Mango Guide

Crop and pest management




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All photos in this manual were taken by the authors (Dr. Max K. Billah and Dr Joseph O. Hunger), photos from other sources have been duly acknowledged. Cover photos are also from https://pixabay.com/.

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1. Setting up a commercial mango orchard

1.1 Introduction

In setting up a mango orchard for commercial production purposes, certain important decisions need to be taken. Such decisions must in the long run, result in profits for the investor. To be able to make profits, the mango orchard must produce fruits of high quality that meets the requirements of standards in international markets, where prices are higher. It is worthy to note that the establishment of a profitable orchard is dependent on good decisions taken prior to the setting up of the orchard. This section of the book describes some of the important factors that need to be considered in the establishment of a commercial mango farm for guaranteed profits.

1.2 Site selection

Profitable mango production for commercial purposes is contingent on the citing of the orchard at strategic locations. Factors that must guide the selection of the location include the accessibility, prevailing climatic conditions, edaphic factors such as soil type and topography and water supply.

It is important that mango orchards are sited at a location that is easily accessible. This facilitates the easier and faster transportation of inputs to the farm and rapid transportation of produce from the orchard to the marketing centres. Easier transportation of produce to marketing sites is very important, due to the fact that the produce is very perishable. Secondly, certain diseases known as latent infections are manifested on the fruits after harvesting, hence when transportation of the fruits to the storage or marketing sites are delayed, the fruits can be destroyed by these latent infections.

Climatic conditions prevailing at a location has a great influence on the flowering and fruit set of mango trees. In areas where there is persistent rainfall throughout the year, trees undergo excessive vegetative growth at the expense of flowering. Even, when the trees flower, the flowers are mostly destroyed by fungal diseases. Also, rainfall during the flowering period will also interfere with flower pollination. All these contribute to poor fruiting patterns and reduced fruit quality. Therefore, avoid siting mango orchards in such high rainfall areas. In contrast, select a location where a well-defined dry spell, lasting for 2–4 months, characterises the climate.

Mangoes can grow very well in a wide variety of soils. Generally, sandy-loam to loamy soil is ideal for mango growth and development. In areas where the soil is clayey, organic matter can be incorporated into the planting holes, prior to transplanting, to enhance the soil structure. Soil maps, detailing the suitability of locations in Ghana for mango production, based on soil types have been developed (Figure 1). These can be consulted for further information on how to select a site for mango production in Ghana.

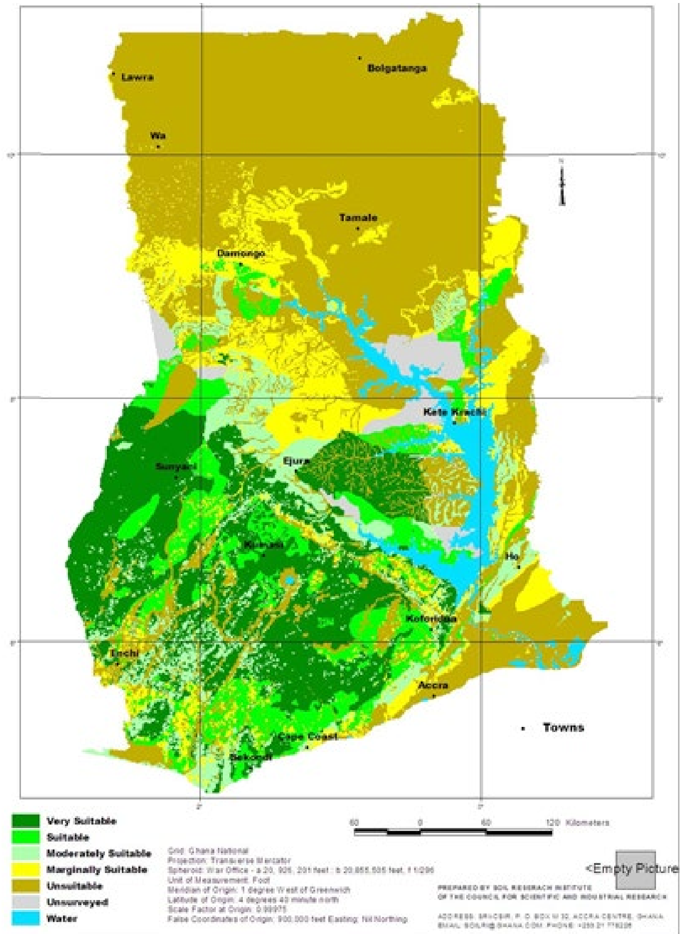
Nearness of mango orchard to a source of fresh water is an important factor to consider in determining where to site your mango orchard. In areas with sparse rainfall distribution, this is very important as at certain times of the season, the trees will require moisture in the soil. During flowering and after fruit set, enough moisture will be needed, especially for fruit retention. Therefore, during these periods, supplementary irrigation from these water sources will be required.

These are some of the few important factors you will need to consider in selecting a location to set up a new mango orchard. However, areas where there exist mango orchards where the trees fruits very well, may be the ideal location for citing your new orchard.

1.3 Land preparations

Land preparation for planting mango involves removal of trees, ploughing of the land followed by harrowing. Removal of trees, especially in a forest land may be achieved with the help of bulldozers. The bulldozers merely uproot the trees and in most cases, will not disturb the top soil. After tree removal, there may be the need for de-stumping followed by removal of all debris from the field. After that, ploughing and harrowing may follow. In cases where bulldozers are not available, hoe weeding can be used to clear the weeds after which tree felling using hand held implements can follow. To enable easier ploughing with tractors, ensure to de-stump the entire field.

Figure 1. *A soil suitability map for mango production in Ghana*



1.4 Field layout

The proper arrangement of the mango trees in an orchard is very important. To allow for free movement of persons and machines to carry out appropriate cultural practices in the orchard, the trees will have to be arranged in rows using appropriate planting distances. Depending on the topography (slope) of the land, a decision will have to be made whether the planting rows should be across or along the slope. In order to avoid erosion in the field, planting across the slope is the best option. Several planting distances are being used in different mango orchards in Ghana. These include 10 m × 10 m and 14 m × 14 m. It also includes shorter distances such as 6 m × 6 m, 8 m × 6 m and 10 m × 5 m. It must be noted that selecting a shorter planting distances makes it difficult to work in the orchard and must always be accompanied by continuous pruning, to enable easy access to the trees for cultural practices. While the wider spacing reduces the number of trees per unit area, it makes it easier to carry out cultural practices in the orchard.

1.5 Planting/transplanting of mango seedlings

Prior to transplanting mango seedlings, there is the need for the planting holes to be prepared in advance. Holes of dimensions about 60 × 60 × 60 at the marked position must be created. The soil from the hole must be mixed with well decomposed manure (approximately 20 kg in weight) and the mixture used to re-fill the holes after which they are watered (if no rains) for the soil to settle. The holes are now ready to receive the seedling. Use a garden line as a guide to ensure that the holes are in lines. In Ghana, where most mango orchards are rain fed, it's advisable to plant your seedlings at the beginning of the major rainy season. This ensures that by the time the dry spell sets in, the seedlings are already established. However, if irrigation facilities are available, the seedlings can be transplanted anytime and then watered regularly, till the plants establish. Note that in most of the time, the seedlings are raised in polybags. Make sure that these bags are removed before the seedlings are transplanted into the planting holes.

It is very important that you plant healthy mango seedlings. This will ensure maximum growth and prevent introduction of diseases and pests into the orchard. The seedlings can either be purchased from commercial nurseries or produced by the farmer. Always, buy your seedlings from recognised and certified nursery operators such as research institutions and universities. When you buy seedlings from these places, you are in most cases assured of uniform seedlings in terms of age and cultivar and good quality seedlings. If you prefer to raise your own seedlings, you will need to follow some basic steps. The next chapter explains some of the basic activities that need to be carried out to raise good and healthy mango seedlings for transplanting in the field.

2. How to raise your own planting materials

2.1 Introduction

Raising your own planting materials may be the better option as you will be assured of a good healthy status of the seedlings prior to transplanting. You will also be guaranteed of the purity of the cultivars and it may also be less expensive. However, the process may require some basic knowledge in grafting of seedlings and may be time consuming. It is therefore the choice of the farmer to determine whether he/she wants to raise their own seedlings or to buy from commercial nursery operators. While mango trees can be raised solely from seeds, these are not advisable in a commercial setting. It takes a much longer time for such trees to produce fruits. Fruits produced from such trees may not be uniform in size, taste or form. In contrast, trees raised from grafted materials fruit earlier and give a more reliable fruiting patterns and fruit uniformity. Grafted seedlings consist of a stock (rootstock) and scion (top). The rootstocks are mainly the local varieties which are more resilient and tolerant to the local conditions, while the scion are mostly twigs taken from mature exotic mango tree of choice. This section details the activities that need to be undertaken to produce planting materials of high quality for the farm.

2.2 Formation of seed beds

This is the first step in the production of the rootstocks. Raise beds of any convenient width and length, however, the dimensions of the bed should be such that you can work easily on it without stepping on it. In areas where soil drainage is an anticipated problem, construct raised beds to facilitate easy shedding of excess water after rains. If available, collect loamy topsoil or sterilised saw dust or rice husks and spread evenly on the bed. An alternative to the use of beds is direct sowing into polybags.

2.3 Collection and extraction of mango seeds

Normally, seedlings from the local cultivars of mango serve as the rootstock of most mango seedlings transplanted in Ghana. Collect discarded seeds of the fruit or harvest the fresh mature fruits and extract the seeds. Seed extraction can be done by cutting the fruit longitudinally and removing the seed or cutting off the flesh, slice by slice (Fig. 2). After extraction, wash the seeds in clean water and air-dry. Then de-husk the seeds by removing the kernel from the shell (Fig. 2E). Sort out the kernel and discard those that are dead, damaged deformed or diseased. If there is the need for storage of the de-husked seeds, do so under shade, however, endeavour to sow them within 3 days after extraction.

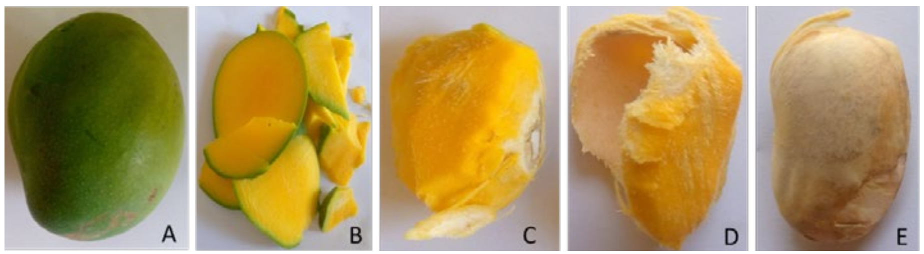


Figure 2. *Extraction of seed from mango fruit. A = selected fruit, B = removed flesh, C = seed, D = seed husk, E = kernel*

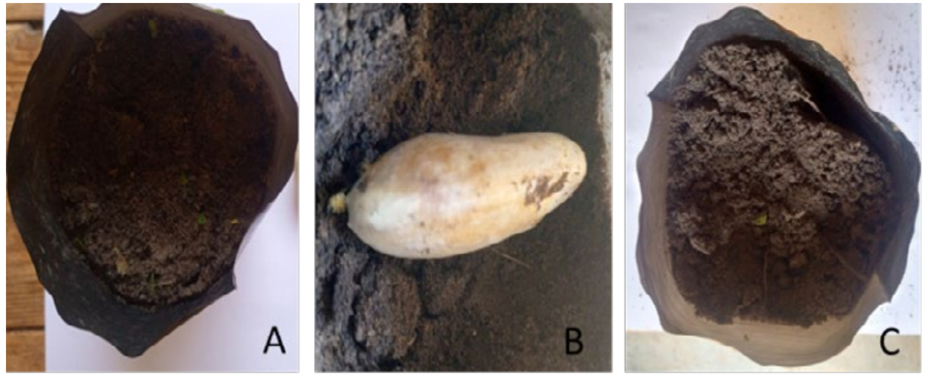


Figure 3. *Direct sowing of seeds in a potting bag. A = potting bag filled with loamy soil, B = mango seed (kernel) sown with the concave side facing down, C = potting bag with the seed covered lightly with the soil*

2.4 Sowing of seeds

Sow the de-husked seeds (kernels) in the nursery bed after treating them with a combination of Copper and Fosethyl-Al based fungicides. To save time and extra work associated with transplanting seedlings from seed bed to the potting bags, sow the seeds directly in the potting bags. Sow the seeds with the concave side facing downwards and cover it lightly with the topsoil (Figure 3). Irrigate the beds at regular intervals, but avoid creating waterlogged conditions. Observe the bed till seedlings germinate. This may take from 2–4 weeks after sowing.

2.5 Transferring of germinated seedlings into potting bags

To encourage the seedlings to grow well, after germination and emergence (when sown on seed beds), the young seedlings must be transferred individually into a potting bag containing a medium made up of topsoil and well decomposed organic manure or compost. The potting bags are available from dealers and can be purchased. The potting bags recommended are of the dimensions, 10–12 cm × 22–30 cm. During the transfer into the bags, separate multiple seedlings that have emerged from the same seed, into individual seedlings and sow them in separate bags. Discard seedlings that appear to be weak or diseased. Carefully lift the seedling from the bed without breaking any developing root and gently insert it in a hole pre-created in the middle of the bag containing the soil. Firm the soil around the neck region of the seedling to complete the transplanting, Water the seedlings and raise a shed over them to reduce the impact of sunshine on the seedlings. To encourage vigourous growth, seedlings can be fertilised with NPK fertiliser at rates of 3 g/seedlings, 4 weeks after transplanting. This can be followed by application of sulphate of ammonia every 2 months. Monitor the seedlings and control any pests and diseases promptly. Seedlings may be ready for budding/grafting between 5-6 months after transplanting. At this stage, the seedling must be about 25 cm tall with stem thickness about the size of a pencil.

Figure 4. *Preparation of scion. A = a pair of secateurs, B = harvested scion with clean and disease-free leaves, C = defoliated scion without any cracks or crevices, D = bad scions showing cracks on the twigs and leaves*

2.6 Preparation of scion

Scions must be harvested from carefully selected healthy and mature trees of preferred cultivar of mango. Selected trees must be those that had shown good fruiting patterns and produced fruits of high quality, consistently for some number of years (at least after 5 years of constant monitoring). Observe the branches and select twigs which are as thick as a pencil and possess an active and healthy terminal bud (If bud is dormant, defoliate the scion on the tree and wait for at least 10 days when the buds are expected to be active). Using pruning scissors or secateurs (Figure 4A) or a very sharp knife cut the scion at length of at least, 10 cm and carefully strip the scion of all leaves with a sharp knife or secateurs (Figure 4B and 4C). The scions must then be wrapped in a neat and moist newspaper or towel during transportation. If available, transport the scions in ice chest and sprinkle water on them prior to covering and transporting. As much as possible avoid mango trees that are showing symptoms of the bacterial black spot, as a source of scions. Do not also harvest scions that have cracked surfaces as these cracks and crevices could be harbouring pests and pathogens (Figure 3D). Scions are best collected during warm and humid weather, just before the selected mother tree begins to produce new leaves.

2.7 Grafting of scions onto rootstocks

Different methods of grafting the mango scion onto the rootstock exist, however, the commonest is known as the Cleft, top or wedge grafting. In this process, the selected seedling (rootstock) is cut flat at the top, at about 20 cm from the surface of the medium. The cut end is then split horizontally into 2 equal halves, to a depth of about 3 cm deep. A scion of almost the same size or slightly smaller than the rootstock is selected and the sides of its base shaped into a wedge. The wedge portion of the scion is then inserted into the cut portion of the rootstock. The two halves are aligned in such a way that their cambium layers come into contact with each other after which they are held together with a grafting tape. To prevent dehydration of the joined parts, the grafted seedling is covered with a transparent polybag, which creates a high humidity conditions for the seedling. This also increases the chances of the graft being successful (take). The polybags can be maintained till the buds are observed to be shooting up. At this point the graft is successful. The grafted materials can be observed till the second flush of leaves has matured (about 4 months after grafting). The seedling can now be transplanted on the field.

3. Maintenance of mango trees in the field

After transplanting, there is need for proper husbandry practices to ensure optimum growth of the seedlings. This includes weed control, proper nutrition provision, irrigation of trees, pruning and flower induction.

3.1 Weed control

Protect the seedlings against weed competition by practicing ring weeding after which a tractor can be used to harrow the inter row spaces. As much as possible prevent bush fires from entering the field by creating fire belts around the orchard, especially during the dry seasons. It is important to note that newly transplanted young mango seedlings can be sensitive to herbicides; hence their usage at the early stages of tree growth must be with care. If irrigation facilities are available, it is possible to intercrop the seedlings with annual crops, such as maize and vegetables, at their early years of growth. This will provide motivation for constant weeding and thereby keeping the young orchard clean. In such cases, ensure to fertilise these crops to prevent them from excessively mining the soil of its nutrients, which may be detrimental to the young mango trees. Once the first sign of flowering occur, discontinue the inter row planting, else some of the vegetables can be alternative hosts for fruit flies and other fungal diseases.

Table 1. *Fertilizer schedule for 100 trees/ha. Adapted from Mango production and Export Marketing*

Age	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
1–3 years	10–15	5	10
4–5 years	20–30	10–15	20–30
6–7 years	25–45	15–20	25–50
8–9 years	30–60	15–25	30–70
10 year & above	40–100	20–45	40–120

3.2 Crop fertilisation

Mango, like any other crop, benefits immensely from the provision of nutrients, in form of fertilisers. Different nutrients, in terms of quantities and types are required by the mango tree. The table below is an example of the major plant nutrients required by mango trees at indicated ages. Apart from these major nutrients, micronutrients such as Boron, Calcium and Magnesium are required for healthy growth of mangoes. Apart from the inorganic sources of these nutrients, there are several organic fertilisers that can furnish the mango plants with these nutrients. It is important to note that excessive fertilisation of trees can promote excessive vegetative growth at the expense of fruiting and this must be avoided.

3.3 Pruning of mango trees

Pruning is mainly the selective removal of excess shoots and branches and dead or injured plant parts. Pruning of mango trees are carried out for a variety of reasons. In the young trees in the field, pruning is carried out to encourage the growing tree to assume a desired frame, especially, outward branching and increased number of leaves. On trees of fruit bearing age, pruning is carried out to control tree growth and improve light penetration in the canopy. This reduces humidity in the canopy and incidence of diseases and increase quality and size of fruits. When pruning is carried out, carrying out cultural practices in the orchard becomes easier.

Depending on the objective of pruning a mango tree, different types of pruning can be identified. These include; 1) production pruning, 2) maintenance pruning, 3) window pruning, 4) skirt pruning and 5) fruit thinning pruning. Production pruning is the type carried out with the main objective of controlling tree height. This is usually carried out at early tree growth period or on mature trees after harvesting of fruits.

When pruning is carried out to remove damaged, dead or diseased plant parts, it is termed maintenance pruning. This can be carried out any time in the fruiting period of the mango tree. Sometimes, some branches on some selected sides of the canopies are removed to facilitate easier penetration of light and agrochemicals. This is called window pruning. Pruning to remove weak and low hanging branches and also to maintain the canopy at a certain height from the ground level is called skirting pruning. On the other hand, removal of unwanted fruits from the panicle is fruit thinning pruning. This is done when a fruit is misshapen, malformed or there are too many of them on a panicle.

Pruning of young mango trees in the orchard is an important activity which is mostly aimed at producing a mature tree with a canopy at a desirable height (3.5–4 m tall) for ease of carrying out cultural practices. To achieve this, pruning of young trees must start early (about 6-8 months) after transplanting. Normally, the young seedlings will have a single main stem. Start pruning when the stem reaches a height of about 100 cm. Cut back the main stem at about 80 cm mark below a node. This will encourage the tree to produce side branches. Select three of these branches to serve as the scaffold of the tree. Allow the side branches to grow as long as 50–60 cm and cut them back under a node to encourage production of side shots from these branches. Allow these new branches to grow to the same 60 cm and cut back again under a node. Continue the selection and cutting back of side branches till the desired frame of the tree is obtained.

To prune mature and fruit bearing mango trees, certain things must be taken into consideration. Mango trees are terminal bearers as they bear their fruits at the tips of horizontal branches. Therefore, branches that are growing vertically, rather than horizontally must be removed. Also, the flowers are usually formed on mature wood i.e. shoots that are about 6 weeks old. Therefore, pruning must be avoided when plants are nearing the flowering period. To ensure that trees are ready to flower during the normal flowering period, prune them immediately after harvest, so that the trees have enough time to produce flushes which will mature on time for flowering to occur. Note that when pruning is carried out close to the pruning period, they will produce flushes rather than flowers.

Pruning of trees of fruit bearing age must be carried out by a trained expert. Poorly cut tree surfaces are entry points for disease causing pathogens. To cut off a branch, make a short cut at the lower part of the branch, followed by a longer cut at the upper portion then trim off the cut surface.

