PRODUCTION GUIDE

TECHNICAL ITINERARY

FOR MANGOES

Mangifera indica

COLEACP

Warning
The technical itinerary for mangoes document sets out all the cultivation practices for growing mangoes. It mainly advocates active substances produced by manufacturers of Plant Protection Products as part of Regulation (EC) 1107/2009, which need to comply with standards regarding residue of Plant Protection Products. Most of these active substances have been tested as part of a field trial programme and the level of residue of each active substance was measured. The recommended approach to controlling pests and diseases is dynamic and will be continually adjusted by the addition of information collected by the COLEACP. Nevertheless, every producer can choose from the products featured on the list of active substances which do not pose any problems with regard to residue levels. Naturally, only those substances which are legally approved in the country in question are authorised for use. Every producer must check with the local authorities as to whether the product they wish to use is featured in the list of approved products.

CONTENTS

CONTENTS

The technical itineraries and guides to good phytosanitary practices are updated regularly.
For more information, see the programme's website:
www.coleacp.org

Mangifera indica
Anacardiaceae Family

1. DESCRIPTION

1.1 Botany and description

Originally from the Indo-Burma region, mango trees diversified further in two other areas of south-east Asia:

- In north-west India, creating monoembryonic varieties with a colourful epidermis, sensitive to anthracnose. The climate in this area alternates between hot and humid summers and cool and dry seasons;

- In Myanmar, Thailand, Indonesia and the southern part of mainland south-east Asia, creating polyembryonic varieties with a dull green epidermis and a relatively good resistance to anthracnose. Here, the climate is more regularly hot and humid.

A century ago, these two types of mango were brought together in Florida, where they gave rise to various descendant varieties through natural or managed hybridisation. This region is seen as a secondary centre of diversification. Most mango varieties on the export market are derived from these hybridisations.

In the original regions, the habitats of the primitive varieties were tropical forests at medium altitudes. In these settings, fruiting is random, with sparse flowering and cryptogamic attacks on flowers and young fruit.

In subtropical areas, temperature changes (25°C in the day / 15°C at night) along with a clear dry season create favourable conditions for good flowering.

Low temperatures are the main factor limiting the extension of cultivation areas beyond 36° latitude N and 33° latitude S.

The morphology and biology of the mango tree

Mango trees grow to a considerable height (10-30m high) and have leaves all year round. The inflorescences form in bunches at the end of the branches on the periphery of the foliage. They are made up of male and hermaphroditic flowers. Each inflorescence has several thousand flowers which, after fertilisation, produce several fruit at best. The average fruit-set ratios are very low at less than 1/1000. Pollination is carried out by insects: flies, thrips and, on very rare occasions, bees.

The fruit produced is a drupe. The thin epidermis is covered in lenticels. Depending on the variety, the colour of mangoes varies from green, yellow, orange and purplish-red, and they can be a single colour or have patches of different colours.

When ripe, the flesh is yellowish-orange. They can be firm, but are usually juicy. The area close to the stone is very fibrous. The abundance of fibres differs depending on the variety. The least evolved varieties, of Indian origin, have a stronger turpentine flavour and are richer in fibre.

The flat seed is protected by a woody tegument.

In monoembryonic varieties, it is made up of single zygotic embryo (derived from pollination, the genetic heritage of which is always different from the parent plant). In polyembryonic varieties, it is made up of one or more nucellar embryoes (derived from the tissue of the nucellus, the genetic heritage of which is always identical to the parent plant). The germination capacity of the seed only lasts a few weeks.

1.2   The phenological cycle – periodic growth

In hot and humid seasons, growth is not constant. Each stage of vegetative growth is followed by a period of apparent rest (periodic growth). The phenological cycle of the mango tree is strongly influenced by climatic conditions. In order to bloom, mango trees need a complete stop in vegetative growth caused by a fall in average temperatures and/or a distinct dry period. In humid tropical areas, the fact that vegetative growth does not stop means that the development cycle of the various parts of the tree is not paused. Flowering and vegetative growth phases follow each other in a desynchronised manner, accentuating the mango tree's natural ability to flower on numerous occasions (often 2 or 3 flowerings per year, with intervals of one and a half months between them).

EXAMPLE OF A PHENOLOGICAL CYCLE – REUNION ISLAND
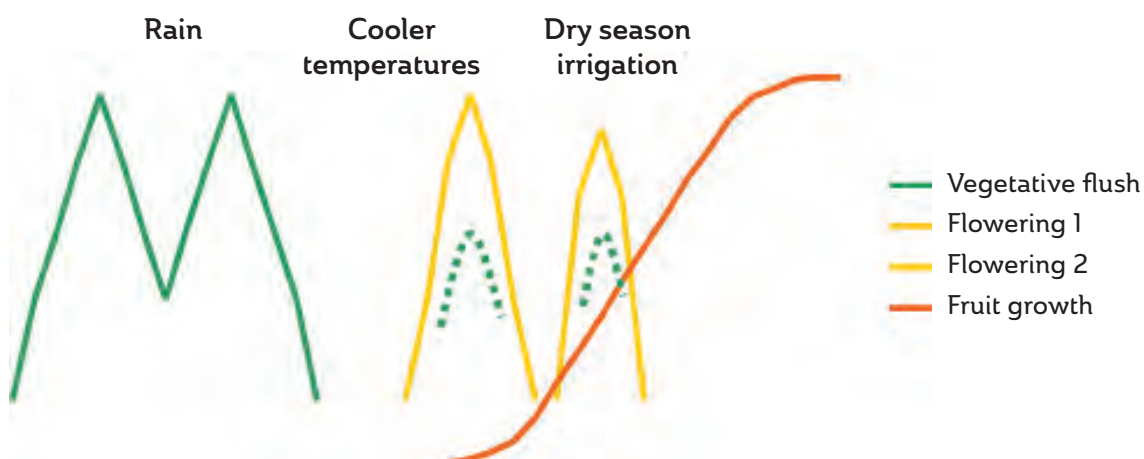
The periods of flowering and fruiting in a number of ACP countries are set out in the table below.

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
Burkina Faso	Fl	Fl-Fr	Fr	Fr	Fr	Fr	Fr				Fl	Fl
Côte d'Ivoire (North)	Fl	Fl	Fr	Fr	Fr	Fr	Fr				Fl	Fl
Cameroon (North)	Fl	Fl	Fr	Fr	Fr	Fr	Fr				Fl	Fl
Dominican Republic	Fl	Fl	Fr	Fr	Fr	Fr	Fr				Fl	Fl
Ghana (North Tamale)	Fl	Fl	Fr	Fr	Fr	Fr	Fr				Fl	Fl
Kenya (East coast)	Fr	Fl-Fr	Fl			Fl-Fr	Fl-Fr	Fl-Fr			Fr	Fr
Mali	Fl	Fl-Fr	Fr	Fr	Fr	Fr	Fr				Fl	Fl
Senegal (Niayes)	Fl	Fl	Fl	Fl-Fr	Fr	Fr	Fr	Fr	Fr	Fr		Fl
Tanzania	Fr	Fl-Fr	Fl			Fl-Fr	Fl-Fr	Fl-Fr			Fr	Fr

Legend

Fl	Primary flowering	Fl	Secondary flowering	Fr	Fruiting	Fr	Secondary fruiting

Notes:

- During certain periods, flowering and fruiting may occur at the same time: Fl-Fr. E.g. southern Ghana, Kenya and even in some areas of Burkina Faso producing the early Amélie variety in February.

- Exports start later following the regression and almost complete disappearance of the Amélie variety for export, thus reducing the volume of exports in March. Amélie mangoes have become niche export products. However, they are used for drying or pulp manufacturing, but it is necessary to wait until they are fully ripe.

- The increase in exports from Côte d'Ivoire in May, although they are particularly high in the early weeks up until week 20.

2. VARIETIES

The choice of the variety results from a compromise between the needs of the producer, the distribution requirements and the customers' expectations. It takes into account a wide range of considerations, including agronomic suitability, resistance to various pests and diseases, suitability for transport and preservation, organoleptic and visual qualities, positioning on the market, and so on.

Among the many mango varieties available, very few can meet all of these criteria for the export market. Usually, Florida-origin mangoes are chosen for export from Latin America or Africa to Europe or North America, although imports of mangoes from Pakistan to Europe have been increasing significantly in recent years.

Three varieties dominate the western markets:

Tommy Atkins:

This early to mid-season variety offers a range of advantages in terms of productivity, presentation, ease of handling and preservation. However, its unremarkable flavour is not particularly popular with the discerning customer, which is an obstacle to its future development in European markets, especially southern Europe. It is prone to a physiological problem known as 'jelly seed'. This partial, early over-ripening leads to the breakdown of the flesh around the stone, giving it a jelly-like appearance.

It features prominently on the export market and is mainly grown in Brazil, Mexico, South Africa and Israel. It is not particularly prominent in west Africa, where the Kent variety is more popular. See Figure 3.

Kent:

Kent is a Florida-origin variety introduced to Africa around 1950 at the trial facility in Foulaya, Guinea. From there, this cultivar was spread to other sites in west and central Africa.

The fruit becomes ripe in the middle of the season. They are egg-shaped, relatively large, with a weight usually between 500g and 900g. The flesh is firm, with a pleasant taste, and they ripen slowly and gradually. Fruit harvested close to maturity can be preserved at cool temperatures for a long time. Along with its excellent organoleptic qualities, the firmness of the flesh and its gradual ripening make it particularly attractive for distribution.

Although challenging to produce, this mango is the benchmark in terms of quality for export markets. It is especially reactive to the climatic conditions and the type of soil. The best fruit, with a red epidermis and well developed and balanced flavours, is obtained from dry, lateritic soil and from trees with good exposure to sunlight. Fruit grown in wet and shady conditions remains green at maturity. This variety is more sensitive to fly bites and anthracnose when conditions are favourable for such attacks. See Figure 2 and 5.

Keitt:

This Florida-origin variety introduced to Africa at the trial facility in Foulaya, Guinea around 1950 was also spread through Africa in the same way as the Kent variety.

The fruit is oval and longer than the Kent variety. Its sides are flattened. It weighs between 500g and 1kg with significant variability making it more difficult to export. The fruit matures late and has a pleasant appearance with good external colouring which varies according to its exposure to sunlight. Parts with good exposure to sunlight have shades ranging from dark pink through a spectrum of coppery tones to bright red. Like for the Kent variety, wet and shady conditions often prevent the skin developing a good colour.

It occasionally suffers from internal physiological flaws and its skin is much more fragile than the Kent variety. Its late production, which used to be seen as a benefit allowing the harvest period to be lengthened, has become a disadvantage due to parasitic attacks on late fruit (flies, fungal diseases, bacterial canker, etc.). See Figure 4.

Secondary varieties

Amélie:

This variety originally from the West Indies was introduced to Mali in the previous century and was then spread throughout west Africa. Its high sensitivity to anthracnose limits its cultivation to the only driest areas (Sudano-Sahel region). The round fruit weighs between 300g and 600g. Its dark orange flesh is soft and pleasant. Large-scale distribution circuits criticise the skin's lack of red colouring and its poor shelf life. To overcome these drawbacks, the mangoes are often harvested early and the skin usually stays green on the shelves. Amélie occupies a limited commercial niche, at the very start of the season between late March and mid-April, when there is a shortage of mangoes on the market and colourful varieties are almost entirely absent. Despite competition from South America, there is still an export flow of this variety until the Kent mangoes arrive in early April. The Amélie variety is popular for processing (especially drying), which has seen a significant increase in Burkina Faso and Mali. See Figure 6.

Zill:

Zill is the earliest of the red varieties reaching maturity between the Amélie and Kent varieties. At maturity, the colour of the skin is bright red and yellow. The orange pulp has a pleasant flavour, which is highly sought-after by many consumers. When the fruit begins to ripen, it develops very quickly and the quality of the pulp degrades rapidly.

The average weight is relatively low. As a result, much of the fruit cannot be exported. The trees produce a limited yield and the branches often break in high winds.

Before the Kent mango season, small volumes of Zill mangoes are still exported, preferably by air, in order to minimise the risks related to preservation. Such exports are extremely marginal. See Figure 1.

VARIETIES

Palmer:

Late variety of elongated fruit with a very colourful skin (purplish-red). It has firm, yellow flesh and a very long shelf life. The production yield is high, but the proportion of fruit which can be exported is low (insufficient average weight). Its sap is acidic and can burn the skin of the fruit, harming its appearance. The early development of its red colouring makes it challenging to determine its cutting point. A large amount of fruit is often harvested before it reaches maturity. Its production period comes just before the Keitt variety, which it competes with. Finally, its elongated shape is another drawback for distribution professionals. Nevertheless, this variety is in fifth position among exported varieties. See Figure 7.

Irwin:

Early and productive variety. The small fruit is very colourful and attractive with a high quality flavour. They preserve well if the harvest is carried out at the right stage. Some producers have great difficulty in correctly judging the development stage of the fruit and harvest it too late (leading to an excessively short preservation period). Guinea was the last country in west Africa to export it, but it has now been replaced by the Kent variety even there.

Valencia pride:

This seasonal variety, with a relatively large and elongated fruit, is sought after for its good quality flavour and especially its very attractive appearance. Since it is unsuitable for preservation, it requires air transport. Exported fruit occupies a niche market. See Figure 8.

Sensation:

Florida-origin variety with unknown parent varieties. The dark red fruit is small to medium size (280-340g) with some yellow markings. Its main benefit is its relative tolerance to bacterial canker. Seasonal variety which is well suited to cooler areas in the subtropical zone, such as some regions in South Africa.

Osteen or Austin:

This Florida-origin mango derived from a Haden stone has now become the main mango variety grown in Europe, mainly in Spain. Extremely colourful, with interesting organoleptic qualities, it is one of the main mango varieties on European markets between September and November. For Spain, its proximity to European consumers is a great asset, allowing them to pick perfectly ripe fruit. However, little is known about the behaviour of this variety in the tropics. It is mentioned here because of its growing significance in European markets.

Figure 1: Zill Variety
Photo Gilles Delhove

Figure 2: Kent Variety
Photo Jean-Yves Rey

Figure 3: Tommy Atkins Variety
Photo Henri Vannière

Figure 4: Keitt Variety
Photo Jean-Yves Rey

Figure 5: Kent Variety
Photo Jean-Yves Rey

Figure 6: Amélie Variety
Photo Jean-Yves Rey

Figure 7: Palmer Variety
Photo Jean-Yves Rey

Figure 8: Valencia Pride Variety
Photo Jean-Yves Rey

Figure 9: Améliorée du Cameroun variety
Photo Jean-Pierre Imele

Figure 10: Apple Mango Variety
Photo Gilles Delhove

More illustrations are available at:

http://www.cgste.mq/intranet/IMG/pdf/fiches_mangues_SECI.pdf

http://www.freshmangos.com/varieties.html

Matching production with market demand

The mango export market is currently dominated by the Tommy Atkins and Kent varieties, which make up three quarters of the total volume exported. Tommy Atkins mangoes come mainly from Latin America and Kent mangoes, although dominant in Africa, are also growing in prominence in Brazil as importers become more aware of the quality of the fruit. It is also the main variety exported by Peru, which, along with Brazil, has become the leading supplier for the European market.

The other varieties occupy a limited share of the market and are positioned in certain specific niches that are still available: early (Amélie) or late harvest, air transport for quality management (Valencia pride), etc.

The améliorée du Cameroun (Cameroon refined) variety, which represents most of Cameroon's production, is also worth mentioning (Figure 9). Probably derived from the south-east Asian variety, it is a polyembryonic mango which is well suited to wet areas near the equator where it flowers in abundance, but it also grows well in dry savannahs. Its main drawback is that it is prone to physiological problems (jelly seed) and, therefore, has a short shelf life. If the plant was produced by sowing, fruit set occurs later than with grafted plants. It is the most popular variety for consumers in central Africa. It is a small mango with green skin and very sweet orange pulp, which is not very fibrous.

It is also worth mentioning Ngowe in Kenya and the Apple mango (Figure 10), which originated in Asia and is now grown extensively in Tanzania and Kenya specifically for the Middle East market. It is a fleshy and plump mango with a regular, rounded shape. It is not very fibrous and weighs between 350g and 500g.

3.   THE NURSERY

3.1   General considerations

Planting healthy, homogeneous and well-formed plants is essential for a successful orchard.

There are several orchard planting techniques:

- Sowing and grafting in the field

- Plant production in nurseries, followed by planting and grafting in the field

- Plant production and grafting in nurseries, followed by the planting of grafted plants.

In general, the technique of planting young plants followed by grafting in the field is the most common in west Africa. However, producing grafted plants in a nursery can ensure greater consistency. The denser the plantation, the more important it is to ensure the homogeneity of the plants. It is also most cost-effective to produce plants in a nursery rather than in a plantation. However, planting young plants helps to develop a better root system than if the plants spend too long in containers.

To overcome this problem, plants which are grafted in the nursery should be planted in the field as quickly as possible and containers of a suitable size (3 litres minimum) should be used, pierced with enough holes to allow the roots to come out rather than turn back inside and down to the base of the container. Finally, on the plantation, all tangled and rolled up roots are severed.

A number of different techniques can be combined. For instance, plants can be grafted in the field and those plants which fail or develop incorrectly can be replaced by plants grafted in the nursery.

There are various propagation techniques: sowing, grafting and layering. In practice, only grafting is used for the production of mango plants whose fruit is intended to be exported. The plant produced is made up of two parts: the rootstock (root system) and the grafted part (the harvested variety).

The nursery production cycle should not exceed 12 to 18 months depending on the climate of the region. Any longer and the plants would be too old and the trauma caused by transplanting and rolling the roots in the bags would prevent them from making a good recovery and hamper the trees' longevity.

Figure 11 below shows sealed greenhouses in which parent plants are grown when an area is infested by a bacterial disease. Figure 12 shows a tree which was kept too long (over two years) in a container which was too small. The main root is rolled in a spiral with folds that stop the sap from circulating normally. The unnourished end of the taproot becomes necrotic and adventitious roots develop around the root crown. Secondary roots grow around the inside of the container. The mortality rate when planting these plants is very high and the survivors develop slowly. The future of the orchard can be compromised right from the planting stage.

Figure 11: Sealed greenhouse (Cirad - La Réunion).
Photo Christian Vernière

Figure 12: A tree which was kept too long (over two years) in a container which was too small.
Photo: Jean-Yves Rey

3.2   Choosing the rootstock

Only polyembryonic varieties should be chosen as rootstocks because they enable plants with consistent seedlings to be obtained (same genetic heritage).

Rootstocks are selected with the aim of influencing the health and productivity of the mango trees, the quality of the fruit and the resistance to soil parasites. However, little research has been conducted on the matter. Consequently, each production region usually uses seeds of one or two polyembryonic mango varieties which are well suited to the local conditions for the production of rootstocks.

The benefit of using seeds derived from polyembryonic varieties is that they produce very consistent young plants provided that plants derived from sexed embryoes are eliminated (although these are rare).

3.3   Choosing seeds for the production of rootstocks

Seeds must come from identified trees, selected for their compliance with the criteria required and with no symptoms of diseases or degeneration.

3.3.1 Preparation of seeds prior to sowing

The fruit should be harvested just prior to reaching maturity. The stones should be separated from the rest of the pulp and stored temporarily on a shady, dry, flat surface before extracting the seed. This operation helps to remove the husk which may cause the young root to roll up during germination. Any defective seed is removed (germination already started, signs of fungal attack or pests (*Sternochetus Mangifera = Cryptorhynchus mangiferae*), and so on).

The germination capacity is time-limited (one to two weeks for unshelled stones depending on the variety and climate). A clear reduction in this germination capacity has been observed after the stone is extracted, falling to close to zero after one week. Sowing is therefore carried out immediately after extraction (on the same day or the morning after providing the stones are kept in a humid environment).

3.3.2 Preparing the hotbed soil for sowing

The goal is to obtain a homogeneous and filtering mix, which is able to hold enough water and nutrients.

This mix is often made up of a base of one third non-clay equilibrated soil, one third coarse sand and one third well-decomposed organic matter.

In west Africa, stockyard poudrette, which is well watered and then ventilated to ensure good fermentation, is a suitable and inexpensive source of organic matter that is easily available in villages.

This fully homogeneous potting mix is then disinfected by solar heating under transparent sheeting or by treating it with $200g/m^2$ of dazomet for each 30cm layer of potting mix. After spreading the mix and ensuring its homogeneity, the compost should be regularly watered. It is important to wait between three weeks and one month before using it.

This compost can then be used to fill bags with a diameter of 15cm and a depth of 20/25cm.

3.3.3 Sowing

Since it is impossible to preserve the seeds, sowing always takes place shortly after the extraction of the seeds during the mango harvest.

Seeds can be sown densely in seed trays or in bags on-site.

The advantage of the first solution is that it is easier to manage the consistency of the plants and sort the plants when planting out. The seed should be lightly pressed into the compost substrate and gently covered by 2-3cm of compost. The substrate should be kept damp, without excess water, by regular watering. Germination requires between 6 and 30 days.

3.3.4 Transplanting

Planting out should be done when the tigella reaches 6-8cm. The radicle will then be around 10cm long. It should be cooled to make planting out easier and encourage the development of secondary roots.

Black polyethylene bags with a thickness of 0,04mm and a volume of 3-5 litres can be used, pierced on the sides and the bottom. The bags can be arranged in parallel lines in ditches with a depth of 0.15m to protect them from solar radiation.

Using polyembryonic seeds means that several seedlings per seed can often be seen. It is important to always ensure that twin plants do not grow in the same bag by removing any superfluous plants. It is possible to plant them out separately, taking good care to divide up the cotyledons to keep their tigella and radicle intact. However, it is advisable to only use the most vigorous plant and get rid of the weaker ones. Thinning out is only advised when there is a lack of plants.

3.4   Grafting

3.4.1 Choosing grafts

The choice and condition of the grafts is extremely important. They should be taken from trees whose varietal authenticity has been verified.

When a graft is taken, it must be "mature", i.e. it has lost its flexibility as the stalk has become woody. The terminal bud should be bulbous, swollen and ready to open, but should not have started opening yet.

If the terminal bud is not displaying these features, it is advisable to strip the leaves off the last 15cm of the branches. This will encourage the terminal buds to swell. They can then be removed between 8 and 15 days later.

3.4.2   Preparing the rootstock

At the moment of grafting, the rootstocks must be at least 6mm in diameter and 30cm tall. They should be prepared two months before grafting by removing all lateral branches, so only the main stalk remains.

3.4.3 Grafting periods

Grafting periods depend heavily on the development of the rootstock and the vegetative development stage of the trees in the tree farm. It is not recommended to carry out grafting during very hot or very rainy seasons, or during cool seasons.

The best results are obtained during seasons which encourage the mango trees to produce a large amount of vegetative shoots.

3.4.4 Grafting techniques

The aim of grafting is to bring the cambiums of the graft into contact with the rootstock so that they bond together. For this to take place, it is important that:

- The meristems are and remain active throughout the period before and after the grafting;
- There is sufficient contact surface between them;
- The bindings used ensure close contact.

It is essential to prevent any of the tissue of both the rootstock and the graft from drying out.

Various different techniques are used and they differ depending on the location. The most common approaches are:

- The splice graft
- The whip graft,
- The side cleft graft,
- The side veneer graft.

Whichever technique is used, the following precautions must be taken:

- Whether in the nursery or on-site, grafting should use healthy grafts (completely free from bacterial canker and fungal diseases especially).

