, Directorate of Horticulture Protection, Ministry of Agriculture of Indonesia, together with GIZ and other related agencies implemented **area-wide management of fruit fly** in orange farming **in Karo district in North Sumatra** over a period of 2 years (2013 to 2014).

The program focused on smallholder farmers. Goal of the intervention was developing an affordable and cost-effective approach to fruit fly management for smallholders while fostering **area-wide collaboration among growers** and developing the supply chain for the required tools with active participation of the private sector.

This required commitment from all stakeholders through numerous activities in the field, such as workshops, informal meetings with local farmers, public awareness campaigns with support of local government units, extension programs on selected methods for fruit-fly management as well as provision of **Methyl-eugenol (ME) blocs for mass trapping**.

The total area under fruit fly management covered **10,156 hectares of orange farms** while involving about **20,000 farmers**. About 570 key farmers were trained by SAS Project alone, and many more by the Directorate of Horticulture Protection.

Area-wide management of fruit fly was very effective: **Damage** to oranges could be **reduced by about 50%**, which translated into **yields of up to 15 tons ha^{-1}**. The average yield before the intervention was about 3 tons ha^{-1}.

Monitoring of management success was done as outlined on page 7, with 1 monitoring trap every 20 ha. **Figure 2** below shows how a fruit fly population gradually decreases (green line) once subjected to area-wide management.

Total costs of the 2-yr -program amounted to about 1.5 Mio Euro.

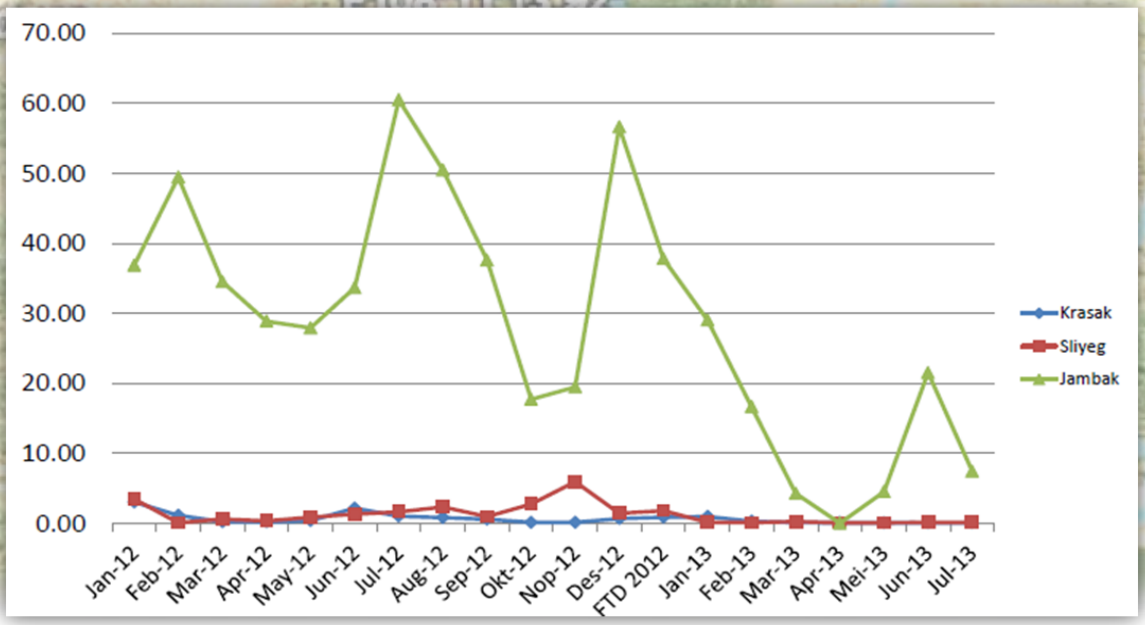
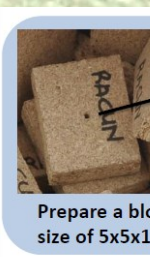


Figure 2: **Changes in FTD index (fruit flies trap^{-1} day^{-1}) over a period of 1.5 years at 3 different sites inside a 15,000 ha mango growing area under area-wide management on Java, Indonesia** (data courtesy of Dwi Iswari). In Jambak (green) fruit fly management was being implemented during the observation period, while on the other two sites (blue, red) fruit fly populations were already under control.