Figure 5. *Pruning of mature mango trees (left) and the pruned tree (right)*

3.4 Flower induction

When the apical buds of mango three branches resume growth, they could either develop into flowers or leaves or both. Whether the buds would be turned into leaves or flowers will depend on the supply of assimilates to the shoot apex during the growth of the trees. When assimilates are supplied to the shoot apex, there is more likelihood of flower formation. However when assimilates are diverted away from the shoots it result in vegetative growth promotion. Factors can cause assimilates to be supplied to the shoots, include water stress, low temperature, flooding, stem girdling, root pruning, mild Nitrogen stress and growth retardants. On the other hand growth stimulants, such as high Nitrogen content and high temperatures cause assimilates to be diverted from shoots resulting in buds growing into leaves rather than flowers. To every farmer, the conversion of buds to flowers is more preferable. Naturally, mango trees can flower on their own However, mango flowering in the tropics is irregular and this could cause the irregular supply of fruits to the markets. There is therefore the need for floral synchronization. To synchronize the flowering, there is the need to induce the trees to flower at the required time. Flower induction can be carried out in the following ways:

1. Application of potassium nitrate at a rate of 200 g/ 16 l of water, applied 3 times at 7 days intervals,
2. Application of ammonium nitrate at a rate of 200 g/ 16 l of water, applied 3 times at 7 days intervals,
3. Application of a basal drench of Paclobutrazol (PBZ) at 4 g a.i. per tree at 120 days before flowering,
4. Smudging, i.e. use of smoke. Flower induction must be carried out when leaves are sufficiently mature i.e., at least 8 weeks after emergence. At this point, the leaves must be dark green and when crushed in the palm makes a crunchy sound to denote that they are brittle or crunchy.

Flower induction may not be necessary in certain instances. For example, a year immediately after the trees have produced a good yield, there is no need to force. This is because mangoes generally produce a good crop every other year. Therefore, when the trees have produced a good crop in a particular year, it may not yield commercial quantities of fruits in the following season. Also, there are some natural conditions that are conducive for the trees to flower. When such weather conditions are present in a particular season, there is no need to induce the tree to flower by any other artificial means. Though there are recommendations to apply a particular chemical at several times to induce the tree to flower, there is no need to continue the application once the flowers begin to appear. When it becomes clear that the rain is about to fall, there is no need to force. This is because when it rains immediately after the application of chemicals to induce the trees to flower, the buds are more likely to form leaves rather than flowers.

It is worthy to note that the environmental conditions needed for flower production are present at particular months in a year and may occur at different months in different locations. In Ghana, for example, mangoes flower in December to January in Wenchi and Nkoranza but in January to February in Atebubu. Inducing mangoes at different times of the year, other than the months that the trees are known to flower in a particular area, will not result in flowering of trees.

4. Major diseases of mango and their control

Mango production in Ghana is affected by the incidence of several diseases. These disease cause poor flowering and patterns and reduce fruit yield both in quality and quantity. They reduce the quality of produced fruits by causing blemishes on their surfaces which reduce their marketability or cause destruction of the fruits both before and after harvest. In some instances, the disease begins in the field, but remains latent until the fruits are harvested. In such cases, it leads to the rejection of whole consignment of fruits being sent to the markets. The major diseases affecting mango production in Ghana include the mango tree decline, stem end rot, anthracnose, bacterial black spot, sooty mould and fruit internal breakdown. In this section, the aetiology (causes), epidemiology (how the disease spreads) and control of the major diseases affecting mango production in Ghana are discussed.

4.1 Mango tree decline

Causal agent

Mango tree decline disease in Ghana is caused by the fungus, *Lasiodiplodia theobromae*. It belongs to the Botryosphariaceae family. It produces black mycelium with dark coloured pycnidia in culture (Figure 6A). The pycnidia contains spores which are hyaline and one celled when immature (Figure 6B) and turns dark and becomes two-celled at maturity (Figure 6C).

Disease symptoms/damages

Leaves on smaller branches become necrotic but remained attached to the tree (Figure 7A). This is accompanied by the splitting or cracking of the bark with slight or profuse gum exudation (Figure 7B). At the advanced stage of the disease, wilting and rapid dropping of leaves occur (Figure 7C) and could lead to total defoliation of trees. At this stage, growth ceases and the entire tree may die (Figure 7D).

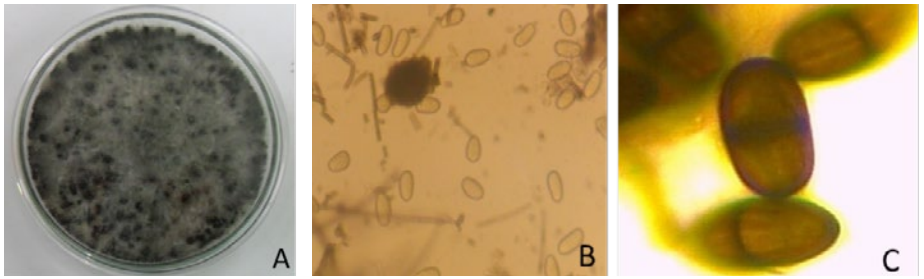


Figure 6. *Cultural and morphological features of* Lasiodiplodia theobromae, *the causal agent of mango tree decline disease in Ghana. A = cultural growth of PDA, B = immature hyaline spores, C = mature dark and septated spores*

Figure 7. *Symptoms of mango tree decline disease on an infected tree. A = healthy and dead leaves hanging on an infected tree, B = bark cracking and gum oozing on stem of an infected tree, C = entire leaves of an infected tree, dead, D = almost total defoliation and death of an infected mango tree*

Pre-disposing factors

- Nutritional deficiency: poor soil nutrients and drought weakens the tree and makes it more susceptible to the fungus.
- Persistent high temperatures, especially associated with bush fires.
- Mechanical injuries caused by pruning materials and termites activities.
- Intercropping mango with crops that mines the soil nutrients.
- Root damages caused by deep ploughing.
- Presence of infected trees and plant parts in the mango orchard.
- Poor orchard sanitation.

Control

Preventive

- Site new orchards far away from infected fields.
- Purchase seedlings from a certified nursery.
- Sanitise all pruning materials before use in the orchard.
- Restrict access to the farm.
- Create fire belts around the orchard to prevent bush fires.

Cultural

- Practice good orchard sanitation. Regularly remove all fallen plant debris from the field.
- Prune off infected plant parts and remove them from the orchard.
- Regularly check the nutrient status of the soil and replace depleted nutrients.
- Space trees well and prevent overcrowding to reduce competition for nutrients.
- Irrigate trees, especially, during drought periods.

Chemical

- Bi-weekly application of approved systemic fungicides; NB. The fungus stays inside the plants and hence it cannot be easily controlled with a contact fungicide such as copper.
- Continue the application of the fungicides till new leaves begin to shoot up from the branches.

4.2 Mango stem end rot

Causal agent

The mango stem end rot disease is in Ghana is caused by four different types of fungi, all belonging to the Botryosphaeriacea family. These are *Lasiodiplodia theobromae* (Figure 6), *Botryosphaeria* sp., *Pseudofusicoccum* sp. and *Neofussicoccum parvum*. Though the fungi are genetically different, the symptoms they cause on the infected mango fruits are the same.

Damages

The disease occurs mainly on the mango fruits. More fruits are damaged by the disease after harvest than before. On both young fruits and mature harvested fruits, the symptoms are the same. This is characterised by diffused areas of water-soaked tissue that radiated from the stem end in fingerlike projections. The infected areas quickly darkened and coalesced into circumpedicular lesions with crenate margins (Figure 8A). Necrosis remained beneath the fruit cuticle and penetrated all fruit flesh within 5–7 days (Fig. 8B). As the lesion aged, grey fluffy mycelia of the causal agent began to show on the fruit surface particularly around the fruit pedicel. A rotten smelling, straw coloured fluid oozed out of the fruits through broken portions of the fruit surface. Normally, immature fruits on the trees exhibit the symptoms only after they have been wounded. In such cases, fruits eventually die and become mummified on the tree. Mature fruits showing the disease symptoms are unfit for consumption and are discarded.

Sources of infection

- The fungi are waterborne and can spread through rain splash from dead twigs.
- The pathogen is endophytic within the twigs and branches and can grow and infect flowers.
- Airborne spores of the pathogen invade the pedicels and xylem and then grow into the ripening fruit.
- Pathogen surviving in leaf litter in the orchard floors.

Pre-disposing factors

- Unprotected flowers at bloom
- Mechanical wounding caused by:
  a. two fruits rubbing against each other
  b. fruit pedicel rubbing on the fruits
  c. insects puncturing the fruits
  d. Sunscalding of fruits.

Control

Preventive

- Due to the endophytic nature of the fungus, preventing it from infecting an orchard is almost impossible.
- Avoid practices that wounds the fruits at fruit set. For example, minimise activities in the orchards during the developmental phase of the fruits in the orchard.

Cultural

- Prune off excess foliage and remove the prune parts from the field.
- Practice good orchard sanitation. Regularly remove all fallen plant debris from the field.
- Do not totally remove the fruit pedicel from the harvested fruits, prior to storage.

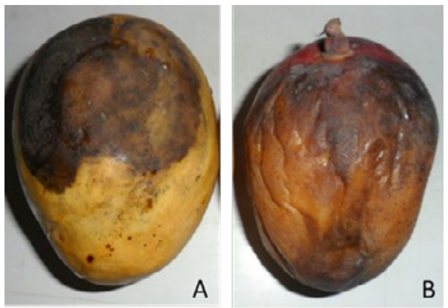


Figure 8. *Symptoms of stem end of diseases on matured and ripe mango fruits. A = fruit showing half of the surface are covered, B = a fruit with total surface area covered by stem end rot symptoms*

Chemical

- Protect flowers with any systemic fungicide till fruit set.
- Bi-weekly application of approved systemic fungicides; NB. The fungus stays inside the plants and hence it cannot be easily controlled with a contact fungicide such as copper.
- After harvesting, dip fruits in hot water alone at temperature of 55°C for 15 minutes or dip in hot water at 53°C mixed with Prochloraz. Dipping fruits in prochloraz solution at ambient temperature can also effectively control the disease.

4.3 Mango anthracnose

Causal agent

Mango anthracnose is caused by a fungus called *Colletotrichum gloeosporioides*. In other parts of the world, *Colletotrichum acutatum* is also responsible for the disease. In Ghana, 3 different types of the *C. gloeosporioides* have been identified. These are *Colletotrichum asianum, Colletotrichum siamense* and *Colletotrichum species*. Though genetically, these organisms are different, their cultural and morphological features (how they look) are the same (Figure 9). Also, the symptoms they cause on the mango tree are the same.

Damages

The causal agent causes a slightly sunken dark brown spots on all parts of the plant which eventually leads to their destruction. The fungus causes necrosis of the flowers which eventually die and become black in colour. On young fruits, the spots produced cause the fruit to shrivel and fall off. In some cases, the spots cover the entire fruit which then becomes mummified. Similar symptoms appear on the leaves, stems and branches. In leaves, the spots reduce their photosynthetic ability and in some cases, the middle of the spot dries up and fall off, leaving shot holes in the leaves.

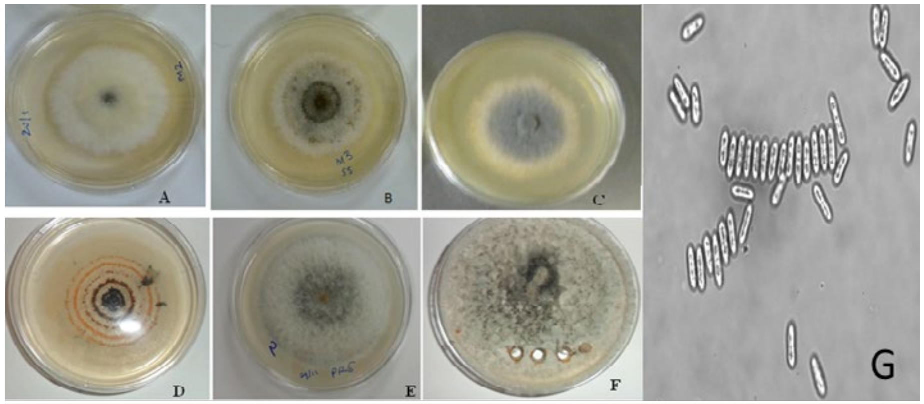


Figure 9. *Cultural and morphological characteristics of the three groups of* Colletotrichum gloeosporioides *causing anthracnose disease of mango in Ghana. A, B, C = cultural growth from the upper part of the plate, D, E, F = cultural characteristics from the reverse of the plate, G = short conical spores of the fungi*

In high disease pressure, infection of leaves results in defoliation. On mature fruits, anthracnose disease symptoms occur in two forms; tear stain symptoms and the dark, slightly sunken spots.

The tear stain symptoms is characterised by the aggregation of numerous tiny spots that are slightly raised and are rough to touch. The pattern created by the symptom on the fruit surface sometimes resemble the back covering of an alligator, causing the symptoms to be described as an alligator skin effect. This symptom is common on fruits that are developing on the trees.

The second symptom, which is the dark sunken spot can also occur on the tree, however, it mostly occur on the fruits after harvest. The spots can range from pin-point size to the entire fruit surface covered. In most cases, the symptoms do not penetrate the pulp, but occasionally, fruits in which the pulp had been penetrated can be found (Figure 10). Due to the destruction of the aesthetic value of the fruits by the symptoms, the marketability of such fruits are also negatively affected. When not controlled, the disease could lead to the rejection of entire consignment of fruits being sent to international markets.

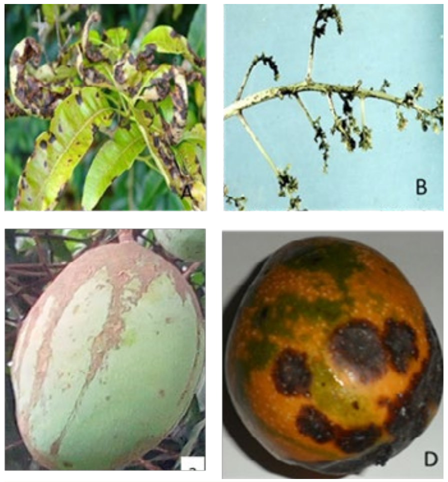


Figure 10. *Symptoms of anthracnose on mango tree. A = symptoms on leaves, B = death of flowers, C = tear stain symptoms on unripe fruit, D = dark sunken spots on mature fruit*

Sources of infection

- The fungus appears to be associated with the tree, endophytically. Hence there will always be the fungus on every mango tree.
- Infected plant parts; leaves, twigs and mummified fruits
- Leaf litter: The pathogen produces sexual spores in the leaf litter which then find their way into the plant canopy.
- Spores laden rain drops.
- Airborne conidia.

Pre-disposing factors

- High humidity and long wetness duration in the tree canopy.
- Unprotected flowers and fruits.

Control

Preventive

- Site orchards in areas where rainfall is not erratic and has plenty sunshine.
- Select varieties that are tolerant to the disease.
- Avoid practices that wounds the fruits at fruit set. For example, minimise activities in the orchards during the developmental phase of the fruits in the orchard.

Cultural

- Prune off excess foliage and remove the prune parts from the field.
- Practice good orchard sanitation. Regularly remove all fallen plant debris from the field.
- Space plants well to reduce overcrowding which will promote high humidity.
- Always prune off excess leaves and branches to open up the canopy. This will facilitate the penetration of sunlight into the canopy.

Chemical

- Protect flowers with any systemic fungicide till fruit set.
- Bi-weekly application of approved systemic or contact fungicides. If Copper is preferred, it must not be applied during the flowering period.
- After harvesting, dip fruits in hot water alone at temperature of 55°C for 15 minutes or dip in hot water at 53°C mixed with Prochloraz. Dipping fruits in prochloraz solution at ambient temperature can also effectively control the disease.

4.4 Bacterial black spot

Causal agent

Bacterial black spot is caused by a bacterium called *Xanthomonas citri* pv. *mangiferaeindicae*. Mostly, bacteria that belongs to the genus *Xanthomonas* are bright yellow coloured on media, however, the one that causes the disease on mango is creamy white and is sometimes described as apigmented (does not contain the pigment that makes the other members to be yellow) (Figure 11A). This bacterium is mostly pathogenic on mango, but have also been found causing disease on cashew. On nutrient agar (a medium used to grow the bacterium), the bacterium looks like a drop of milk and each drop is made up of several thousands of individual cells. When the bacterium is taken through the Gram stain techniques, the cells are stained red (Figure 11B) and hence the bacterium is described as gram negative. Shape of individual cell is described as short rod (Figure 11C).

Damages

The mango bacterial black spot causes damages to all plant parts and could lead to heavy premature fruit drop, sometimes estimated to be as high as 70% of the entire seasons' fruit production. The damages are as follows:

Defoliation of twigs: These defoliated twigs can range from one to several per tree. Mostly these are found poking upwards with rounded edges showing cracked surfaces. The fallen leaves could be seen littering the orchard floor.

Cracking of bark of mango tree: The barks of infected trees can crack and depending on the hardiness of the bark, will be accompanied by oozing of latex.

Leaf spots/blight: The blight could be as a result of individual spots coalescing together to form a larger spot or one spot that has enlarged to cover an extensive area. Such spots/blights are surrounded by yellow chlorotic areas of the leave surface. In most cases, the spots/blight are found in-between two veins and hardly cross a vein.

Premature fruit drop: Fruits that are nearing maturity are found to have dropped in high numbers on the orchard floor. The dropped fruits show one or more-star shaped spots on the fruit surface.

Fruit spot: Spots on fruits began as small translucent slightly raised spots. With time the spots darken and erupt in a star shaped manner. The eruption is often accompanied by oozing of latex.

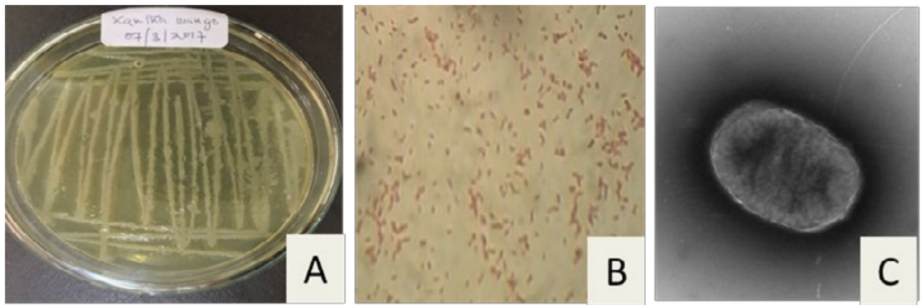


Figure 11. *Cultural and morphological features of* Xanthomonas citri *pv.* mangiferaeindicae. *A = creamy growth on nutrient agar, B = red coloured individual cells, C = electron microscopic image of a single cell*

Figure 12. *Some damages caused by the mango bacterial black spot disease. A = defoliated twigs, B = large numbers of abscised leaves, C = slightly raised dark spots on the surface of an infected leaf. (Source: J. O. Honger)*

Figure 13. *Damages of mango bacterial black spot on fruits. A = rotting of fruit pedicel accompanied by oozing of latex, B = large numbers of abscised fruits on the orchard floor, C = typical star crack symptoms accompanied by oozing of latex on a fruit*

Sources of infection

- Infected plant parts such as fruits, leaves and twig
  The bacterium exists on these plant parts either as parasites (causing disease) or endophytes (not causing disease). In either case, when such plant parts are transferred elsewhere, they transport the bacterium as well, resulting in the spread of the bacterium.

- Aerosols
  Aerosols refer to very fine mist of air that is generated during windstorms. However, during mid-day, these are also produced by plants transpirations. Aerosols can travel long distances and as they move, they collect large volumes of the bacterium from infected field and dumps them wherever their reach. Aerosol is an important mode of transfer of bacterium from soil to the tree parts.

- Contaminated farming tools/implements
  Contaminated pruning shears, cutlasses and other implements that are used for cultural practices in mango orchards. When these tools and implements are used on an infected tree, the bacterium rubs against and attaches itself to these tools and implements. When these contaminated tools and equipment are used in an uninfected tree, the bacterium is transferred to the tree.

- Wind driven bacteria-laden rain drops
  Bacteria hide either in crevices or holes or on the leaf surfaces of plants in absence of water. During rainstorm, the rain-drops that fall on these plant surfaces induce the bacterium which them enters into these drops and multiply rapidly. As the wind blows, these drops are blown away to other plants. Depending on the speed of the wind, these drops can be carried over long distances.

- Irrigation water and water used for mixing chemicals
  The bacterium causing the mango bacterial blight multiplies rapidly in any fresh water, which does not contain any anti-bacterial chemicals. They are washed freely from infected plant parts into these sources of water such as streams and rivers. When such infected water is used to irrigate the trees or to mix and apply chemicals such as insecticides and herbicides, the treated tree becomes infected.

- Tree to tree contact
  The bacterium that causes the disease is highly contagious and therefore, when a branch of an un-infected tree rubs over a branch of an infected tree, there is high chance that the bacterium would be transferred. This is common in farms where the trees are closely spaced or are poorly maintained.

Predisposing factors

- Location of farms
  When a mango orchard is sited at a locality where the disease is prevalent or close to an infected field, the orchard is more likely to be infected than when it is sited in an area where the disease is not present.