- The plant matter should be disinfected by soaking it in a mixture of insecticide, fungicide and bactericide before grafting. The grafts can also be disinfected by soaking them for 15 minutes in a bleach solution (1% active chlorine and, if possible, add a wetting agent).

  Note: Ensure that the grafts do not have any cankers because the chlorine solution cannot penetrate them.

3.4.5 Postgrafting care

The bud normally begins to open between 15 and 20 days after grafting. To speed up growth, in the event of a side graft (side cleft or side tongue graft), the top of the rootstock should be lopped off, leaving behind a tab that is long enough to train the young graft. In windy conditions, the bindings should be kept on until the graft has become firm. In other cases, the bindings should be removed during the second vegetative growth stage.

During the period between grafting and sale, the plants should be weeded, irrigated and fertilised each week with 0.5g of diluted nitrogen in 1 litre of water per pot.

3.5 Plant protection measures in nurseries

Plants in nurseries may suffer from attacks from pests and diseases. Unlike adult plants which are able to withstand attacks from certain parasites without suffering too much damage, young plants in nurseries with fewer reserves are much more sensitive. The nursery phase is a pivotal stage in the future of the plantations. Poor management can lead to the rapid spread of pathogens and pests in new orchards.

Pesticides which can be used in nurseries are the same as those used to protect orchards. Their methods for use are similar with regard to the concentrations of active matter in solutions. The application of pesticide mixtures depends on the layout of the plants in the nursery. The wettability level should be slightly denser (run-off point) for anti-mealybug fungicides or insecticides, and slightly less dense for other insecticides.

For more information on these practices, see below: phytosanitary protection (Chapter 5).

See the table in Appendix 1 for more details on effective active substances which can be used to combat pests and diseases.

3.5.1 Main pests

Plants are attacked by different types of pests in nurseries:

- General pests (acrididae, various true bugs (*Lygus* spp., *Anoplocnemis curvipes*), diaspididae, mealybugs, etc.etc.). These pests also attack young plants. The resulting damage is no greater than that caused to adult trees, but it is more dangerous given the fragility of young plants.

- Mango tree pests in nurseries (terminal bud acarids, young leaf thrips) can considerably hinder the growth of plants. It is necessary to protect the plant with systemic products which can reach pests inside the buds.

- Pests affecting the vegetative part of the mango trees are also present in nurseries. (Mealybugs *Rastrococcus invadens*, citrus and mango tree thrips *Scirtothrips aurantii,*cacao tree thrips *Selenothrips rubrocinctus.,* blossom gall midges *Procontarinia matteiana,* etc.).

- Weevils deserve a special mention. As noted previously, the stones used in the nurseries must be completely untouched by weevils to ensure that they do not contribute to the pest problem.

Using Plant Protection Products: Refer to Chapter 5 on phytosanitary protection of orchards and the COLEACP E-GAP (Good Agricultural Practices) website available in "COLEACP Resources" here for more information on using these products.

3.5.2 The main diseases

- Powdery mildew (*Oidium mangiferae*), anthracnose (*Colletotrichum gloeosporioides*), and bacterial canker (*Xanthomonas citri* pv. *mangiferaeindicae*) are serious diseases affecting mango trees and can also occur in nurseries.

  Using Plant Protection Products: Refer to Chapter 5 on phytosanitary protection of orchards and the COLEACP E-GAP (Good Agricultural Practices) website available in "COLEACP Resources" here for more information on using these products.

4. ORCHARDS ESTABLISHMENT

Figure 13: Orchard in Tanzania
Photo: Gilles Delhove

Figure 14: Orchard in Senegal
Photo: Jean-Yves Rey

4.1 Requirements

4.1.1 The climate

To grow and fruit correctly, mango trees prefer a tropical climate with a clearly defined cool and/or dry season. Drops in temperature and water supplies are necessary to trigger flowering and fruiting. Mango trees cannot withstand frost and their vegetation threshold is around 16°C. Moreover, good pollination of the flowers requires temperatures which do not go below 14°C during flowering.

4.1.2 Water requirements

The mango tree's powerful root system allows it to get water from groundwater near the surface. In this case, the orchards are not irrigated. However, contrary to common belief, mango trees are sensitive to water shortages during periods of high physiological activity. Photosynthesis drops significantly if the plant becomes dehydrated. Outside the 2/3-month period when vegetation stops growing prior to flowering, trees require optimal watering. This involves a combination of rainfall, groundwater absorbed by the root system and irrigation.

Calculating the climatic demand can help you estimate the requirements of the mango trees, which can vary throughout the year and can reach 200-250mm per month during the hottest and driest season.

4.1.3 The soil

Mango trees grow in a wide range of different soils. Deep, filtering soils with no waterlogging problems are preferred.

Undesirable soil features, such as excessively high salinity or pH, very low water reserves and very compacted surface or shallow soil horizons.

4.2   Plot organisation prior to planting

4.2.1 Erosion and drainage measures

Surface preparations should be carried out to limit erosion and enable a rapid evacuation of water during the rainy season. Mounds and drainage ditches, etc. should be created before planting begins. This work should not excessively disrupt the pre-existing soil horizons in the area set aside for the planting itself.

4.2.2 Windbreak network

It is very useful to protect against the wind in order to reduce the orchard's water consumption, limit negative mechanical effects of the wind and restrict the spread of certain diseases between plots. It is best to plant windbreak trees (*Casuarina equisetifolia*, *Acacia auriculiformis*, etc.) before the mango trees.

When using hedges, windbreaks or living fences, it is advisable to avoid species which compete strongly with mango trees (e.g. eucalyptus) or those which are hosts to pests and diseases affecting mango trees. These cases are rare, but include species which host fruit flies and fruit just before mango trees (e.g. cashew trees).

Figure 15: Living fence made up of Euphorbia tirucalli, Capparis tomentosa and various thorny Acacia spp. This type of fence plays various roles: demarcation of plots, windbreak, defensive hedge, etc.

Figure 16: The plot to the left of the passage is surrounded by Australian pine trees, which act solely as windbreaks. This is why they are supplemented by a barbed wire fence. On the right, Prosopis windbreaks are reinforced by a walled enclosure.

4.2.3 Planting density

Correct density helps to optimise production levels, makes it easy to move around the orchard and provides good lighting and aeration to adult trees.

Density levels can vary significantly. Traditional plantations with vigorous varieties and uncontrolled foliage development have a lower density of around 100 plants per hectare. With less vigorous varieties, density can be higher: between 150 and 400 trees per hectare if the development of the foliage is pruned. Nowadays, very few orchards are designed to be high density.

For high density planting, regular trimming is vital. Otherwise, after a few years, the foliage will overlap and all the branches will need to be pruned. There will then only be a few leaves left at the end of the vertical branches. See Figure 17.

In pruned orchards, some producers plant trees in areas of 5m x 5m, while other prefer 4m x 4m or 5m x 3m. We believe that distances of 7m x 5m or 7m x 4m between the fruit trees help to optimise the yield and quality of fruits, while leaving enough space for equipment to pass up and down the rows.

All techniques used in the orchard are connected. The relationship between densities, pruning, phytosanitary protection, nutritional input and harvest methods is a perfect illustration of this.
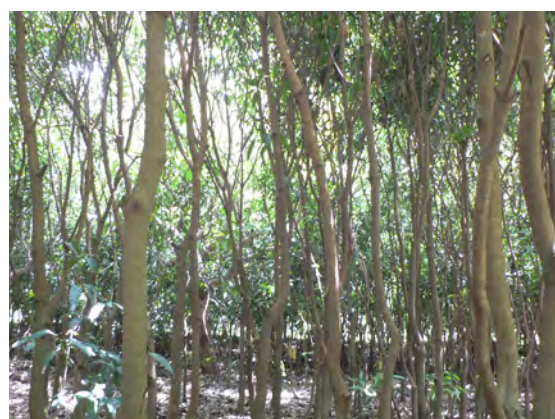
Figure 17: Unpruned mango trees in a high density plantation. After a few years, there are no leaves or branches in the lower section. Production is consequently almost zero.

Figure 18: Alternating lines of mango trees and citrus trees

4.2.4 Soil preparation

4.2.4.1 Mechanised cultivation

If the soil is compacted, a cross subsoiling 70-80cm deep is necessary. Tilling prior to planting should be carried out to create small embankments along the planting line. The initial fertiliser and soil enrichers should be applied before the final tilling to ensure they are buried well into the soil.

4.2.4.2 Non-mechanised cultivation

A 50cm x 50cm x 50cm hole is dug where each tree will be planted. The earth is mixed with 20kg of well-decomposed manure, along with 500g of superphosphate or tricalcium phosphate, 200g of potassium sulphate, and, if necessary, some dolomite. The hole is then filled in to create a mound with the earth mixture.

In some conditions, structuring the soil with soil-improving plants is recommended. Some species, especially Brachiaria grasses, help to structure the soil at a depth of over 1m. However, these soil-improving plants provide significant competition for the plant being cultivated. Therefore, they should be planted two years before the mango trees and destroyed before the mango trees are planted. An alternative approach involves destroying the soil-improving plants along the mango tree planting lines and then gradually reducing the width of the remaining grass strips as the mango trees develop. The choice of the soil-improving plant depends on the environmental conditions (soils, rainfall, etc.).

4.3   Plantations

4.3.1 Plantation layout

It is important to stake out the layout carefully to ensure that there is good alignment between the lines, rows and diagonals.

When digging the holes, so as not to lose the benefit of good layout planning, the stake marking the position of each tree should be replaced by two more stakes placed outside the planting hole, aligned using a planting rod.

4.3.2 Planting

Planting should be scheduled for the start of the rainy season. In these conditions, the plants will recover more easily. The mango tree with its root ball, removed from its plastic bag or pot, should be planted at the top of the mound. A raised bowl should then be fashioned using soil taken from the space between the lines. Initial watering can help to lightly compact the earth and ensure good contact between the soil and the root ball. Straw-mulching after the initial watering helps to maintain a humidity level to promote the growth of young roots.

4.4 Upkeep of the plantation

4.4.1 Irrigation

Mango trees have relatively significant water requirements. Often, the powerful, rotating root system of the mango tree allows it to find water in deep layers. If the water resources are sufficient, no irrigation is required. If not, irrigation can be carried out in a number of ways: trickle irrigation, microjets, mini-sprinklers, basin irrigation or furrow irrigation. The last two methods waste a lot of water.

Water requirements can be estimated through a calculation combining the potential evapotranspiration (PET) and the crop coefficient (Kc), which varies depending on the physiological stage of the plant. A further correction must take into account the development of the trees. The requirements of a young plantation are therefore very different from those of a mature orchard.

KC VALUES DEPENDING ON THE PHENOLOGICAL STAGE
(Mango trees - North-east Brazil)
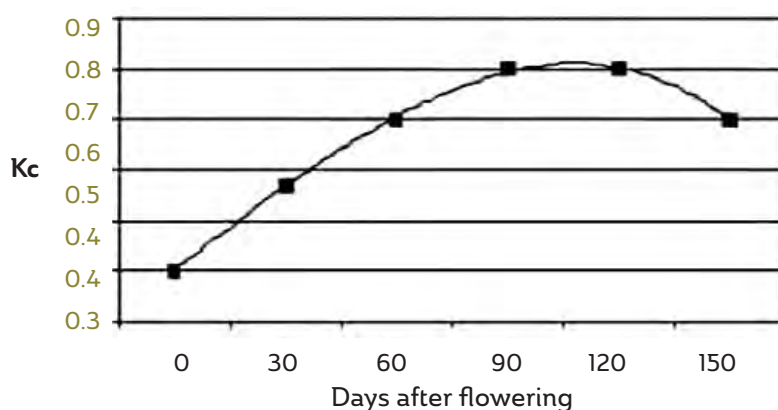
Figure 19: Example of the changes in Kc values for mature Tommy Atkins mango orchards in Brazil (Silva, 2000).

During a season, the water consumption of an orchard varies significantly as the PET and crop coefficient (Kc) change.

Over the first five years of an orchard, transpiration from the mango trees develops very quickly as the foliage grows. Managing irrigation by mainly using climate data is a delicate operation. It is better to base irrigation decisions on changes in soil humidity using tensiometer sensors placed between 20cm-40cm deep.

Choosing and managing an irrigation technique must take into account the climatic demand and development of trees, the soil's water retention capacity, the flow rate of the irrigation system and the water quality. The frequency of water input depends heavily on the technique chosen. The principle of trickle irrigation is based on a frequent but limited supply. When carried out correctly, this should provide several irrigations per day, meeting the daily needs of the plants. With mini-sprinklers or microjets, watering is carried out less frequently with 2-3 irrigations per week meeting the plants' water requirements for several days at a time.

4.4.2 Role of various nutrients in fertilisation

4.4.2.1 Nitrogen

This element is critical for trees to grow. Since it is highly soluble, nitrogen is generally applied gradually throughout the year.

An excess of nitrogen can have a negative effect on the quality of mangoes. Imbalances in the Ca/N ratio are responsible for physiological disorders known as internal breakdowns*. This is why most modern fertiliser programmes for mango trees aim to limit nitrogen input to 300g per tree per year, unless the soil has a particularly serious deficiency.

It is important to avoid adding too much nitrogen during the stage when the fruit is growing. It should be added mainly between the harvest and the period when the vegetative growth stops.

* see the description in the chapter on physiological diseases.

4.4.2.2 Phosphorous

Phosphorous promotes the development of the root system, the start of flowering and the hold of the fruit on the tree. Phosphate fertilisers are not very soluble and it takes them a long time to work their way into the soil. However, some fertilisers, such as superphosphate, are a little more soluble. This element should be used mainly in the initial fertiliser treatment. Thereafter, phosphorous can be added every two or three years, underneath the foliage and slightly buried under the soil. Low pH and high levels of iron, especially in lateritic soils, can reduce the effectiveness of phosphorous.

4.4.2.3 Potassium

Uptake of this element by the fruit is high. It plays a key role in the organoleptic quality of the fruit and its preservation after the harvest. Potassium fertilisers should be added every year, taking account of the productivity of the orchard.

4.4.2.4 Calcium

Calcium can be added to acidic soils in the form of dolomite, natural phosphate (or tricalcium phosphate) and gypsum. Calcium deficiency leads to poor quality fruit and poor preservation.

4.4.2.5 Magnesium

Magnesium plays a key role in the formation of chlorophyll pigments.

Magnesium deficiency rarely affects young leaves. Symptoms are most often visible on leaves which are a few months old. Deficiencies can be identified by a discolouration of interveinal areas, which turn yellow. A green chevron is often visible at the base of the limb. An excess of magnesium can lead to a potassium/calcium imbalance. Magnesium is applied in dolomite form if the pH of the soil is acidic and magnesium sulphate if the pH is high.

4.4.2.6 Boron

Boron plays an important role during the pollination of flowers and the growth of the fruit. During flowering, it is sometimes necessary to spray the leaves to meet the immediate boron requirements.

4.4.2.7 Zinc

Zinc combines with iron and manganese to create chlorophyll.

The symptoms of a zinc deficiency are relatively distinct. When new vegetative shoots appear, the leaves are small and have discoloured limbs between the veins. Excess phosphorous can lead to zinc deficiencies.

4.4.3 Mineral fertiliser

To create a fertiliser plan, producers need information about the major mineral element content of the soil and leaves. It is also important to know the orchard's production level in order to assess the uptake of mineral elements by the fruit.

Leaf analysis provides good indications regarding the normal growth of the tree. If this is not done, nutrients can build up in the leaves because of the poor development of the tree due to other causes (lack of water or root and vascular problems). In the first few years after planting, annual input is gradually increased until reaching a ceiling at around 10 years.

It is difficult to produce a benchmark fertiliser grid which could be used across a wide range of different situations. As a result, the windows in which the input levels used in different production regions fall for plantation densities between 150 and 350 trees per hectare are provided below.

FERTILISER IN KG PER HECTARE

Age	Nitrogen (N)	Phosphorous (P2O5)	Potassium (K2O)
1 to 3 years	10 to 15	5	10
4 to 5 years	20 to 30	10 to 15	20 to 30
6 to 7 years	25 to 45	15 to 20	25 to 50
8 to 9 years	30 to 60	15 to 25	30 to 70
10 years plus	40 to 100	20 to 45	40 to 120

These indicative values should be adjusted according to soil and leaf analysis results.

The period of application and the proportion of fertiliser to use are important factors. They can be adjusted based on the timing of the rainy season in non-irrigated systems.

Element	Percentage of annual fertiliser	Input format	Period of input
Nitrogen	50%	in the soil	After the harvest
Nitrogen	30%	in the soil	Flowering - fruit-set
Nitrogen	20%	in the soil	Enlargement of fruit
Potassium	50%	in the soil	After the harvest
Potassium	50%	in the soil	Flowering - fruit-set
Phosphorous	100%	in the soil	Before the rainy season
Boron	100%	Leaf spraying	Before flowering
Zinc	100%	Leaf spraying	On young vegetative shoots

The recommended mineral fertilisers vary significantly depending on the sources. They depend on the type of soil, previous crops, technical itineraries (irrigation enables the plants to grow more quickly and leads to losses due to leaching), yield, etc. (see Technical itinerary for mangoes, chap. 4.4.)

The uptake of mineral elements per tonne of fruit is significantly different according to different authors.

UPTAKE OF MINERAL ELEMENTS PER TONNE OF FRUIT
(in grams)

Elements	Ted Winston (Australia)	Oosthuise (South Africa)
N	845	1500
P	180	324
K	1285	2352
Ca	1150	274
Mg	240	212
B	2	6
Zn	2	6
Fe	6	13

Note: phosphorous, potassium, magnesium and others are generally expressed in weights of P_2O_5, K_2O and MgO in French-language documents, and P, K and Mg in English-language documents.

We can therefore make the following general suggestions:

Young plants require nitrogen and phosphorous. Phosphorous helps the development of the root system. Since these young trees grow faster when they are irrigated, they can be given 200g-250g of nitrogen per plant in the first year, which can be increased by 100g-150g per year until the third year if irrigated and by 50% in dry conditions.

Dosages of K should be the same as for nitrogen, while doses of P should be equivalent to 50% of the nitrogen doses. Magnesium doses should be one third of the K dosage.

Highly insoluble calcium-based fertilisers (tricalcium phosphate or dolomite) should be mixed with earth in planting holes to make them more readily available for the roots.

The aim is therefore largely to balance the uptake while also limiting the addition of nitrogen to 500-600g per tree per year in order to prevent physiological disorders.

Physiological defects are caused or worsened by imbalances between nitrogen and cations. It is therefore advisable to maintain this balance with additions of potassium and magnesium. In acidic soils, calcium can be added (e.g. lime or limestone-rich fertilisers) to compensate for the acidity.

In addition to general recommendations, it is important to note that soil and leaf analyses are necessary to ensure effective fertiliser management.

Like all crops, mango trees require major, minor and trace elements, some of which can help the plant react against external attacks. A deficiency can have various different causes: deficiency of nutrients in the soil, attacks, blockages following absorption problems, excessive acidification or alkalinisation of the soil, vascular or root diseases, etc. It is therefore better to opt for leaf sprays over spreading fertilisers over the soil. However, spraying fertilisers onto the leaves is much more expensive and can damage leaves and young branches.

4.4.4 Weed control - protection from fire

Young mango trees are sensitive to herbicides, especially soil-applied herbicides. It is better to weed by hand close to the plants. For the application of contact or systemic herbicides, the use of a protective cover is essential to prevent any spray reaching the trunk or leaves. In irrigated areas, intercropping is often carried out in the first few years. This helps to keep the young orchard tidy and makes the monitoring and upkeep of the plants easier.

In non-irrigated orchards in savannah areas of west Africa, light tilling helps to limit the development of weeds in the rainy season. One final surface tilling at the start of the dry season helps to keep the soil clear throughout the season.

As for all plant protection products, exporting producers must carefully monitor any changes in the regulations of importing countries regarding the use of herbicides, especially glyphosate. Although is may be possible to use certain products while ensuring compliance with the MRLs and the regulations of the producer country, some certifications are much stricter.

5. PLANT PROTECTION

5.1 Preliminary comment

Given the ongoing changes to phytosanitary regulations and standards governing the using of Plant Protection Products, especially regarding the European Union's Maximum Residue Limits (MRLs) and the Codex Alimentarius, the COLEACP published the E-GAP (Good Agricultural Practices) database online in 2018 as a tool to assist in developing technical itineraries.

The E-GAP brings together the MRLs established by the EU and the Codex Alimentarius for key horticultural crops in ACP countries. It also sets out good agricultural practices (doses, intervals between treatments, periods before harvesting, etc.), which ensure that these MRLs are complied with. Additional information such as the type of pesticide, the authorisation status of the active substance in the EU, the classification recommended by the World Health Organisation (WHO) and the resistance group (FRAC code for fungicides, IRAC classification for insecticides) is also available[1].

To date, the E-GAP is one of the only databases to provide information specifically designed to support the horticultural sector in ACP countries. Data on good agricultural practices (GAP) is obtained from a variety of sources, including the COLEACP's field trials of PPPs, data from manufacturers of PPPs and the scientific literature.

The E-GAP is accessible to all COLEACP members and beneficiaries in the e-service section of the COLEACP website: here

Producers must also refer to their national or regional regulations as well as the specifications for their certifications before deciding to use a plant protection product.

Phytosanitary protection must be measured. In other words, it must be based on good knowledge of the orchard and a detailed observation of the development of diseases and pest populations.

---

1 The COLEACP also wishes to highlight the importance of complying with the instructions on the labels of PPPs. Moreover, before using any product, it is advisable to consult the latest regulatory amendments in the EU database on pesticides and in the Codex Alimentarius.

5.2 Steps to implement an integrated plant protection approach

What to do?	How?	When?	Why?
IDENTIFY	▪ By visually checking the different parts of the plant ▪ By threshing the inflorescences ▪ By installing fruit fly traps	Every week, from flowering to harvest	To spot diseases or pests as soon as they appear in the orchard and before the damage becomes too great
ESTIMATE / QUANTIFY	▪ Carry out accurate sampling ▪ Evaluate accurately by counting	Every month from the harvest until the next flowering, or even more frequently if a risk is identified	To gather the necessary data to make decisions. Treatment should only be carried out when the crop is genuinely threatened, not before or after
DECIDE and CHOOSE	▪ Adapt the strategy according to a clearly identified and assessed risk	After each inspection of the orchards	For a timely intervention as part of a measured approach, using the most appropriate method to control the disease or pest and preserve auxiliary species

5.3 Identification of the risk periods according to phenological stages

It is critical to know at which stage of the crop a disease or pest is likely to appear. This topic is addressed later in the document.

5.4   Geographic distribution of diseases and insects

Diseases	West Africa	Southern Africa and Indian Ocean	The Caribbean	Ecological context conducive to strong expression
Anthracnose	X	X	X	All areas
Powdery mildew	X	X	X	Cool areas (especially areas at high altitude or latitude)
Alternaria	X			Alternating between dry periods and light rain
Peduncle rot	X	X	X	All areas
Fusarium wilt	X	?	?	All areas
Other post-harvest rot (*Aspergillus, Cladosporium, Fusarium, Penicilium, Rhizopus, Stemphylium*)	X	X	X	All areas
Scab	X	X	X	All areas
Sigatoka	X	X	X	All areas
Bacterial canker	X	X		All areas

Pests	West Africa	Southern Africa and Indian Ocean	The Caribbean
Fruit flies *Ceratitis* spp.	X	X	X
Fruit flies *Bactrocera* spp.	X	X	
Fruit flies *Anastrepha* spp.			X
Fruit tree mealybug*	X		
Diaspididae	X	X	X
Termites	X		
Weaver ants	X	X	
Thrips	X	X	X
Acrididae**	X		
Gall midges	X	X	
Whiteflies	X	X	
True bugs	X	X	
Mango stone weevils	X	X	X

* Organic control is challenging in inland areas
** Especially in the Sudano-Sahel region

5.5   Pests

5.5.1 Fruit flies: *Bactrocera dorsalis, Ceratitis cosyra, C. fasciventris, C. quinaria, C. silvestrii*

Illustrations of the pest in Appendix 3-3: Fruit flies

Highest susceptibility stage:
Fruit at the latest stage of development, mainly from ripening to harvest.