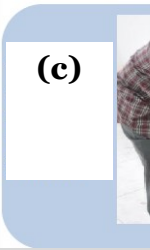
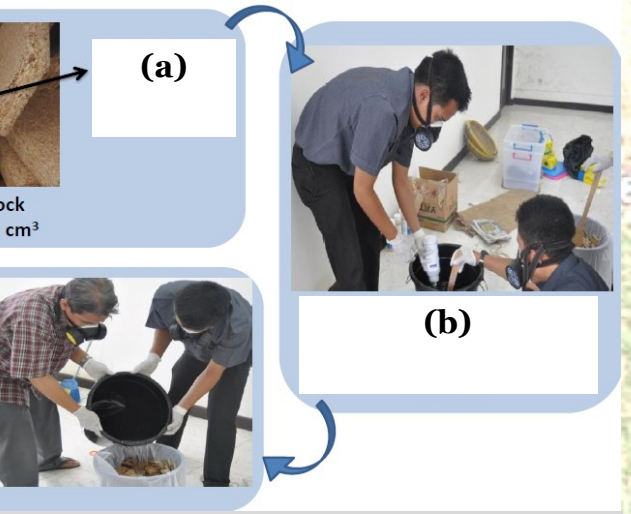


Figure 4:
(a) in ME sol
added while

Area-wide management (contd)

Figure 3: Farmer group meetings and 'socialization' campaigns to educate and alert local fruit crop growers are an important part of the implementation of area-wide fruit fly management. **Communication with the rural population needs to be maintained over extended periods** to make collaboration among farmers work and monitor adoption of the introduced technologies and methods of Integrated Pest Management (IPM).



ME blocs can be self-made by soaking chipboard blocs
lution for 1 night (c). Appropriate insecticides may be
using protective gear (b).

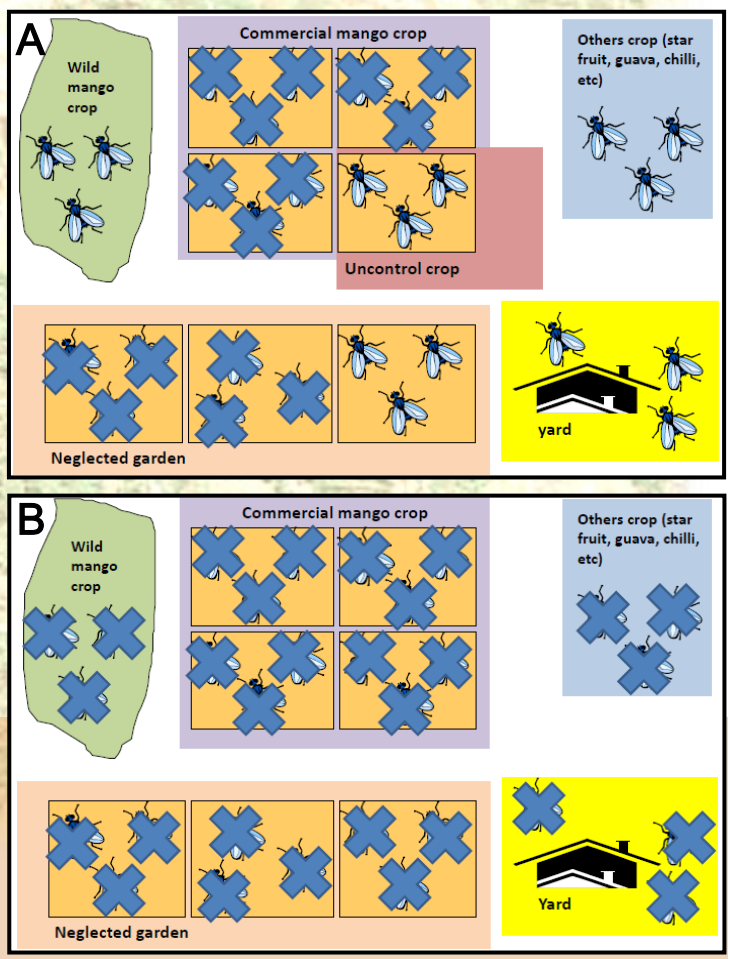


Figure 5: Conventional IPM using sprays of pesticides to control fruit flies (**A**) often fails, because only a part of the fruit fly population is targeted. In contrast, **area-wide management** using attractants like Methyl-eugenol and mass trapping (**B**) reaches all fruit fly populations in a given area, also in refuge habitats. However, reduction of fruit flies takes a while, and requires collaboration of growers.

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http://www.asean-agrifood.org

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