- Type of mango cultivar
  Different mango cultivars react differently to infection by the bacterium. In Ghana, the Keitt and Palmer cultivars are highly susceptible to the disease, while cultivars such as Haden, Tommy Atkins, Kent and Julie, are less susceptible. In general, cultivars that matures earlier (latest in the month of May) in the Coastal Savannah Zone, escapes the peak destructive period of the disease. This is the reason why cultivars such as Tommy Atkins and Julie are least affected by the disease in the major mango production season in Ghana. Between May and June, where there are lots of rainfall in the Coastal Savannah Zone of Ghana, the population of the bacteria increases in most infected mango orchards,. Coincidentally, that's the period when the Keitt cultivar in most orchards is nearing maturity. During that periods, the lenticels of the fruits open as respiration increases. This provides plenty of spaces for the bacterium to enter and cause the disease. That's why the Keitt variety, which is predominant in Ghana, suffers heavy damages due to the disease, compared to the early maturing cultivars.

- Persistent rainfall
  Persistent rainfall, especially, during the fruit latter stages of fruit development, contributes to the spread and proliferation of the disease. During rainfall, the raindrops hit the fruit surface causing wounds. These serve as entry points for the bacterium to cause the disease. Since the bacterium multiplies rapidly in presence of water, its population increases rapidly during rainfall and this enables it cause damages to the fruits. Also, during rainfall periods, any protective fungicides on the fruits surfaces are washed away making the fruits vulnerable to the pathogen.

- Poor pruning practices
  Pruning of mango is a very important exercise for disease control. However, if it is not properly handled, it predisposes the tree to the bacterium. For example, Pruning always results in open wounds. These serve as ideal points for bacteria to enter the tree, multiply and cause the disease.

- Poor farm sanitation
  Bacteria can exist in the soil on plant debris for a long time. When these debris more plant debris are allowed to remain in the orchard floor, they serve as an important store of the bacterium for future infection of the trees. Secondly, the causal bacteria survive in several weed species from where they are transferred onto the mango trees to cause disease. Therefore, the weedier a farm is the more difficult it is to control the disease. Generally, bacteria prefer a tree canopy with high relative humidity which allows them to multiply faster and cause the disease. Such high humidity is found in trees with 'unkempt' canopy that is allowed to grow excessively. Tree to tree transfer of the bacteria easily occur when branches of trees rub over each other. This is very common in orchards with shorter plant spacing/high tree density.

- Repeated wetting of tree foliage
  Since the bacterium responsible for the disease proliferates better in presence of water, activities or events that provides free water in the tree foliage, contributes to the development of the disease. Apart from rainfall, other farming activities that contribute to the wetting of the foliage include the application of plant protection products, application of foliar fertilisers and overhead irrigation method. Foliar fertilisers and plant protection products are applied using knapsacks and mist blowers. Some of this equipment generates drops that can cause wounds on fruits and hence facilitate the penetration of the fruits by the bacterium. Apart from that, the water used to mix these products is a source of free moisture for the bacterium to grow and multiply and cause the disease.
- Uncontrolled access to the farm by humans and farming implements
  This is most significant during and immediately after rainfall. During these periods, most of the leaves may have collected rain water laden with bacterium. As humans move in the field, this contaminated water is splashed onto the fruit surfaces to initiate the disease. Also, when infected farm machines are allowed access into the orchard, the trees are exposed to the bacterium for possible infection.
- Delayed fruit harvesting
  The bacteria can infect the fruit at all stages, therefore, when left on the tree for too long, most fruits are likely to be destroyed. It has been observed that in most cases, when fruits are left on the trees, even though they are matured, most farmers continue with the application of insecticides to ward off fruit flies. This practice as explained earlier, provide free water for the bacterium to grow and multiply. In these cases, the fruits are exposed to destructive populations of the bacterium.

Control

Preventive

- Ensure that you purchase all seedlings from a certified nursery dealer. Ensure that the seedlings are not showing any symptoms of the disease on any of its parts before you purchase them.
- Restrict movement to the farm and as much as possible don't allow trucks and trays that have come into contact with diseased plant parts, to enter into the farm.
- Planting of windbreaks around the orchard can also minimise the potential transfer of bacterium through aerosols from an infected farm to your farm.

Cultural

- Site new mango orchards at areas where the disease is not prevalent. Also, avoid areas with plenty of rainfall at periods when fruits are still developing in the field.
- Select cultivars that have been shown to be least affected by the disease. For example, early maturing cultivars of mango escapes the very destructive periods of the disease in the major mango growing areas of Ghana. Cultivars such Haden, Kent, Julie and Tommy Atkinson are less affected while cultivars such as Keitt and Palmer are highly susceptible to the disease.
- Adopt good pruning practices. It is advisable to prune un-infected trees before pruning infected ones. After pruning any infected tree, sterilise the tools in 10% dilution of parazone and rinse in water before using it on an uninfected tree. To minimise the population of the bacterium in the field, collect and burn all pruned plant parts at a safer location away from the farm. Avoid burying the pruned plant parts in the field. This is because the bacteria are naturally soil inhabitants and can survive in the soil debris for a long time. For the same reason, avoid using the pruned plant parts as mulch in the field. This will increase the population of the bacteria in the field. Sometimes, heavily infested trees in the middle of the farm serves as the main source of bacteria. The entire foliage of such trees must be pruned off.

- Maintain a clean farm, free from plant stubbles and weeds. Ensure that the trees are well spaced apart to improve aeration. Carry out periodic pruning of trees to reduce humidity in the tee canopy and encourage penetration of sunlight.
- Avoid the repeated wetting of tree foliage. Overhead/sprinkler irrigation is one major way by which the canopy of trees can be wetted repeatedly. This increases humidity in the canopy and also provides free moisture for the bacterium to thrive. As much as possible, avoid these methods of irrigation and instead practice flooding or furrow irrigation. Also, reduce the frequency of application of water-based solutions such as insecticides and foliar fertiliser. As these active ingredients are not effective against the bacterium, the water they contain rather helps the bacterium to grow and multiply. Therefore, as much as possible use traps rather than insecticides or else mix the insecticide with an approved fungicide, known to be lethal to the bacterium, before application.
- Harvest fruit as soon as they mature. This is because the fruits can be infected at any point in time as far as they remain on the tree. Note that due to the need for a pre-harvesting time to prevent chemical residues in fruits, it is not advisable to continue applying fungicides on fruits when they have reached physiological maturity. In that case, the fruits will be left without protection and they will be destroyed by the bacterium.

Chemical

- After pruning of trees apply Copper oxychloride or Copper oxide at the recommended rate at bi-weekly intervals till flowering begins.
- During the flowering period, avoid the copper sprays; rather, protect the flowers with Vincocide at the recommended rates, till fruit set.
- After fruit set, resume the application of the copper sprays at bi-weekly intervals. Continue the application until at least 2 weeks to fruits physiological maturity.

4.5 Sooty mould

Causal agent

Sooty mould is caused by the fungus, *Capnodium citri.* The fungus grows on honeydew, a sticky, sugary secretion that is produced by some insects (plant hoppers, Mealybugs, etc.) to attract other insects. It produces dark velvety mycelia, which are superficial, on the colonised plant surface. In most cases, mealy bugs, the insects that produce the honey dew on mango in Ghana, are found accompanying the fungus on the infected plant parts.

Damages

- The dark velvety growth on the surface of leaves, reduce the photosynthetic ability of the leaves (Figure 14A).
- The mycelium of the fungus protects the mealy bugs (Figure 14B) and makes it difficult to eradicate them.
- Severely affected leaves may drop resulting in heavy defoliation of twigs.
- Growth on flowers results in reduced fruit set and can also result in premature fruit fall.
- The growth taints mature fruit, reducing fruit quality (Figure 14C).

Sources of infection

- Diseased leaves serve as primary source of inoculum.

Pre-disposing factors

- Uncontrolled populations of mealy bugs and the presence of the sugary substances they produce.
- The age of trees. Disease can be very severe in very old orchards than in new ones with younger trees.
- Dense canopy with poor light penetration, favours the growth and development of the disease.
- Poor insect pest control practices which active ingredients that rapidly eliminates natural enemies but which are less toxic to the mealy bugs.
- High humidity, without continuous rainfall favours the proliferation of the fungus and the disease it cause.

Control

Preventive

- Site new orchards in areas where the disease is not prevalent.
- Purchase and transplant, only clean seedlings free from the disease symptoms.
- Restrict the movement of infected materials, such as leaves and fruits and materials that are coming from an infected field, into the uninfected orchard.

Figure 14. *Symptoms of sooty mould disease on mango leaves and fruits. A = black velvety growth on leaves, B = black velvety growth accompanied by mealy bugs (white insects), C = fruits tainted with the growth of the fungus*

Cultural

- Prune trees regularly to reduce canopy density and to improve sunlight penetration.
- Remove infected plant parts and dispose of them by burning.
- If disease keeps recurring in an old orchard, consider removing the trees and replanting.
- Avoid indiscriminate use of insecticides, which may kill the natural enemies of the mealy bugs, but which are not able to kill the mealy bugs.

Chemical

- Control both the insect and the fungus simultaneously. Select insecticide (botanicals and biological agents) that have been shown to be effective against the mealy bugs.
- Dilute starch, which comes off in flakes after drying and in process removes the black velvety growth, can be applied on the trees.
- Alternatively, apply Bordeaux mixture (1%) after insecticidal sprays, to gradually destroy the fungus.

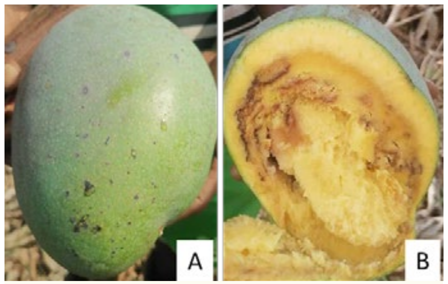


Figure 15. *Symptoms of mango fruit internal decay. A = unequal ripening of the fruit surface, B = jellylike mass and rotten tissues around the seed*

4.6 Mango fruit internal breakdown

Causal agent

The cause of this disease is not certain; however, calcium deficiency is the probable cause. Tree different types of the disease/disorder can be distinguished. These are Jelly seed, stem end cavity and soft nose. The three types all produce the same symptoms; however, the point at which they occur on the fruit is the main distinguishing factor. Jelly seed affects the interior of the mesocarp while stem end cavity affect the proximal end (shoulder) of the fruit. Soft nose, on the other hand occurs at the distal end (tip) of the fruit.

Damages

- On the affected fruit surface, there appear regions of un-equal ripening. The regions where the underlying tissues had broken down, appeared to ripe faster than the other parts of the fruit surface.
- Internally (when the fruit is cut opened) breakdown of tissues around the seed of the affected fruits, is observed. There appears a jelly like mass in the affected portion of pulp which is deeper yellow orange in colour and softer compared to the rest of the mesocarp.
- Apart from the aesthetic value of the fruit which is reduced by the disorder, the affected fruit is usually unfit for consumption.

Pre-disposing factors

- Heavy fruiting of trees i.e. high number of fruits or fewer, but big sized fruits.
- Size of fruits. The bigger the fruit, the more likely it will show the symptoms.

Control

- Supplement the copper levels in the soil with foliar fertilisers containing copper.
- After fruit set, apply Calcium chloride (2%) on the young fruits.

5. Major insect pests of mango in Ghana

Different types of insect pests afflict production in Africa, and perhaps none have gained greater notoriety than the fruit flies (Diptera: Tephritidae). The enormous losses they cause through direct damage to fruits and vegetables and loss of market opportunities through imposition of strict quarantine regulations by importing countries to prevent entry and establishment of fruit flies demand urgent need for implementation of sustainable management practices for fruit flies control.

The introduction of uniform and strict quarantine restrictions and the maximum residue level (MRL) regulations in the European Union compound the existing fruit fly problem and jeopardize the lucrative export of fresh fruits and vegetables from Africa. Lack of local expertise in fruit fly management makes it difficult to respond in a timely and efficient manner to the challenges imposed by fruit flies. The correct identification of fruit flies occurring in a particular area and their damage symptoms is a first step towards developing appropriate management strategies.

In view of the fruit fly-related trans-boundary invasions arising from increased travel and trade in fruits and vegetables, there has been the critical to develop training and other manuals in support of fruit fly management activities in the country and the sub-region region.

This guide will provide agricultural scientists, extension workers and quarantine specialists with information on the life cycle, damage symptoms, distribution and host plants of major fruit fly species of fruits and vegetables in Ghana and those of potential invasive species in Africa. The purpose, tools and methodology for fruit fly monitoring, suppression and host fruit processing and handling are also comprehensively covered.

Additionally, brief sections on safety precautions during monitoring and suppression, and packaging, handling and shipment of specimens to facilitate identification are provided. This guide also provides a simple, user-friendly pictorial views to most of the common fruit fly species to allow for rapid identification of the major species found on fruits. This guide is to be considered as a 'working document', parts of which are to be regularly updated as fruit fly taxonomy and management techniques continue to improve and global experience in control programmes continues to expand.

5.1 Fruit flies

Generally, management of fruit flies is a sensitive and an intensive venture for 2 reasons – fruit flies are mostly known to be invasive species, and they are considered as quarantine pests. This double-status of fruit flies means that their management requires careful and thorough handling, and it is essential that the procedures that are used are thoroughly understood, harmonized, and meticulously executed over large areas so as to feel the impact of the measures that are put in place. It is therefore critical that the methodologies are clearly spelt out, systematically explained, and carefully translated into practical hands-on field application to the understanding of stakeholders.

To understand what steps to take, one needs to be conversant with how the pest behaves in the field, and how those behaviours tend to affect the fruits and vegetables we so much seek to protect.

Damage symptoms

Direct damage: Direct damage begins when the female fly punctures the fruit skin and lays eggs underneath it. Damage symptoms vary from fruit to fruit. During egg-laying, fruit-rotting bacteria from the intestinal flora of the fly are introduced into the fruit. These bacteria multiply and cause the tissues surrounding the egg to rot. When the eggs hatch, the rotten fruit tissue makes it easier for the larvae to feed. The puncture and feeding galleries made by developing larvae provide access for pathogens to develop and increase the fruit decay. Generally, the fruit falls to the ground as, or just before the maggots pupate.

Indirect losses: Nearly all fruit fly species are quarantine pests. Indirect losses result from quarantine restrictions that are imposed by importing countries to prevent entry and establishment of unwanted fruit fly species.

Fruit Fly Biology and Ecology

The female fruit fly has a sharp and pointed ovipositor at the tip of the abdomen, which it uses to puncture the fruit and lay its eggs under the skin of the fruit and flies away. After 2–5 days, the elliptical-looking eggs hatch s and begin to feed on the pulp of the fruit, and undergo three larval stages. Fully mature larvae are usually creamy-white, very active, and have the ability to "loop and jump" – this ability helps them when the pop out of the fruit and pupate in the soil. They keep jumping until they find the right soil conditions/hiding place where they can easily burrow in the top few centimetres (2–7 cm) of soil. At this stage, the larva is protect in a brownish dark case, and is described as a puparium (*pl* – puparia), which does not feed. After about 10–15 days, a new adult ecloses from the puparium. The newly eclosed fly stays inactive for about an hour or two for its wings to be stretched and hardened, looks for a good source of protein from the leaf surfaces (bird droppings, honey dew, etc.), and the cycle continues (Figure 16).

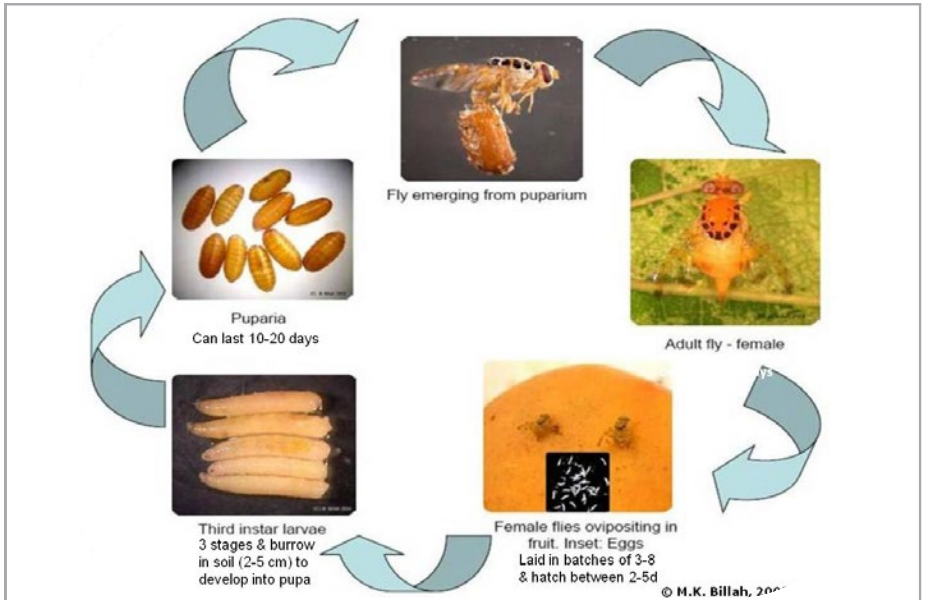


Figure 16. *Generalized life cycle of fruit flies. (Source: M. K. Billah)*

Usually stakeholders are just taught how to apply tools or measure to control or manage fruit flies. This approach does not take into consideration the understanding of stakeholders, and therefore becomes prescriptive.

In this manual, care is taken to relate the control/management measures to the developmental cycle of the fruit fly. In which case, stakeholders will for example understand why they are applying the recommended measures. For example, fruit fly puparia can lie in the soil for 10–15 days before a new adult emerges. And when this happens, the first thing the adult flies look for, is a source of protein on the leaf surfaces for proper body development and egg maturity (in females) before they start their damaging activities. So when a more aromatic and highly-scented protein bait (which is poisoned) is spotted on the leaf surfaces, the adult flies in their attempt to satisfy their hunger and meet their developmental needs, will find the spot spray more attractive and feed on it. Such an explanation quickly links the control measure to the life cycle of the fly and makes the stakeholder understand why and how the bait application works. This then brings out the curiosity in them to ask more questions to ensure better understanding.

Major indigenous and invasive fruit flies in Africa

The economically important fruit fly species in Africa include: *Ceratitis anonae* Graham; *Ceratitis bremii* Guérin-Méneville; the Mediterranean fruit fly (Medfly), *Ceratitis capitata* (Wiedemann); *Ceratitis colae* Silvestri; the mango fruit fly, *Ceratitis cosyra* (Walker); *Ceratitis ditissima* (Munro); *Ceratitis fasciventris* (Bezzi); the cacao fruit fly, *Ceratitis punctata* (Wiedemann); *Ceratitis quinaria* (Bezzi), the Natal fruit fly, *Ceratitis rosa* Karsch; *Ceratitis rubivora* Coquillett; *Ceratitis silvestrii* Bezzi; the melon fly, *Bactrocera cucurbitae* (Coquillett); the oriental fruit fly, *Bactrocera dorsalis* (Hendel); the Solanum fruit fly, *Bactrocera latifrons* (Hendel); the olive fruit fly, *Bactrocera oleae* (Rossi); the peach fruit fly, *Bactrocera zonata* (Saunders); *Dacus bivittatus* (Bigot); the lesser pumpkin fly, *Dacus ciliates* (Loew); the pumpkin fly, *Dacus frontalis* Becker; *Dacus lounsburyii* Coquillett; *Dacus punctatifrons* Karsch; *Dacus vertebratus* Bezzi; the coffee fruit fly, *Trirhithrum coffeae* Bezzi; and *Trirhithrum nigerrimum* (Bezzi). Of these, *B. zonata, B. latifrons, B. oleae, D. frontalis* and *D. lounsburyii* have not been recorded in Ghana, and only a single male specimen of *C. rubivora* was recorded in a Trimedlure trap on a miracle fruit tree (*Sensepalum dulcificum* [Schumach. & Thonn.] Daniell) at Mampong-Akwapim (June, 2010) in the Eastern region of Ghana (Billah unpublished data).

Of particular concern are four invasive species of the genus *Bactrocera*, including *B. dorsalis, B. zonata B. latifrons* and *B. cucurbitae*. These species are already established in various parts of Africa, where they cause huge losses to fruit and vegetable production. While *B. zonata* presence is now been reported in Egypt and in Indian Ocean Islands of Mauritius and Reunion, *B. latifrons* is reported only from Tanzania and Kenya in the solanaceous crops. It is therefore important that due diligence is given to those crops to establish whether or not that species is present in the country. Ironically *B. latifrons* does not respond to any of the commonly known attractants in use in the country. It is only attracted to alpha ionol or Latilure, whose attractiveness is enhanced by the addition of Cade oil as a synergist. It therefore stands to reason that the best and only way to establish the presence of this pest would be by host fruit sampling and incubation.

Closely related and morphologically similar species to *B. dorsalis*, that are not yet in Africa, are *B. kandiensis* (Sri Lanka fruit fly), *B. correcta* (Guava fruit fly), all of which are potentially invasive species. Interestingly, all these species also respond to the powerful male attractant, Methyl eugenol. It is therefore important that mass trappings of *B. dorsalis* are sorted out, critically examined and properly identified to avoid the situation where they may be casually passed off as *B. dorsalis*.

Monitoring

Basic Principles

For any pest management action to be taken, the presence of the pest and the crops are associated with in an area must be established. The most reliable way of establishing the presence of fruit flies in an area, is by monitoring. Therefore, the sensitivity, quality of data and the extent to which such data can be used, all depend on the careful planning and design of the monitoring process.

What is Monitoring?

It is any action that will help or facilitate the making of pest management decisions. Monitoring can be categorized:

- Early detection
- On-farm monitoring
- Area surveillance

Why Monitor?

To forewarn farmers of on-going changes in pest populations.