Varietal susceptibility:
Amélie, Brooks, Davis Haden and Miami late are among the most sensitive but the two main export varieties, Kent and Keitt, are also sensitive.
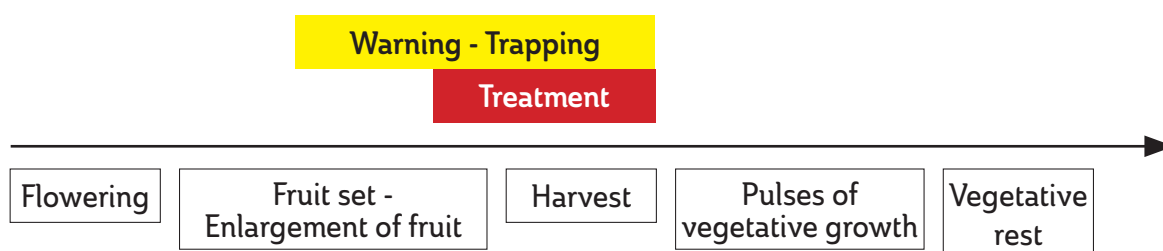
Figure 20: Cultivation stages sensitive to fruit flies

Other host plants:

Many other fruit trees, including guava trees, papaya trees, citrus fruit trees (oranges, mandarins, etc. especially those with a thin skin and a non-acidic pulp), cherimoya trees, Indian almond trees, cashew trees, shea trees, and so on, as well as market garden plants such as cucurbits. The range of host plants varies from one species to another and depends on the country in question.
For more information, see http://www.africamuseum.be/fruitfly/AfroAsia.html

Appropriate period for intervention:
A trapping system is the only way to determine the fly population thresholds and establish the most suitable treatment methods. This monitoring should be in place one month after flowering and continue until the end of the harvest.

Symptoms and damage:
Adult female flies, which vary in size from approximately 3.5mm to 10mm depending on the species, make two types of bite marks in the fruit:

- Bites for feeding, which result in small superficial marks on the epidermis. This damage only has a limited effect on the fruit and few consequences.
- Egg-laying bites the size of a needle, which are visible on the epidermis of fruit that hasn't been harvested in the form of small brown marks combined with small droplets of resin.

After the eggs hatch inside fruit that has been bitten into, maggots develop and dig tunnels by feeding on the pulp. The damaged parts of the fruit mature very quickly. Fruit which is damaged early fall prematurely and rot on the ground. Fruit which

is not badly affected or which is bitten late may remain on the tree for harvesting.

Due to the larger populations of flies as the season continues, late varieties are often bitten more frequently. Numerous host plants nearby can sometimes lead to high populations from the very beginning of the harvest season.

Since flies are classified as a "quarantine insect", no bitten fruit containing larvae can be exported, otherwise the entire batch of mangoes may be rejected or destroyed by the European phytosanitary services. Therefore, any fruit with bite marks must be detected and removed during the harvest and on-site sorting.

Development cycle and conditions conducive to infestation:

After mating, the female lays her eggs (1mm) in a bunch under the epidermis of fruit close to maturity. After between two and five days, the eggs hatch and larvae emerge. After spending between 9 and 15 days in the fruit, maggots (7-9mm) at the third larval development stage leave the fruit and transform into pupae on the ground. Adult flies emerge from these pupae (4-5mm) after a period of time which varies significantly depending on the climatic conditions (temperature, rainfall, dry conditions). In humid but not excessively wet conditions, with temperatures between 25°C and 30°C, the length of the life cycle is between 15 and 20 days for *Ceratitis capitata* and up to 30 days for *Ceratitis cosyra*. Ceratitis flies are polyphagous and multivotine (several generations in one year). They migrate from one species to another depending on the season and the maturity stage of the fruit. Having host plants nearby, including fruit which reaches maturity before mangoes, considerably increases the risk of infestation in mango tree orchards.

Observation methods – Trapping system:

Currently, detection trapping is mainly used to monitor fly populations. It is not a method of control. This method uses two types of lure:

- Sex-based lures, or parapheramones, which only attract males,
- Food-based lures, usually protein hydrolysates, which attract male and female flies (mostly females, with a few immature males).

These lures have helped develop trapping systems to capture adult flies and assess the infestation levels. Along with the lure, a trap also contains an insecticide tablet. Choosing the lure(s) to use depends on the species targeted.

For increased effectiveness, part of the trap should be coloured yellow (attractive colour). Each production region should conduct experiments to establish the relationship between the level of infestation shown by the trapping system and the level of harmfulness. This helps to define the infestation thresholds to trigger treatment (for more information on fruit flies, refer to the brochure produced by the CTA (Technical Centre for Agricultural and Rural Cooperation ACP-EU)).

Choice of traps:

There are several types of trap. The most commonly used models are Addis, MacPhail and Tephritrap.

CHOICE OF ATTRACTANTS AND INSECTICIDES FOR A CAPTURE-BASED MONITORING SYSTEM:

Sexual attractants	Effective on	Observations
Trimedlure	Males of the species *Ceratitis capitata, C. fasciventris* and *C. anonae*	Change the lure every month
Terpinyl	Males of the species *Ceratitis cosyra, C. sylvestrii, C. quinaria,* and *C. fasciventris* (AW)	
Methyl eugenol	Males of the species *Bactrocera dorsalis* and *C. bremii*	
Insecticide	**Effective on**	**Observations**
Dichlorvos	All flies	Change the insecticide every month
Food-based lure	**Effective on**	**Observations**
Three components	All female fruit flies (and sometimes males)	Change the lure every month

Preventative measures:

The preventative measures for reducing fruit fly populations are limited. They involve the plantation and the entire surrounding environment:

▪ Collect and destroy fallen and bitten fruit, in the orchard itself and surrounding orchards. Fruit can be collected in leak-proof black plastic bags and placed in direct sunlight in order to destroy the larvae with heat. An even better approach involves placing the fruit in devices called augmentoriums (Figure 21), which prevent the adult flies escaping but allow any of the flies' parasitoids to leave. This technique is especially useful when the flies' parasitoids are present and provided that the climatic conditions allow them to survive inside the augmentorium.

Figure 21: Augmentorium - Photo: CIRAD

▪ Destruction of unhelpful host plants.

Control without using Plant Protection Products:

- Using auxiliary species: Ants (Figures 22 to 25) and other insects destroy some larvae in the fruit and some pupae on the ground, but natural parasitism on flies is low. Populations can only be effectively dealt with through biological control methods.

Figure 22: Oecophylla longinoda predating fruit fly larvae
Photo: Jean-François Vayssières

Figure 23: Adult C. cosyra captured by ants
Photo: Jean-François Vayssières

Figure 24: Oecophylla longinoda predating adult Bactrocera dorsalis
Photo: Jean-François Vayssières

Figure 25: Nest of Oecophylla longinoda
Photo: Jean-François Vayssières

- Using sterile males: There are some national programmes which use sterile males to disrupt the reproduction of flies. In order to be effective, such programmes must be coordinated and conducted over very large areas. In west Africa, some national programmes have been carried out with international organisations (e.g.: IAEA/International Atomic Energy Agency).

- Mass trapping of males: carried out by attracting males using synthesised pseudopheramones. The number of traps per surface unit is higher than for detection trapping. In order to be effective, this mass trapping needs to be conducted everywhere for the whole year to prevent populations coming back from reinfestation sites. Moreover, unlike food-based lures, sex-based lures are specific to each species or group of species. Therefore, in west Africa, although B. dorsalis is the dominant species, flies of the *Ceratitis*

genus, especially *C. cosyra,* generally make up between 10% and 30% of the overall fruit fly population in some areas, particularly at the peak of the *C. cosyra* population early in the season before the *B. dorsalis* arrives in earnest. Orchards with traps which only contain methyl eugenol throughout the year have found very high numbers of ceratitis flies because they do not need to compete with the *B. dorsalis* flies.

Application of Plant Protection Products:

There are two intervention methods available. Which one is implemented depends on the infestation level detected by the trapping system and the parasite pressure connected to the orchard's environment. Their practical implementation requires approval of their methods for use in each production area. In light of ongoing changes to phytosanitary regulations and standards governing the use of Plant Protection Products, it is advisable to consult the E-GAP (Good Agricultural Practices) database by clicking on COLEACP Resources here in order to check the authorisation status of the active substance in the EU and ACP countries, the MRLs (maximum residue limits) and the good agricultural practices which ensure compliance with these MRLs.

- Local treatment: a food-based lure (protein hydrolysate) mixed with an insecticide. This mixture is applied in the form of large droplets to a limited amount of foliage not carrying fruit (around $1m^2$/tree). The treatment is effective for around eight days. It must be reapplied in the event of over 25mm of rainfall. This local application method, carried out using backpack sprayers, enables treatment to be applied just before, or even during, the harvest, because it is possible to avoid touching the fruit.

- General treatment: insecticide is applied across the entire orchard surface at a rate of 800-1000l of solution/hectare in the case of a mature orchard (see the tables of effectiveness of active substances on pests and diseases in Appendix 1). Some substances can also be used during the harvest period, providing that compliance with the Pre-Harvest Intervals (PHIs) adjusted to the MRLs is ensured. In light of ongoing changes to phytosanitary regulations and standards governing the use of Plant Protection Products, it is advisable to consult the E-GAP (Good Agricultural Practices) database by clicking on COLEACP Resources here in order to check the authorisation status of the active substance in the EU and ACP countries, the MRLs (maximum residue limits) and the good agricultural practices which ensure compliance with these MRLs.

NB: local treatments can produce disappointing results in a number of cases:

- Orchards surrounded by fruit tree plantations and/or hedges with wild fruit, which are infested with flies themselves.
- Very high level of parasite pressure due to poor prior pest control (large quantities of bitten fruit on the ground, no general treatment at the start of the season to prevent the early spread of flies, etc.).

*Figure 26: Fruit flies feeding on insecticide
applied to leaves*
Photo: Jean-Yves Rey

See the table of usable active substances in Appendix 1.

5.5.2 Mealybugs

Illustrations of the pest in Appendix 3-3: Mealybugs

Sucking homoptera insects. Mealybugs feed on the sap of a plant and sometimes inject toxic saliva, which causes a reaction: yellowing of leaves and, in the event of serious attacks, drying out of entire branches.

They can be split into two main categories: mealybugs with a waxy shell and mealybugs with soft, hairy bodies.

5.5.2.1 Waxy shell mealybugs

These include diaspididae and some lecanines. The most significant pests include: *Aulacapsis tubercularis; Lepidosaphes gloverii; Pseudaonidia tribitiformis*, etc.

Application of Plant Protection Products:
Controlling waxy shell mealybugs involves using white oil, which acts as an asphyxiant.

Since mealybugs are most vulnerable at the young, mobile larvae stage, treatment is most effective at this stage of the development cycle. See the tables of effectiveness of active substances for pests and diseases in Appendix 1. In light of ongoing changes to phytosanitary regulations and standards governing the use of Plant Protection Products, it is advisable to consult the E-GAP (Good Agricultural Practices) database by clicking on COLEACP Resources here in order to check the authorisation status of the active substance in the EU and ACP countries, the MRLs (maximum residue limits) and the good agricultural practices which ensure compliance with these MRLs.

5.5.2.2 Soft and hairy-bodied mealybugs

These include *Icerya* sp., *Pseudococcus* sp., *Coccus mangiferae*; *Rastrococcus* sp.. The two most significant pests for mango trees are: Icerya seychellarum; *Rastrococcus invadens* (mango tree mealybug).

These mealybugs are generally controlled by natural enemies. Mealybugs tend to spread rapidly after insecticides targeting other pests are applied. However, control by natural enemies can sometimes prove insufficient for *R. invadens.*

Mealybugs with shields are often observed on trees displaying poor growth.

5.5.2.3 Mango tree mealybug: Rastrococcus invadens

Highest stage of susceptibility:
Colonisation of new vegetative shoots, followed by development and spread throughout the period of high physiological activity, from flowering to harvest.

Other host plants:
Various fruit trees, including citrus fruit trees, guava fruit trees, breadfruit trees, papaya trees and ornamental plants such as frangipani, rose bushes, fig trees, crotons, and so on.

Appropriate period for intervention:
After the harvest, after any pruning and thinning, and before the appearance of new vegetative shoots.

Size before first treatment

1st   2nd

| Flowering | Fruit set - Enlargement of fruit | Harvest | Pulses of vegetative growth | Vegetative rest |
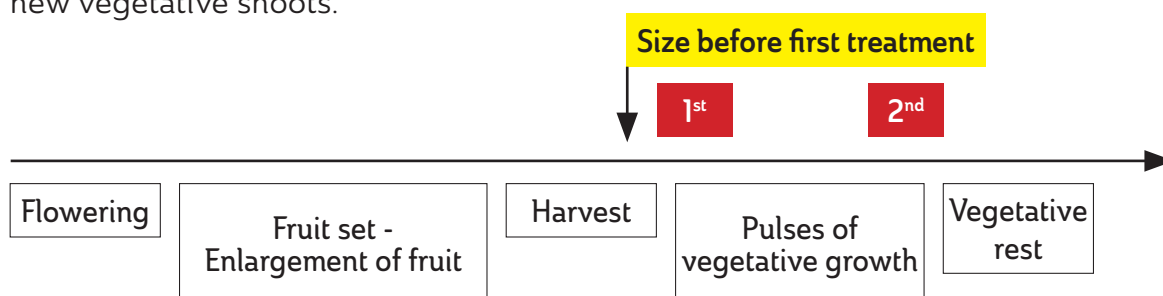
Symptoms and damage:
The first development stages of the mealybug can go unnoticed. During the mango trees' vegetative growth stage and as the populations of mealybugs develop, drops of honeydew start to appear. This dripping can be intense enough to be likened to rainfall. They cover the underside of the leaves. Thereafter, a fungus develops on the honeydew, forming an opaque, black surface layer known as sooty mould (Appendix 3-3, Figure 99). The photosynthesis process of the trees is therefore severely disrupted. The intensity of the flowering and production are hampered as a result. Trees which are severely attacked during the rainy season do not flower the following season.

Significance of the pest depending on production regions:

Conditions conducive to infestation:
The mealybug, originally from Asia, was introduced accidentally to west Africa without its natural parasites, thus enabling it to spread. The scale of the damage in each new affected zone can be explained by the absence of any natural parasites, which have not yet been able to develop sufficiently.

Introducing these parasites into coastal areas helped establish excellent organic control of the pest. In inland regions, populations of parasitoids drop dramatically as temperatures fall in Harmattan season. As temperatures rise again, mealybug numbers grow much faster than their parasites. The damage then becomes very visible. Later on, it stabilises as parasite control improves.

Observation methods:

In a contaminated area, many mango trees covered in sooty mould is a good initial indication. Spotting affected trees is simple: a damp area under the foliage, shiny leaves in the dry season and sooty mould during the rainy season and in following seasons. Fruit tree mealybugs can be detected on the underside of leaves by the presence of long silky strands.

Preventative measures:

Port areas are very often the source of any accidental introduction of external pests. Vans and lorries then help to spread the mealybugs. Vehicles must not be parked under trees in infested areas and, likewise, should not be parked under mango trees in an unaffected area when they have come from an infested area.

Control without using Plant Protection Products:

Organic control is possible with parasitoids from Asia, such as: *Anagyrus mangicola* and *Gyranusodea tebegy,* and to a lesser extent with natural endemic parasites such as ladybirds. Therefore, widespread chemical methods should be avoided at first, as this would destroy parasitic entomofauna.

While organic control has produced excellent results in coastal areas, it appears to be more problematic in inland environments (Sahel region).

Application of Plant Protection Products:

Chemical control methods should only be used after the limitations of organic control have been observed.

Treatments must be carried out after the harvest is over and before new vegetative shoots emerge so as not to jeopardise future flowering. Two treatments 15 days apart are advisable in the event of a serious attack. In the event of a treatment that is only partially successful, a further treatment may be carried out between one and three months later, at the start of the dry season. It is advisable to prune the mango trees before applying any plant protection products to enable them to penetrate properly. Using tractors fitted with a spray hose is essential to ensure that all of the foliage is sufficiently covered, including both sides of the leaves, and the inner and outer parts of the tree.

See the tables of effectiveness of active substances for pests and diseases in Appendix 1. In light of ongoing changes to phytosanitary regulations and standards governing the use of Plant Protection Products, it is advisable to consult the E-GAP (Good Agricultural Practices) database by clicking on COLEACP Resources here in order to check the authorisation status of the active substance in the EU and ACP countries, the MRLs (maximum residue limits) and the good agricultural practices which ensure compliance with these MRLs.

5.5.3 Thrips

Illustrations of the pest in <u>Appendix 3-3: Thrips</u>

Scirtothrips aurantii (citrus and mango tree thrips); *Selenothrips rubrocinctus*

S. aurantii is a very small and very mobile biting insect, which attacks various different plants. On mango trees, they look for shelter and feed on young shoots which are rich in sap.

Symptoms and damage:
When attacked, young leaves acquire a characteristic indented appearance. Young fruit (under 3cm in diameter) is covered in a cork-like coating. In the event of a serious attack, the fruit stops growing and falls.

Conditions conducive to infestation:
Risks of spreading are higher in hot, dry weather.

Observation methods:
Regular threshing of the end of the branches above a white sheet can help to assess the size of populations present.

Application of Plant Protection Products:
The control strategy adopted must ensure that auxiliary species, which play a key role, are preserved. With this in mind, spinosad has had good results for mango and citrus trees. Repeated use of the same active substance can lead to resistance, so the chemical family should be changed regularly. It is important not to exceed three treatments per year.

See the tables of effectiveness of active substances for pests and diseases in Appendix 1. In light of ongoing changes to phytosanitary regulations and standards governing the use of Plant Protection Products, it is advisable to consult the E-GAP (Good Agricultural Practices) database by clicking on COLEACP Resources <u>here</u> in order to check the authorisation status of the active substance in the EU and ACP countries, the MRLs (maximum residue limits) and the good agricultural practices which ensure compliance with these MRLs.

5.5.4 Mango blossom gall midges (*Erosomyia mangiferae*) and mango leaf gall midges (*Procontarinia matteian*a)

Illustrations of the pest in <u>Appendix 3-3: Gall midges</u>

Gall midges are tiny flies (diptera), which bite into developing flower stalks or very young leaves in order to lay their eggs.

Symptoms and damage:
In inflorescences, the development of maggots causes deformations or brown, necrotic marks. If flowering is poor, there may well be a high concentration of bites on the existing floral panicles, which leads to more significant harm being done. Observing the floral panicles is the only way to estimate the level of infestation. In high risk areas, as soon as five bites are observed per stalk on 100 panicles in the orchard, insecticide use should be swiftly planned. Young leaves react to bites by developing very characteristic scabs. Adult trees are not particularly disrupted. However, young trees in nurseries or newly planted trees should be protected.

In this case, it is very difficult to establish an intervention threshold because the damage is only ever observed after it has taken place. Information on at-risk areas and sensitive stages (production of new shoots with leaves) can be used as a guide.

Application of Plant Protection Products:
See the tables of effectiveness of active substances for pests and diseases in Appendix 1. In light of ongoing changes to phytosanitary regulations and standards governing the use of Plant Protection Products, it is advisable to consult the E-GAP (Good Agricultural Practices) database by clicking on COLEACP Resources here in order to check the authorisation status of the active substance in the EU and ACP countries, the MRLs (maximum residue limits) and the good agricultural practices which ensure compliance with these MRLs.

5.5.5 Whiteflies: *Aleurodicus dispersus*

Illustrations of the pest in Appendix 3-3: Whiteflies

Homoptera of the *aleurodidae* family are commonly known as spiralling whiteflies because of the characteristic way they lay their eggs in spirals on the underside of the leaf limb.

This polyphagous pest attacks various cultivated and wild plant species.

Other host plants:
Various species of fruit tree, including avocado trees, African pear trees and, to a lesser extent, some citrus trees such as pomelo trees.

Highest stage of susceptibility:
The adult female lays its eggs on the underside of the limb of young, mature leaves. Around eight days later, larvae hatch out, which take 25-30 days to develop. Rain negatively affects the survival and development of the eggs and larvae.

Symptoms and damage:
The secretion of honeydew by larvae leads to the development of sooty mould on the top of the leaves. This honeydew is very harmful to the physiological functioning of mango trees. Risks of spreading are highest during long dry seasons.

Control without using Plant Protection Products:
Parasitoids such as *Encarcia haitiensis* (hymenoptera) feed on these larvae and provide biological control.

Application of Plant Protection Products:
See the tables of effectiveness of active substances for pests and diseases in Appendix 1. In light of ongoing changes to phytosanitary regulations and standards governing the use of Plant Protection Products, it is advisable to consult the E-GAP (Good Agricultural Practices) database by clicking on COLEACP Resources here in order to check the authorisation status of the active substance in the EU and ACP countries, the MRLs (maximum residue limits) and the good agricultural practices which ensure compliance with these MRLs.

5.5.6 True bugs: *Anoplocnemis curvipes, Lygus* spp.

Illustrations of the pest in <u>Appendix 3-3: True bugs</u>

Highest stage of susceptibility:
These pests infest new shoots by biting into the buds, leading to the characteristic deformations. This pest is feared because it can destroy new shoots very quickly. This can take just a few days, or even a few hours in some cases. It is essential to react quickly in the event of an attack.

In Ghana, some species inject a toxin into the bacterial canker marks on the fruits they have bitten into. As a result, they can considerably worsen the damage caused by bacterial canker and the fruit becomes entirely unsuitable for consumption.

Application of Plant Protection Products:
See the tables of effectiveness of active substances for pests and diseases in Appendix 1. In light of ongoing changes to phytosanitary regulations and standards governing the use of Plant Protection Products, it is advisable to consult the E-GAP (Good Agricultural Practices) database by clicking on COLEACP Resources <u>here</u> in order to check the authorisation status of the active substance in the EU and ACP countries, the MRLs (maximum residue limits) and the good agricultural practices which ensure compliance with these MRLs.

5.5.7 Acrididae

Illustrations of the pest in <u>Appendix 3-3: Acrididae</u>

These orthoptera can be gregarious (desert and migratory locusts), moving around in huge swarms and devastating crops or nongregarious such as grasshoppers, the most dangerous of which is the *Zonocerus variegatus.*

Highest stage of susceptibility:
They are especially dangerous for young trees by feeding on the leaves and new shoots. Regular monitoring is required to protect against grasshoppers. When a swarm lands on an orchard, rapid intervention is essential to drive it away or destroy it. Implementing control measures in advance is essential.

Acrididae attacks can be serious for young plants in nurseries or orchards. Young acrididae are gregarious and not particularly mobile. Chemical control is easier and more effective at this stage, before the damage becomes too significant. The control measures should not be limited to a small plot, but should be applied to the entire crop area.

Application of Plant Protection Products:
Control measures generally involve synthetic pyrethroids (deltamethrine, lambda-cyhalothrin, etc.), organo-phosphates (fenitrothion, malathion, etc.), or other insecticides such as fipronil. Widespread use of pesticides has given rise to resistance. It is therefore advisable for each region to check with the plant protection services regarding the effectiveness of active substances. Biopesticides containing *Metarhizium anisopliae* or *M. acridum* have proven to be very effective.

See the tables of effectiveness of active substances for pests and diseases in Appendix 1. In light of ongoing changes to phytosanitary regulations and standards governing the use of Plant Protection Products, it is advisable to consult the E-GAP (Good Agricultural Practices) database by clicking on COLEACP Resources <u>here</u> in

order to check the authorisation status of the active substance in the EU and ACP countries, the MRLs (maximum residue limits) and the good agricultural practices which ensure compliance with these MRLs.

5.5.8 Termites

Illustrations of the pest in <u>Appendix 3-3: Termites</u>

There are various different species of termites.

Highest stage of susceptibility: All stages
Other host plants: Various woody or semi-woody plants.
Appropriate period for intervention:
There is no specific period when it is best to take action. It is better to carry out treatments just after the harvest to minimise the side-effects of pesticides on the quality of the fruit.

Symptoms and damage:
It is important to distinguish between two types of symptoms.
- Visible crusting on the trunks and lower parts of the scaffold branches. These attacks are very superficial. They are often temporary and are relatively easy to combat.
- More widespread dieback of parts of the mango tree, gradually worsening over a period of several months.

This can be a relatively frequent occurrence. On rare occasions, it is attributed to underground attacks by termites destroying the root system. Digging close to the mango trees suffering dieback is an easy way to check whether termites are responsible.

In general, the most dangerous damage is located around and on the base of the trunk and the area near the large roots. This damage is not caused by large termites (macrotermes), which build large mounds, but by microtermes. It therefore makes no sense to attack macrotermes, which play an important role in maintaining the soil's ecology.

Conditions conducive to infestation:
Termite attacks occur throughout west Africa. This problem occurs much more in the Sahel region than in coastal areas because when trees are under stress due, for instance, to water shortages, they attract termites and are less able to tolerate their activities.

Observation methods:
Look for crusting on trunks and scaffold branches. If you observe leaves wilting and small branches drying out, dig around the trunk to detect any underground attacks.

Preventative measures:
Termites are part of the biocenosis of orchards. Their activity is useful for processing woody debris. Avoid encouraging too many colonies from developing by removing large woody debris or dead trees from the orchard. Paint limewater onto tree trunks to limit the activity of flying termites.

Control without using Plant Protection Products:

Studies are currently being carried out to test the effectiveness of entomopathogenic fungi such as: *Metarhizium anisopliae* or *Beauveria Spp*. Other teams are working on the use of fungicide which destroy termites' symbiotic fungi to remove their food source. However, no effective large-scale control method has yet been discovered. (see Chouvenc *et al.*).

Application of Plant Protection Products:

The range of usable active substances is limited. Controlling termites involves specific local ground treatments. Doses are generally given in grams of active substance per m². It is best to carry out treatments after the harvest to prevent any residue being left on the fruit and, if possible, just before or at the start of the rainy season. For instance, in Mali, treatments are applied after the final harvests at the start of the rainy season, then two months later, towards the end of the rainy season. To ensure the product works its way into the soil well, it is advisable to rake the soil lightly before applying the pesticide. The pesticide should be applied at the base of the trunk and in the soil around the trunk and be followed by generous watering to help it work its way into the soil. Trials conducted in Senegal (Assié and Sané) have shown that pesticide can be applied locally, at the base of the trunk within a radius of 30cm from the tree, and that treating the entire surface underneath the tree is unnecessary. This considerably reduces the amount of PPP to be used per tree or per hectare.

Termites can easily detect individuals which have been infected, either by entomopathogenic organisms or pesticides, and reject them from the colony. A plant protection product may therefore be effective against termites in the laboratory but may quickly lose its effectiveness in the orchard because protection ends as soon as the product degrades. Some products are an exception to this rule. This is the case for fipronil and neonicotinoids, including thiacloprid, acetamiprid, imidacloprid, thiamethoxam, etc. Since these pesticides are difficult to detect, they can reach the queen, having been transported there through contact between infected termites.

This mode of action explains the effectiveness and duration of these products.

See the tables of effectiveness of active substances for pests and diseases in Appendix 1. In light of ongoing changes to phytosanitary regulations and standards governing the use of Plant Protection Products, it is advisable to consult the E-GAP (Good Agricultural Practices) database by clicking on COLEACP Resources here in order to check the authorisation status of the active substance in the EU and ACP countries, the MRLs (maximum residue limits) and the good agricultural practices which ensure compliance with these MRLs.

> *However, even if they are authorised in producer countries and the MRLs comply with European regulations, they are highly controversial due to their environmental impact, especially on bees. They may be banned at any time. Some specifications, especially those regarding environmental protection certifications, completely forbid their use.*

5.5.9 Mango stone weevils

Illustrations of the pest in Appendix 3-3: Mango stone weevils

These pests are quarantine insects for the EU. Among the main west African exporting countries, this insect is present in some coastal areas but production areas for export used to be unaffected. However, some orchards in exporting areas have started to become infected. This is forcing producers and exporters to carry out regular checks, both in the orchards and the packaging facilities. Since weevils are quarantine insects in the European Union, several imports were intercepted in 2019 due to the presence of these pests.

Highest stage of susceptibility:
The females lay their eggs randomly in recesses on the surface of the fruit as it ripens. After hatching, the larvae make their way through the flesh to the stone, which is still being formed. In general, one larva reaches adulthood per fruit. Larval development usually takes place inside the stone and very rarely in the flesh of the fruit. In most cases, adult weevils leave the stone one or two months after the fruit drops from the tree. Adult weevils remain in diapause under bark or rocks until the next flowering. When active, they only move around at night.

Symptoms and damage:
Their activities damage the flesh of ripe fruit and infested stones are likely to limit the reproduction of plants in nurseries and orchards. A serious infestation can cause the fruit to fall from the tree prematurely.

Preventative measures:
- Transport fruit from infested areas to healthy areas with caution, incinerating the stones after use, especially when the fruit is used in processing or eaten directly.
- Be highly vigilant in monitoring orchards.
- At the packaging facility, split open the stones of fruit being sampled upon arrival at the facility and reject any infested batches.

Adopt preventative measures in orchards (sticky strip traps, physical barriers) and ensure they are clean and tidy (remove weeds from around the trunks as these can enable adults to return to the trees, etc.).

Control without using Plant Protection Products:
Using poultry, especially guinea fowl, has not proven effective because the insects move around at night, while guinea fowl feed in the day.

The adult weevil can be the prey of weaver ants, see Figure 27, rodents, lizards and birds.

The species of African weaver ant *Oecophylla longinoda* is among its natural predators in west Africa.

Figure 27: Adult weevil captured by ants
Photo: Jean-François Vayssières

Application of Plant Protection Products:

Effective control methods against these insects involve spraying insecticides into the foliage and, above all, onto the trunk and main branches, especially with organophosphates (*chlorpyriphos,* fenthion, etc.) or spreading insecticide mixture (neonicatinoids) onto the trunk. However, it is advisable to refer to previous comments regarding these products.

See the tables of effectiveness of active substances for pests and diseases in Appendix 1. In light of ongoing changes to phytosanitary regulations and standards governing the use of Plant Protection Products, it is advisable to consult the E-GAP (Good Agricultural Practices) database by clicking on COLEACP Resources here in order to check the authorisation status of the active substance in the EU and ACP countries, the MRLs (maximum residue limits) and the good agricultural practices which ensure compliance with these MRLs.

TABLE SUMMARISING OBSERVATION AND TREATMENT PERIODS FOR CONTROLLING THE MAIN MANGO TREE PESTS
(with regard to the phenological cycle)

	Flowering	Fruit-set Enlargement of fruit	Harvest	Vegetative growth	Vegetative rest
Fruit flies			Trapping		
Fruit tree mealybug and diaspididae				Pruning before treatment	
Termites					
True bugs	Monitoring by beating				
Thrips					
	Visual inspections The blossom gall midge does more damage than the leaf gall midge				
Mango blossom gall midge					
Mango leaf gall midge					
Whiteflies					
Acrididae	Depending on acrididae congregations in the area				
Mango stone weevil	Trapping or monitoring inspections				
	Applications on the trunk and/or on the foliage				

■ Comments   ■ Treatment during critical periods   ■ Optional treatments depending on infestation

5.6 Fungal diseases

5.6.1 Fungal diseases which develop in orchards but mainly known for causing post-harvest rot

Highest stage of susceptibility:

The same pathogens can cause damage to the plant at different points in its cycle and to different parts. As a general rule, young tissue is very sensitive, which explains the significant damage observed on young leaves and shoots, inflorescences and very small fruit. Tissue differentiation leads to a higher resistance to infections.

At the end of the cycle, mature fruit or fruit close to maturity are also particularly vulnerable. Moreover, as plant tissue ages and fruit is in storage, some infections, which have been latent during the previous stages can be reactivated and cause branches to wither and rot marks on fruit to appear, sometimes long after the moment of infection itself. Some very widespread and much feared diseases, such as anthracnose, are often excessively blamed when the identification process is imprecise and rushed.

Symptoms and damage:

On fruit, they lead to rot which initially appears in the form of black marks (Figure 62 - Appendix 3-1). However, not every visible black mark on the epidermis is necessarily due to anthracnose. Other fungi or pathogenic bacteria and other physical alterations can lead to similar symptoms (Figures 65 to 72 - Appendix 3-1). The summary table below detailing the fungi which produce post-harvest lesions on mangoes after incubation in the producer country or when imported to Europe highlights the significant differences in prevalence. It is therefore important to commit time and effort to identifying the causative pathogens prior to enacting any disease control strategy.

SUMMARY TABLE SHOWING THE PREVALENCE OF FUNGI BETWEEN JULY AND SEPTEMBER 2004 ASSOCIATED WITH POST-HARVEST ROT ON MANGOES PRODUCED IN SENEGAL AND ANALYSED AFTER INCUBATION AT AMBIENT TEMPERATURE IN SENEGAL OR UPON IMPORT TO EUROPE

Type of rot Fungus	Relative frequency		
	In Senegal		Import to Europe
	In July	In August and September	From July to September
Isolated spots			
Alternaria	++	-	++++
Cercospora	-	-	++++
Colletotrichum	-	++++	-
Curvularia	+	-	-
Drechslera	+	+	-
Phoma	+	++	-
Stemphylium	+	-	++++
Not identified	+++	++++	-
Peduncular (stem end) rot			
Dothiorella	+	-	++++
Lasiodiplodia	+	+	-
Pestalotiopsis	-	-	+
Phomopsis	-	-	++
Various spots with saprophytes			
Aspergillus	++	-	++
Cladosporium and Penicillium	-	-	+++
Fusarium	-	-	+

-: not detected; + detected on less than 10% of fruit or lesions per batch; ++ detected at least once on 10% to 20% of fruit or lesions per batch; +++ detected at least once on 21% to 40% of fruit or lesions per batch; ++++ detected at least once on 41% to 80% of fruit or lesions per batch.

Number of batches of 40 mangoes analysed in Senegal: 7 on 17/07; 13 on 14/08; 4 on 14/09. Number of rot marks analysed on 10 batches of imported mangoes, 128 in total, varying between 8 and 18, depending on the batch.

5.6.1.1 Anthracnose: Colletotrichum gloeosporioides

Symptoms and damage:
Characteristic symptoms are visible on the leaves. They are jagged brown marks, which are necrotic in the centre. These marks can merge together. Larger necrotic marks then develop. They are ≥1cm in diameter and always have jagged edges. In some cases, the necrotic parts can fall off. In these cases, the leaf looks pierced when the central parts are infected, or rough when the infection is at the edges.

Young shoots can be infected in conditions which are very favourable for infestation and then wither.

On the inflorescences, the symptoms are brown marks on the floral stalk and flowers, early necroses on flower buds and the mummification of very young fruit just after the petals fall.

Serious infestations during flowering can considerably reduce the production potential of the tree with flowers and very young fruit failing to develop.

On the surface of the fruit, the infection cycle includes the germination of a spore and the formation of an external appressorium. This then germinates shortly after. The resulting hypha passes through the initial layers of cuticle and epidermis without using pre-existing openings (lenticels or damage). Inhibiting substances, resorcinols, in unripe fruit hinders their progress. Appressoria in the process of germination remain latent until the harvest. The symptoms appear in the form of epidermal marks just before harvest or, most often, after the harvest, during preservation (Figure 63 - Appendix 3-1). These marks are often in a line, creating a characteristic teardrop pattern (Figure 64 - Appendix 3-1). They can fuse together creating larger marks. At a more advanced stage, rot can gradually extend into the flesh. In the final stage, orange-pink sporulations can be observed at the centre of the black marks.

Conditions conducive to infestation:
Water plays a key role in the contamination process because spores are always transported by liquid. When humidity levels are high, masses of mucilaginous spores are produced on the surface of existing lesions on the leaves, inflorescences, stalks, etc. Rainfall on several occasions or possibly heavy dew run-off is needed to spread the spores from these damaged parts to healthy host parts nearby (inflorescences, young leaves, fruit). After rainfall, high humidity levels (≥ 95%) and temperatures between 10°C and 30°C, ideally around 25°C, are very favourable conditions for the germination of spores and the formation of appressoria (latent form). The contamination of the surface of fruit by run-off of spore suspensions leads to the characteristic "teardrop" pattern of marks.

Highest stage of susceptibility:
Young leaves, inflorescences and very young fruit are particularly sensitive. This is also the case for fruit after the harvest. Very small areas of damage to the skin of the fruit incurred during the harvest, packaging or transport can lead to the re-emergence of latent infections or direct infection by conidia present on the fruit during the rainy season.

Other host plants:

Various species of fruit trees are attacked by *Colletotrichum gloeosporioides* , including avocado trees, citrus trees, cashew trees, banana trees, coffee plants, papaya trees, etc. A very diverse range of species can also be affected, such as sugar cane, alfalfa, chilli pepper, etc. Nevertheless, populations of the pathogens which colonise these hosts, especially mango trees, are very heterogeneous. Differences in the range of hosts or aggressiveness levels as well as levels of sensitivity to fungicides have been highlighted.

Application of Plant Protection Products in orchards:

Treating an orchard at the flowering/fruit set stage is very beneficial when possible i.e. in orchards where trees are still young or pruned so as to keep them at an acceptable height for spraying. Trials carried out in Senegal and Côte d'Ivoire by the COLEACP in 2014/2015 showed that anthracnose attacks can only be kept at an acceptable level with treatment at flowering/fruit-set.

RECOMMENDED TREATMENTS:

Stage	Number of treatments	Method of application	Usable active substances
Flowering/ fruit-set	1 to 3 applications depending on the products[1]	Spraying in the orchard	copper, azoxystrobin, trifloxystrobin + fluopyram
Enlargement of fruit	Only during periods of dew during the dry season. Every fortnight during the rainy season[1]	Spraying in the orchard	copper, azoxystrobin, etc.
Post-harvest	1 application	Generally soaking fruit in a basin	prochloraz, fludioxonil

[1] follow instructions of product manufacturers

See the tables of effectiveness of active substances for pests and diseases in Appendix 1. In light of ongoing changes to phytosanitary regulations and standards governing the use of Plant Protection Products, it is advisable to consult the E-GAP (Good Agricultural Practices) database by clicking on COLEACP Resources here in order to check the authorisation status of the active substance in the EU and ACP countries, the MRLs (maximum residue limits) and the good agricultural practices which ensure compliance with these MRLs.

5.6.1.2 Round rot spots caused by other pathogens on mango

A wide range of pathogenic fungi on mango tree leaves or branches can lead to latent infections in the fruit. These infections become apparent relatively quickly after the harvest in the form of rot marks often distributed randomly across the surface of the mangoes. These marks can be easily confused with those caused by anthracnose.

Alternaria: *Alternaria alternata*

Symptoms and damage:
On the leaf, small round black marks, between 1-3mm in diameter are spread evenly across the limb. The symptoms are more obvious on the underside of the leaves than on the top. Attacks to the inflorescences, two to three weeks after budburst, lead to a significant reduction in fruiting. Small lesions can also form on the stalks.

On the fruit, the mycelium created by the germination of spores passes through the lenticels and colonises the tissue between the cells. It then becomes latent before the symptoms appear. On ripe fruit, this mycelium continues to grow and leads to the formation of small round black surface marks which develop around the lenticels. The marks are often concentrated around the peduncle region given the abundance of lenticels on this part of the fruit (Figure 65 and 66 - Appendix 3-1). These marks can grow and merge into large, black patches, which can extend into the pulp. Alternaria lesions on fruit are usually more limited, darker and firmer than those caused by anthracnose. The centre of the lesions caves in slightly and is covered in brown-olive spores in conditions of high humidity.

In some conditions, the infection of the inflorescences can spread endophytically to the peduncle and fruit. It remains latent until maturity and then manifests through the development of peduncle rot.

Conditions conducive to infestation:
Fruit is usually infected by infected leaves and flowers or by dying leaves and stalks which have fallen to the ground. The spores which form on these areas are transported to the fruit by the wind or are washed there by rain or heavy dew. For a latent infection to become established, relative humidity must remain at 80% for 350 hours and the extent of the damage increases if the high humidity levels continue for longer periods. Long humid periods and very dense vegetation preventing the dissipation of humidity promote the development of this disease. These factors and the difference in the quantity of spores explain the significant differences in the extent of attacks suffered by orchards in the same region. *Alternaria* was one of the main causes of rot marks on mangoes in Mali in 2004. For two in every ten batches of mangoes harvested between July and September 2004 in Senegal and analysed upon receipt and distribution in Europe, the proportion of marks caused by *Alternaria* was above 50%.

Highest stage of susceptibility:
Fruit can be infected at any point in its development cycle providing that the conditions are favourable for infection.

Other host plants:
Alternaria alternata is associated with lesions on many plants and often appears as a secondary infection in lesions produced by other causes. As yet, little is known about the pathogenic capacity and parasitic specialisation of this species.

- Sigatoka: *Cercospora* sp.

In 2004, for three out of every ten batches of mangoes from Senegal analysed after being imported, the proportion of lesions caused by *Cercospora* sp. exceeded 33%. Small black lesions caused by this fungus rarely reach 1cm in diameter. Initially limited to the skin, the rot can later spread to the pulp of the fruit. The surface then caves in slightly (Figure 67 - Appendix 3-1). In the literature, *C. mangiferae* is described as a pathogen which affects the leaves, but is very rarely identified as being an agent that causes rot marks on fruit.

- Stemphylium: *Stemphylium* spp.

Stemphylium sp. was identified as the cause of almost 30% of lesions analysed upon arrival in Europe or during the storage of mangoes produced between June and September 2004 in Senegal. For four out of every ten batches, the rate of prevalence of *Stemphylium* exceeded 75%. The lesions are generally

round, less than 1,5cm in diameter, and brown or black in colour (Figure 68 - Appendix 3-1). The epidermis tends to cave in. When cut open, infected tissue is brownish-red and tends to remain firm. Despite being commonly observed and occurring frequently on fruit, there is nothing in the literature yet about the pre-harvest parasitic phase of *Stemphylium*. Storing fruit in a controlled atmosphere at 13°C can encourage the development of rot caused by S. *vesicarium*.

- *Drechslera* sp., *Phoma* sp. and *Bipolaris* sp.

These fungi were identified sporadically on lesions developing on mangoes being stored after the harvest in Senegal. They are sometimes classified as leaf pathogens on mango trees.

5.6.1.3 Peduncular rot associated with the genera Lasiodiplodia, Dothiorella, Phomopsis and Pestalopsiopsis

Several fungi are associated with rot which often develops on the fruit after the harvest, first appearing around the peduncle. *Lasiodiplodia theobromae (syns. Botryodiplodia theobromae, Diplodia natalensis)* causes rotting of fruit, stalks and branches in many plants in tropic regions. This species is often thought of as a pathogen which colonises plants in the event of weakness or damage. It is characterised by the formation of brown bicellular conidia in pycnidia emerging in colonised tissues.

Conditions conducive to infestation:
Dothiorella dominicana and other species of *Dothiorella* are often encountered on fruit from subtropical regions or high areas in tropical regions. The name *Dothiorella* applies to an asexual stage of reproduction characterised by the formation of various mucilaginous conidia in the pycnidia. Rainfall helps to spread these conidia, as is the case for *Colletotrichum*. The genus *Botryosphaeria* has been acknowledged as the sexual stage of certain *Dothiorella* taxa. The pseudoperithecia at this stage form gradually on the branches, shoots, inflorescences or leaves colonised by this fungus and help it survive during the dry season. The ascospores are often expelled when the fungus becomes wet during fructification following rain showers or periods of heavy dew, and are then spread by the wind.

Various other types of conidial reproduction, such as *Hendersonia, Lasiodiplodia, Botryodiplodia, Diplodia natalensis* and *Nattrassia* are also connected to the sexual reproduction of *Botryosphaeria*. The naming of some of these conidial stages, including *Dothiorella,* has recently been called into question, hence the general confusion and multiple synonyms which are used, especially with regard to mango trees. Accurate identification is still important since the differences in development and pathogenic capacity of these different species must be taken into account in order to optimise the protection of the fruit.

Phomopsis mangiferae has similarities with *Dothiorella* but nothing is yet known about the sexual stage.

Pestalopsiopsis mangiferae produces very dark mucilaginous conidia in fructifications similar to those of *Colletotrichum*. They are also spread by rainfall.

Symptoms and damage:
The development of the symptoms varies depending on the fungi in question. *Dothiorella spp.* and *Lasiodiplodia theobromae* cause diffuse, translucid, watery marks, which spread out from the peduncle in irregular patterns (Figure 69 - Appendix 3-1). A surface necrosis appears underneath the cuticle, before spreading rapidly into the pulp and causing rotting.

Phomopsis mangiferae and *Pestalopsiopsis mangiferae* cause dark lesions spreading more slowly from the peduncle.

Highest stage of susceptibility:
Several fungi responsible for peduncle rot can colonise mango tree branches and cause them to wither either before or after the formation of lesions and cankers. The buds can be infected before they open. Some fungi in this group also colonise branches with endophytes without initially causing any symptoms. This colonisation can extend to the inflorescences and, from there, reach the peduncle of the fruit several weeks after flowering. The infections remain latent until the fruit reaches maturity.

The peduncle can also be infected directly during the harvest, especially through the contamination of a lesion by conidia which form in abundance on plant debris lying on the ground or mixed into the soil as well as on rotting fruit left on the ground. *Lasiodiplodia* attacks are therefore more frequent on fruit picked close to the ground.

Marks caused by fungi associated with peduncle rot can also develop randomly on other parts of the fruit during storage (Figure 70 - Appendix 3-1) or can develop in a teardrop pattern. These are the result of latent infections by conidia and/or ascospores as the fruit develops, in similar conditions as those described for anthracnose or alternaria. Contamination can also be made more likely by micro-damage to the epidermis caused by handling during harvest and packaging.

The formation of rot depends on storage temperatures after the harvest. Rot becomes visible between three and seven days after the harvest at 25°C and between 10 and 20 days at 13°C. In the event of a mixed infection, *Lasiodiplodia*

theobromae is predominant over *D. dominicana* at 30°C. The opposite is the case at temperatures of 25°C or less. Between 13°C and 18°C, *D. dominicana* can be inhibited by certain strains of C. gloeosporioides.