Accurate methods for fruit fly population surveys are a prerequisite for effective decision-making at pest suppression, as well as those attempting to establish fruit fly free or areas of low prevalence.

By monitoring, we are able to:

1. Identify fruit fly pests in an area – this information becomes the basis of the establishment a baseline reference of what is present in an area or country.
2. Determine the distribution and identify local hot spots of pest species – it tells where the different species can be found, and in where their numbers are high. Most of the time, items (i) and (ii) are used together in the determination of the pest status of production areas (i.e. areas low-, medium- or high- pest prevalence). Documentation of changes in fruit fly populations and shifts at national or regional levels are usually carried out be National plant Protection Organizations (NPPOs) as Area Surveillance.
3. Track changes in population levels – this is important because as seasons change, different species may have different proportions, and these have huge implications on the management strategies that are used during the period. Population fluctuation levels can easily be carried out at the farm level by farmers.
4. Determine efficacy of control measures – while control measures are put in place to manage pests, monitoring affords the chance to see how pest numbers change after application.
5. Facilitate early detection of new pests/species in an area – in the event of the introduction of invasive species in an area, they can easily be detected if monitoring is consistent and properly done. To be on the safe side, detection traps must be set up to run all year round, especially at the ports of entry and areas that are more prone to new introductions. Early Detection programs part of the mandate of each nation's Quarantine Services, and must be done on Regular basis. The earlier such invasive species are detected, the better the strategy that can be put in place to mitigate their effects.

For reliable assessment, two forms of monitoring must be carried out – (a) use of traps, and (b) fruit collection and incubation.

Monitoring by use of traps

The use of traps is faster at collecting flies for identification and achieving the purpose of monitoring. Fruit collection and incubation is more tedious as it involves collections of large volumes of different fruits and incubation over periods of up to 4 or 5 weeks (depending on stage of fruits collected). Fruit incubation, however, has the added advantage of determining (i) actual levels of fruit infestations (in single fruits or in bulk samples), (ii) proportions of different fruit flies in fruits, (iii) the presence of parasitoids and their parasitism levels, and (iv) the possibility of establishing the host fruit range of the flies identified.

Monitoring tools

Attractant-based assessments are usually used in trap monitoring, while host fruit surveys use incubation (to monitor fruit infestation levels).

The attractant types used include olfactory cues such as Food baits, para-pheromones and male lures, as well as visual cues like colour, shape and size of traps (Cunningham, 1989; Heath *et al*., 1997; Lux *et al*., 2003a).

Properties of food baits

Ammonia is the principal attractant originating from these lures, and they are either available as liquid food-baits (e.g. NuLure, SUCCESS® Appat (GF-120), Great Fruit Fly Bait (GFFB) or as dry synthetic baits (e.g. BioLure).

- Liquid food bait should be changed every 1–2 weeks, while dry synthetic attractants can last for 4–6 weeks
- Attract only males
- Highly species-specific
- Highly efficient (attract flies from long distances)

They are available in both liquid and in slow release dispensers (Table 2). For monitoring purposes, lures in slow release dispensers are more handy. Dispensers can last for 4–6 weeks (and at times, longer).

Para-pheromones or male lures

These mostly attract male fruit flies (except for the Olive fly, *Bactrocera oleae*, which has a female sex pheromone). They are species-specific and can high attract flies from long distances (Cunningham, 1989; Economopoulos and Haniotakis, 1994; White and Elson-Harris, 1994). Male lures are mostly para-pheromones (i.e. synthetic versions of the natural pheromone products). They are available in both liquid form, and as polymeric plugs in the form of a controlled-release formulation (Figure 17). Those in liquid form last 2–4 weeks in the field, while the polymeric plugs can last between 6–8 weeks. Minimum intervals between traps baited with para-pheromones should be 50–100 m.

Methyl eugenol (ME): This is the most powerful of all the fruit fly attractants. It strongly attracts males of many *Bactrocera* species e.g. *B. dorsalis, B. correcta* and *B. zonata*. They are long lasting, and may attract flies from a distance of up to 500 m.

CueLure (CUE): This attracts males of many *Bactrocera* and *Dacus* species, e.g. *Zeugodacus (Bactrocera) cucurbitae*. They are moderately persistent, and may attract flies up to a distance of 300 m.

Trimedlure (TML): Trimedlure, Ceralure or Capilure attracts males of some *Ceratitis* species, including *C. capitata* and *C. rosa*. It is a synthetic product described as Tert-butyl 4 (and 5)-chloro-2-methylcyclohexane-1-carboxylate, and does not occur in nature.

Terpinyl acetate (TA): This is a natural ester compound, which is a moderately attractive natural ester compound to males of many *Ceratitis* species, including *C. rosa* and *C. capitata*.

Ceratitislure: This is highly persistent and attractive to males of *C. cosyra* (Ware, 2002). It is commercially available as a blue-coloured capsule, with an attractant impregnated in a sponge.

Alpha-ionol + Cade oil: This combination attracts males of the Solanaceous fruit fly, *Bactrocera latifrons* (Flath *et al*., 1994; McQuate *et al*., 2001, 2004). The alpha-ionol is commercially known as Latilure, and its use with the Cade oil enhances the attractiveness of Latilure. They are usually dispensed on different cotton wicks (i.e. 2.0 ml alpha-ionol and 1.0 ml cade oil) in the same trap to give it a synergistic effect. Alpha-ionol [4-(2,6,6-trimethyl-2-cyclohexen-1-yl)-3-buten-2-ol] is a colourless insoluble liquid in water, but soluble in alcohol, while Cade oil is a distillation product from twigs of Juniper wood, *Juniperus oxycedrus* L.

Spiroketal: This product attracts males of the Olive fruit fly, *Bactrocera oleae*. It is described as as 1,7-dioxaspiro-[5,5] undecane, and can be combined with a protein bait or ammonium bicarbonate for monitoring (IAEA, 2003; Yokohama *et al*., 2006).

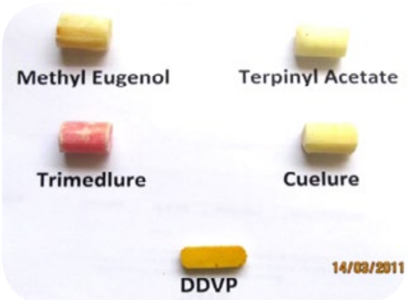


Figure 17. Polymeric plugs of some para-pheromone lures and a piece of DDVP block (killing agent)

Table 2. *Fruit fly species commonly encountered in Africa and their attractants.*

Species	Male Attractant	Male & Female Attractant
Bactrocera dorsalis (Hendel)	Methyl Eugenol (ME)	3-Component lure (Putrescine + Tri methylamine + Ammonium acetate, PTA or Biolure 3C) Protein Bait
Bactrocera cucurbitae (Coquillett)	CueLure (CUE)	3-Component lure (PTA or Biolure 3C) Protein Bait
Bactrocera latifrons (Hendel)	Alpha-ionol + Cade oil	Protein Bait
Bactrocera oleae (Rossi)	Spiroketal	Ammonium bicarbonate Protein Bait
Bactrocera zonata (Saunders)	Methyl Eugenol (ME)	3-Component lure (PTA or Biolure 3C) Protein Bait
Ceratitis anonae Graham	Not Known	3-Component lure (PTA or Biolure 3C) Protein Bait
Ceratitis bremii Guérin-Méneville	Methyl Eugenol (ME)	Protein Bait
Ceratitis capitata (Wiedemann)	Capilure, Trimedlure, Terpinyl acetate	Ceratitislure, Queslure, Biolure 3C Protein Bait
Ceratitis colae Silvestri	Not Known	Protein Bait
Ceratitis cosyra (Walker)	Ceratitislure, Terpinyl acetate	Queslure, Biolure 3C Protein Bait
Ceratitis ditissima (Munro)	Methyl Eugenol (ME)	Protein Bait
Ceratitis fasciventris (Bezzi)	Terpinyl acetate	Biolure 3C Protein Bait
Ceratitis punctata (Wiedemann)	Methyl Eugenol (ME)	Protein Bait
Ceratitis quinaria (Bezzi)	Terpinyl acetate	Protein Bait
Ceratitis rosa Karsch	Capilure, Trimedlure, Terpinyl acetate	Ceratitislure, Queslure, Biolure 3C Protein Bait
Ceratitis rubivora (Coquillett)	Trimedlure	Biolure 3C, Protein Bait
Dacus ciliatus (Loew)	CueLure (CUE)	Biolure 3C, Protein Bait
Dacus frontalis Becker	CueLure (CUE)	Protein Bait
Dacus lounsburyii Coquillett	CueLure (CUE)	Protein Bait
Dacus punctatifrons Karsch	CueLure (CUE)	Protein Bait
Dacus vertebratus Bezzi	Vertlure	Protein Bait
Zeugodacus bivittatus (Bigot)	CueLure (CUE)	Biolure 3C, Protein Bait

Placement of traps

Before trap placement, all components of the trap should be labelled (i.e. base, lid) with the institution name, trap code with trap ID number, date, location, orchard or farm name, and permanently mark as being used for a particular attractant (ME/Cuelure/TML/TA/Food Bait).

Traps must be placed about 2–4 m above ground within the canopy layer on host trees on twigs or branches in semi-shaded parts preferably in the upwind part of the canopy (and not exposed directly to the sun). The trap should be hung in such a manner that branches and leaves are nearby (to provide resting places for arriving flies), but not touching the trap so as to serve as entry points for ants. The leaves serve as landing platforms from where the flies re-orient themselves and fly towards the traps. Distance between traps (monitoring for population fluctuation) will be as follows; Food bait traps (10–30 m spacing), Male lure traps (>50 m spacing), and Visual/colour (5–10 m spacing).

When using dry traps baited with para-pheromones, the middle third portion of the hanging wire is coated with a thin layer of 'Stickem' (Tanglefoot®) or solid grease to prevent entry of ants, which would feed on captured specimens. The Tanglefoot® should not be applied on the hook of the trap, as this would not allow for cleaning and servicing of traps.

Use ribbons (or paint spray) to mark positions of each trap, in such a manner that the ribbon can easily be seen from the point of preparation in the field. A sketch of the survey route and trap position should be plotted. The references of the trap location should include visible and permanent landmarks. The application of geographic positioning systems (GPS) can be a very effective tool in both trap location as well as analysis of trap captures. Geographical coordinates of each trap should therefore be referenced, taking such readings from the edge of the farm, and in the middle of the farm where the tree selected by the Project consultant is located.

In an appropriate datasheet (Annex 1), the trap ID number, location (area), trap station (e.g. farm or forest name or house property), habitat type (e.g. mango orchard), trap type, trap lure, date of placement, collection date and GPS coordinates should be noted, as well as details on the fruit fly and non-target species collected. General ecological or environmental observations (such as rains, storms, high winds, fires, etc.) should also be noted in the comment or remark column of the datasheet. They could help in the explanation of trends in results and discussions.

Wind meters and Data-loggers (where available) should be engaged to take readings of wind speed, temperature (maximum and minimum) and relative humidity.

Trap and attractant handling

- Place traps on host plants not likely to be sprayed with insecticides.
- Entry holes of traps should not be obstructed by tree foliage.
- For liquid food baits in traps, add borax to prevent deterioration of specimens.
- Avoid spilling contents on ground and on side of traps.
- For male lures in traps.
- Use one lure per trap.
- Use different operators for each lure to avoid cross contamination.
- Separate lures in different packages when going to the field of lures.
- Wire suspending trap should be coated with Tanglefoot® glue to prevent entry of ants.

Fly collection and trap servicing

- Check all traps once a week for collection of fly catches.
- For dry male lures, gently unscrew the top from the bottom of the trap and empty contents into collection vial.
- The collection vial should have label of the same information on the trap being emptied.
- Clean any debris or dirt on trap with soft camel hair brush and screw lid back.
- For food bait used as trap lures, trap content (flies in liquid) should be poured through a sieve and a little about of water poured over it to wash bait before transferring to the labelled collection vial.

- The sieving is done over a bucket or receptacle container which is later emptied into a dug pit and covered (and not thrown away in the open in the field).
- The procedure should be repeated for each and every trap in the field.
- Male lure traps will have the para-pheromone plugs and killing agent returned into the traps, and will only be replaced after the stipulated period of 4–6 weeks of collection.
- Food bait traps will have the liquids replaced with fresh mixtures on weekly basis.
- To minimize weight and possibility of mishandling, the 70% alcohol can be added to the content of the collection vials when the specimens arrive in the collection centre/laboratory, and during counting.
- After counting, specimens from the same lure trap can be bulked together (e.g. ME 1 + ME 2 + ME 3 + ME 4), divided into three (3) portions and a third ($^{1}/_{3}$) taken as a representation of the ME trap from a particular farm. This will serve as the prepared portion to be forwarded for taxonomic identification. This process then frees 3 of the 4 vials for each trap.
- For the purpose of easing pressure on field workers, collections from different farms that are far apart should be staggered, so that they can be collected on different days of the same week.

Trapping and baiting

There are several reasons for monitoring fruit flies. It helps to (i) identify fruit fly pests in an area (if it is not already known), (ii) it helps to determine the distribution of pest species in an area, (iii) it identifies local hot spots with high populations of the pest, (iv) tracks changes in population levels, (v) determines efficacy of control measures, and (vi) facilitates early detection of new fruit fly pests in an area.

This is based on the fact that fruit flies respond to several chemical odours that emanate from food sources or from insects of the same species or sex. These odours can be used as tools for the manipulation of fruit fly behaviour in their management by baiting and trapping them. Two main types of attractants are used for monitoring and trapping fruit flies. These are para-pheromones or (male lures) and food baits.

Para-pheromones are highly volatile and species specific and attract only male flies and when they are used in conjunction with poisons the system, is termed "male annihilation" technique. Para-pheromones are available in liquid and solid slow-releasing (polymeric) forms on the market. The most common para-pheromones used include Methyl eugenol (ME), Cue lure (CUE), Trimedlure (TML), Terpinyl acetate (TA) and Vertlure (VERT). Male lures in liquid form last between 2–4 weeks in the field, while polymeric plugs can last for up to 6 weeks. The minimum interval between para-pheromone-baited traps should be 30–50 m. The only locally available para-pheromones are TIMAYE® and STOPMATING® (solid block impregnated with a mixture of methyl eugenol and an insecticide).

Trap types

Several trap types have been developed and used for catching fruit flies in an effort to monitor or suppress their populations. Some of the commercially available traps are, Steiner trap, McPhail trap, Tephri trap, Multilure trap, Jackson trap, Easy trap, Sensus trap, Lynfield or 'Bucket" trap and the Boll trap (Figure 18). Traps made out of local materials have been found to be equally effective. The types of traps used for fruit fly monitoring depend on the nature or type of attractant (IAEA, 2003).

The most widely used traps contain para-pheromone or pheromone lures that are male specific. The para-pheromone Trimedlure (TML) captures the Medfly (*Ceratitis capitata*) and the Natal fruit fly (*C. rosa*). The para-pheromone methyl eugenol (ME) captures a large number of *Bactrocera* species including: the Oriental fruit fly (*B. dorsalis*), the Peach fruit fly (*B. zonata*), the Carambola fruit fly (*B. carambolae*), the Guava fruit fly (*B. correcta*), and the Sri Lanka fruit fly (*B. kandiensis*). The para-pheromone Cuelure (CU) also captures a large number of *Bactrocera* including: the Melon fly (*Zeugodacus cucurbitae*), the Pumpkin fruit fly (*Dacus bivittatus*), the Lesser pumpkin fruit fly (*Dacus ciliatus*), and the Jointed pumpkin fruit fly (*Dacus vertebratus*).

Para-pheromones are generally highly volatile, and can be used in different types of traps. TML, ME and CUE may be available in polymeric plugs with controlled release formulations that can provide longer lasting attractants for field use.

Attracted flies are retained in panel and delta traps using a sticky material. Para-pheromones may also be mixed with a sticky material and applied to the surface of the panels. Killing agents used in panels, delta-traps and in bucket traps when used dry are usually a form of a volatile toxicant such as DDVP (2,2-Dichlorovinyl dimethyl phosphate), Naled (dimethyl 1,2-dibromo-2,2-dichloroethylphosphate), and Malathion (Diethyl 2-[(dimethoxyphosphorothioyl) sulfanyl] butanedioate), although some of these are repellent at higher doses.

Figure 18. Different fruit fly traps used for monitoring, depending on attractant type. A = McPhail trap, B = homemade Lynfield or Bucket trap, C = Jackson trap, D = Steiner trap, E = Tephri trap, F = Multilure trap, G = Ball trap, H = collection of different traps, including the big Israeli trap (with green hanging wire) at the back

Practical training component

To train advisors and farmers on fruit fly monitoring and suppression (trap setting, bait application and data collection) the following topics should be covered:

1. Hands-on training on host fruit survey and processing, using improvised and homemade incubation chambers.
2. Fruit fly host fruit survey (purpose, tools and methods) and relevance to fruit fly management.
3. Use of fruit fly collection data – analysis, implications and protection.
4. Discussion on handling, packaging and shipment of specimens.
5. Traps will be laid in a Randomized Complete Block Design (in alternating fashion to avoid replicated traps of the same kind following each other).
6. Fruit fly trap collections will be carried out on weekly basis by Technicians who will count and hold collections for safe keeping at the farm / plot level.
7. After each weekly collection, traps of the 4 para-pheromone traps will be rotated around the 4 trees selected by the consultant i.e. after emptying trap TM, it is moved to the position of trap CU, and trap CU moved to the position of trap TA, which eventually moves to the position of trap ME and ME moving to the position of trap TA (in a rotational fashion around the reference tree in each quadrant).
8. This is repeated for each of the 12 remaining traps in the other 3 quadrants of the farm.
9. It ensures that traps of a particular lure does not stay in the same position throughout the trial period, to elicit a learning behaviour from the flies thereby making them move to a particular part of the farm without going through the exploration process.
10. After every 4–6 weeks (when the attractancy of the lures seem to be diminishing, traps will be serviced by cleaning and replacing with fresh attractants.
11. Plastic collection vials (25 ml, 50 ml and 100 ml) will be used to preserve adult flies and parasitoids collected in 70% Ethanol.

For use of this guide for practical training purposes, appropriate data sheets have been developed for trap catches, non-targets species, as well as fruit collection and Incubation (Annex 1, 2, 3). These data sheets will serve as the hard copies of the raw data from the field (from which soft copies can be generated and stored electronically), and should be filed and stored away from the soft copies as backup. These will serve as part of data required by some certification bodies.

When sub samples of specimens are taken for confirmation, full details of trap and lure type, farm name and location, collection date and country, should be provided on a piece of paper as an on-bottle label, with a duplicated copy placed inside each representative vial. This will ensure traceability in case of specimen mix-up.

Parameters under consideration

Use of Fly Trap Data

When fly data is collected either from traps or from incubation, show of the numbers alone does not carry so much weight until they have been expressed in the requisite form that is generally accepted, understood, and used in the import-export trade. These standard units allow comparison across-the-board.

Reporting trapping results

This is usually reported as number of flies per trap per day (F/T/D), which is a population index representing the average number of flies captured in one trap in one day that the trap is exposed in the field (IAEA, 2003). The function of this population index is to give a relative measure of the size of the adult population in a given space and time. It can be used to compare fly populations between regions, determine population fluctuations in time and determine differences in size of adult population between different areas (e.g. between treated and untreated areas).

It is calculated as follows:

Relative Fly Density = F/T/D

where,

F = Total number of flies collected from an area
T = Number of serviced traps used in the collection
D = Number of days traps were exposure during the collection period

This is a standard index used by the FAO and IAEA (IAEA, 2003), which allows comparison (i) across different localities, (ii) over different exposure periods, and (iii) irrespective of the number of traps used. This index will therefore allow the comparison of relative fly population levels from all orchards in the different parts of the country, and for that matter, all the different agro-ecological zones under consideration.

Weekly and/or monthly plots of the indices can also be plotted over the period of collection from different treatment farms, zones and regions for a quick visual comparison of fly population fluctuation trends.

Based on these updates, an all-year-round plot can be generated to see the trend of fly population fluctuations – peak periods, low periods and how they can be related to the phenology of the crops in question. These will also be related to meteorological data, to be used as a crude measure of forecast at the grower level to tell when they need to take practical actions in their fields.

The meteorological data (wind speed, relative humidity and temperature) collected in the fields by use of Data Loggers can be used to establish the relationship between population fluctuation trends and the immediate climatic conditions. These, together with other environmental factors (over repeated periods), can then be synthesized and used as "crude early-warning guides" or as predictors of fly populations for local, zonal and regional areas. This information can then be used to develop protocols based on ISPMs 9 and 26, with the aim of ensuring compliance to international export standards of ascertaining the pest status of selected areas of production.

Monitoring by use of fruit collection and incubation

Here, the basic actions taken include collection of fruits from the orchard /farm / plot under consideration, and incubated to find out what comes out of the fruits, as outlines below.