Other host plants:
Some causes of peduncle rot are specific to mango trees (*D. dominicana*, *Pestalotiopsis mangiferae,* etc.), while others, such as *Lasiodiplodia theobromae*, can grow on various different hosts. Accurately identifying the fungus responsible for the peduncle rot observed in the orchard is therefore important to help locate the source of the infection.

5.6.1.4 Fusarium wilts: Fusarium

This disease is illustrated in (Figure 93 - Annexe 3-1).

Conditions conducive to infestation:
Fusarium wilts on mango trees (caused by various species of *Fusarium,* including *Fusarium oxyporum, F. subglutinans, F. mangiferae* and *F. tupiense*) are widespread throughout the world, especially in Asia (India) and America. West Africa seemed to have been spared, but fusarium wilt damage (mainly *Fusarium tupiense*) has been observed in Casamance (especially in the western area) in the south of Senegal (Senghor *et al.,* 2012)

Symptoms and damage:
This disease causes deformations in the inflorescences, leading to very short internodes. The flowers become sterile and dry out.

Preventative measures:
Use healthy and uninfected grafts.

Control without using Plant Protection Products:
Curative mechanical measures (cutting and burning of contaminated tree parts). However, tests should be conducted to establish curative methods for managing this disease, which is more effective and less restrictive than cutting off branches.

5.6.1.5 Other post-harvest rots

Various types of marks develop on the fruit after the harvest when damage becomes contaminated by a series of saprophytic fungi: *Aspergillus, Cladosporium, Fusarium, Penicillium, Rhizopus, and so on.*

Highest stage of susceptibility:
Rot marks develop from the peduncle (Figure 72A - Appendix 3-1) or randomly across the fruit (Figure 70 - Appendix 3-1), depending on the site of contamination. These marks are similar to those caused by the reactivation of latent infections by pathogenic fungi.

Conditions conducive to infestation:
These fungi require a certain level of humidity to produce spores. The spores of most of these fungi are formed on slightly damp debris. They are often dry, have a capacity of survival in the soil and are spread with dust by the wind.

5.6.1.6 Protection of orchards

Protecting mango orchards against causes of post-harvest rot must be done through an integrated approach from the creation of the orchard to the harvesting of the fruit. Preventative control measures and phytosanitary maintenance are vital for ensuring the general health of the trees, reducing the length of periods of high humidity that can encourage infections and reducing the quantity of inoculum during sensitive cultivation stages. An orchard protection strategy based mainly on the use of fungicides is rarely satisfactory. The use of fungicides must be measured and saved for specific protection in conditions where certain fungi infections are very likely to emerge.

Careful handling during the harvest can help to limit the risk of damage and contamination, as well as the reactivation of latent infections which took hold as the fruit developed. Post-harvest treatments deactivate latent infections and prevent them from developing during the marketing process.

See the summary table below on the value of various protection methods, sources of inoculum, conditions of infection and development of these fungi.

5.6.1.6.1 Preventative measures:

Preventative measures can help to significantly reduce the risk of contamination.

When planting the orchard:
- Choose plants from nurseries which have expertise in controlling various diseases;
- Leave enough space in the plantation to allow air to circulate.

Maintaining the orchard:
- Remove superfluous branches to aerate the foliage and prevent cramped areas;
- Limit the height of the mango trees by pruning so that the phytosanitary treatments can cover the whole of the foliage.

Before flowering:
- Cut away all dead or partially necrotic parts as these could cause further contamination.

After flowering:
- Regularly collect and burn necrotic or dead parts of the tree laying on the ground (remains of inflorescences, dry branches, dead leaves, including leaf litter, etc.);
- Train low branches to keep the fruit away from ground;

SUMMARY TABLE OF MAIN FUNGI ASSOCIATED WITH POST-HARVEST ROT IN WEST AFRICA:
SOURCES AND SPREAD OF INOCULUM, CONDITIONS OF INFECTION AND DEVELOPMENT, AND VALUE OF PROTECTION MEASURES

-: no; +: minor association; ++: moderate association; +++: strong association; ? relationship unknown.

Fungus	Source of inoculum			Spread		Latent infection		During harvest	Development		Value of protection measures				
											In the orchard			Post-harvest	
	leaves	flowers, branches	Debris, ground, fruit	rain	wind	external	internal	During harvest	< 24°C	> 24°C	Preventative measures	Chemical control measures	Care during the harvest	Hot water	Chemicals
Alternaria	++	++	++	++	+++	+++	+	+	++	+	+++	+	++	+++	+++
Cercospora	++	?	?	++	++	+++	-	?	?	?	+++	?	++	?	++
Colletotrichum	++	++	+	+++		+++	-	+	+	+++	+++	+	++	+++	+++
Stemphylium	?	?	+	?	?	+++	-	+ ?	+++	?	+++	?	++	?	++
Dothiorella	+	+++	+++	+++	+	++	+++	+++	+++	++	+++	-	+++	++	+++
Lasiodiplodia	-	++	+++	+++	?	+	+++	+++	+	+++	+++	-	+++	+	+++
Aspergillus	-	-	+++	-	+++	-	-	+++	++	++	++	-	+++	++	++
Cladosporium, Penicillium	-	-	+++	-	+++	-	-	+++	++	++	++	-	+++	++	++
Fusarium	-	-	+++	++	+	-	-	+++	++	++	++		+++	?	++

Figure 28: Training low branches to keep the fruit away from ground
Photo: Henri Vannière

- Apply measures to limit the populations of fruit flies (See 5.5.1.) ;
- Collect fallen fruit regularly, bury it in a ditch and cover it with soil to prevent spores being spread by the wind or insects;

During the harvest:
- Handle mangoes carefully to prevent damage;
- Prevent the fruit from being in contact with the ground, especially with abrasive sandy and muddy soils during the rainy season;
- Managing dripping sap by placing fruit on easy-to-clean stands (See point 6.3.1.).

Throughout the year, and more regularly during flowering and fruit set periods in the rainy season:

- Conduct simple epidemiological monitoring: observing the phenological stages of the mango trees, keep weather records, log the appearance of symptoms and assess the level of contamination on new shoots, leaves and inflorescences.

5.6.1.6.2 Application of Plant Protection Products prior to the harvest

Applying Plant Protection Products prior to the harvest can be justified if preventative measures frequently prove insufficient in limiting the development of one or more diseases when wet periods (rains, heavy dew) coincide with a very sensitive stage of the cycle, such as flowering or fruit set. The time when these events coincide determines the best moment to apply such a treatment. Most current active substances act through contact and only have a weak curative effect. Moreover, since latent mycelium has no active metabolism, it is not very sensitive to the application of fungicides.

Treatments must therefore be preventative and be scheduled at varying intervals:

- Every ten days, just before and during flowering;
- Every two to three weeks afterwards, if necessary, depending on the progress of the flowering and how often the products applied are washed off by rain.

Nevertheless, it is important to bear in mind that:

- The effectiveness of sprays is only very partial given how hard it is to fully treat all of the foliage and the fact that products are easily washed off during the rainy season, which encourages infection;
- Special protection equipment is required to reduce the risks of contamination of applicators when spraying the products;
- Repeated spraying can cause the MRL to be exceeded and the imports to be refused as a result;
- Repeated spraying can lead to the spread of strains which are resistant to the products applied and to all those which have the same mode of action. This then leads to a relatively swift drop in effectiveness;
- Spraying can have a negative impact on microflora that combat causes of post-harvest rot and paradoxically lead to an increase in those agents;
- treating large trees significantly increases the risk of products drifting beyond the intended area and contaminating the environment.

Systematic treatment must therefore be avoided. In Australia, a warning system based on the duration of wetting and the temperature during the sensitive stages helped to reduce the number of treatments carried out.

To treat a mature orchard, the solution volumes used are around 1000l/hectare.

See the tables of effectiveness of active substances for pests and diseases in Appendix 1. In light of ongoing changes to phytosanitary regulations and standards governing the use of Plant Protection Products, it is advisable to consult the E-GAP (Good Agricultural Practices) database by clicking on COLEACP Resources here in order to check the authorisation status of the active substance in the EU and ACP countries, the MRLs (maximum residue limits) and the good agricultural practices which ensure compliance with these MRLs.

Fungi differ in their sensitivity to various fungicides (See fungicide sensitivity table below). Products must therefore be chosen according to the specific problems encountered in the orchard in question.

SENSITIVITY TO FUNGICIDES OF FUNGI ASSOCIATED WITH POST-HARVEST ROT ON MANGOES

Fungus	Intrinsic sensitivity to chemical fungicides				
	Benzimidazole 1	Imidazole 2	Strobilurin 3	Phthalimide 4	Dithiocarbamate 5
Alternaria	0	++	0	++	++
Cercospora	++	++	++	/	/
Colletotrichum	+++*	++*	+++	++	++
Stemphylium	++	+	++	/	/
Dothiorella	++	++	++	/	/
Phomopsis	++	+	++	/	/
Aspergillus	+++	++	+++	/	/
Penicillium	+++	+	++	/	/

0: not very sensitive; + a little sensitive; ++ quite sensitive, +++ very sensitive / no information
Existence of resistant strains Examples of active substances:
1. benomyl, carbendazime, thiabendazole, thiophanate-methyl
2. imazalil, prochloraze
3. azoxystrobine, pryrachlostrobine, trifloxystrobine, kresoxim-methyl
4. captan
5. mancozeb, maneb

Alternaria is not very sensitive to benzimidazoles (thiophanate-methyl, benomyl) or strobilurins. A level of control can be achieved prior to the harvest by spraying captan- or dithiocarbamate-based solutions (mancozeb, maneb).

Colletotrichum is naturally very sensitive to benzimidazoles, which are therefore often recommended for pre-harvest treatments. Nevertheless, effectiveness in orchards is inconsistent. This may be due to local prevalence of resistant strains or misidentification of fungi present. Captan- or dithiocarbamate-based solutions (mancozeb, maneb) provide a level of protection, but not as much as benzimidazoles in the event of strains which remain sensitive to such products.

Benzimidazole-based pre-harvest treatments are more effective at controlling peduncle rot caused by *Lasiodiplodia* than captan-based or mancozeb-based treatments. Copper oxychloride-based sprays are sometimes advised to prevent peduncle rot. On crops, *Dothiorella* is relatively sensitive to benzimidazoles and strobilurins but data on the effectiveness of products containing these substances are not yet available. This is also the case for *Cercospora* and *Stemphylium*.

When choosing pre-harvest treatment products, it is important to take into consideration any post-harvest treatments and the benefits of using fungicides with different modes of action for these two types of treatment. Using benzimidazoles or strobilurins before the harvest can lead to a rise in resistant strains and a drop in the effectiveness of these fungicides when used post-harvest. Consequently, it is important to save these high-performance fungicides for post-harvest treatments

only, which are simpler and more effective, rather than risk the emergence of resistant strains.

In light of ongoing changes to phytosanitary regulations and standards governing the use of Plant Protection Products, it is advisable to consult the E-GAP (Good Agricultural Practices) database by clicking on COLEACP Resources here in order to check the authorisation status of the active substance in the EU and ACP countries, the MRLs (maximum residue limits) and the good agricultural practices which ensure compliance with these MRLs.

5.6.1.7 Post-harvest treatments

Post-harvest treatments at the packaging facility generally prove more effective than spraying fungicides prior to the harvest. Washing in hot water (See 6.3.3.1.1.) and applying wax help to deactivate or limit the additional development of many latent infections. Applying fungicide after the harvest ensures all the fruit is treated in the same way and guarantees a better forecasting and consistency of residue. If a fungicide is used at the moment when a latent infection starts to develop again, it is often successfully stymied. Fungicides also protect lesions against invasion from saprophytes, even with relatively low concentrations of active substances.

5.6.1.6.1 Heat treatments

Hot water treatments are curative and are only carried out at the packaging facility. This technique requires a high level of technical expertise. The fruit is immersed in a basin of hot water for five minutes. The temperature across the whole tank, especially at the start of the soaking process, and the duration of the immersion must be very strictly controlled. The temperature established for a given variety (e.g. 51°C for Kent mangoes) must not vary by more than one degree. Temperatures are always between 50°C (the lower limit for an effective treatment) and 55°C, above which the fruit is damaged. The fruit must be handled with great care in the field and at the packaging facility because heat treatment accentuates even the slightest epidermal lesion. This applies in particular to regions with sandy soil. Heat treatment helps to deactivate most superficial latent infections caused by *Colletotrichum, Alternaria* and *Dothiorella.* Its effectiveness can be increased by adding sodium hypochlorite or calcium hypochlorite and by applying wax. Wax can slow down the ripening process and the activation of latent infections.

In the event of high parasitic pressure or peduncle infection, heat treatment is not sufficient. Consequently, it is often combined with fungicide treatment.

5.6.1.7.2 Application of Plant Protection Products in the packing facility

Several types of active substances with preventative and curative properties have produced significant results for controlling anthracnose and other causes of post-harvest rot:

  ▪ Thiabendazole (benzimidazoles);
  ▪ Imazalil and prochloraz (imidazoles);
  ▪ Azoxystrobin (strobilurin).

For controlling anthracnose, imazalil and especially thiabendazole have produced less impressive results than the other fungicides mentioned. In practice, they are rarely used.

See table B in Appendix 1 on the effectiveness of active fungicide substances in treating diseases. Until 2020, prochloraze was deemed the most effective authorised active substance, especially when combined with hot water heat treatment.

However, the European Union then lowered the MRLs, often to the threshold detection level, which has radically changed the way post-harvest fungal diseases can be tackled and effectively banned the use of most post-harvest fungicides because the thresholds set out are often below the levels required to be effective. This is the case for prochloraze, which had become the leading post-harvest product for controlling fungal diseases in mangoes.

The most frequently used product is now fludioxonil.

To combat anthracnose in west Africa, the recommended post-harvest treatment is as follows:

Stage	Number of treatments	Method of application	Usable active substances
Post-harvest	1 application	Generally soaking fruit in a basin	prochloraz, fludioxonil

In light of ongoing changes to phytosanitary regulations and standards governing the use of Plant Protection Products, it is advisable to consult the E-GAP (Good Agricultural Practices) database by clicking on COLEACP Resources here in order to check the authorisation status of the active substance in the EU and ACP countries, the MRLs (maximum residue limits) and the good agricultural practices which ensure compliance with these MRLs.

5.6.2 Powdery mildew: *Oidium mangiferae*

Symptoms and damage:
When young tissue is attacked, it is covered in a white felt-like coating (mycelium) (Figure 79 - Appendix 3-2). The mycelium quickly colonises the inflorescences and causes the necrosis of the tissue (Figure 80 - Appendix 3-2).

Highest stage of susceptibility:
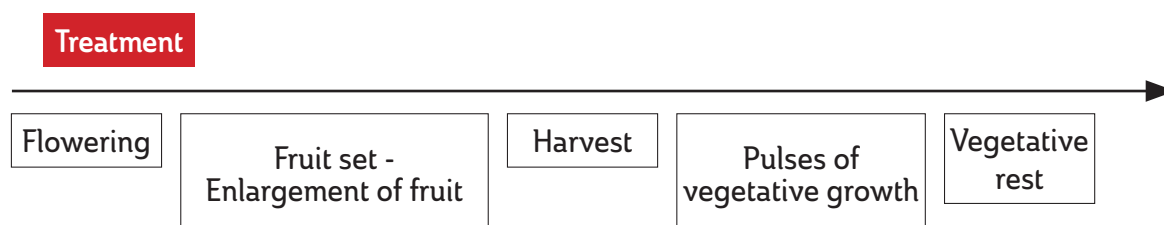Very young leaves and inflorescences are generally the most sensitive areas.

Conditions conducive to infestation:
The diseases can be particularly serious when temperatures are mild and the air is humid, without being excessively damp (no rainfall). High temperatures and heavy rain do not allow the spores to germinate in good conditions.

The conidia are transported by the wind. They germinate at temperatures between 9°C and 32°C (optimal temperature: 23°C) and relative humidity levels as low as 20%. These temperature and humidity conditions are usually present at the start of the cycle when new leaves and especially flowers are starting to appear.

In the tropics, higher, cooler areas are more affected by this disease than hot and humid coastal areas.

Treatment

Flowering	Fruit set - Enlargement of fruit	Harvest	Pulses of vegetative growth	Vegetative rest

Appropriate period of intervention:
In areas where the disease is present, treatments aim to protect the flowers, since they contain the tree's production potential. This treatment must be carried out early, before full flowering, as soon as a change in the colour of the flower stalks is observed.

Application of Plant Protection Products:
In conditions which are favourable for the emergence of these diseases, preventative treatments should be carried out on healthy flowers using contact fungicides. Since these products get washed off by the rain, the product should be reapplied every eight to ten days and more frequently if there is more than 25mm of rainfall.

As soon as the first symptoms appear, only curative treatments with systemic fungicides can stop the disease developing. Different chemical families should be used in rotation, sometimes with contact fungicides, to prevent resistant strains from emerging. Inexpensive micronised sulphur remains the basic active ingredient for preventative treatments.

See table B in Appendix 1 on the effectiveness of active fungicide substances in treating diseases. In light of ongoing changes to phytosanitary regulations and standards governing the use of Plant Protection Products, it is advisable to consult the E-GAP (Good Agricultural Practices) database by clicking on COLEACP Resources here in order to check the authorisation status of the active substance in the EU and ACP countries, the MRLs (maximum residue limits) and the good agricultural practices

5.6.3 Scab: *Elsinoe mangiferae*

Conditions conducive to infestation:
This disease only affects the hottest, most humid production regions. Infection requires flowing water (rainfall).

Highest stage of susceptibility:
Scab appears most commonly in new orchards and nurseries. Young plant tissue is sensitive.

Symptoms and damage:
On the leaves, brown or black marks with pointed edges develop, growing to around 5mm in diameter. On young fruit, the marks are grey with a jagged, black border. As the fruit grows, these marks become darker and form a slightly cracked crust. The marks remain superficial and do not affect the flesh of the fruit. They can cover a large amount of the fruit (Figure 75 – Appendix 3-2).

Application of Plant Protection Products:
Fungicide spray applied when new vegetative shoots or flowers start to appear and on young fruit ensures effective control of the disease. The doses used are similar to those applied when combating anthracnose.

See table B in Appendix 1 on the effectiveness of active fungicide substances in treating diseases. In light of ongoing changes to phytosanitary regulations and standards governing the use of Plant Protection Products, it is advisable to consult the E-BPA database by clicking on COLEACP Resources here in order to check the authorisation status of the active substance in the EU and ACP countries, the MRLs (maximum residue limits) and the good agricultural practices which ensure compliance with these MRLs.

5.7   Bacterial canker: *Xanthomonas citri* pv. *Mangifera indicae*

Mango bacterial canker is caused by a phytopathogenic bacteria belonging to the species *Xanthomonas citri.*

Other host plants:
This species is highly specialised in terms of hosts, meaning that the bacteria are only pathogenic for a limited range of plants. In order to highlight this highly specific pathogenic capacity, scientists have subdivided certain bacteria into pathovars (abbreviated as pv.), which refers to the host plant they attack. Therefore, *X. citri* pv. *mangiferaeindicae* is a pathogen of *Mangifera indica,* the mango tree. Some of these pathovars are enemies of fruit trees, in particular *X. citri* pv. Citri, which causes Asiatic citrus canker and *X. citri* pv. *anacardii,* which causes cashew tree angular leaf spot in Latin America. Recent work has shown that strains of *X. citri* pv. *Mangiferae indicae* in Burkina Faso attack cashew trees. (Zombre *et Al.,* 2016).

Geographic distribution:
Bacterial canker is widespread throughout the world, especially in Asia (Japan, India, Malaysia, Thailand, Philippines, etc.), Australia, UAE, the Indian Ocean Islands (Comoros, La Réunion, etc.), and east and southern Africa (Kenya, South Africa, etc.). Until recently, west Africa appeared to have been spared. However, since 2010, this disease has been identified in Ghana, Burkina Faso and Mali. Its

presence has now been confirmed in most African countries (Mali, Burkina Faso, Ghana, Côte d'Ivoire, Benin, Togo, etc.) and its distribution area may be even more extensive.

Tropical storms help greatly in spreading the inoculum over distances which go beyond the boundaries of the plantations themselves.

Conditions conducive to infestation:
The bacteria is mainly transported by rain, but can also be spread by farming activities. Internal tissue can be contaminated through natural openings (stomata, lenticels) or lesions.

In unaffected areas, which west Africa used to be, the initial contamination is typically caused by infested plant material being introduced. This is also the case within countries, between distant regions. Inoculum can be transported via infected fruit, but the likelihood of it passing from a diseased fruit (intended for consumption or processing) to a healthy tree is much lower than it being passed on via propagating material (or movement of infected young plants). Human actions are therefore almost always responsible for initial contaminations.

Within any given area, the disease can then be spread by the transport of infected plant material and natural elements. Rain plays a major role but only spreads the bacteria from one part of a tree to another or to neighbouring trees if the foliage is touching. The bacteria mainly survive in necroses and cankers on leaves, stems and fruit on the tree and spread through rainfall. Mango pickers often protect the mangoes in crates with layers of leaves, usually mango leaves. This practice should be avoided since it is a source of transmission.

The spread is worsened when rain is combined with strong winds ($\geq$ 8m/s), with distances of spread increasing depending on wind speeds. It has been demonstrated that a moderate storm with average hourly wind speeds of 10-15m/s enables the pathogen to be spread over distances of at least 250m.

The risks are particularly high at the start and end of the rainy season when storms are accompanied by strong gusts of wind. The combination of heavy rain and strong wind has a double effect: (i) it causes damage to the plant tissue, enabling the bacteria to enter, (ii) it spreads the bacteria through the air over large distances. Damage becomes more significant as the rainy season progresses.

In the Indian Ocean islands where the disease is present, cyclones often lead to the disease being reactivated, especially in drier areas. In the years that follow, if there are no further cyclones in these dry areas, which receive around 500mm of rain, the conditions and the trees return to normal. However, the underlying potential for recontamination remains and could re-emerge the next time the conditions are right.

Highest stage of susceptibility:
Very young leaves are not sensitive because the stomata are not yet functional. However, they become very sensitive when the limb develops, and the symptoms

appear after the leaves straighten. The sensitivity of the leaves gradually drops as they age. However, the sensitivity of the fruit increases with time, and becomes highest around one month prior to the harvest.

Symptoms and damage:

The bacteria survives as epiphytes on contaminated mango trees and plants do not always display visible symptoms

Bacterial canker of mango trees leads to a number of different symptoms. The marks on the fruit are often in a teardrop pattern. Contamination is always external. The photos showing all the symptoms can be seen in (Figures 81 to 92 - Appendix 3-2).

On the leaves: the damage begins with small oily marks, which change into raised and pointy necrotic black marks, often contained within the boundaries of the veins of the leaf. These marks are surrounded by a lighter, oily halo on the underside and a yellow halo on the top of the leaf. Initially, the marks are small, but they can merge together and create larger necrotic patches. After several months, the lesions dry out and become discoloured, turning brown and ashy grey. The leaves can fall in the event of serious contamination. Cankers become visible on the leafstalks and the main vein. Badly affected leaves fall off and long, leafless branches become visible.

On the branches and peduncles: the bacteria causes raised marks, cracking and cankers. After penetrating young stems, it survives inside them during the dry season. Gum containing the bacteria oozes from the cankers, especially during the rainy season. These cankers can weaken the scaffold branches and make them vulnerable to strong winds.

On the fruit: the first symptoms appear as small marks concentrated on the lenticels. These small raised black marks are often arranged in a teardrop pattern. As they develop, these marks tear in a star-shape. Infectious gum seeps from these craters.

The disease is very dangerous for various reasons, which can differ depending on the climatic area in question.

- The damage it causes to branches and foliage (cankers which allow other diseases to enter, leaves dropping, etc.) weaken the tree and harm the flowering and development of the fruit.
- It causes young infected fruit to fall from the tree.
- The cankers on the fruit as they approach maturity lead to losses during the harvest, which can reach up to 85% in the wet season.
- The bacteria survive in the cankers, becoming permanent sources of contamination.

Preventative measures:

- Do not transport any contaminated plant matter from infested areas to healthy areas.
- In an infested area, infested plants and grafts should never be transported to a healthy orchard.

- Eliminate infected trees if the disease is not widespread. On a country-wide level, the decision is made by the national plant protection organisations.
- Take this risk into account when setting up new orchards and aerate existing orchards.
- Encourage the installation of effective windbreak hedges and avoid sprinkler irrigation (opt for trickle irrigation over mini-sprinklers, which make the lower parts of the trees wet).
- Avoid carrying out any crop management activities when the foliage is wet.
- Prune and burn all infested parts, which could cause re-inoculation.
- Destroy infested fruit lying on the ground.
- Experiment with varietal resistance: there are significant differences in sensitivity between the varieties. In general, all the Florida-origin varieties are sensitive. This is the case for the main export varieties: Kent and (especially) Keitt. However, less sensitive late-season varieties could be considered for national and subregional markets. Good levels of partial resistance have been observed with Sensation and Heidi varieties.
- Shift the production schedule: this can be done to avoid high risk periods (rainy season). It is worth noting that many of these recommendations are similar to those given for the control of fruit flies, especially *B. dorsalis,* which tends to spread during the same period as bacterial canker.

Curative measures:
- Two types of treatment are possible:
  - Antibiotics are strongly advised against in agriculture because when they spread into the natural environment they can lead to resistance to antibiotics used in human and veterinary medicine. They are also ineffective against cankers because they cannot penetrate dead tissue.
  - Copper-based products (750g of active substance per hectare per treatment for the most effective mixtures) are the only products that can be used to treat bacterial canker. These are not systematic products and act through contact. The trees and fruit therefore need protecting throughout the high risk periods. Copper is authorised in organic farming providing the annual limit is complied with.
- Make it easier to treat the orchard: limit the height of the trees, ensure equipment can move freely among trees, limit tree density, etc.

5.7.1. How is bacterial canker distinguished from fungal diseases?

The marks on the leaves are jagged while those caused by anthracnose or sigatoka are more rounded. The slightly raised marks caused by Xanthomonas also helps to distinguish it from fungal infections. However, the collection of the symptoms taken together (raised jagged black marks with an outer ring, cankers on leaves and stems, raised marks on fruit, craters on fruit, etc.) enable a visual diagnosis to be reached.

A visual diagnosis can be reached initially but it is highly recommended to conduct laboratory tests to confirm, at the very least, new cases in a new country or new province. Laboratory tests can be carried out in the laboratory in La Réunion cited in the appendix. A fast shipment method (express mail) should be used so that the samples are of a sufficient quality when they arrive and the analyses can be carried out correctly. Ideally, small quantities of dry leaves affected by the disease should be wrapped in sealed paper envelopes. Unripe fruit can also be wrapped in dry newspaper and sent. Plastic bags should not be used. This laboratory diagnosis usually involves molecular biology tests and inoculations of mango trees.

5.8   Carrying out phytosanitary treatments on mango trees

The method for applying pesticides differs depending on the main objective. Controlling some pests, such as mealybugs, requires large volumes of mixture to be applied at high pressure (with hoses) so that the insecticide fully penetrates the foliage. In other cases, it is enough to apply fine droplets to the surface of young leaves and inflorescences (using spray bottles). A dense mist should therefore be created, ensuring that it is correctly dispersed across all of the foliage and inflorescences, including the highest and lowest parts.

Before any treatment, it is therefore advisable to determine the method of application, choose the most suitable equipment for the situation and adjust its settings accordingly. A preliminary test using water can be used to determine how many trees can be treated with a single tank. This information combined with the density of the plantation can be used to determine the dilution of the pesticide in order to comply with the dosage of active substance per hectare.

Every product must be applied in compliance with the recommended dosage set out by the manufacturer on the packaging or instructions. As well as ensuring effective treatment, this dosage also prevents any phytotoxicity problems and ensures the fruit is not harmed. It is also important to check whether mixtures of active substances are compatible.

Details on carrying out phytosanitary treatments are set out in Appendix 5.

5.9   Physiological diseases

Sunburn

In dry savannahs, fruit trees under stress, exposed to the setting sun, display visible symptoms on the epidermis ranging from single light marks to genuine necroses. In some cases, visible marks may be small but internal damage can be significant as the underlying pulp is weakened. Sunburn can lead to significant losses. There are a number of simple techniques which can limit the damage, but they are rarely implemented because they are little known. In some cases, sunburn occurs following significant periods of dehydration and only providing more water can help to limit this effect. However, sunburn can also occur in irrigated orchards, especially on the west-facing side of the tree, which is exposed to the setting sun.

Limewater-based mixture, along with additives that help the mixture to stick to the epidermis, helps protect the fruit from sunburn. There are also commercial kaolin- or calcium carbonate-based products which protect trees from sunburn and also repel fruit flies.

Physiological defects - internal breakdown

Mangoes are vulnerable to internal physiological defects not caused by any particular pathogen. They are classified under the general term 'internal breakdown' and cannot always be detected from the outside of the fruit. These defects can be very different in appearance: soft nose, jelly seed, spongy tissue, etc. (see Oosthuise bibliography). They have a serious negative effect on the quality of fruit.

Internal breakdown leads to the localised softening of the pulp and the occasional change in the colour of the skin in that area. In the affected areas, hollows can appear and vascular tissue can turn brown. Underneath the area where the peduncle enters the fruit, it is occasionally possible to observe hollows in the pulp surrounded by necrotic tissue. When the effect is very serious, the pulp starts to ferment and gives off an unpleasant smell.

The various symptoms are often associated with varietal sensitivity: soft nose is most common among the Kent, Smith and Keitt varieties. It is sometimes associated with the germination of roots in the pulp. Jelly seed and hollow spaces are most common in the Tommy Atkins variety.

In many exporting areas, these effects develop on Kent and Keitt varieties and are one of the main quality problems.

Little is known about the cause of these defects. Currently, as well as the varietal factor (greater sensitivity of India-origin varieties or their hybrids), an imbalance in calcium nutrition is often identified as a cause (nitrogen/cation imbalance). The frequency of physiological defects in otherwise healthy orchards set up on the sites of former stockyards confirms the hypothesis that a nutritional imbalance in calcium levels and excess nitrogen is involved. Other environmental factors, such as a humid micro-climate, also increase the likelihood of these defects appeared.

PHYTOSANITARY PROTECTION

TABLE SUMMARISING OBSERVATION AND TREATMENT PERIODS FOR CONTROLLING THE MAIN MANGO DISEASES
(with reference to the phenological cycle)

	Flowering	Fruit-set Fruit enlargement	Harvest	Vegetative growth	Bud dormancy
	All diseases require periodic visual inspection to trigger treatment as soon as the first symptoms arise when weather conditions are adverse				
Anthracnose	Very high susceptibility	Treatment depending on precipitation	Post-harvest	Protection of young leaves	
Alternaria					
Peduncle rot					
Powdery mildew					
Bacterial canker					
Scab					

Legend:
- Yellow: Comments
- Red: Treatment during critical periods
- Orange: Optional treatment depending on weather conditions
- Pink: Post-harvest treatment

6. HARVEST

General considerations

To ensure that the fruit reaches optimum quality in terms of taste, it must be picked as late as possible, before the natural ripening process begins. The period of flowering stretches over at least three weeks, or even several months in areas where the same variety has numerous flowering periods.

However, even in areas with a single flowering period, different fruit on the same tree is not all at the same stage of ripeness at the time of the harvest.

Bringing the harvest forward offers a number of advantages since it reduces health risks and over-ripeness upon arrival. Nevertheless, this usually means exporting mainly unripe fruit which has not reached its optimal organoleptic qualities. At a time when some countries are making great efforts in this area, aided by very short transport times (e.g. Spain), more distant exporting countries need to strive to improve the organoleptic qualities of the mangoes they export or risk seeing their customers look elsewhere.

Harvesting fruit at adequate average maturity imposes strict conditions:

- Proficiency in harvesting criteria, which requires experienced fruit pickers, pending the development of non-destructive equipment for estimating maturity (research currently underway),
- Ensuring the best possible consistency in maturity in the field (harvest in various runs in the same plot, highly experienced fruit pickers, etc.) and in the packaging facility,
- Effectively managing pests and diseases,
- Controlling the cold chain.

Implementation

Before beginning the harvesting process, samples taken from across the entire plot help to estimate the quality of the fruit:

- Ripeness,
- Presence and significance of pests and diseases,
- Presence and significance of physiological flaws, physical alteration to the skin: sunburn, scratches, etc.

For export markets, plots with too many flaws will be set aside. It is important to check that no treatment has been recently applied that does not comply with the PHIs (Pre-harvest Intervals).

The harvest requires well-trained staff, who comply with the instructions about:

- Differentiating between fruit from different flowering periods,
- Selecting mangoes which fit the criteria defined by the packaging facility,

- Handling fruit with care by preventing impacts, scratches, and contact with any source of contamination: dead leaf litter, dirty harvest crates, damp and/or sandy/gravelly soil, etc.
- Manage dripping sap and prevent the fruit from being stained by latex,
- Sorting the fruit again before it is transported to the packaging facility,
- Arranging the fruit correctly in the transport crates.

Selecting mangoes for export shall take into account:

- The external physical appearance: at least one coloured side, well embedded peduncle and rounded shoulders, no damage or scratches due to rubbing, no marks of any kind, etc.
- over or under-ripeness,
- Deformations and physiological flaws: soft nose (softness close to the stylar end), sunburn, etc.
- Bites from flies or ants, etc.

6.1   Cutting point

The mango is a climacteric fruit. This means the ripening process starts on the tree and continues after harvest:

- If harvested too early, the fruit becomes wrinkly without ever ripening properly.
- If harvested too late, its shelf life is too short to be transported over large distances.

Managing the cutting point is a key concern for exporters and must take into account the mode of transport being used: plane or boat. Air transport allows fruit to be picked at a later stage, while boat transport needs it to be harvested earlier.

There is currently no reliable, non-destructive method for assessing the ripeness of mangoes in the field. Determining the cutting point remains a partially empirical operation and takes various criteria into account:

- The gap between flowering and the harvest,
- The development of the flesh colour (light yellow colour),
- The development of the skin colour,
- The shape of the fruit (especially the shoulders),
- Appearance of bloom (off-white, powdery coating) on the skin, etc.

Observing the colour of the flesh is the most reliable method. This is one of the main reference points used in the main exporting countries. The destructive nature of this method limits its use. At the start of the harvest, assessing the average ripeness level of the fruit in a plot is carried out using representative samples. In addition, periodic checks throughout the harvest can prevent any deviations.

The difference in the maturity levels of the mangoes on the same tree and/or orchard is a significant constraint. Managing these differences is largely dependent

on the methods and expertise of the fruit pickers. Every area has its own particular references using some or all of the criteria set out above.

Appearance of fruit upon arrival in Europe

The fruit below were picked before reaching a sufficient level of ripeness. Part or all of the pulp is white. This fruit will never have good organoleptic qualities. Unripe fruit wrinkles when picked before the rain comes due to a lack of irrigation. It is not very plump and the loss of water during the preservation stage causes the effect which can be seen in the photo on the right.
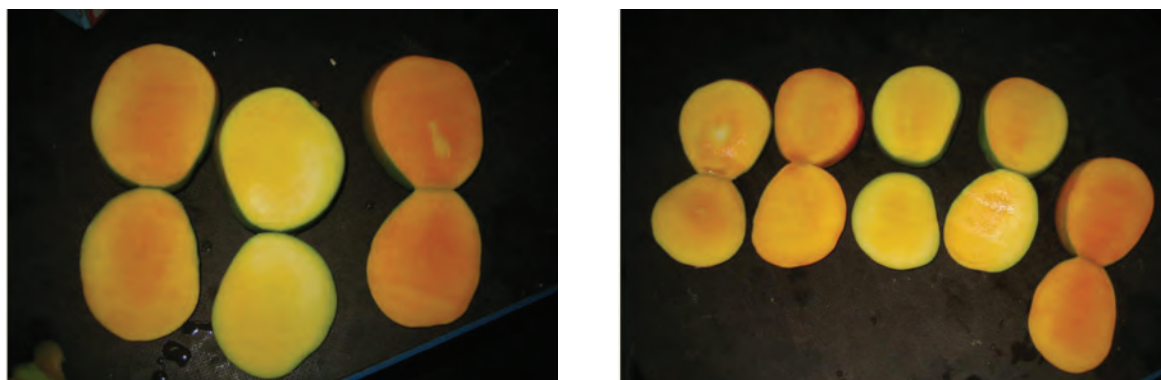
Figure 29: Fruit picked before reaching a sufficient level of ripeness

The fruit below are at a sufficient level of ripeness.
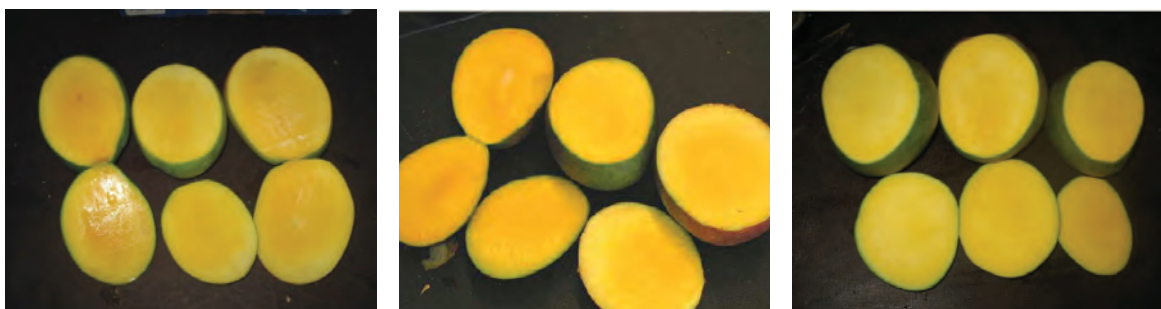
Figure 30: Fruit picked after reaching a sufficient level of ripeness

The fruit below is over-ripe compared to control fruit.

Figure 31: Over-ripe fruit

The fruit below has internal physiological flaws which were not detected during the harvest or packaging stages and which triggered a secondary infection by fungal or bacterial rot.
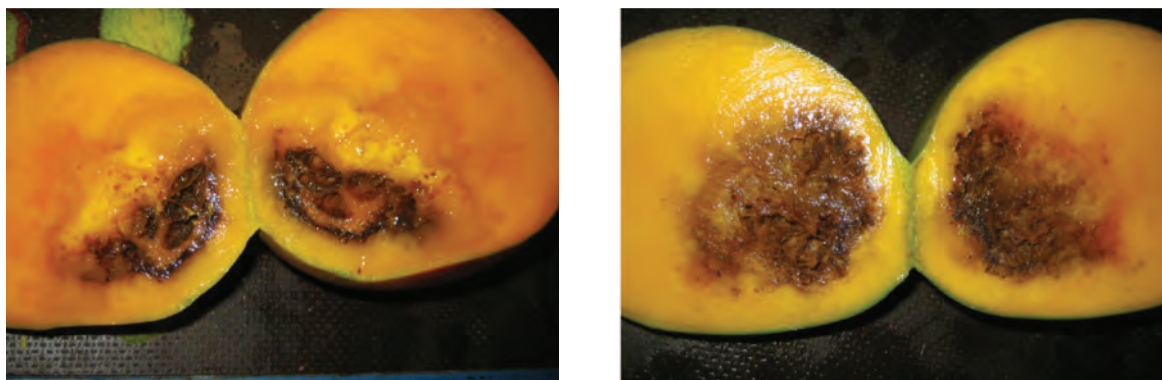
Figure 32: Fruit with physiological flaws

6.2   Precautions to be taken during the harvest

Freshly picked mangoes secrete latex from the cut peduncle for between several minutes to an hour after being harvested.

This latex burns the skin, causing irreversible damage. The fruit must be handled with the utmost care during and just after the harvest to prevent this type of damage occurring. Depending on the production area, mangoes are harvested with peduncles of differing lengths. Although operating methods vary, the objective remains the same: ensuring that the latex and the epidermis of the fruit do not come into contact, either directly or indirectly.

In west Africa, the fruit is generally picked by hand, leaving a long peduncle on the mango. The use of blunt tools (canes) must be forbidden.

The Brazilian technique, which involves fruit picking devices with a bag or net attached, is unsuitable due to the amount of latex secreted and the size of the trees that are generally left to grow without restrictions. If the peduncle breaks, latex secretions are released in the bag or net and therefore burn the fruit inside it. Dripping sap is less important in Brazil due to the lower turgescence in mangoes grown there. This difference is due to various factors: different varieties, dry climate during the harvest period, cultivation techniques, including water stress before harvest, etc.

In west Africa, due to the mangoes' different behaviour, pickers use an alternative technique. A blade fitted to the end of a stick allows them to cut the fruit on the outside of the tree and another picker catches it before it touches the ground. The fruit on the inside of the tree is picked by hand by pickers who climb the tree or use ladders.

Harvesting platforms are ideal devices, but are too costly to be used.

The harvest should not have a negative impact on the preservation of the fruit. In the orchard, all sorting and temporary storage processes should be carried out in the shade and in a clean environment to prevent the fruit picking up any pieces of dirt or being contaminated by pathogens from dead leaves, or necrotic branches, inflorescences or fruit. This is often overlooked but it is the cause of various preservation problems (fungal infections, alterations of the flesh).

Most pickers lay mango leaves in the bottom of the crates to protect the fruit while it is being transported to the packaging facility. Although it is effective, this practice should be completely forbidden because it contributes significantly to the spread of invasive diseases, especially bacterial canker. Leaves of other plants can be used, and are just as effective, without spreading diseases which affect mango trees.

The annotated photos in this chapter show the key techniques to follow or avoid. They show how to handle freshly harvested fruit and manage the dripping sap. These practical recommendations are important for preserving the visual quality of the mangoes and preventing any secondary contamination risk by pathogenic flora.

Good harvesting practices

The broad definition of the peduncle includes the stalk of what used to be the floral panicle. A stricter definition only includes the peduncle of the fruit. The burning sap is in the peduncle of the fruit and not the panicle. A stalk can carry several fruit.

In Brazil, Tommy Atkins mango harvest from pruned hedgerows. A worker cuts the long peduncles and another holds the net underneath.
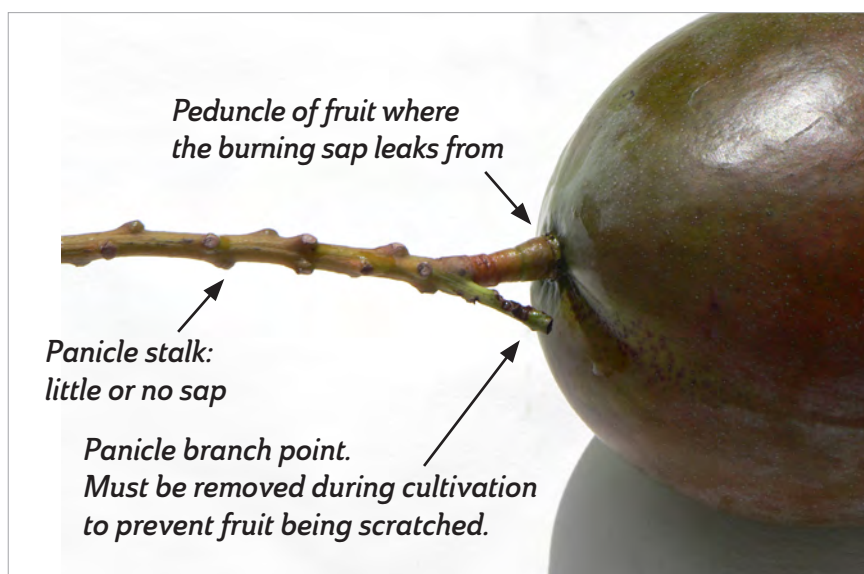

Peduncle of fruit where the burning sap leaks from

Panicle stalk: little or no sap

Panicle branch point. Must be removed during cultivation to prevent fruit being scratched.

Figure 33: Peduncle
Photo: Jean-Yves Rey

Traditional fruit picker. The peduncles are wedged in the upturned V and removed in one swift movement. This tool allows pickers to reach fruit which is very high up in the tree. It is advisable to replace the pieces of wood with sharp metallic blades.

Figure 34: Harvest of Tommy Atkins mangoes

Figure 35: Traditional fruit picker

After cutting the penduncle, if the secateurs remain clean.

Fruit which is detached from the tree is collected in a bag before touching the ground. Seasoned mango pickers catch the mangoes by hand.

Figure 37: Fruit picked with entire peduncle intact

Figure 36: Mango harvesting technique using a bag

During the harvest, the peduncles are preferably cut at a length of 10-15cm. The mangoes are arranged with the peduncle facing downwards so that they are not stained by the latex. However, when the peduncles are actually cut to their final length in the field (which is the case for almost all west African exports), it is unhelpful to cut the stalks to a length of 10-15cm as was done in the past.

The peduncles will be cut again to their final length in the field before being transported or in the packaging facility (see point 6.3.1 below on good practices for managing dripping sap).

When transporting the fruit over long distances or along tracks, it is highly advisable to cut the peduncles to their final length in the field because when a peduncle breaks during transport, all the surrounding fruit is burnt by the sap.

Figure 38: Cutting peduncles in the field

Cutting peduncles in the field: the fruit is held with the peduncle facing downwards and the peduncle in the broad sense is cut with secateurs at the level of the stalk (or rachis).

After cutting the peduncle, if the secateurs remain clean.

6.3 Post-harvest

6.3.1. In the field

The peduncle is quickly cut to a length of around half a centimetre from the point where it enters the fruit. During this step, the mango is placed top-down to prevent any latex coming into contact with the skin. (Figure 39). The fruit stays in this position until the latex has stopped flowing (between 30 minutes and one hour). Some producers use rigid equipment (metal or wooden frame holding a wide-mesh grill) to stand the fruit on during this step. The advantage of such a device is that it prevents the fruit coming into contact with the ground. This approach is highly recommended to prevent infestations via peduncle diseases (but also other contaminations set out in paragraph 5.6.1 and others). The fruit is then placed in a plastic crate in two overlapping layers, ensuring that it is held securely in place.

Good sap flow practices

Figure 39: Cutting the peduncle before packaging
Photo: Jean-Yves Rey

Cutting the peduncle down to the fruit: this is the length the peduncle must be cut to before packaging (either in the field or upon arrival at the packaging facility, and not during the harvest).