- Collect a reasonable number of fruits (30–100, depending on sensitivity of study) from the four quadrants of each farm in paper bags, and properly label with location, date, collector's name, host plant name, state of fruit, etc.
- Weigh and incubate fruits from each farm separately over a pupariation medium in plastic rearing containers/chambers. Rearing chambers (Figure 19) can be made from two plastic containers of same size (with lids) – one with holes made at the base through which larvae can pass into the second, when it is nested in the second. A section of the lid of the one with the fruits can be cut open and fitted with organza netting material for ventillation (Figure 19A). If such containers are not available, simple open containers (Figure 19D) can be improvised for the purpose.
- The pupariating medium could be moistened coarse sand (washed, dried and heat-sterilized at 100°C for 20–30 minutes, to minimize mortality of larvae), and make it easier for puparia retrieval from extremely wet sand. If this is not done, fine soil will form mud around larvae and puparia, and will kill them when it dries up.
- Fruits can be held singly (for individual damage assessment) or in bulk (for damage assessment of farm or area).
- At 3–4 day intervals, sieve sand to retrieve puparia.
- Count and place puparia in petri dishes lined with moist filter paper or blotting paper, and hold in cages till emergence (Figure 20).
- Continue with sieving until fruits are completely rotten, and dissect rotten fruits to retrieve any hidden puparia before discarding remains.
- Note dates, and count any emergences from the puparia.
- This process also serves as the only means of sampling for indigenous natural enemies or parasitoids in the area, and therefore, ALL emergences must be collected, recorded and properly identified taxonomically.
- After emergence, provide flies and/or parasitoids with a source of water (by way of cotton wool soaked in water) and a source of food (fruit fly adult diet or a fine streak of honey on the roof of the cage for the parasitoids).
- Hold emerged insects for 3–4 days till full adult features are developed before freeze-killing for preservation (to facilitate easy taxonomic identification).

This process allows damage assessment both in individual fruits and in the bulky samples taken. Fruits used for this exercise should be picked from the trees (and not from the ground). The two sources will give different infestation levels, and will not be a true reflection of the situation under consideration.

It is usually more reliable in the listing of plants / fruits as hosts to the pests that emerge from the fruits. Flies may be attracted to traps in fields (indicating their presence in the area), but the plant/ fruit may not necessarily be a host until the fly develops and successfully emerges from the fruit. This serves as a confirmatory step in drawing host plant lists, and where the quality of the data generated can easily be compromised.

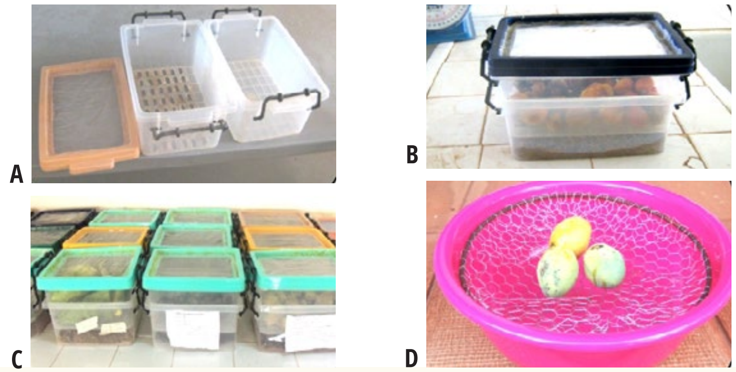


Figure 19. Preparation of plastic containers as incubation chambers. A = Plastic containers with holes made in the bottom of one (to hold fruits) and the other left intact (to hold sand). Lid of one cut and fitted with netting material for ventilation, B = Container with holes (containing fruits) nested in the second one (containing moist sand), C = Labelled incubated chambers neatly arranged in a rearing room. D = Open plastic tray that can be covered and used as incubation chamber

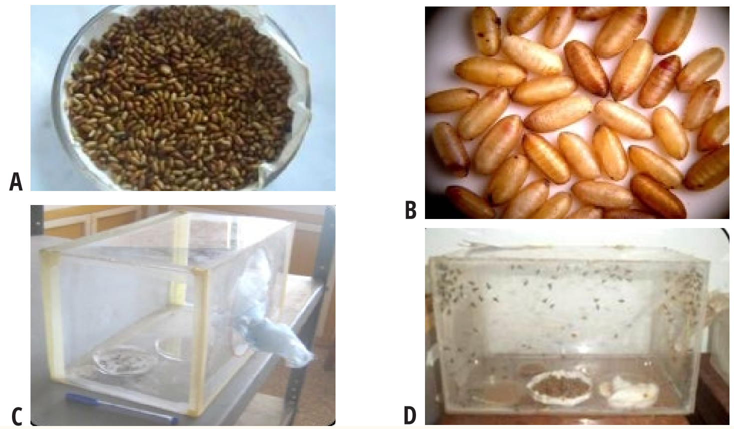


Figure 20. Fruit fly puparia collection from incubated fruits. A = Freshly collected puparia in a petri dish lined with filter paper, B = Close shot of fruit fly puparia, C = Cage for holding petri dishes with puparia, D = Emergence of flies and/or parasitoids in a holding cage

Reporting fruit incubation results

This data can be reported in two ways (i) as number of puparia per weight of fruit (puparia/kilogram), or (ii) as number of puparia per fruit (puparia/fruit), which is a ratio of the total number of puparia obtained in a sample to the total weight of the sample (Cowley *et al.*, 1992). It represents the average number of immature fruit fly stages present either in a specific weight (kilogram) or in a specific number of fruits. It is an indication of the infestation or damage level of the fruits. This method makes it possible to compare levels of infestations even though the number and sizes of fruits and vegetables collected may vary considerably throughout the sampling period. It is therefore advisable that samples are collected more that once during the fruiting season (i.e. at the green mature stage and at the mature harvestable colour-break stage) (Annex 3).

It can be used to compare levels of fly infestations or damage levels of fruits collected from different farms, areas or zones. In the application of field management methods, it is used as a confirmatory tool to tell how effective the control or management option been able to prevent or reduced the number of flies from infesting or attacking the fruits – the lower the index, the better the protection method.

It is calculated as follows:

$$\textbf{Puparia/kg} = \frac{\text{Total number of puparia in collected sample}}{\text{Total weight of fruit in kg}}$$

or

$$\textbf{Puparia/fruit} = \frac{\text{Total number of puparia in collected sample}}{\text{Total number of fruits in collected sample}}$$

Conclusion

Benefits of monitoring

- On-farm monitoring
  - Continuous monitoring not important after assessment
  - Assessment is used for decision-making
  - On-farm monitoring can be done at the beginning, and intensity much reduced afterwards
- Area surveillance
  - Provides important scientific information for control strategies at national level
- Detection monitoring
  - Highly essential
  - Should be done continuously

Organic management methods

Traps and para-pheromones

Under conventional production, traps are usually baited with attractants or para-pheromones that are species-specific. After attraction, flies are killed by the accompanying killing agents that are usually placed in the traps. In the case of organic production, all the different types of para-pheromones can be used, but will require the specific use of a new generation type of trap - the Ecoman Biotech® Fruit Fly Trap (Ecoman Biotech, Beijing, China) (Figure 21). The trap is designed to attract the flies into the trap where they find it very difficult to get out. So even without any killing agent, the trapped flies die naturally inside the trap, as a result of the nature of the design of the lid. The side of the lid has guiding rails or walls that lead attracted insects on in a semi-circular fashion, and eventually to four entry holes (each with a diameter of 1 cm) through which attracted flies gain entry into the trap (Figures 21B and 21C). With four of such semi-circular guiding walls, the lid provides a "labyrinth-like" guide leading to the entry holes. On entry, insects do not stand the chance of getting out of the trap and thus always retain the numbers that are collected for counting.

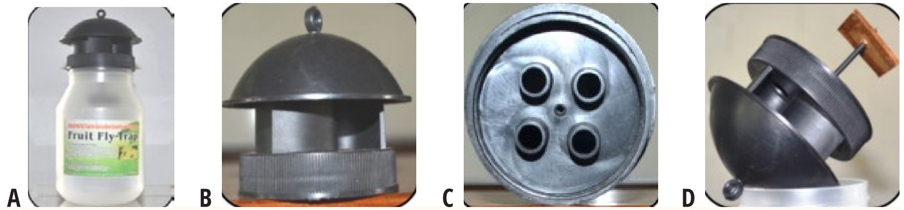


Figure 21. *Recommended trap for use in organic production systems. A = Assembled Ecoman Biotech® Fruit Fly Trap, B = Lid of trap showing the "labyrinth-like" entry holes, C = Trap lid showing the four entry holes from the inside part. D = Absorbent disc fixed to trap lid to carry the attractant (if it is in liquid form)*

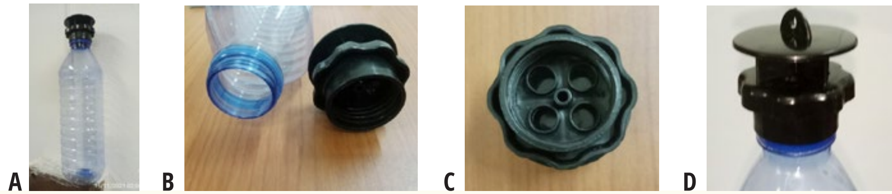


Figure 22. *Improved and affordable trap for fruit flies. A = Assembled water bottle trap fitted with the customized trapping lid, B = Size of the customized lid to fit the opening of most water bottles, C = Trap lid showing the four small entry holes from the inside part. D = A close short of the lid fitted to the water bottle*

In a recent study by Yedu (2021), the performance of six different traps (3 Imported + 3 Home-made) were compared using the same attractant (Methyl Eugenol) over a a 10-week period in three different environments in Legon, Accra. Among the three home-made traps was the use of a 500 ml empty water bottle which was fitted with a smaller version of the lid of the Ecoman trap, with entry holes as small as 0.7 cm in diameter. This trap out-performed all the other 5 traps, and was closely followed by the regular Ecoman trap.

The lid is customized to fit the opening of any standard water bottle with a diameter of 2.9–3.0 cm, including common brands like *Aqua Blue, Bel Aqua, Nero, Paradise Pac, Slemfit, Special Ice* (both new and old bottle designs), *Verna, Voltic* (both round and square bottles), to mention but a few. The added advantage is that these empty water bottles virtually cost nothing (affordable), they are readily available, and accessible – thus meeting the "3-A Management Consideration" (affordability, availability and accessibility). The chances of increasing the density of traps per unit area to undertake mass trapping and achieving fly population suppression can be done within a very short period.

The use of food baits

Despite all the efforts at combating the numerous fruit fly species, the strategies have always been finding species-specific pheromones and baiting them in traps, which usually attract mostly the males. Meanwhile for the females that actually lay the eggs in the fruit, they are not directly targeted by the pheromone traps. It was in this respect that food baits were introduced to attract "all hungry flies". Based on the knowledge of the biology of the pest that adult flies always need a carbohydrate food source, water and protein for proper development, the protein food bait was consequently introduced to complement the other control strategies.

The advantages of the protein food bait include the fact that:

1. They are products that are already mixed with the killing agent or insecticide. In the case of organic production, the killing agent used is Spinosad (Spinosyn A + Spinosyn D), which is a naturally-derived, insecticide generated during fermentation by the actinomycete bacteria, *Saccharopolyspora spinosa*. It has been approved for use in certified organic agriculture in the U.S. by the USDA National Organic Standards Board, and has also been authorized by other government and private certifying bodies in the U.S. including the Organic Materials Review Institute, and by similar organizations in other countries including Argentina, Australia, Guatemala, New Zealand, Peru, and Switzerland.
2. The added killing agent or insecticide is a usually very minimal (0.1–1.0%).
3. Requires only dilution of mixtures for application, thus making it easy to use.
4. Use of coarse droplets at low pressure minimizes spray drift, and there is very little likelihood of contamination.
5. They are less harmful to beneficial organisms like pollinators, and environmentally friendly.
6. Can easily be incorporated into any IPM programme.
7. Highly sweet-scented and attracts various fruit fly species.
8. They use very minimal volumes of water per product – this may be a good climate-smart agric feature (in the face of climate change and global warming). For example GF-120, 1 l : 5 l water, GFFB, 1 l : 3 l water, CeraLure, Used as Trap lure.
9. They only require small volumes of the mixture per tree (50–60 ml) – no blanket spraying is involved.
10. Mixtures are directly only onto foliage as spot sprays – this allows conscious effort at keeping spray away from fruits.
11. The small volumes do allow use of handy and inexpensive spray equipment.
12. They are delivered as Spot sprays over 1 m × 1 m area of the canopy per tree.
13. Spot sprays are less time-consuming than cover spraying whole trees.
14. Spray spots on trees can be changed after each application without losing effect.
15. They target ALL adult fruit fly species of all ages – males, females, young and old.
16. The normal male-female catch rate is around two females per every male (IAEA, 2003).

With these characteristics, protein food baits have now become central to the effective management of fruit flies, as they go beyond the species-specific pheromone traps and other remedy methods. It is in this light that policy formulations have been instituted in certain jurisdictions for the application of food baits when fruit fly outbreaks are report, so they can capture all fruit flies, irrespective of the species.

The downside of the food bait is that:

1. They come in liquid form, and so they are usually bulky.
2. The bulky nature means heavier to import, and therefore makes their importation very expensive.
3. pH of exposed protein baits drop with time, and they lose their attraction with time.
4. They must be applied on regular basis to ensure fresh nature of the food.
5. Baits are easily washed away in regions of high rainfall.
6. Constancy of supply of suck bulky imports are usual not assured.

These drawbacks have forced many countries to either develop food baits from various local protein sources or process existing ones into dry and lighter forms. A typical example is the FreeDome® Food Bait device (Biofeed Ltd, Israel) which was recently evaluated in Ghana. The device is made of a 20 × 20 cm polypropylene material that hangs like a kite, with a maximum horizontal distance of 24 cm in the middle. It has a bright yellow colour that mimics the colour of ripe fruits, and serves as a long distance cue to fruit flies. At the lower part of the kite, is a bright red round absorbent material which mimics the round shape of fruits, and serves as a receptacle for the drops of the food bait released from the holding container (Figure 23).

Figure 23. *FreeDome® trapping device in a mango orchard in*

The protein food bait is held in a 100 ml bottle which is usually inverted downwards and held in receptacle at the top of the kite. A small hole is usually made near the base of the bottle, and drops of the food bait released as at when a drop is completely let out of the bottle or consumed by the flies based on a principle known as the Gravity Controlled Food Release (GCFR). This ensures controlled release of bait and becomes self-dispensing based on need, environmental conditions, and "demand" or consumption rate of the flies. After heavy rainfall, droplets washed away are replaced immediately without farmer re-applying bait. The polypropylene material ensures it does not get sun-beaten or rain-battered with time. This makes the 100 ml bait last as long as 150 days under various environmental conditions in the field.

Some commercially-available food baits include:

- Buminal – Bayer SA, France
- CeraTrap – Bacelona, Spain
- Corn Steepwater – Corn Products, USA
- Great Fruit Fly Bait (GFFB) – Ecoman Company, China
- Hym-lure, Savoury Food Industries Ltd, Johannesburg, South Affrica
- Masoferm E802 – Corn Products International, Eldoret, Kenya
- Mauritius Yeast – Mauritius
- NuLure – Miller Chemical, PA. Hanover, Germany
- Ohly STV – Hamburg, Germany
- Pinnacle Protein Bait – Brisbane, Australia
- Promar – Malaysia
- Royal Tongalure – Tonga
- Solbait – USDA, USA
- SUCCESS Appat (GF-120) – Dow AgroSciences, IN, USA
- Torula Yeast – ISCA Technologies, Riverside, CA, USA

Food baits in various forms and under different names have successfully been used to achieve crop protection ranging from 60–90% in other Pacific Island Countries and Territories such as Vanuatu, Papua New Guinea, Fiji Islands, and the Federated States of Micronesia (FSM).

General fruit fly management strategies and how they work

This involves the use of Bait Sprays (Baits + chemicals-BAT), Male Annihilation Techniques (MAT), Sterile Insect Techniques (SIT), Orchard sanitation, Cultural and other remedy methods, Biological control, and Post-harvest treatments. The most important non-management strategy is Awareness Creation & Capacity Improvement /Development, because it is the experienced human capital that will put all the management tools together to make them work. Meanwhile, direct chemical spraying is now not acceptable in fruit fly management (Billah & Wilson, 2016).

Male Annihilation Techniques (MAT)

This involves the use of para-pheromones - Trimedlure and Terpinyl acetate (for *Ceratitis* species), Methyl eugenol (for *Bactrocera* and a few *Dacus* species), CueLure and VertLure (for Dacus & a few *Bactrocera* species).

Bait Application Techniques (BAT)

Using Food baits – see above.

Biological control – Use of Parasitoids, Predators and Pathogens

Orchard sanitation / Cultural

Post-harvest treatments and

Other remedy methods

Historical usage over time

In the light of changes that have necessitated/ warranted keeping abreast with control strategies, the following quickly come to the fore:

- expanding ranges of species beyond 'traditional' home ranges, etc.;
- indigenous and invasive species in Africa and particularly in Ghana;
- world trade changes;
- improved transportation and movement across the world;
- increased consumption patterns and quest for healthy unblemished F&Vs;
- increased pesticide use and environmental concerns.

Management challenges

The tropical world is endowed with a wide diversity of insects, and there is the co-existence of a complex of fruit flies in Africa, coupled with paucity in knowledge of their biology and ecology, most of the strategies are either *not applicable or unjustified*. These are exacerbated by high economic costs, poor quarantine settings, low investments and profits, and highly fragmented small scale settings.

The "African Ground Plan"

This involves the combination of methods in an "integrated pest management" (IPM) fashion. The primary IPM components include Baiting and Trapping, orchard sanitation / cultural methods, and post-harvest treatments.

Biological control

Use of parasitoids and predators – with the exploratory visit to the purported aboriginal home of the Africa Invader fly, *Bactrocera dorsalis*, some natural enemies were identified and are now being mass-reared for use in Africa. This visit was embarked by Fruit fly Taxonomist, M.K. Billah over a 10-month period between 207 and 2008 (Billah – personal experience).

The two most established ones are one egg-parasitoid, *Fopius arisanus* (Sonan), and one larval-parasitoid, *Diachasmimorpha longicaudatus* (Ashmead), both of which belong to the family Braconidae (Figure 24).

There are other indigenous parasitoids that also have the potential to complement the activities of the classical agents. They include *Psyttalia concolor*. *P. perproximus, Fopius caudatus*, and a few other unidentified *Fopius* species.

Figure 24. *Some natural enemies of fruit flies. A =* Fopius arisanus *(with the characteristic 'beaded' thoracic design), B =* Psyttalia concolor*, and C =* Diachasmimorpha longicaudatus *(also with a characteristic 'continuos-grooved' thoracic design.*

5.2 Fruit fly species and their distribution

A/ Ceratitis cosyra (Walker) (Diptera: Tephritidae)

Common name: Mango fruit fly

Distribution: *Ceratitis cosyra* is a native African species mainly found on mango and widespread in Africa. It has been reported from Benin, Botswana, Central African Republic, Democratic Republic of Congo, Côte d'Ivoire, Ghana, Guinea Kenya, Madagascar, Malawi, Mali, Mozambique, Namibia, Nigeria, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe (White and Elson-Harris, 1992; De Meyer 1998; Copeland *et al*., 2006; De Villiers *et al*., 2013).

Host plants: Typical host range of *C. cosyra* includes mango (*Mangifera indica*), guava (*Psidium guajava*), sour orange (*Citrus aurantium*), marula (*Sclerocarya birrea*), wild custard apple (*Annona senegalensis*) and wild apricot (*Landolphia* sp.) (White and Elson-Harris, 1992). There are also other records from the following families; Anacardiaceae, Anisophylleaceae, Annonaceae, Apocynaceae, Chrysobalanaceae, Combretaceae, Ebenaceae, Fabaceae, Flacoutiaceae, Lauraceae, Myrtaceae, Passifloraceae, Rosaceae and Rubiaceae (De Meyer *et al*., 2002b).

The economic importance of *C. cosyra* has been growing since the widespread commercialization of mango and the introduction of exotic mango varieties. The abundance of *C. cosyra* is influenced by: the bimodal nature of rainfall in sub-tropical Africa; mixed cultivation of early- and late-maturing mango varieties that ensures mangoes are present in the field for a long time; the fact that mango fruits twice a year in some areas; and the proximity of wild hosts to mango orchards. In eastern Africa, *C. cosyra* is the most abundant fruit fly species on mango after *B. dorsalis*, while the reverse is true for West Africa.

B/ Ceratitis ditissima (Diptera: Tephritidae)

Common name: West African citrus fly

Distribution: This species is known to be localized mainly in West Africa, particularly Benin, Cameroon, Congo, Côte d'Ivoire, Ghana, Mali, Mozambique Nigeria, Uganda, and Zimbabwe (Vayssières *et al*., 2007; Foba *et al*., 2012; Aidoo *et al*., 2014).

Host plants: The host range of *C. ditissima* is not that wide, but it is the main species on citrus in West Africa.

(Source: Georg Goergen, IITA, Benin)

(Source: Georg Goergen, IITA, Benin)

C/ Ceratitis rosa (Diptera: Tephritidae)

Common name: Natal fruit fly

Distribution: *Ceratitis rosa* is known from Angola, Democratic Republic of Congo, Ethiopia, Ghana, Kenya, Malawi, Mali, Mauritius, Mozambique, Nigeria, La Réunion, Rwanda, Seychelles, South Africa, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe (White and Elson-Harris, 1992).

Host plants: The host range of *C. rosa* is broad, recorded from over 100 fruit species (White and Elson-Harris, 1992; De Meyer *et al.*, 2002; Copeland *et al.*, 2006; De Villiers *et al.*, 2013)). In most of Africa, it damages mango (*Mangifera indica*), papaya (*Carica papaya*), guava (*Psidium guajava*) and custard apple (*Annona reticulata*). *Annona cherimola, Annona muricata, Annona senegalensis, Citrus* sp., *Eriobotrya japonica, Gloriosa* sp. and *Prunus persica*. It is also a common pest of coffee (*Coffea arabica*) in eastern Africa. *Ceratitis rosa* is a pest of phytosanitary concern that could potentially restrict international trade (Barnes, 2000; Barnes *et al.*, 2007; EPPO, 2007).

D/ Ceratitis fasciventris Bezzi (Diptera: Tephritidae)

Distribution: *Ceratitis fasciventris* was formerly regarded as a variety of *C. rosa*. It occurs in Angola, Burundi, Central African Republic Côte d'Ivoire, Democratic Republic of Congo, Ethiopia, Equatorial Guinea, Ghana, Guinea, Kenya, Mali, Nigeria, Namibia, Rwanda, Sao Tomé & Principé, Tanzania, Uganda, and Zambia (White and Elson-Harris, 1992; Copeland *et al.*, 2006; De Meyer *et al.*, 2015; M. Billah, unpublished data).

Host plants: Recorded from over 40 plant species (De Meyer *et al.*, 2002b). It is a major pest of mango (*Mangifera indica*), guava (*Psidium guajava*) and coffee (*Coffea arabica*) in eastern and western Africa. Others include *Annona senegalensis, Casimiroa edulis, Citrus limoni, Citrus reticulata, Coffea canephora, Dovyalis caffra, Eriobotrya japonica, Ficus* sp., *Harpephyllum caffrum, Passiflora* sp., *Persea americana, Prunus persica, Syzygium jambos, Theobroma cacao, Ziziphus jujube*, as well as other wild fruiting species.

(Source: Bob Copeland,icipe, Nairobi, Kenya)

(Source: Georg Goergen, IITA, Benin)

E/ Ceratitis punctata (Diptera: Tephritidae)

Common name: Cocoa fruit fly

Distribution: This species is found in Cameroon, Congo, Democratic Republic of Congo, Côte d'Ivoire, Guinea, Kenya, Rwanda, Senegal, South Africa Tanzania, Uganda, Zambia, and Zimbabwe (De Meyer 2000; Hala *et al.*, 2006; N'depo *et al.*, 2013).

Host plants: Mango, Cocoa.

(Source: Bob Copeland, icipe, Nairobi, Kenya)

F/ Ceratitis anonae Graham (Diptera: Tephritidae)

Distribution: *Ceratitis anonae* is found in Benin, Cameron, Central African Republic, Côte d'Ivoire, Democratic Republic of Congo, Gabon, Ghana, Equatorial Guinea, Kenya, Mali, Nigeria, Sao Tome & Principe, Senegal, Togo, Tanzania and Uganda (White and Elson-Harris, 1992; Badii *et al.*, 2015).

Host plants: Attacks nearly 50 fruit species. In most of the countries where it is found, it has been reared from guava (Psidium guajava), *Annona muricata, Annona senegalensis, Areca triandra, Citrus paradisi, Citrus sinensis, Coffea canephora, Eugenia uniflora, Mangifera indica, Murraya* sp., *Nephelium lappaceum, Persea americana, Psidium guajava, Rollinia mucosa, Terminalia catappa, Theobroma cacao, Vitellaria paradoxa,* and *Ziziphus jujube* (White and Elson-Harris, 1992; De Meyer *et al.*, 2002b; M. Billah, unpublished data).

G/ Ceratitis capitata (Wiedemann) (Diptera: Tephritidae)

Common name: Mediterranean fruit fly of Medfly

Distribution: *Ceratitis capitata* is the most widely distributed pest fruit fly species. It is recorded from Algeria, Angola, Benin, Burkina Faso, Burundi, Cameron, Congo, Democratic Republic of Congo, Côte d'Ivoire, Egypt, Ethiopia, Gabon, Ghana, Guinea, Kenya, La Réunion, Liberia, Libya, Malawi, Mauritius Morocco, Mozambique, Niger, Nigeria, Sao Tome & Principé, Senegal, Sierra Leone, Seychelles, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda and Zimbabwe (White and Elson-Harris, 1992; De Villiers *et al.*, 2013). Outside its aboriginal home of Africa, it has also been reported in Australia, several European countries, Central, North and South America, the Middle East, Oriental Asia, the Atlantic Islands, Indian Ocean Islands, Pacific Ocean Islands, the West Indies and nearby islands (White and Elson-Harris, 1992).

Host plants: Extremely polyphagous and reared from over 300 commercial and wild host plants (White and Elson-Harris, 1992; De Meyer *et al.*, 2002b).

(Source: Georg Goergen, IITA, Benin)

(Source: Georg Goergen, IITA, Benin)

H/ Ceratitis rubivora (Coquillett) (Diptera: Tephritidae)

Common name: Blackberry fruit fly

Distribution: *Ceratitis rubivora* is recorded from Cameroon, Ghana, Kenya, Malawi, Tanzania, South Africa, Uganda and Zimbabwe (White and Elson-Harris, 1992).

Host plants: Principally a pest of berry of the genus *Rubus*, occurring on blackberry (*R. fruticosa*), loganberry (*R. loganobaccus*) and raspberry (*R. idaeus*) (White and Elson-Harris, 1992; De Meyer *et al.*, 2002b).

I/ Ceratitis quinaria (Diptera: Tephritidae)

Common name: Five-Spottef fruit fly

Distribution: Countries with established infestations of *C. quinaria* include Benin, Botswana, Burkina Faso,, Côte d'Ivoire, Guinea, Ghana, Namibia, Malawi, Mali, Senegal, South Africa, Sudan, Togo, Yemen and Zimbabwe (Hancock *et al.*, 2001; White and Elson-Harris 1992; De Meyer 1998; De Meyer *et al.*, 2002; Vayssières *et al.*, 2005).

Host plants: mango trapping and rearing data indicate that *C. quinaria* is most abundant during the dry season, causing damage only to early-maturing cultivars of (Vayssières *et al.*, 2005). There is a positive relationship between high temperature, relative humidity and rainfall.

(Source: Bob Copeland, icipe, Nairobi, Kenya)

J/ Ceratitis silvestrii (Diptera: Tephritidae)

Distribution: This species has been reported attacking mango in Nigeria, Senegal, Mali, Burkina Faso and Niger (Vayssières *et al.*, 2005). *Ceratitis silvestrii* is an important pest of mango in several parts of West Africa, mainly found co-existing with *C. quinaria* (Ouedraogo *et al.*, 2010; Sawadogo *et al.*, 2013). *Ceratitis silvestrii* is most abundant during the dry season causing damage to early-maturing mango cultivars (Vayssières *et al.*, 2009). In Mali, 7.28 % of fruit flies reared from mango were *C. silvestrii* (Vayssières *et al.*, 2007) and in Benin 2.77 % of fruit flies were *C. silvestrii* (Vayssières *et al.*, 2015).

(Source: Georg Goergen, IITA, Benin)

(Source: Georg Goergen, IITA, Benin)

K/ Bactrocera dorsalis (Diptera: Tephritidae)

Common name: Africa invader fly

Distribution: *Bactrocera dorsalis* is a recently described invasive fruit fly species of Asian origin (Drew *et al.*, 2005). In Africa it has been recorded from Angola, Benin, Bostwana, Burkina Faso, Burundi, Cameroon, Central African Republic, Cape Verde, Chad, Comoros Archipelago, Côte d'Ivoire, Mayotte, Republic of the Congo, Democratic Republic of Congo, Ethiopia, Eritrea, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, Kenya, Liberia, Mali, Mauritania, Mozambique, Namibia, Niger, Nigeria, Senegal, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zimbabwe and Zambia (Drew *et al.*, 2005; Vayssières *et al.*, 2005; Mwatawala *et al.*, 2006; Correia *et al.*, 2008; Rwomushana *et al.*, 2008; Goergen *et al.*, 2011; Manrakhan *et al.*, 2011; Virgilio *et al.*, 2011; De Meyer *et al.*, 2008, 2012; Ibrahim Ali *et al.*, 2013; Aidoo *et al.*, 2014; Fekadu and Zenebe, 2015; Hussain *et al.*, 2015; Isabirye *et al.*, 2015). It was discovered in Sri Lanka soon after it was reported from Africa (Drew *et al.*, 2005).

Host plants: It has been reared from mango (*Mangifera indica*), lemon orange (*Citrus limoni*), tomato (*Lycopersicum esculentum*), banana (*Musa* spp.), guava (*Psidium guajava*), marula (*Sclerocarya birrea*), custard apple (*Annona muricata*), Indian almond (*Terminalia catappa*), *Sorindea* sp. and avocado (*Persea americana*) (I. Rwomushana, unpublished data; Z. Seguni et al., unpublished data).

(Source: Georg Goergen, IITA, Benin)

Mango, however, appears to be the primary host plant (Ekesi *et al.*, 2006). *Garcinia mannii, Terminalia catappa, Ziziphus mauritiana, Garcinia mannii, Terminalia catappa, Ziziphus mauritiana, Irvingia gabenensis, Syzigium jambo, Erioborya japonica, Ficus sycomorus, Sclerocarya birrea, Psidium guajava, Vitellaria paradoxa, Psidium guajava. Diospyros Montana, Saba senegalensis, Maerua duchesnei, Syzigium malaccense, Chrysphyllum albidum, Citrus limon, C. sinensis C x paradisi Citrullus colcynthis Annona sinensis, C. x paradisi, Citrullus colcynthis, Annona senegalensis, Lycopersicon esculentum, Citrullus lanatus, Capsicum frutescens, Cucurbita maxima Momordica charantia C reticulata Persea americana Blighia Momordica charantia, C. reticulata, Persea americana, Blighia sapida, Spondias mombin, Averrohoa carambola, Anacardium occidentale, Annona muricata, Cucurbita pepo, Cucumis sativus, Musa x paradisiaca, Sarcocephalus laifolius, Carica papaya, Spondias cytherea, Lagenaria siceraria*.

Currently, B. *dorsalis* is continuing to spread, not only in latitude but also in altitude However, the continuous spread and colonization of higher altitudes seems to be limited by climatic conditions, host availability and suitability, and inter-specific competition with cold-tolerant species. The species is thought to have invaded Africa from the Indian subcontinent and it was discovered in Sri Lanka after it was first reported from Africa (Drew *et al.*, 2005), where it has become a significant pest of quarantine and economic importance.

L/ Zeugodacus cucurbitae (Coquillet) (Diptera: Tephritidae)

Common name: Melon fly

Distribution: *Zeugodacus cucurbitae* is an invasive pest species in Africa and is recorded from Benin, Cameron, Egypt (Lower Nile Valley), Ghana, Kenya, Nigeria and Tanzania (White and Elson-Harris, 1992; R. Hanna *et al*., unpublished data; M.K. Billah, unpublished data). It is native to Oriental Asia and has also been reported from Hawaii, Iran, the Indian Ocean Islands of Mauritius and Reunion, and the New Guinea area (White and Elson-Harris, 1992).

Host plants: This pest has been reared from over 125 fruit species. Plants in the family *Cucurbitaceae* are, however, the usual hosts.

Zeugodacus cucurbitae is an invasive pest species in Africa and has been recorded from Benin, Burkina Faso, Burundi, Cameroon, Côte d'Ivoire, Democratic Republic of Congo, Ethiopia, Gambia, Ghana, Kenya, Malawi, Mali, Mozambique Niger, Nigeria, Sierra Leone, Senegal, Sudan, Tanzania, Togo, and Uganda (White and Elson-Harris 1992; Vayssières and Carel, 1999; De Meyer *et al.,* 2007, 2015).

Zeugodacus cucurbitae is abundant throughout Central and East Asia (including Pakistan, India, Bangladesh, Nepal, China, Indonesia and the Philippines) and Oceania (including New Guinea and the Mariana Islands) (Dhillon *et al*., 2005; Drew 1989; Drew *et al*., 1982; Drew and Romig 2013). In some of these regions it has been introduced more than once and subjected to a number of eradication programmes (Suckling *et al*., 2014). It has been detected a number of times in the Hawaiian Islands and California (Papadopoulos *et al*., 2013) and its presence there was also the result of accidental human-mediated introduction. The first record of this species from the African mainland was restricted to coastal Tanzania and Kenya, and dates back to 1936 (Bianchi and Krauss 1937). Despite its occurrence in eastern Africa for many decades, *Z. cucurbitae* apparently did not spread rapidly to other parts of the continent until the late 1990s when it was reported from other parts of Africa. Currently, it is present in more than 25 countries namely: Tanzania, Kenya, Mauritius, La Réunion, Gambia, Côte d'Ivoire, Seychelles, Mali, Burkina Faso, Guinea, Nigeria, Cameroon, Senegal, Ghana, Benin, Niger, Democratic Republic of Congo, Togo, Sudan, Sierra Leone, Uganda, Burundi, Ethiopia, Malawi and Mozambique (Vayssières and Carel 1999; White *et al*., 2001; De Meyer *et al*., 2012, 2015). The wide dispersal of this insect has increased awareness of its economic significance but not much research has been devoted to this species in comparison to other cucurbit-infesting fruit flies, except in La Réunion (White and Elson-Harris 1992; Vayssières and Carel, 1999; Ryckewaert *et al*., 2010) and Mauritius (Sookar *et al*., 2012, 2013).

L1

(Source: Georg Goergen, IITA, Benin)

L2

(Source: Bob Cipeland, icipe, Nairobi, Kenya)

M/ Bactrocera zonata (Saunders) (Diptera: Tephritidae)

Common name: Peach fruit fly

Distribution: *Bactrocera zonata* is native to South and Southeast Asia. In Africa it occurs in Egypt and the Indian Ocean island of Mauritius. It has also been reported from Israel.

Host plants: Attacks over 20 host plants (White and Elson-Harris, 1992). It is a major pest of mango (*Mangifera indica*) in Egypt, Mauritius and Sudan.

Bactrocera zonata mainly attacks peach, guava and mango (White and Elson-Harris 1992; Allwood *et al*., 1999; Shehata *et al*., 2008). It is reported from some of the islands in the Indian Ocean (Mauritius and La Réunion) and is now widespread in northern Africa (Egypt and Libya). There is a potential risk of invasion for Sub- Saharan region (De Meyer *et al*., 2007, Ni *et al.,* 2012) have predicted that, under current climatic conditions, *B. zonata* would be able to establish itself throughout much of the tropics and subtropics.

In Egypt *B. zonata* reaches significantly higher abundances than any of the other native fruit fly species (Elnagar *et al*., 2010). It appears to prefer warmer conditions and seems well adapted to hot climates. Since its introduction in Egypt, *B. zonata* has gradually become so widespread that it has surpassed *C. capitata* as the major fruit pest in Egypt. The abundance of *B. zonata* is significantly correlated with temperature and relative humidity and its population growth rate is higher than that of native species. The availability of suitable host plant species plays a role in the abundance of *B. zonata*. (El-Gendy and Nassar Atef 2014). In Mauritius, it mainly feeds on mango, guava, peach and jujube (Sookar *et al*., 2014). In Egypt, sour orange was the most susceptible host, followed by sweet orange and guava (Amro and Abdel-Galil, 2008). At Fayoum governorate (Egypt), *B. zonata* infested 15.5% of Navel orange, 10% of grapefruit, 7% of mandarin, 5.7% of sour orange, 0.3% of lemon and 0.6% of Valencia orange (Saafan *et al*., 2005). Potato tubers collected from Giza governorate, Egypt, during 2004 were also found to be infested by *B. zonata* (El-Samea and Fetoh, 2006).

This is one of the most harmful tephritid species. It is native to India where it was first recorded in Bengal (Kapoor, 1993). It is present in South and Southeast Asia: Bangladesh, Bhutan, Iran, Laos, Myanmar, Nepal, Oman, Pakistan, Saudi Arabia, Sri Lanka, Thailand, United Arab Emirates, Vietnam and Yemen. In Africa, *B. zonata* was first recorded in Egypt in 1924 and since then it has spread to Libya, the Indian Ocean islands of Mauritius and La Réunion (Hashem *et al*., 2001; Quilici *et al*., 2005). Recently it has been reported from several regions in Sudan, suggesting a southward spread and potential risk of invasion of the sub-Saharan region (El-Samea and Fetoh 2006; De Meyer *et al*., 2007; Shehata *et al*., 2008; Elnagar *et al*., 2010; EPPO 2013). This clearly demonstrates that this pest has the ability to establish outside tropical climates (Hashem *et al*., 2001), and adapt to local conditions (Iwahashi and Routhier 2001). Pest risk analysis suggests that *B. zonata* would be capable of entering, establishing and spreading in coastal areas of the Mediterranean region, causing significant damage to horticultural production (Delrio and Cocco 2010).

M

(Source: Aruna Manrakhan, CRI, South Africa)

N/ Dacus bivittatus (Bigot) (Diptera: Tephritidae)

Common name: Pumpkin fly

Distribution: *Dacus bivittatus* is known from Angola, Cameron, Democratic Republic of Congo, Ghana, Kenya, Malawi, Mozambique, Nigeria, Senegal, Sierra Leone, South Africa, Tanzania, Uganda and Zimbabwe (White and Elson-Harris, 1992).

Host plants: Mainly attacks cucurbits and has been reared from cucumber (*Cucumis sativus*), cantaloupe (*Cucumis melo*), watermelon (*Citrullus lanatus*), white egusi (*Cucumeropsis mannii*), African horned cucumber (*Cucumis metuliferus*), Bitter gourd (*Momordica charantia*), Chayote (*Sechium edule*), Luffa (*Luffa aegyptiaca*), Oyster nut (*Telfairea pedata*), Pumpkin (*Cucurbita pepo*) and White flower gourd (*Lagenaris siceraria*). A few other non-cucurbit hosts have also been recorded (White and Elson-Harris, 1992).

Dacus ciliatus is widely distributed in Africa occurring in Angola, Benin, Botswana, Burkina Faso, Cameroon, Chad, Democratic Republic of Congo, Côte d'Ivoire, Egypt, Ethiopia, Gabon, Ghana, Guinea, Kenya, Lesotho, Madagascar, Malawi, Mozambique, Namibia, Niger, Nigeria, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia and Zimbabwe (White and Elson- Harris 1992).

Dacus bivittatus is a widespread species occurring throughout Africa, especially in Angola, Cameroon, Chad, Egypt, Eritrea, Democratic Republic of Congo, Ghana, Kenya, Malawi, Mozambique, Nigeria, Senegal, Guinea, Seychelles, Mayotte and the Comoros, Sierra Leone, South Africa, Tanzania, Uganda, Botswana, Guinea, Côte d'Ivoire, Togo, Benin, Gabon, Congo, Ethiopia, Sudan, Somalia, Rwanda, Namibia, Zambia, Lesotho, La Réunion, Mauritius, Madagascar and Zimbabwe (White and Elson-Harris 1992; IIE 1995; White *et al.*, 2000; Bordat and Arvanitakis, 2004; De Meyer 2009; De Meyer *et al.*, 2015).

O/ Dacus ciliatus Loew (Diptera: Tephritidae)

Common name: Lesser pumpkin fly

Distribution: *Dacus ciliatus* is widely distributed in Africa occurring in Angola, Botswana, Cameroon, Chad, Democratic Republic of Congo, Egypt, Ethiopia, Ghana, Guinea, Kenya, Lesotho, Malawi, Mozambique, Nigeria, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Tanzania, Uganda, Zambia and Zimbabwe (White and Elson-Harris, 1992).

Host plants: A pest of cucurbit crops recorded from nearly 20 commercial host plants (White and Elson Harris, 1992). A few non-curcubits including beans (*Phaseolus* spp.), cotton (*Gossypium* sp.), okra (*Abelmoschus esculentus*) and tomato (*Lycopersicum esculentum*) are also hosts. Several wild Cucurbitaceae are also host to *D. ciliatus* (White and Elson-Harris, 1992).

(Source: Bob Copeland, icipe, Nairobi, Kenya)

(Source: Georg Goergen, IITA, Benin)

This species is widespread in Africa but also occurs in the Near and Middle East, and South Asia. On the African continent it appears to thrive in the drier regions, such as the Sahelian, Karoo, Angola, Botswana, Cameroon, Chad, Democratic Republic of Congo, Egypt, Ethiopia, Ghana, Guinea, Kenya, Lesotho, Malawi, Mozambique, Nigeria, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Tanzania, Uganda, Côte d'Ivoire, Burkina Faso, Togo, Benin, Niger, Gabon, Madagascar, Namibia, Zambia and Zimbabwe (White and Elson-Harris 1992). It has also been reported on the Indian Ocean islands of Mauritius and La Réunion (White 2006) and on Madagascar (Mansell 2006).

P/ Dacus frontalis Becker (Diptera: Tephritidae)

Common name: Pumpkin fly

Distribution: *Dacus frontalis* occurs in the Cape Verde Islands, Egypt, Ghana, Kenya, Lesotho, South Africa, Sudan, Tanzania and Zimbabwe (White and Elson-Harris, 1992). Outside Africa, it occurs in Saudi Arabia and Yemen Arab Republic.