Fruit is often placed peduncle-downwards on the clean ground while the sap sets. However, it is better to place them on tables to prevent pathogens which cause peduncle rot from infecting the peduncle. The top of the tables have either a grill or parallel iron rods. These tables are becoming increasingly popular in west Africa because, while they cannot entirely prevent peduncle rot, they help to limit its occurrence. (Figures 42-43)

Figure 40: Cutting peduncles before placing the fruit on tables

Figure 41: Fruit placed on the ground (to be avoided)

Figure 42: Table type 1

Figure 43: Table type 2

Figure 44: Fruit in crates to be exported by plane before packaging

After the latex has set, the fruit is placed in crates. The fruit must not have any grains of sand or similar on it which may damage the skin during transport. In rainy conditions, fruit placed on the ground should be washed before being placed in crates.

6.3.2. Transporting the fruit from the orchard to the packing facility - grading

The fruit must be transported quickly. Upon arrival, the fruit is arranged in batches according to identified origin and placed in the shade. The definitive compliance inspection should preferably be carried out a few hours before the mangoes arrive at the packaging facility. This enables any defects caused by the harvest or transport to be detected. Accepted fruit is then weighed.

6.3.3. Packing at the station

It is important to have a light, well-aerated and spacious premises to carry out all packaging operations. The fruit is stored there in grouped batches (origin, variety) before being processed one by one.

The facility must have clean equipment in good condition, including washing tanks, sorting and packaging tables covered in a layer of foam, and possibly a mechanical calibrating machine and a treatment bath. It is important to ensure that the water resources are good quality and sufficient to carry out all the washing and cleaning operations on the fruit using clean water.

Staff must be trained in advance, must comply with cleanliness instructions and be thorough in carrying out their tasks. Everyone handling mangoes must have short nails to prevent causing any damage.

The packaging process must include the following steps at the very least:

1. Pre-washing of fruit in a tank, where the water is regularly changed,
2. Manual washing with clean water that is regularly changed,
3. Cleaning with clean sponges,

4. Wiping,

5. Sorting to remove any fruit which fails to comply with the export criteria. Special attention should be paid to fly bites (quarantine insect),

6. Grading (see references for calibration and weight of fruit in the appendix),

7. Crating,

8. Weighing and adjustment of weight in each box,

9. Storage,

10. Placement in pallets,

11. Storage in a cold room.

Packing in the station

In small facilities, the fruit is pre-washed in simple tanks. It is preferable to have two tanks: one for pre-washing and the other for the washing itself. (Figure 45) In larger facilities, the fruit is transferred to a delivery tank and then transported by a mechanical conveyor belt. (Figure 46).

Figure 45: Simple pre-washing tanks
Photo: Michel Gbonamou

Figure 46: Mechanical conveyor belt Photo: Michel Gbonamou

After the initial pre-wash, if the peduncles haven't already been cut, they should be cut mechanically down to the fruit, which is then immersed in a second tank to help the sap to set (Figure 47).

Regardless of the technique used, the water should be changed regularly, especially when the peduncles are cut at the facility. On modern packaging lines, the fruit is not washed but sprayed with a high pressure jet (Figure 48).

Figure 47: Tank for setting the sap in Brazil

Figure 48: High-pressure jet tank

After soaking, the fruit is brushed to remove any impurities on its surface. This Tourangelle brushing machine has brushes with short, hard bristles and a buffer above with long, flexible bristles that dry the fruit and make it shine. (Figures 49-50)

Figure 49: Fruit brushing device

Figure 50: Tourangelle brushing machine

6.3.3.1 Controlling fungal diseases - Heat treatments

Various methods for controlling fruit flies and post-harvest fungal diseases (anthracnose, peduncle rot, alternaria, etc.) can be implemented during the packaging process at the facility.

Fruit soaked in hot water to combat fungal diseases or fruit flies must be clean. Indeed, sap stuck to the skin can lead to burns under the effect of heat.

6.3.3.1.1 Treating fungal diseases

It is important to remember that fungal and bacterial diseases often develop from areas of damage on the fruit. Although visibly damaged fruit is removed during packaging, there are instances of micro-damage which are not always detectable as well as areas of "unavoidable damage" such as the cutting of the peduncle.

Basic precautions (described in previous chapters) taken when harvesting, cutting the peduncle, handling and transporting the fruit to the packaging facility are consequently the first step in the battle against post-harvest diseases.

The basic principle involves combining a heat treatment (soaking fruit in a tank of hot water or washing it with a hot water jet) with the application of a fungicide (soaking or spraying).

It is essential to know the nature of the fungus or fungi to be targeted so that a suitable protocol can be put in place. Not all fungal diseases are caused by anthracnose. There are a number of factors that vary depending on the problem to be resolved, including the exact water temperature, the length of the treatment, whether to use soaking or spraying, and so on. Indeed, some members of the parasitoid complex causing peduncle diseases (*L. theobromae* or *D. dominicana*) are only destroyed at temperatures around 55°C/56°C, which is at the very upper limit of what the fruit can tolerate. Likewise, the fungicide will differ depending on the nature of the pathogen. For more details on the protocols to follow, refer to chapter 5.6 fungal diseases.

The tables in the appendix demonstrate that the visual symptoms (necrotic marks) are not enough to easily distinguish one disease from another and only laboratory analyses can give an accurate diagnosis.

Soaking fruit to combat fungal diseases: soaking tank with hot water containing a fungicide (Figure 52). The solution reaches half way up the fruit, which is rolled through the tank on rollers. This process can be replaced by showers combined with firm brushing. The hotter the water, the shorter the operation must be. (10 minutes in the case of the tank used with this machine). If the fruit is soaked in fungicide then coated in wax, it should be dried using fans blowing room temperature or hot air depending on the natural weather conditions.

Figure 51: Fan for drying fruit (Photo: Jean-Yves Rey)

Figure 52: Soaking fruit in a tank of hot water containing a fungicide (Photo: Jean-Yves Rey)

6.3.3.1.2 Treatments against fruit flies

Various countries, including the USA, require any exported mangoes arriving in their territory to be systematically treated to combat fruit flies. European countries do not have this requirement.

It is worth noting that fruit fly eggs and larvae can be destroyed in the fruit by subjecting it to a heat treatment (soaking in hot water tank).

The most commonly used technique involves sorting the mangoes into two categories according to their weight: more than 450g and less than 450g. Batches of mangoes of a similar size are then immersed in a tank of hot water at 46.1°C for 75 minutes for the smallest fruit and up to 90 minutes for the largest. Heating and cooling require about the same amount of time. This heat treatment is therefore a long and costly process.

There are other methods using steam flow, which have been developed in New Zealand.

All these methods are burdensome and expensive to implement. They are only accessible to facilities processing high volumes of mangoes (tens or even hundreds of tonnes per day).

Soaking to destroy fruit fly larvae before shipment to the USA. The cages are gradually lowered into the tanks. The operation takes several hours including various stages of heating, soaking at a constant temperature and cooling.

Figure 53: Soaking tank to eliminate fruit flies
(Photo: Jean-Yves Rey)

6.3.3.1.3 Waxing

Heat treatments have a negative effect on the appearance of the skin of the mangoes. Applying wax and polishing the fruit gives the mangoes a shiny finish. The waxes are manufactured using synthetic or natural products.

Currently (September 2012), the additives authorised in Europe on fresh mangoes are as follows:

E 473 - 474	Sucrose esters of fatty acids - sucroglycerides	Fresh fruit, surface treatment
E 905	Microcrystalline wax	Treatment of the surface of mangoes and other fruit
E 912	Montanic acid esters	Treatment of the surface of mangoes and other fruit
E 914	Oxydised polyethylene wax	Treatment of the surface of mangoes and other fruit

Beeswax (E 901), carnauba wax (E 903) and shellac (E 904) have also been authorised for treating the surface of mangoes since 25 December 2012.

As well as the aesthetic benefits, these products play a role in gas exchange. The waxy film around each fruit creates a seal in which the atmospheric composition (O_2/CO_2 ratio) is different from the ambient atmosphere. These coating techniques are currently subject to more in-depth studies to ascertain their effects on the development of the external colouring of the mangoes and the improvement of their shelf life.

6.3.3.2 Sorting and grading

Sorting must be carried out on a long conveyor belt by highly skilled operators. This is a key stage in the packaging process to ensure the quality of the product. Sorting is carried out to remove all fruit with unacceptable defects, including insect damage or insect presence, especially quarantine insects (fruit flies), fungal and bacterial diseases, over-ripeness or under-ripeness, damage and defects to the epidermis, sunburn, deformations, etc. Physiological defects are mainly identifying by touching the fruit, but they are not easy to detect.

Different models of calibrating machines are used depending on the output of the packaging facility. Rotating calibrating machines can process between 500 and 800 tonnes a season depending on the layout of the facility, while mechanical or electronic machines can be used to package between 2000 and 5000 tonnes a year, or even more depending on the length of the working day. The accuracy of production line calibrating machines is much better than rotating machines. Despite this, rotating calibrating machines are still an excellent, robust and inexpensive piece of equipment for exporters who are just starting up.

The quantity of mangoes packaged each day depends as much on the skill of the staff and the organisation of the work as the output of the calibrating machine.

Figure 54: Sorting device
(Photo: Jean-Yves Rey)

Figure 55: Grading machine with small pots
(Photo: Jean-Yves Rey)

6.3.4. Crating and palletising

After sorting and calibration, the fruit is grouped by size into 4kg or 5kg boxes (containing between 6 and 12 mangoes in each depending on their size). The fruit is placed horizontally and sometimes protected individually by tissue paper or polystyrene sheaths to prevent damage during transport. The boxes are then placed onto pallets with corner pieces and horizontal hooping:

- For boat transport, in compliance with ISO standards (1.2m x 1m), these pallets are often more robust;

- Air transport, 1m x 1m.

As soon as the pallet is filled, the boxes are marked individually with the variety reference, the size, the packaging facility, and so on. Each pallet is identified by a reference code providing information on the order number and the origin of the batch(es) of fruit in it. These references are recorded on an inventory which is used for the traceability system.

For exports to destinations like the European Union, wooden pallets must be disinfected (using steam) prior to shipment in compliance with the regulations in force.

Figure 56: Box sealer (Brazil)
(Photo: Jean-Yves Rey)

Figure 57: Boxing calibrated fruit and finalising the preparation: stickers, marking, traceability. (Photo: Jean-Yves Rey)

A number of facilities in Africa use this machine rather than building the boxes by hand (more efficient use of cardboard, increased robustness, etc.).

Figure 58: Pallets
(Photo: Jean-Yves Rey)

Figure 59: Preparing the pallets
(Photo: Jean-Yves Rey)

6.3.5. Cold storage – the cold chain

Between the harvest and boxing of the fruit, the mangoes must always be handled at an ambient temperature between 20°C and 30°C. Lower temperatures have a very positive effect on shelf life but it is important to be aware of the point at which this effect becomes negative.

Mangoes do not tolerate temperatures which are too low. Temperatures under 10°C often cause physiological damage (brown spots on the skin, browning of the flesh, etc.).

Conservation temperatures are therefore between 8°C and 12°C. The precise temperature depends on the variety and the ripeness of the fruit (riper fruit can tolerate slightly lower temperatures). A period of 24 hours between picking and cold storage boosts the fruit's resistance to colder temperatures.

When placed in pallets, large volumes of fruit require cooling. It is challenging to achieve heat exchange with fruit placed in the middle of pallets.

There are various techniques for quickly reducing the temperature of mangoes:

- Hydrocooling, which involves immersing the fruit in cold water for a short time just before the end of the packaging and boxing process. This technique makes the fruit wet and is sometimes incompatible with other operations. It requires an effective drying system.

- Forced ventilation involves blowing a powerful stream of cold air through all the boxes in a pallet in order to cool the mangoes down quickly. This technique is most commonly used by large packaging facilities.

When the middle of the pallets have been cooled, they are placed in a refrigerated enclosure at a temperature between 10°C and 12°C. The humidity is kept at 90% and the air is renewed to prevent any increase in CO_2 and ethylene.

Precooling can be beneficial when packaging facilities are far from the destination. This also helps to reduce the emergence of fungal diseases post-harvest.

Container waiting to be loaded. When packaging facilities are far from the port, containers must be connected to a power supply when stationary. During transit, an electricity generator (on the top and on the front of the container) provides the cooling system with electrical power.

Full containers must be connected to an electrical power supply when stationary. (Packaging facilities, stations, ports: the fruit terminal at Ferkessédougou on Figure 61)

Figure 60: Container waiting to be loaded
(Photo: Michel Gbonamou)

*Figure 61: Electrical connection
of containers when stationary*
(Photo: Jean-Yves Rey)

6.3.6. Transport

Before being loaded, fruit must be inspected by customs and plant protection services. Mangoes are exported in two ways:

- By plane
- By boat

Although air transport is faster, it is still important to comply strictly with the basic principles in terms of storage to prevent the quality of the fruit being affected.

It is vital to pay close attention to the following two aspects:

- avoid exposing the fruit to excessively high temperatures, which can happen, for instance, in closed lorries in direct sunlight waiting to be loaded.

- Avoid breaking the cold chain by exposing the fruit to ambient conditions. Whenever the fruit leaves cold storage, it very quickly becomes covered in condensation, especially in humid climates or coastal areas. This condensation can have disastrous effects since it can soak the boxes and promote the development of diseases.

For sea freight, the pallets are placed in refrigerated containers, which are transported by lorry, boat and lorry again before arriving at the importer in Europe. This series of transport operations takes between one and four weeks depending on the distance between production site and destination. Throughout the logistics flow, strict compliance with the cold chain is critical.

In the case of refrigerated transport, the physiological activity of the fruit slows down, but gas exchange continues. For temperatures around 10°C, the hourly production of CO_2 is between 12 and 16 ml/kg and for ethylene it is between 0.1 and 0.5 µl/kg. In an enclosed space with no ventilation, the concentration of these two gases can increase significantly.

The concentration of CO_2 in the container should never exceed 8% or irreversible damage may occur. It is best to keep it around 1%.

It is well-known that ethylene levels around 100 ppm can speed up the ripening process.

For these reasons, constant ventilation with an hourly flow rate that corresponds to the volume of the container helps to maintain suitable atmospheric conditions.

During all stages of boat and lorry transport, temperature, humidity and atmospheric composition must remain stable and compliant with the storage requirements:

- Temperature between 8°C and 10°C (data continually recorded for each container).
- Humidity at around 90% without reaching 95%
- Fresh air to prevent a rise in CO_2 and ethylene content.

Before loading the container, it is important to check the shutters to ensure that the ventilation system is working correctly.

The exporter must specify the temperature, humidity and ventilation requirements to the courier. In-built recorders can be used to check the correct application of these instructions for the temperature and, occasionally for humidity, but very rarely for atmospheric composition.

Given the overall duration of the transport, breaks in the cold chain have an even more negative effect in the event of sea transport compared to air transport.

BIBLIOGRAPHY

COLEACP resources:

E-GAP: https://eservices.coleacp.org/fr/vue-substance-active-culture

Publications:

CAMPBELL R.J. 1992., MANGO, a guide to mangos in Florida. Fairchild Tropical Garden

De CARVALHO GENU P.J. & De QUEIROZ PINTO A.C., 2002. A cultura da Mangueira. Embrapa – Brasilia. CHAMBRE d'AGRICULTURE DE LA REUNION, 2002. La Mangue - Dossier Technico-Economique.

Thomas Chouvenc a,, Nan-Yao Su a, J. Kenneth Grace b. Fifty years of attempted biological control of termites – Analysis of a failure. Biological Control 59 (2011) 69–82

De LAROUSSILHE F., 1979. Le Manguier, Collection des techniques agricoles et productions tropicales, Maisonneuve & Larose. GALAN SAUCO V., 1999. El cultivo del Mango. Ediciones Mundi-Prensa.

Greatly Enhanced Ease in Mangoes On Small Trees, Oosthuise, S. A., SQM 2005 www.sqm. org

LAVILLE E., 1994. La protection des fruits tropicaux après récolte. CIRAD-COLEACP, 189p. LITZ R.E. (ed.) 1998. The Mango: Botany, Production and Uses, CAB International.

MARCHAL J., 1984, les Manguiers, in L'analyse végétale dans le contrôle de l'alimentation des plantes tempérées et tropicales. Col Technique et Documentation Lavoisier, Chap 9, pp 399-411.

NAKASONE. H.Y. and PAULL. R.E. 1998 Tropical Fruits, CAB International.

NT Mango Orchard Nutrition Workshops; T. Winston, Tropical Horticultural Consulting P/L Part. 2; 2013

Oosthuyse. S.A., Disorders of Fibreless Mangos Grown in South Africa for Export, S A Mango Growers' Assoc. Yearbook. Vol. 13

Senghor, A.L., Sharma, K., Kumar,L., Bandyopadhyay,R.,First Report of Mango Malformation Disease Caused by Fusarium tupiense in Senegal, Plant Disease, October 2012, Vol 96, Number 10, P. 1582, 2012.

BIBLIOGRAPHY

Bibliography on Xanthomonas citri bacterial canker of fruit trees in west Africa

Bruno Austin (de) L., Somda I., Rey J. Y., Traoré Y. N., Niang Y. Vernière C. et Pruvost O. (2010) Un nouveau fléau des cultures fruitières en Afrique de l'Ouest : les bactérioses des agrumes et des mangues provoquées par Xanthomonas citri La lutte régionale contre les mouches des fruits en Afrique subsaharienne. Lettre d'information N°10, novembre 2010.

Leduc, A., Vernière, C., Boyer C., Vital K., Pruvost, O., Niang, Y., and Rey J. Y. (2011) First report of Xanthomonas citri pv. citri pathotype A causing Asiatic Citrus Canker on Grapefruit and Mexican lime in Senegal, Plant Disease, October 2011 - Volume 95, Number 10, P. 1311.

Pruvost O., Boyer C., Vital K., Vernière C., Gagnevin L. and Traoré Y. N. (2012) First report in Mali of Xanthomonas citri pv. mangiferaeindicae causing mango bacterial canker on Mangifera indica L. Plant Diseases, Posted online on 1 Feb 2012, First Look.

Pruvost O., Boyer C., Vital K., Vernière C., Gagnevin L., de Bruno Austin L., Rey J. Y. (2011) First report in Ghana of Xanthomonas citri pv. mangiferaeindicae causing mango bacterial canker on Mangifera indica, L., Plant Disease, June 2011 - Volume 95, Number 6, P. 774.

Pruvost O., Boyer C., Vital K., Vernière C., Gagnevin L., et Somda I. (2011) First report in Burkina Faso of Xanthomonas citri pv. mangiferaeindicae causing bacterial canker on Mangifera indica L., Plant Disease, Oct. 2011 - Volume 95, Number 10.

Traoré Y. N., Bui Thi Ngoc L., Vernière C., and Pruvost O. (2008) First Report of Xanthomonas citri pv. citri

causing Citrus Canker in Mali Plant Disease Jun 2008, Volume 92, Number 6.

Natural Infection of Cashew (Anacardium occidentale) by Xanthomonas citri pv. mangiferaeindicae in Burkina Faso

Zombre C.,Sankara P., Ouédraogo S.L., Wonni I., Boyer K., Boyer C., Terville M., Javegny S., Allibert A. , Vernière C., and Pruvost O. Natural Infection of Cashew (Anacardium occidentale) by Xanthomonas citri pv. mangiferaeindicae in Burkina Faso; Plant Disease Volume 100, Number 422 Feb 2016.

International mango symposiums:

ISHS - Acta Horticulturae N° 231. Second International Symposium on Mango (Vol 1-Vol 2), 1985, Bangalore, India. ISHS - Acta Horticulturae N° 291. Third International Mango Symposium, 1989, Darwin, Australia.

ISHS - Acta Horticulturae N° 341. Fourth International Mango Symposium, 1992, Miami, USA.

ISHS - Acta Horticulturae N° 455. Proceedings of the 5th international Mango Symposium (Vol 1-Vol 2), 1996, Tel Aviv.

ISHS - Acta Horticulturae N° 509. Proceedings of the 6th international Mango Symposium (Vol 1-Vol 2), 1999, Pataya Thailand. ISHS - Acta Horticulturae N° 645. Proceedings of the 7th international Mango Symposium, 2002, Recife, Brazil.

WEBSITES:

http://www.extento.hawaii.edu/kbase/crop/crops/i_mango.html

https://gd.eppo.int/taxon/CRYPMA/distribution

http://www.hort.purdue.edu/newcrop/morton/mango_ars.html

http://www.horticultureworld.net/mango-india2.html#DISEASES

http://www.infoagro.com/frutas/frutas_tropicales/mango2.html

https://mango.co.za/

APPENDICES

APPENDIX 1:

Spectrum of activities of active substances

The spectrum of effectiveness is derived from existing authorisations, various publications on mango production, information from companies manufacturing phytosanitary products and field effectiveness trials conducted by the COLEACP*. In light of ongoing changes to phytosanitary regulations and standards governing the use of Plant Protection Products, it is advisable to consult the E-GAP (Good Agricultural Practices) database available in "COLEACP resources" in order to check the authorisation status of the active substance in the EU and ACP countries, the MRLs (maximum residue limits) and the good agricultural practices which ensure compliance with these MRLs.

TABLE: EFFECTIVENESS OF DIFFERENT ACTIVE SUBSTANCES OR BIOLOGICAL AGENTS
A: INSECTICIDES

Active substances or biological agents	Pests									
	Fruit flies	Fruit tree mealybugs	Waxy shelled mealybugs	Termites	Thrips	Gall midges	Whiteflies	True bugs	Weevil	Acrididae
Abamectin					X					
Acetamiprid		X		X	X		X			
Azadirachtin*	X									
Beauveria Bassiana *	X									
Bifenthrin	X			X			X	X		X
Cypermethrin							X			
Deltamethrin	X				X		X	X		X
Fenitrothion	X									X
Fipronil				X						X
White oil			X							
Imidacloprid	X	X		X	X	X	X			
Kaolin*	X				X					
Lambda-cyhalothrin	X				X		X	X		X
Malathion	X	X			X			X		X
Spinosad	X				X			X		
Thiacloprid	X				X		X			
Thiamethoxam	X	X	X	X	X		X		X	

* effectiveness proven by field trials conducted by the COLEACP

B: FUNGICIDES

Active substances	Diseases					
	Anthracnose	Alternaria	Peduncle rot	Powdery mildew	Scab	Bacterial canker
Humic acids + fulvic acids + plant extracts*	X					
Azoxystrobin + Difenoconazole*	X		X			
Bacillus amyloliquefaciens QST 713	X		X			
Captan	X	X				
Copper	X		X		X	X
Imazalil	X	X	X			
Fludioxonil	X					
Geranial-Neral-Myrcene*						X
Mancozeb	X				X	
Maneb	X	X			X	
Metalaxyl-m	X					
Prochloraz	X	X	X			
Propiconazole	X					
Sulphur				X		
Thiabendazole			X			
Thiophanate-methyl	X			X		
Thymol-Eugenol-Citronellal-Citronellol*			X			X
Thymol-Gamma Terpinene-Eugenol*						X
Trifloxystrobin	X					

* effectiveness proven by field trials conducted by the COLEACP

APPENDIX 2:
REGULATIONS AND PESTICIDES RESIDUES

Given the changes to the phytosanitary regulations and standards governing the use of plant protection products, the COLEACP published the E-GAP database online in 2018, which can be accessed by all its members and beneficiaries. To date, this is one of the only databases to provide information specifically designed to support the horticultural sector in ACP countries. Data on good agricultural practices (GAP) is obtained from a variety of sources, including the COLEACP's field trials of PPPs, data from manufacturers of PPPs and the scientific literature.