Host plants: It is a pest of cucurbits attacking cucumber (*Cucumis sativus*), pumpkin (*Cucurbita pepo*), sweet melon (*Cucumis melo*) and watermelon (*Citrullus lanatus*). Colocynth (*Citrullus colocynthis*) is an important alternative host. It also attacks a species of gourd (*Coccinia* sp.) and a squash (*Cucurbita* sp.) (White and Elson-Harris, 1992).

Dacus frontalis is also widely distributed in the African continent. Amongst the dif- ferent tephritid species, it is considered locally as a very serious pest of cucurbits in many countries in Africa and the Middle East (Ekesi and Billah 2007). It was reported in Tunisia for the first time in 2015, where it was found in several locations (Hafsi *et al.*, 2015). It has also been reported in South Africa, Kenya, Zimbabwe, Namibia, Tanzania, Eritrea, Angola, Lesotho, Congo, Botswana, Nigeria, Cape Verde, Benin, Egypt and Sudan. There are also some records of its presence in North Africa in Algeria and Libya. It also occurs outside Africa in the Middle East in Yemen, the United Arab Emirates and Saudi Arabia (White 2000; EPPO 2003; Ekesi and Billah 2007).

Q/ Dacus lounsburyii Coquillett (Diptera: Tephritidae)

Distribution: *Dacus lounsburyii* is reported from Angola, Kenya, South Africa and Zimbabwe (White and Elson-Harris, 1992).

Host plants: It is a rare species that attacks mainly cucurbits including pumpkin (*Cucurbita pepo*), sweet melon (*Cucumis melo*) and watermelon (*Citrullus lanatus*) (White and Elson-Harris, 1992).

(Source: Bob Copeland, icipe, Nairobi, Kenya)

(Source: Bob Copeland, icipe, Nairobi, Kenya)

R/ Dacus punctatifrons Karsch (Diptera: Tephritidae)

Distribution: *Dacus punctatifrons* occurs in Angola, Cameroon, Ghana, Nigeria, Kenya, Sierra Leone, South Africa, Tanzania, Uganda, Zambia and Zimbabwe (White and Elson-Harris, 1992). It also occurs on the Indian Ocean island of Mauritius and in Yemen.

Host plants: It has been reared from pumpkin (*Cucurbita pepo*), cucumber (*Cucumis sativus*), bitter gourd (*Momordica charantia*), chayote (*Sechium edule*) and wild watermelon (*Passiflora foetida*) and a few wild Cucurbitaceae (White and Elson-Harris, 1992).

Dacus punctatifrons is widespread and has been recorded in several African coun- tries including Angola, Benin, Botswana, Cameroon, Congo, Democratic Republic of Congo, Ethiopia, Gabon, Ghana, Guinea, Côte d'Ivoire, Kenya, Liberia, Malawi, Mozambique, Niger, Nigeria, South Africa, Sudan, Tanzania, Togo, Uganda, Sierra Leone, Zambia, Namibia, Burundi, Rwanda, Swaziland, Madagascar and Zimbabwe, with a (possible) adventive population in Yemen (White and Elson-Harris, 1992; Mansell, 2006; White and Goodger 2009; De Meyer *et al.*, 2015).

S/ Dacus vertebratus Bezzi (Diptera: Tephritidae)

Common name: Jointed pumpkin fly

Distribution: This pest is found in Angola, the Gambia, Ghana, Kenya, Nigeria, Senegal, South Africa, Tanzania, Zambia and Zimbabwe (White and Elson-Harris, 1992). It also occurs in the Indian Ocean island of Madagascar, and in Saudi Arabia and Yemen.

Host plants: A pest of cucurbits with strong prefer- ence for watermelon (*Citrullus lanatus*). It also attacks cantaloupe (*Cucumis melo*), cucumber (*Cucumis sativus*), squash (*Cucurbita maxima*) and white egusi (*Cucumeropsis mannii*). Several other wild *Cucurbitaceae* are also attacked (White and Elson-Harris, 1992).

This species is a widespread cucurbit feeder, occurring in most Afro-tropical countries including, Angola, Botswana, Cameroon, Chad, Democratic Republic of Congo, Ethiopia, Ghana, Guinea, Kenya, Malawi, Mozambique, Nigeria, Senegal, South Africa, Sudan, Tanzania, Uganda, Côte d'Ivoire, Burkina Faso, Togo, Benin, Niger, Gabon, Madagascar, Namibia, Zambia, Zimbabwe, Gambia, Liberia, Mali, Burkina Faso, Gabon, Eritrea, Madagascar, Rwanda, Swaziland, Mayotte and the Comoros as well as the Arabian Peninsula (Bordat and Arvanitakis, 2004; De Meyer *et al.* ,2015).

(Source: Georg Goergen, IITA, Benin)

(Source: Georg Goergen, IITA, Benin)

5.3 Other insects

A/ Mango Seed/Stone Weevil (MSW) – *Sternochetus mangiferae* (Fabricius)

Eggs are elliptical, about 0.8 mm long and 0.3 mm wide and are creamy-white in colour when freshly laid. They are laid singly in small cavities made by the females in the skin of young fruits, and may also be laid into inflorescences. The females then cover each egg with brown exudates and cut a very small crescent-shaped area (0.3 mm) in the fruit, near the back end of the egg. The wound creates a sap flow, which hardens and covers the egg with a protec- tive coating. Several eggs may be laid in each fruit. Incubation requires 5 to 7 days.

The larvae are white grubs with curved bodies, have brown heads, and have no legs. New larvae are slender and elongated, and about 1 mm long. Mature larvae are about 17 mm long. After hatching, the larvae burrow through the flesh and into the seed before they mature to be hard. Development of the larvae is usually completed within the maturing seed, and occasionally within the flesh.

The pupae are whitish when newly formed, but change to a pale red colour just before the adult emerges. They are about 8 mm long and 7 mm wide, and pupation takes place within the stone of the fruit.

The adults have a compact body about 8 mm long, and are dark greyish-brown with paler patches. They are usually active at dusk, and can fly, but not known to be strong fliers. They feign death or pretend to be dead when touched or disturbed.

They are well camouflaged on the bark of mango tree trunks, in branch terminals, or in crevices near mango trees during non-fruiting periods. They may also live in leaf litter around the tree. During flowering the adults leave their hiding places and move into the canopy of the tree to feed on new growth and to mate. Females start egg laying 3 to 4 days after mating, when the fruits are about marble-size. Adults feed on mango leaves, tender shoots or flower buds, and can live for up to two years. The life cycle takes about 40 to 50 days.

Figure 25. *Abdominal morphology of* Sternochetus *spp. (Source: Poonchaisri and Chaowalit, 2008)*

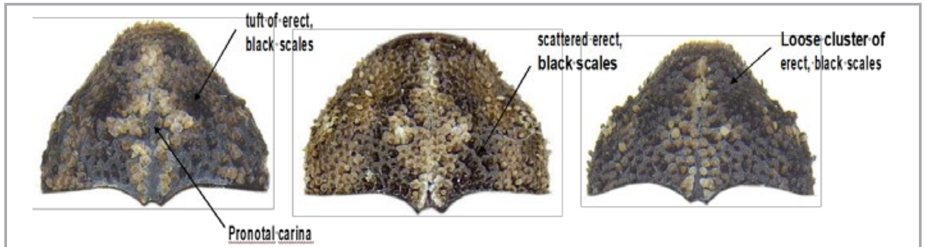


Figure 26. *Pronotal morphology of* Sternochetus *spp. (Source: Poonchaisri and Chaowalit, 2008)*

Management

Adults usually emerge after fruits fall and enter a diapause until the following fruiting season. Long-range dispersal occurs through the transport of fruit, seeds, seedlings and/or cuttings containing larvae, pupae or adults. The greatest damage caused by this pest is to interfere with fruit export because of quarantine restrictions. The damaged fruits have obvious hard, amber-coloured, protective resin marks over eggs on the fruit skin, often resulting in fruits being downgraded. For late-maturing cultivars, emerging adults can cause post-harvest damage to the fruit flesh. *S. mangiferae* infestation can increase fruit drop during early fruit development, and reduce the germination capacity of seeds.

Mango seed weevil is a quarantine pest. Probably its greatest significance as a pest is to interfere with the export of fruit because of quarantine restrictions imposed by importing countries and the market requirement for blemish-free fruits. This is particularly troublesome in the case of the mango seed weevil because, in many instances, weevil attack remains undetected in the field, and is first noticed in storage or in transit. The international quarantine infestation threshold of the mango weevil is 2.5% (i.e. one out of 40 fruits) (Soe *et al.*, 1974; Bagshaw *et al.*, 1989). This rather low threshold requires that serious attention is paid to the problem posed by the weevil.

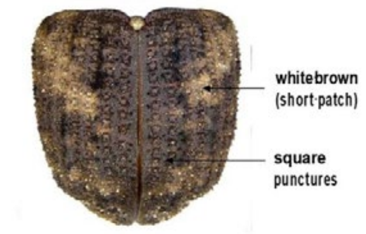


Figure 27. *Elytral morphology of* Sternochetus *spp. (Source: Poonchaisri and Chaowalit, 2008)*

Figure 28. *Morphology of* Sternochetus *spp. (Source: Oberprieler, 2008)*

Table 3. *Morphological identification of mango weevil,* Sternochetus *(Source: Oberprieler, 2008; Poonchaisri and Chaowalit, 2008).*

Scientific name	Pronotum	Elytra	Aedeagus
Sternochetus olivieri (Faust)	Medially with a conspicuous carina (keel) in basal $^2/_3$ of length, which is flanked on either side by a line of white scales and its anterior end (in middle of pronotum) by tuft of dense, erect black scales.	Large, whitish macula (patch) stretching from just behind humeri (shoulders) to top of declivity, inscribing a black, inverted medial triangle before middle of length and sometimes posteriorly interrupted by a fainter, dark, transverse band above declivity.	With sides nearly parallel, apically broadly rounded and no internal scerites.
Sternochetus mangiferae (Fabricius)	With sides nearly parallel from base to beyond middle, inter-striae flat to faintly but evenly costate (ridge), strial punctures rectangular to square, whitish macula forming a more or less distinct V and transverse posterior band.	With erect black scales scattered over basal part of pronotal disk.	With pair of internal sclerites separate, not touching apically.
Sternochetus frigidus (Fabricius)	Narrowing from base to apex, odd interstriae except sutural one distinctly costate-tuberculate, strial punctures round, whitish macula fragmented but usually forming a vague anterior inverted triangle inscribing a similar, smaller black median triangle and a broken posterior band on declivity.	With erect black scales arranged in medial pair of loose cluster.	With pair of internal sclerites overlapping apically.

5.4 Bugs

Several species of bugs feed on mangoes. The adults have well-developed wings and can fly when disturbed, while their young ones (nymphs) look like the adults but have no wings. The wings only develop with time until they are fully matured as adults. Both adults and nymphs feed by inserting their needle-like mouthparts into young softer tissues to such up sap or juices. This feeding activity leads to die-back, tip wilting, fruit fall, or fruit deformation, depending on the type of bug and point of feeding. The feeding points may also serve as entry points for secondary infections of other disease-causing organisms.

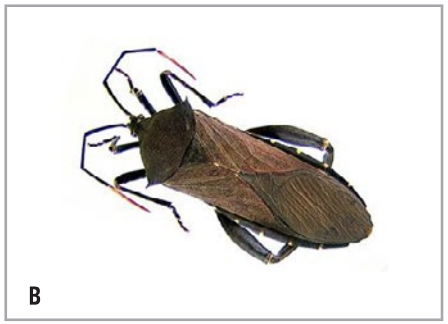
A/ The Coconut bug – *Pseudotheraptus devastans* (Hemiptera: Coreidae)

This is a reddish brown bug that lays eggs singly but scattered on fruits over fruits, flowers, small twigs, and blossom stems. The nymphs are light brown with relatively long thick antennae (up to the length of the rest of the body). They feed on the fruits, causing dark brown or grey damage indentations on the skin of young fruits, which eventually drop. In mature fruits, they cause sunken lesions on the skin.

In recent times, another species, *Gonocerus acuteangulatus* (Goeze), similar to the Coconut has been recorded on mango in the Greater-Accra, Central and Volta regions of Ghana (Billah, M.K., unpublished data).

B/ Tip Wilters (Hemiptera: Coreidae)

These are sap-sucking insects of many agricultural crops, including many in the genus *Anoplocnemis* Stål. They are large (about 25 mm long) dark-coloured bugs. Both adults and nymphs feed on flower stalks, on mid-vein of young leaves or on young vegetative flushes, leading to the wilting and death of new growths. The trees are then forced to develop new shoots, which may result in considerable growth retardation. These pests are particularly devastating to young trees (Varela and Seif, 2005).



(Source: Georg Goergen, IITA, Benin)

C/ Helopeltis bug

This is also known as the Mosquito bug, and about 7–9 mm long. They are slender in shape, with long legs and antennae, and vary in colour from red, orange or brown to yellow. Adults and nymphs feed on fruits and young shoots which cause dark lesions with a light brown centre on fruits, while stem lesions tend to cause longitudinal splits which become corky. The young shoots tend to die back as a result of the toxic saliva that leads to vigorous secondary branching.

(Source: Varela & Seif, 2005)

D/ Thrips

Thrips are minute (0.5–2.0 mm), slender insects with long narrow wings that are fringed with hairs. When at rest, the wings lie dorsally along the body. Thrips species mostly feed by puncturing and sucking up the contents, and vary in colour from black or brown to yellowish orange. There are over 6,000 species with so many of them closely related, and therefore very difficult to identify.

The females lay eggs into the plant tissue which hatch into small green wingless larvae after a few days. The nymphs (young thrips) are cream yellow with two bright red bands around their body. The nymphs and the adult feed by rubbing and sucking the sap from the surface, dropping faeces onto the surface and leaving dark rusty stains. They also feed on young fruits leaving permanent, rough, greyish, scars which makes the fruits unmarketable on maturity. High populations of flower thrips, *Frankliniella* spp. may lead to loss of fluid and pollen, and consequently cause flower shrinkage, loss of pollen, flower abortion or poor fruit formation.

Several species are found on mango however their roles vary accordingly. When found on flowers, fruits, young leaves or twigs, they are known to cause leaf malformation and stunted growth, lesions or chlorotic spots on fruits, at times leading to fruit drop. Examples of such species include the Citrus thrips, *Scirtothrips aurantii* Faure, and the Red-banded thrips, *Selenothrips rubrocinctus* (Giard). Thrips may be very important pests during the dry season.

Management

As a result of their small sizes, thrips are very difficult to manage with pesticides as their hiding places become difficult to access. Pruning helps get rid of thrips. The use of natural enemies becomes one of the most efficient methods. These natural enemies include ladybird beetles, predatory thrips and predatory mites, which need to be conserved in the orchard. Thrips on flowers can be eliminated as soon as scouting shows signs of damage by using a mild insecticide like insecticidal soap or neem oil. Insecticidal soap kill harmful insects like mites, aphids, thrips, white flies and immature leafhoppers. The fatty acids in the soap dissolve the insects' exoskeleton, causing them to dehydrate.

If chemicals are needed under extremely high populations (especially in commercial orchards), insecticides that can be used include Abamectin, Azadirachtin, Deltamethrin, Lambda-cyhalothrin, which must be confirmed from the EPA approved list of chemicals. When using a pesticide, always wear protective clothing and follow the instructions on the product label, such as dosage, timing of application, and pre-harvest interval.

(Source: Heather Broccard-Bell, Gardeningknowhow.com)

E/ Aphids

Aphids are tiny oval to pear-shaped soft-bodied insects (1.0–2.5 mm) with long antennae and usually a pair of horn-like structures (cornicles) at the posterior end of the abdomen. They could be brown, reddish-brown to blackish-brown or greyish-green to blackish-green, and covered with a light powdery dusting. They could also be winged or wingless, with the wingless ones being the most common. Females do not usually lay eggs, but give birth to wingless young ones called nymphs. Both adults and nymphs live in clusters on the underside of young leaves, on petioles, young branches, and suck sap which leads to slight rolling, twisting or bending of the leaf midribs. They usually suck more than needed, and the excess is excreted as honeydew which tastes sugary. With time, the honeydew gets contaminated and dries off on the surfaces as sooty mould, and eventually leading to minimizing photosynthetic activities of the leaves and the market value of the fruits.

Aphids are usually controlled by natural enemies such as ladybird beetles, lacewings, hover flies and parasitic wasps. The tiny nature of the pest requires that close and frequent scouting is undertaken to detect early infestation and prevent population build up. Heavy infestation may warrant spraying with mineral oils, ash and soapy solutions, and only at affected parts.

Management

Since these bugs usually feed on a wide range of crops and are mobile, it is difficult to control them as they can always reinvade orchards from neighbouring crops. The best way is to regularly monitor and collect them by hand, especially on young trees during flushing and fruit development. Predators such as assassin bugs, spiders, praying mantises, and ants, are important for controlling or deterring them. Weaver ants and tree-nesting ants give effect protection against many of the bugs, especially the Coconut bug.

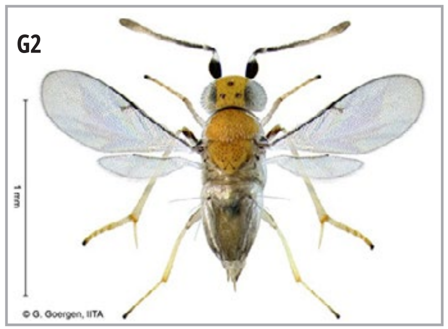
F/ Mango Mealybugs

Mealybugs are small soft-bodied sap-sucking insects with a white woolly covering on the body. The woolly material tends to form a non-wetable fluffy that covers the dorsal side and most part of their bodies. It is this feature that prevents liquids from reaching the body, and thus giving them the characteristic notoriety of them being very difficult to control/manage by chemical sprays. They occasionally occur in large numbers on tender leaves, petioles, twigs, and fruits. They suck so much sap, and usually get rid of the excess by excretion which has a sweet taste known as honey dew, that attracts other organisms, including ants, which collect the honey dew and protect the mealybugs from natural enemies. After a long period, they get contaminated with micro-organisms and dust, and eventually lead to the formation of a thin layer mould on the surfaces known as sooty mould, which reduces photosynthetic activity, and cause leaf drop. Severe infestation may lead to leaves turning yellow and gradually drying and shedding of leaves or inflorescence, reduce fruit setting, and shedding of young fruits.

G/ Rastrococcus invadens (Green)

Common name: Mango mealybug

Field Characters: Body oval; slightly rounded in lateral view; body light yellow to pale green; mealy wax thin, allowing body colour to show through, without a medial longitudinal crest; with triangular-shaped bare area on medial area of body, widest portion of bare area on prothorax or head, narrowest on abdomen; ovisac absent; with 17 pairs of unusually long lateral wax filaments, anterior 2 pairs (head) nearly as long as body, next 6 pairs (thoracic) all about same length next 9 pairs (abdominal) becoming progressively longer at the posterior end, anterior-most pair about equal to greatest width of body, posterior pair nearly 4 times length of body. It occurs on foliage of hosts. Ovoviviparous, first instars light yellow.



G2: *Gyranusoidea tebygi* – Mango mealybug parasitoid
(Source: Georg Goergen, IITA, Benin)

6. Harvesting of mango

6.1 Introduction

Proper harvesting of mango fruits is essential for maintaining fruit quality after harvest and to extent the shelf life of the fruits. When mango fruits are not harvested properly, they do not ripe well and may deteriorate faster in storage. Proper harvesting of fruits entails harvesting fruits only when they are at the appropriate maturity stage and the adoption of proper harvesting procedures. This chapter discusses the importance and how to determine the maturity level of the fruit. It also discusses the strategies for the proper harvesting of the fruits when they are mature.

6.2 Importance and determination of mango fruit maturity level

Mango fruits for the market must be harvested when they are mature. When fruits are harvested when they are not mature, they will not ripe properly and may shrivel and become rubbery with poor skin and pulp colour. Such fruits may emit very little aroma and cannot be marketed. It is therefore important, that the maturity of a fruit is determined before harvesting. Determining the physiological maturity period of a mango fruit can be achieved through several methods. These include:

1. The application of knowledge of the maturity period of the variety. Most mango cultivars mature between 100–120 days after fruit set. When the fruit set period is known, the maturity of the fruit can be determined without cutting through the fruit.
2. Nature of the fruit shoulders at the pedicel end. When mango fruits are physiologically matured, the shoulders are slightly raised causing the fruit pedicel to slightly cave in.
3. Colour changes on the fruit skin. In a physiologically mature fruits, the deep green colour becomes faint (getting shades of yellow) with some tiny yellow spots, almost invisible, appearing on the skin.
4. Colour of the fruit pulp. When a mature fruit is cut open, the colour of entire pulp or some portions may appear yellow in colour. If the yellowing is slight (just around the seed), fruit will ripe but will take about 2 weeks to ripe. On the other hand, when the entire pulp is yellow, the fruit will ripe in 3 days after harvest. A chart for determining when mango fruits can be harvested for different purposes, have been developed by the South African Mango Growers Association. This chart converts the intensity of the yellow of the pulp to a unit on a scale of 0–0.6. On this scale, fruits with pulp ratings of 0.35–0.6 are acceptable for export.
5. Specific gravity of the fruit. Fruits that mature and can be harvested have highest specific gravity compared to those that are not matured. Determination of the specific gravity can be achieved by the use of the floatation test. In this test, mango fruits are dropped gently in a container full of water. If the fruit sinks rapidly, they may ripe quickly. Those that float on the surface of the water are not mature. On the other hand, fruits that are mature and which will store for longer periods and develop good flavours will float just below the water surface or sinks slowly to the bottom of the container are at the best period for harvesting. To utilise this method successfully, fruits from a tree can be sampled at random and the test carried out. If the result indicates that the fruits are not mature, harvesting can be delayed.
6. The brix level (soluble solids content) of the fruit. When the fruit is cut opened, few drops of the juice can be squeezed out and the sugar brix level is determined with the aid of a refractometer. For a mature fruit, the brix level must range between 7–15%.

6.3 Harvesting of mango fruits

Mango fruits are highly perishable and their perishability is accelerated in storage, if they are bruised in any way, prior to storage. Due to this, the harvesting process must as much as possible, prevent bruising of the fruits. Do not shake/agitate the mango tree as a way of forcing the fruits to detach from the trees, as a means of harvesting. When such fruits impact on the land surface, they produce clumps when ripe and are therefore not fit for the market. When harvesting fruits, you must note that not all fruits will be at the same maturity level, therefore, you should harvest only the fruits that show signs of maturity. As much as possible harvest fruits with hand by cutting the fruit together with the entire pedicel, with the aid of secateurs. Gently place the fruits in a crate, making sure to take all the necessary precautions to prevent skin bruising. For fruits that are beyond the reach of the hand, a net can be fitted at the end of a long pole and used for the harvesting. This may require a little practice to perfect the method. Harvested fruits are then subjected to the appropriate post-harvest activities for storage or marketing.

6.4 Sorting of harvested fruits

Though care must be taken during the harvesting process such that diseased or malformed fruits are not harvested for marketing, some wrong judgement on the part of the harvester can result in the harvesting of these undesirable fruits. Therefore, after harvesting, fruits need to be sorted out. In such cases, fruits that obviously cannot be marketed due to certain undesirable qualities are sorted out from the fruits of the desired quality. Sorting must be done under shade and the fruits must be prevented from touching the soil or rotting leaf litter. This is because they can be infected by disease causing agents that are present in the soil and the leaf litter, even after harvest. Fruits finally selected for the market are then conveyed to the processing plant for post-harvest treatment.

7. Postharvest handling of mango fruit

Proper handling of mango fruits after harvest is very critical for the success of the marketing aspect of the crop. This is due to the fact that at this stage, any blemish caused on the fruits surface of the fruits will render the fruits unmarketable. This is especially important in the case of fruits that are intended for the international markets, where fruit quality standards are high. Any mishandling of the fruits at this stage could therefore impact negatively on the profitability of the entire production system. This chapter discusses some of the ways by which the fruits must be handled to ensure that the final products meet the required quality standards.

7.1 De-sapping of harvested fruits

Freshly harvested mango fruits contain a lot of latex, which can be very corrosive to both the external surfaces of the fruit and to the one handling the fruits. Extreme care must be taken to prevent the latex from touching the surface of the fruit. To allow the latex to flow out of the fruit safely, use secateurs to cut back the fruit pedicel to about 5 cm from the fruit surface and invert the fruit on a suitable device for about 30 minutes to allow the latex to flow out. One of these devices is a metal or wooden frame over which a loose webbed mesh is stretched to hold the fruits. This ensures that the latex flowing from the fruits do not touch the fruit surface and also prevent the fruits from touching the ground. When it is evident that the flowing of latex is completed, the fruits can then be placed in plastic crates, normally in two layers. The two layers ensure that the fruits hold each other firmly and minimises rubbing of fruits against each other during transportation, which could result in bruises.

7.2 Hot water treatment against latent infections

Diseases, such as stem end rot and anthracnose, begin in the field but remain latent and destroy the fruits after harvest. These disease need to be eradicated before the fruits begin to ripe, lest, they will create blemishes on the fruit surface during the ripening process, to reduce their marketability. The eradication is achieved by dipping the fruits in hot water at specific temperature and dipping period. For most mango varieties, a temperature of 55°C and dipping period of 10–15 minutes will be enough to eradicate these latent infections. Depending on the technological know-how availability, the hot water treatment is done in several ways. In some cases, large metallic frames/ tanks containing water are heated to the required temperature after which the crates containing the fruits are lifted into the tank. The tanks are designed in such a way that all the crates can be submerged totally for the intended duration, after which the crates are lifted. In some areas, the crates containing the mango fruits are placed on a conveyer belt and are passed through the hot water and then received at the other end. Some producers place the fruits, without crates, in hot water and allow the fruits to float from one end to the other, where they are collected and re-packed into the crates. It must be noted, that while different systems are in place for the hot water treatment of fruits, the objectives are the same and each producer can design their own system to suit their settings.

Though hot water treatment of fruits can be effective, its effectiveness can be improved by the addition of fungicides, to the water prior to the treatment of the fruits. Fungicides such as Imazalil and Prochloraz have been found to be effective in this regard. Application of Prochloraz at 1–2 ml per litre of water has been found to be very effective. However, the country of import, if the fruits are intended to be exported, must be taken into consideration in the use of the fungicides. For example, while Prochloraz is permitted on fruits intended to be exported to Europe and the Middle East, it has not been labelled for fruits in USA. Therefore, Prochloraz cannot be used on fruits destined for the USA. Normally, heat treatment of mango fruits serves a dual purpose of getting rid of fruit flies as well. However, if the sole aim is to treat against latent fungal infections, then prochloraz in water at ambient temperature will also yield good results.

7.3 Packaging of fruits

After hot water treatments, it is important that the temperature of the fruits is lowered to the prevailing ambient temperature of the environment. This can be achieved by allowing fans to blow air over them. The gently cooling of fruits, prior to cold storage is very important as rapid cooling will result in formation of green spots on the fruits, when they ripe. This spots will destroy the aesthetic value of the fruits and predispose them to microbial destruction. Fruits can then be sorted out into sizes and placed in cartons for marketing or storage prior to marketing.

8. Step by step guide for seasonal production of mango fruits

Depending on the rate of development of transplanted mango seedlings, the trees will start bearing fruits at commercial quantities between 4–5 years after transplanting. Mango is a seasonal crop and flowering to fruiting occur at specific periods of the year. For the trees to yield fruits of desirable qualities and in commercial quantities, certain cultural practices must be carried out before the tree flowers to the time that the fruits mature. This section gives a summary of these activities and the suggested periods that each is carried out depending on the location of the farm, whether in the Coastal Savannah Zone of Ghana (where two mango productions seasons exist) or in the other parts of the country (where only one season exist). For ease of reference, the stage at which each activity must be carried out and the activity to be carried out have been presented in a tabular form.

Table 4.

Stage	Activities
Pre-flowering Dec-March (Major season) June-July (Minor season)	• Prune excess foliage, including leaves and twigs developed during the previous season and remove all pruned parts from the field. Gather these in a pit far away from the trees and burn. The ashes from the burned plant parts can be spread under the root zone of plants. • Immediately spray any systemic fungicide to facilitate early wound healing and prevention of opportunistic fungi such as *Lasiodiplodia theobromae* from infecting the tree, through wounds. • Apply herbicides if the field is weedy and create fire belts around the farm to prevent bush fires, if the orchard is in an area prone to bushfires. • Commence flower induction programme, by applying potassium nitrate either singly or in combination with calcium.
Flowering	• Protect flowers against anthracnose. Apply Carbendazim or any systemic fungicide approved to be used on mango at bi-weekly intervals at weekly intervals. Avoid Copper based fungicides.
Post flowering: Fruit set	• If BBS is endemic in your area apply Oxolinc acid at recommended rate at biweekly intervals for three consecutive times. If oxolinic acid is not available, apply Copper oxychloride at 10 days intervals for 3 consecutive times. • If there is drought in your area, consider irrigating the field to improve fruit retention. Avoid overhead irrigation. • Protect young fruits against stone weevils by following the recommendations applicable in the area.

Stage	Activities
Post flowering: Fruit development	• Apply copper oxychloride at 10 days intervals till 7 days before fruit maturity, if BBS is endemic in your area. • If BBS is not endemic in your area, apply systemic fungicide at biweekly intervals and end at 3 weeks to fruit maturity or apply Copper at 10 days intervals and end at 2 weeks to fruit maturity. • Conduct selective pruning if trees are producing too many leaves. Carefully remove branches that do not have fruits to open up the canopy. Also, if there are too many fruits per twig, consider pruning some off, to promote better fruit size and quality. • Protect fruits nearing maturity against fruit flies, using the recommendations applicable to your area.
Harvesting	• Harvest fruits as soon as they mature. Depending on the variety, mango fruits mature physiologically between 100–110 days after fruit set. This can be used to determine the harvesting period. Or else, you can depend on colour of the fruit (see colour chat below) or the brix level (you need an instrument called a Refractometer). Also, you can use the slightly raised shoulders of the fruit as a sign of maturity. • Harvest mature fruits with the aid of a picking device consisting of a pair of string–operated shears and a collection plastic crate. Do not allow harvested fruits to hit the ground; therefore don't shake the tree for the fruits to drop as a means of harvesting. • Harvest the fruit with the entire fruit stalk and gently drop it in a crate.
Post-harvest	• Reduce the length of the fruit stalk to about 5 m from the fruit. • Drain the latex from the fruits through the cut stalk by placing the fruits head down on a wire mesh placed on a raised platform. • Immediately after harvest and draining of latex, dip fruits in hot water at 55°C for 5–15 minutes, depending on the variety. This will destroy any latent infection present. To make this treatment more effectively, add Prochloraz to the hot water. When Prochloraz is added, the temperature of the water can be reduced to about 52°C. After hot water treatment, air-dry the fruits and sort them, if they are for export. • Sort the fruits based on size, colour (ripeness) and texture. If some fruits are found to be insufficiently colored, they can be subjected to a follow-up ripening by placing them for 36 hours at 22°C in an atmosphere containing 100 ppm of ethylene. Any fruits that are still green after this treatment cannot be exported. • Pack fruits in boxes for the market.

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List of Annexes

Annex 1 – Pesticides approved[1] for mango production in Ghana

Trade name	Active ingredient	Target disease	Remarks
A. FUNGICIDES			
Bosun 300SC	Boscalid (20%)+Kresoxim methyl	Anthracnose	Systemic
Caldo Bordelles Valles	Copper(II) sulphate+Calcium hydroxide	Anthracnose	Contact; organic and conventional use
Callet 50 WP	Carbendazim (50%)	Anthracnose	Systemic; conventional use
Curenox	Copper oxychloride	Anthracnose/Bacterial black spot	Contact; conventional use
Folpan 50 WP	Folpet 500 g/kg	Anthracnose	Contact; conventional use
Goldazim	Carbendazim 500 g/l	Anthracnose/Stem end rot/ Tree decline	Systemic; conventional use
Maneb 80 WP	Maneb (80%)	Anthracnose	Contact; conventional use
Merpan	Captan 500 kg/kg	Anthracnose	Contact; conventional use
Raintop M70	Thiophanate-methyl	Anthracnose/Stem end rot/ Tree decline	Systemic; conventional use
Shavit F	700 g/kg Folpet+1.5 g/kg Triademenol	Anthracnose	
Topsect 70	Thiophanate methyl	Anthracnose/Stem end rot/ Tree decline	Systemic; conventional use
FUNGICIDES – PROVISIONALLY CLEARED IN GHANA			
Banco D450	Chlorothalonil 400 g/l+ Difenoconazole (50 g)	Anthracnose/Stem end rot/ Tree decline	Systemic; conventional use
BBS master	Oxolinic acid	Bacterial black spot	Systemic; conventional use
Mangoda 10 WG	Difenoconazole	Anthracnose/Stem end rot/ Tree decline	Systemic; conventional use

[1] As per register of pesticides under the EPA act, 1994 (act 490), updated December 2021.

Trade name	Registration No. / Date of Issue	Concentration of Active Ingredient	Uses
B. INSECTICIDES			
Agricombi 40 EC	FRE/1902/1519G September 2019	Fenvalerate (10%) + Fenitrothion (30%)	Insecticide for the control of aphids, mites and weevils in cocoa, fruits and vegetables
Alphacep 10 EC	FRE/1902/1488G June 2019	Alpha-cypermethrin (100 g/l)	Insecticide for the control of insect pests in vegetables and fruits
Bomec EC	FRE/19202/1455G February 2019	Abamectin (18 g/l)	Insecticide for the control of aphids, caterpillars, whiteflies, grasshoppers and bollworms in vegetables and fruits
Buffalo Supa 40EW	FRE/1723/1211G October 2017	Acetamiprid (400 g/l)	Insecticide for the control of insect pests in vegetables and fruit crops
Carinho WP	FRE/18202/1377G August 2018	Carbendazim (500 g/kg)	Insecticide for the control of leaf spot, leaf mould and stem rot in vegetables
Decis Forte 100 EC	FRE/20183/1636G June 2020	Deltamethrin (100 g/l)	Insecticide for the control of insect pests in fruits and vegetables
Dimeking 400EC	FRE/1899/1435G December 2018	Dimethoate (400 g/l)	Insecticide for the control of insect pests in fruits, cotton and vegetables
Dimex 400 EC	FRE/17202/1204G October 2017	Dimethoate (400 g/l)	Insecticide for the control of aphids, fruit flies and leaf miners in vegetables, fruits and pineapples
Fastrack 10 SC	FRE/1902/1487G June 2019	Alpha-cypermethrin (100 g/l)	Insecticide for the control of insect pests in vegetables and fruits
Fenitrothion 50 EC	FRE/1902/1515G September 2019	Fenitrothion (50%)	Insecticide for the control of chewing, boring and sucking insects in fruits, vegetables and cereals
Levo 2.4SL	FRE/1908/1529G October 2019	Oxymatrin (2.4%)	Insecticide for the control of insect pest in vegetables and fruit crops
Methoate 40EC	FRE/1825/1332G July 2018	Dimethoate (400 g/l)	Insecticide for the control of insect pests in vegetables and fruit crops
Movento 100 SC	FRE/20183/1635G June 2020	Spirotetramat (100 g/l)	Insecticide for the control of mealy bugs in pineapple and pawpaw
Nutrel SL	FRE/18137/1417G November 2018	Hydrolysed Protein (24%)	Insecticide for the control of insect pests in cereals, citrus and manago
Savahaler WP	FRE/18202/1376G August 2018	Methomyl (250 g/kg)	Insecticide for the control of insect pests in vegetables, fruits, cotton and soybean
Seed Shield	FRE/1957/1552G October 2019	Imidacloprid (350 g/l)	Insecticide for the control of insect pests in field crops
Success Appat	FRE/2005/1643G July 2020	Spinosad (0.24 g/l)	Insecticide for the control of fruit flies in citrus, mango and vegetables
Sunpyram 20WG	FRE/2057/1584G January 2020	Nitenpyram (20%)	Insecticide for the control of chewing and sucking insect pests in tree crops
Super Tiger 2.5 EC	FRE/2067/1613G May 2020	Lambda-cyhalothrin (25 g/l)	Insecticide for the control of insect pests in vegetables
Vigilant 25 EC	FRE/1910/1484G June 2019	Bifenthrin (25 g/l)	Insecticide for the control of aphids, bollworm, jassids, whiteflies, mites and hoppers in cotton and mango

Trade name	Registration No. / Date of Issue	Concentration of Active Ingredient	Uses
C. INSECTICIDES – PROVISIONALLY CLEARED IN GHANA			
Away	PCL/20149/1633G May 2020	Emamectin-benzoate (1.9%)	Insecticide for the control thrips, aphids, whiteflies and caterpillar in leafy vegetables, mango, citrus, pawpaw and tomato
Knock Out	PCL/20149/1634G May 2020	Bifenthrin (30g/l) + Acetamiprid (16g/l)	Insecticide for the control of insect pests in vegetables, mango, eggplant and citrus
Lamdoc 25 EC	PCL/20213/1677G May 2020	Lambda-cyhalothrin (25g/l)	Insecticide for the control of insect pests in fruits and vegetables
Leopard 20 SL	PCL/19137/1473G November 2019	Imidacloprid (200g/l)	Insecticide for the control of mango hopper, aphids, leafminers, jassids in mango, okra and groundnut
Magicforce Gold	PCL/19145/1438G October 2019	Lambda-cyhalothrin (15g/l) + Acetamiprid (20g/l)	Insecticide for the control of beet army worm, aphids, stem borers, beetles, leafhoppers, bollworm, leaf miner, diamond back moth in cabbage, cucumber, okra, pepper, maize, sorghum, rice, legumes, mango and citrus
Organic Farming Aid (OFA)	PCL/20266/1639G May 2020	Acetic acid (2.3%)	Insecticide/fungicide for the control of Fall armyworm, other insect pests and *Phytophthora* rot in maize, vegetables, fruits and tree crops
Organic JMS Stylet Oil	PCL/2008/1547G January 2020	White Mineral Oil	Insecticide/ fungicide for the control of aphids, mites, thrips, powdery mildew, botrytis and rust in vegetables and fruits
Pyrethrum 5EW	PCL/19257/1469G November 2019	Pyrethrum (50g/l)	Insecticide for the control of chewing and sucking insect pests in outdoor and protected crops
Termifos 48 EC	PCL/20249/1760G August 2020	Chlorpyrifos (480g/l)	Insecticide for the control of mealybugs, thrips, leaf miners and aphids in vegetables and for wood treatment
Termichem 5SC	PCL/2005/1694G May 2020	Fipronil (50g/l)	Insecticide for the control of termites on wood

Annex 2 – Fruit fly trapping data sheet

1.1 Fruit fly field trapping data sheet

Locality: .... Farmer/Farm name:................................

GPS Readings: Lat:.................. Long: .... Alt (m):.....................

Date:..................................

Points	Pheromone	Number of individuals
1	ME 1	
1	TM 1	
1	TA 1	
1	CU 1	
2	ME 2	
2	TM 2	
2	TA 2	
2	CU 2	
3	ME 3	
3	TM 3	
3	TA 3	
3	CU 3	
4	ME 4	
4	TM 4	
4	TA 4	
4	CU 4	

1.2 Laboratory fruit fly identification data sheet

Locality: .... Farmer/Farm name: ....

GPS Readings: Lat: .... Long: .... Alt (m): ....

Date	Treat-ment + Trap No	*B. dorsalis*			*C. cosyra*			*C. capitata*			*B. vertebratus*			*B. cucurbitae*			*Bactrocera* sp.			*Dacus* sp.			Remarks
		Total	m	f	Total	m	f	Total	m	f	Total	m	f	Total	m	f	Total	m	f	Total	m	f	
	ME 1																						
	ME 2																						
	ME 3																						
	ME 4																						
	TM 1																						
	TM 2																						
	TM 3																						
	TM 4																						
	TA 1																						
	TA 2																						
	TA 3																						
	TA 4																						
	CU 1																						
	CU 2																						
	CU 3																						
	CU 4																						

* For the purposes of uniformity, all countries must use the same types of traps. And for sustainability, growers must be trained on how to construct home-made traps.

Annex 3 – Calculation of relative fly densities

Site	Plot #	No. Flies (F)	No. Traps (T)	No. Days (D)	Rel Density F/T/D
XX	Xx				
YY	Yy				
ZZ	Zz				

Date	Treat-ment	Non-Target Organisms										Remarks
		Ants	Spiders	Beetles & Weevils	Other flies	Bees & Wasps	Butterflies & Moths	Cockroaches	Lacewings	Crickets & Hoppers	Others	
	ME 1											
	ME 2											
	ME 3											
	ME 4											
	TM 1											
	TM 2											
	TM 3											
	TM 4											
	TA 1											
	TA 2											
	TA 3											
	TA 4											
	CU 1											
	CU 2											
	CU 3											
	CU 4											

Annex 4 – Fruit incubation data sheet (for bulk and individual incubation)

Locality: .... Farmer/Farm name:. ....

GPS Readings: Lat: .... Long: .... Alt (m):. ....

Set Date	Fruit	Fruit Stage	No.	Wt.	No. Puparia	Flies	M	F	Parasitoids

Fly emergence date: .... Parasitoid emergence date:. ....

Compiled by: .... Sign: . ...

District XXX						
	Plot	No. Fruits	No. Puparia	Pup/Fruit	Diff. (C-T)	% Change (C–T) / C × 100
1st Sample	Treated (T)					
	Control (C)					
2nd Sample	Treated (T)					
	Control (C)					
Combined	Treated (T)					
	Control (C)					

Annex 5 – Fruit flies

The *Ceratitis* species

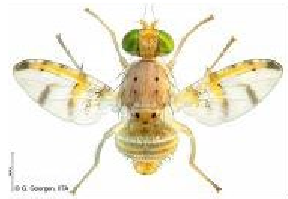
Ceratitis ditissima (Munro)

Ceratitis punctata (Wiedemann)

Ceratitis capitata (Wiedemann)

Ceratitis cosyra (Walker)

Ceratitis silvestrii Bezzi



Ceratitis quinaria (Bezzi)

Ceratitis fasciventris Bezzi

Ceratitis rosa Karsch

Ceratitis anonae Graham

The *Bactrocera* and *Dacus* species

Bactrocera dorsalis (Hendel)

Dacus bivittatus (Bigot)

Dacus ciliatus Loew

Dacus vertebratus Bezzi

Zeugodacus cucurbitae (Coquillet)

Dacus punctatifrons Karsch

Bactrocera oleae (Rossi)

Bactrocera latifrons (Hendel)

Bactrocera zonata (Saunders)

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