The E-GAP brings together the MRLs established by the EU and the Codex Alimentarius for key horticultural crops in ACP countries. It also sets out good agricultural practices (doses, intervals between treatments, periods before harvesting, etc.), which ensure that these MRLs are complied with. Additional information such as the type of pesticide, the authorisation status of the active substance in the EU and ACP countries, the classification recommended by the World Health Organisation (WHO) and the resistance group (FRAC code for fungicides, IRAC classification for insecticides) is also available[2].

To access the COLEACP database, E-GAP, enter your username and password in the e-service section of our website and click on COLEACP Resources here

Note on the status of active substances in the EU

For a Plant Protection Product to be marketed in the EU, its active substance must be authorised by the European Commission.

Regulation (EC) 1107/2009 (replacing the previous Directive 91/414/EEC) came into force on 14 June 2011. On 25 May 2011, the Commission adopted Implementing Regulation (EU) 540/2011. The appendix of this document lists the active substances which are deemed approved. These Regulations and all other related regulations can be accessed via the search tool available at:
http://ec.europa.eu/food/plant/protection/evaluation/index_en.html

It should be noted that if an active substance is not authorised in the EU, this does not mean that it cannot be used in ACP countries for foodstuffs intended to be sold in Europe providing that the residue levels comply with the EU's MRLs.

---

2   The COLEACP also wishes to highlight the importance of complying with the instructions on the labels of PPPs. Moreover, before using any product, it is advisable to consult the latest regulatory amendments in the EU database on pesticides and in the Codex Alimentarius.

Note on MRLs:

The quantities of pesticide residue in food must not represent a danger for consumers and should remain as low as possible.

The Maximum Residue Limit (MRL) is the maximum concentration of pesticide residue legally permitted in or on food or animal feed.

MRLs and the European Union (EU)

Following Regulation (EC) No 396/2005, MRLs were standardised across the EU.

The European Commission (EC) establishes the MRLs for food marketed in EU countries, whether it is produced in the EU or in third countries.

Appendix I of the Regulation contains the list of crops (Regulation (EC) 178/2006) to which the MRLs apply, appendix II contains the definitive MRLs and appendix III sets out a list of temporary MRLs. The list of substances for which an MRL is not necessary is set out in appendix IV (Regulation (EC) 149/2008). When there is no specific MRL for a substance/crop, a default MRL of 0.01mg/kg is applied.

When determining an MRL, the European Union takes the Codex MRL into account as long as it was established for the same agricultural practices and passes the food risk calculation. When there is an appropriate MRL in the Codex, the import tolerance shall be set at that level.

The EU's standardised MRLs came into force on 1 September 2008 and are published in the MRL database on the Commission's website https://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/mrls/?event=search.pr

Information is also available in the document "New rules on pesticide residue in food"[3]

How are MRLs applied and checked in the EU? :

- Farmers, traders and importers are responsible for food safety and, as a result, compliance with the MRLs.

- The authorities of member states are responsible for checking and applying the MRLs.

- To ensure effective and uniform application of these limits, the European Commission has a coordinated multi-annual control programme which sets out for each member state the main combinations of crops and pesticides to monitor and the minimum number of samples to take. Member states must report their results to the Commission, which publishes them in an annual report. Reports are now published by the European Food Safety Authority (EFSA)[4].

---

3 https://www.efsa.europa.eu/fr/topics/topic/pesticides#limites-maximales-de-r%C3%A9sidus
4 http://www.efsa.europa.eu/en/scdocs.html

▪ If pesticide residue levels are identified as posing a risk to consumers, information is sent via the Rapid Alert System for Food and Feed (RASFF) and necessary measures are taken to protect consumers. The database[5] and the annual RASFF report[6] are available on the European Commission's website.

MRLs in ACP countries

ACP countries which do not have their own MRLs generally recognise Codex MRLs for food marketed in their countries.

The Codex Alimentarius Commission was set up in 1961 by the Food and Agriculture Organisation of the United Nations (FAO) and the World Health Organisation (WHO) in order to draw up an international food code and food standards. Membership of the Codex Alimentarius Commission is open to all member states and associate members of the FAO and WHO. Along with the members of the European Union, over 180 countries are members of the Codex Alimentarius Commission.

Although they are not officially included in the structure of the Codex Alimentarius Commission, joint FAO/WHO meetings on pesticide residue help to convey expert opinions of scientists independent from the Commissions and its specialised committees in order to establish the Codex maximum residue limits (Codex MRL) for pesticides. These MRLs are recognised by most member countries and are widely used, especially by countries which do not have their own system for assessing and establishing MRLs.

The Codex MRL database is available at the following website: www.codexalimentarius.org.

---

5 https://webgate.ec.europa.eu/rasff-window/screen/search?event=SearchForm&cleanSearch=1
6 https://ec.europa.eu/food/safety/rasff-food-and-feed-safety-alerts/reports-and-publications_fr

APPENDIX 3–1:
ILLUSTRATIONS OF POST-HARVEST DISEASES ON FRUIT

Not all marks on fruit are indicative of an anthracnose attack. The following photos illustrate this point.
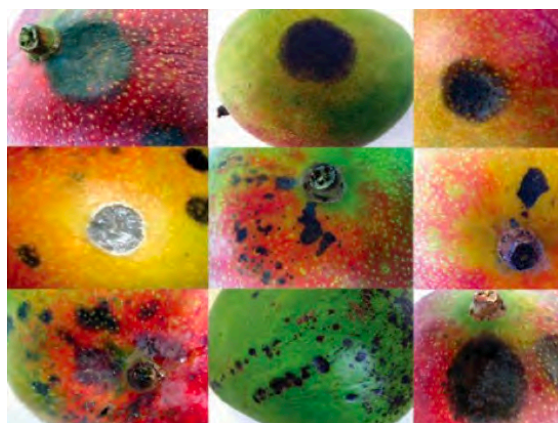
Figure 62: None of these mangoes is suffering from an anthracnose attack caused by Colletotrichum gloeosporioides.

Anthracnose

Figure 63: Anthracnose marks caused by Colletotrichum sp.
(Photo - P.M Diédhiou)

Figure 64: Teardrop marks caused by Colletotrichum sp.
(Photo – H. Vannière)

Alternaria
Marks caused after harvest by *Alternaria* sp:

Figure 65: Fresh lesions concentrated in the peduncle area
(Photo - B.P Gerbaud, CORDER)

Figure 66: More advanced marks caused by Alternaria sp.
(Photo - H. Vannière)

Sigatoka
Post-harvest rot marks associated with *Cercospora* sp.

Figure 67: Post-harvest rot marks associated with Cercospora sp.
(Photo - P. Gerbaud, CORDER)

Stemphylium

Figure 68: Slightly concave rot marks associated with Stemphylium sp.
(Photo - P. Gerbaud, CORDER)

Rot associated with *Dothiorella* and *Lasiodiplodia* sp.

Figure 69: Peduncle rot associated with Dothiorella and Lasiodiplodia sp.
(Photo - P.M Diédhiou)

Figure 70: Widespread marks developing randomly on the surface of the fruit
(Photo - P. Gerbaud, CORDER)

Rot marks developing after contamination of the peduncle during the harvest (A) or damage to the skin (B) caused by *Aspergillus* sp.
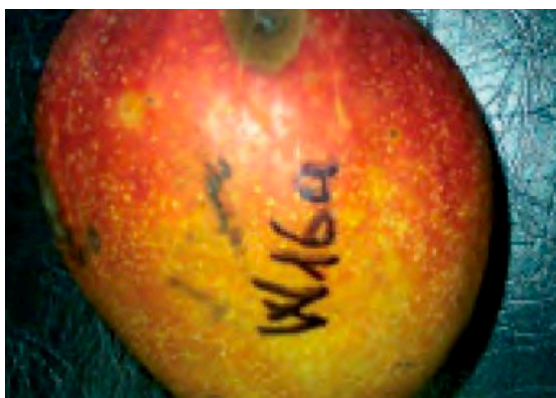

Figure 71: B
(Photo - P.M Diédhiou)

Figure 72: A
(Photo - P.M Diédhiou)

APPENDIX 3-2:
ILLUSTRATIONS OF DISEASES IN THE ORCHARD

Bacterial canker: *Xanthomonas citri*

Figure 74: Fruit attacked by Xanthomonas

Scab

Figure 75: Fruit attacked by scab

Anthracnose

Figure 76: Damage on inflorescence caused by anthracnose

Figure 77: An anthracnose attack on a leaf

Figure 78: Anthracnose attack at the base of the flower stalk
(Photo - Henri Vannière)

Powdery mildew

Figure 79: Leaves attacked by powdery mildew

Figure 80: Inflorescences attacked by powdery mildew

Bacterial canker: *Xanthomonas citri* pv. *Mangiferaeindicae*
(photos Jean-Yves Rey)

Figure 81: Damage on the top of a leaf. The centre of older marks becomes grey. They are surrounded by a yellow ring. On both sides, the marks are visibly bound by the veins, giving them a jagged appearance.

Figure 82: Cankers on branches with a gum-like secretion.

Figure 83: Marks on the underside of a leaf. Black marks are surrounded by a lighter, oily halo.

Figure 84: Damage on fruit.

Bacterial canker (continued): *Xanthomonas citri* pv. *Mangiferaeindicae*
(photos Jean-Yves Rey)

Figure 85: Craters on a branch. Gum containing bacteria drip from these lesions, especially when the rains return.

Figure 86: Apical necrosis. The apical buds are destroyed and do not produce any new shoots or inflorescences.

Figure 87: Large marks with secondary infection by other diseases and fly bites, as well as small, raised marks in a teardrop pattern.

Figure 88: Cankers with a gum-like secretion on a branch.

Figure 89: Damage on fruit.

Figure 90: Advanced necroses and cankers on a branch which has lost most of its active leaves.

Bacterial canker (continued): *Xanthomonas citri pv. Mangiferaeindicae*
(photos Jean-Yves Rey)

Figure 91: Main necrosis and raised teardrop marks.

Figure 92: Large mark, within which fruit flies have laid their eggs, with the centre opening up in a star shape. Around the main mark, smaller marks create star-shaped patches.

Fusarium wilt: *Fusarium*
(photo: Gilles Renoux)

Figure 93: Fusarium tupiense damage on flowers in Casamance

APPENDIX 3-3:
ILLUSTRATIONS OF PESTS
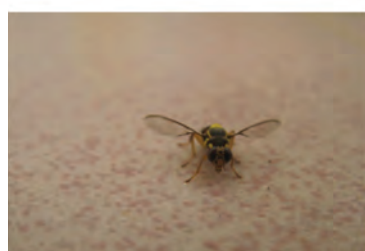
Fruit flies

*Figure 94:
Ceratitis sp.*

*Figure 94:
Bactrocera dorsalis
(Photos: Gilles Delhove)*

Figure 95: Damaged fruit

*Figure 96:
Egg-laying*

Figure 97: Larva

Fruit tree mealybug: *Rastrococcus invadens*

Figure 98: Larvae on the underside of a leaf
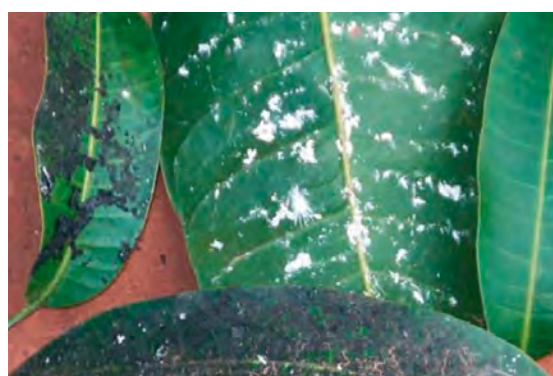*(Photo Jean-Yves Rey)*

Figure 99: Sooty mold on the top of leaves
(Photo Jean-Yves Rey)

Mealybugs

Figure 100: Mealybug larvae

True bugs: *Anoplocnemis*

Figure 101: Adult anoplocnemis

Acrididae

Figure 102: Acrididae

True bugs: *Lygus spp.*

Figure 103: Lygus spp adult and larvae

Acrididae: *Senegalese grasshopper*

Figure 104: Oedaleus senegalenis

Thrips

Figure 105: Thrips

Selenothrips

Figure 106: Selenothrips damage on young fruit

Scirtothrips

Figure 107: Scirtothrips damage on young leaves

Gall midges

Figure 108:
Adult erosomyia

Figure 109: Bitten inflorescence
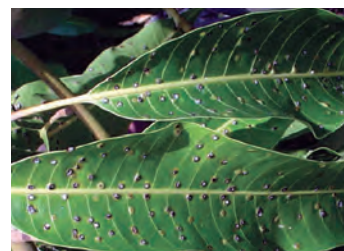*(Photo Henri Vannière)*

Figure 110: Damage on leaves
(Photo Henri Vannière)

Whiteflies: *Aleurodicus dispersus*

Figure 111: Aleurodicus
dispersus larvae

Figure 112: Adult
Aleurodicus dispersus

Termites

Figure 113: Crusting on a trunk

Figure 114: Withering tree following an attack

Microcerotermes build tunnels in the trunk and work their way into lesions or stumps of dried out branches, expanding the area of necrosis. This damage usually affects isolated branches.

*Figure 115: Tunnel in a trunk*
(Photo Baptiste Assié)

Figure 116: Stump of dried out branch
(Photo Baptiste Assié)

Figure 117: Microcerotermes soldiers
(Photo Baptiste Assié)

However, amitermes are thought of as the most dangerous termites for mango trees (usually the species *A. evuncifer*). They establish their colonies at the base of the trunk, the trunk collar or underground, usually under the plaster left by Odontotermes, worsening the damage already caused.
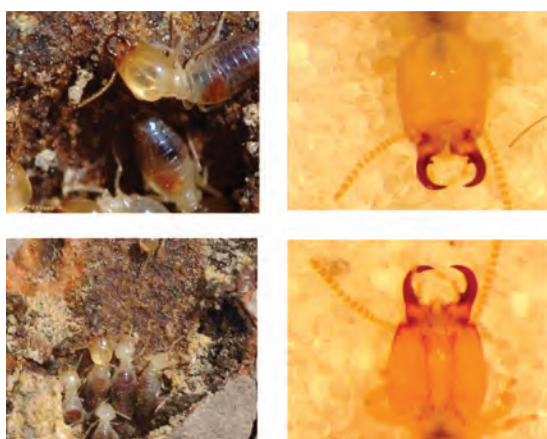
Figure 118: Characteristic amiterme damage

Figure 119: Amitermes soldiers
(Photo Baptiste Assié)

Damage characteristic of Amitermes over the top of damage characteristic of Odontotermes. On the right of the photo, the blackish area of damage is the Amitermes' harvesting site. On the left, there is a lighter, shallower area of damage, which is an older lesion caused by Odontotermes.

Mango stone weevil

Damage to fruit caused by **mango stone weevils**. Some varieties suffer serious attacks but the weevils do not reach the stone (Julie in Guadeloupe, in this case). For other varieties, the opposite is true: little visible damage but the insects are in the stone.

Figure 120: Damage to fruit caused by mango stone weevils (Photo Jean-Yves Rey)

Figure 121: Internal damage (Photo Jean-François Vayssières)
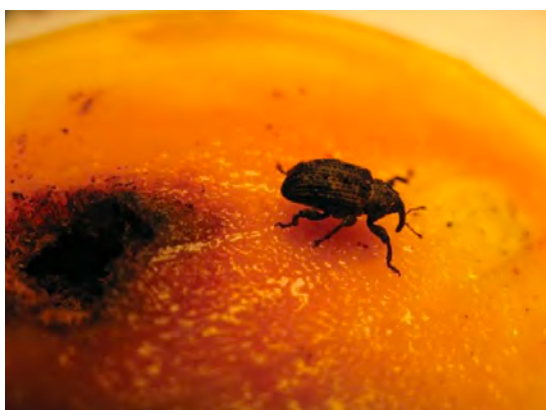
Figure 122: Adult (Photo Jean-François Vayssières)

APPENDIX 4:
CARRYING OUT TREATMENTS

The method for applying pesticides differs depending on the main objective. Controlling some pests, such as mealybugs, requires large volumes of mixture to be applied at high pressure (with hoses) so that the insecticide fully penetrates the foliage. In other cases, it is enough to apply fine droplets to the surface of young leaves and inflorescences (using spray bottles). A dense mist should therefore be created, ensuring that it is correctly dispersed across all of the foliage and inflorescences, including the highest and lowest parts.

Before any treatment, it is therefore advisable to determine the method of application, choose the most suitable equipment for the situation and adjust its settings accordingly. A preliminary test using water can be used to determine how many trees can be treated with a single tank. This information combined with the density of the plantation can be used to determine the dilution of the pesticide in order to comply with the dosage of active substance per hectare.

Every product must be applied in compliance with the recommended dosage set out by the manufacturer on the packaging or instructions. As well as ensuring effective treatment, this dosage also prevents any phytotoxicity problems and ensures the fruit is not harmed. It is also important to check whether mixtures of active substances are compatible.

A set of scales and a dosage glass are essential for correctly creating the mixture in the treatment tank.

Phytosanitary protection

Which spraying devices should be used?

The product should be sprayed onto the crop:

- Either with a pneumatic backpack sprayer fitted with a centrifugal pump to spread the product steadily and consistently across the crop, including the high parts of the trees.
- Or with a pressurised spraying device (towed or carried on a tractor with a capacity of between 200 and 1000 litres) with jets that spread the active product diluted in liquid steadily and consistently in the form of droplets carried by a powerful current of air onto the parts of the plant to be treated.
- Treatment tanks fitted with hoses for spraying are available, which require both high pressure and a high flow rate. This equipment is recommended for treating mealybugs.

Practical advice:

- Do not carry out treatments when the temperature is too high in order to prevent burns.
- Carry out treatments when there is no wind to prevent the significant amounts of spray drifting onto neighbouring crops.
- Do not carry out treatments when rain is forecast because 25mm of rainfall or more will wash contact products or systemic products off the leaves if applied less than three hours before.
- Alternate between different types of active substances as frequently as possible to prevent resistant strains from emerging.

Spraying trees:

There are usually two types of pesticide doses indicated. One is the quantity of product to apply per hectare, while the other is the quantity of product per volume of water, assuming that the volume stated covers one hectare.

Recommendations on the quantities of product to be applied assume that the trees in question are of average size and age, and that the entire surface area of the orchard is sprayed (and not one or two trees here and there). It is straightforward to adjust the equipment to ensure that it sprays a constant quantity of mixture per hectare regardless of the crop development stage. Backpack sprayers are more difficult to adjust because the volume of mixture used per hectare depends on the size (volume) of the trees and the number of trees per hectare.

To adjust a backpack sprayer and establish the concentration of the mixture of a given pesticide, it is important to follow these steps:

1. Choose a plantation row or area where the trees are of an average size and the spaces between them are representative of the spaces in the plantation as a whole once it has reached its full production stage.
2. Fill the tank with a given quantity of water (e.g. 20 litres).
3. Spray the trees so as to cover the vegetation in a suitable way to combat the pest or disease in question.
4. After spraying 20 litres of water, count the number of trees that have been sprayed (e.g. 12 trees).
5. Then determine the surface area that has been treated with the 20 litres.
   12 trees = 0.10 hectare
   120 trees per hectare (density of the plantation)
6. Determine the volume of litres per hectare used by dividing the volume by the surface area.
   20 litres
   0.10
   = 200 litres/hectare
7. Finally, determine the level of dilution required in order to comply with the dose of the product per hectare. E.g. for a product in a solid state:
   1 kg/hectare
   = 5 g/l
   200 litres/hectare

APPENDICES

Or for a product in a liquid state:

1 l/hectare

200 litres/hectare

= 5 ml/l

This level of dilution must be maintained for the adjusted sprayer and the pest targeted at every stage of the crop's development to prevent any phytotoxicity problems from emerging.

The below correlation tables show various frequently used pesticide preparation solutions using liquid formulations.

TREATMENT OF 1000 L/HA

	Surface area treated 1 hectare	Surface area treated 1000 m^2	Surface area treated 100 m^2
Authorised dosage	Product to be diluted in 1000 litres of water	Product to be diluted in 100 litres of water	Product to be diluted in 10 litres of water
0.5 l/ha = 0.05 l/hl	500 ml	50 ml	5 ml
1 l/ha = 0.1 l/hl	1 l	100 ml	10 ml
1.25 l/ha = 0.125 l/hl	1.25 l	125 ml	12.5 ml

TREATMENT OF 500 L/HA

Product doses per surface area unit are the same as those for a treatment of 1000 l/ha. However, the volumes of water used change. The mixture would therefore be twice as concentrated.

	Surface area treated 1 hectare	Surface area treated 1000 m^2	Surface area treated 100 m^2
Authorised dosage	Product to be diluted in 500 litres of water	Product to be diluted in 50 litres of water	Product to be diluted in 5 litres of water
0.5 l/ha = 0.1 l/hl	500 ml	50 ml	5 ml
1 l/ha = 0.2 l/hl	1 l	100 ml	10 ml
1.25 l/ha = 0.25 l/hl	1.25 l	125 ml	12.5 ml

TREATMENT OF 2000 L/HA

Product doses per surface area unit are the same as those for a treatment of 1000 l/ha. However, the volumes of water used change. The mixture would therefore be twice as diluted.

	Surface area treated 1 hectare	Surface area treated 1000 m^2	Surface area treated 100 m^2
Authorised dosage	Product to be diluted in 2000 litres of water	Product to be diluted in 200 litres of water	Product to be diluted in 20 litres of water
0.5 l/ha = 0.025 l/hl	500 ml	50 ml	5 ml
1 l/ha = 0.05 l/hl	1 l	100 ml	10 ml
1.25 l/ha = 0.0625 l/hl	1.25 l	125 ml	12.5 ml

Product dose = dose of active ingredient (g/ha)

COLEACP

TECHNICAL ITINERARIES

Cayenne Pineapple *(Ananas comosus)*
MD2 Pineapple *(Ananas comosus)*
Avocado *(Persea americana)*
Passionfruit *(Passiflora edulis)*
Okra *(Abelmoschus esculentus)*
Common bean *(Phaseolus vulgaris)*
Mango *(Mangifera indica)*
Papaya *(Carica papaya)*
Peas *(Pisum sativum)*
Cherry tomato *(Lycopersicon esculentum)*

GUIDES TO GOOD CROP PROTECTION PRACTICES

Garlic, onion, shallots *(Allium sativum, Allium cepa, Allium ascalonicum)*
Amaranth *(Amaranthus* spp.)
Organic pineapple *(Ananas comosus)*
Aubergine *(Solanum melongena, Solanum aethiopicum, Solanum macrocarpon)*
Organic avocado *(Persea americana)*
Banana *(Musa* spp. – matoke, apple banana, purple banana, mini banana and other banana varieties)
Citrus (*Citrus* sp.)
Coconut (*Cocus nucifera*)
Cucumber (*Cucumis sativus*), courgette, custard marrow (*Cucurbita pepo*) and other edible-skin gourds from the genuses *Momordica, Benincasa, Luffa, Lagenaria, Trichosanthes, Sechium* and *Coccinia*
Ginger (*Zingiber officinale*)
Common bean (*Phaseolus vulgaris*)
Yam (*Dioscorea* spp.)
Lettuce (*Lactuca sativa*), spinach (*Spinacia oleracea* and *Basella alba*), brassica (*Brassica* spp.)
Lychee (*Litchi chinensis*)
Organic mango (*Mangifera indica*)
Manioc (*Manihot esculenta*)
Melon (*Cucumis melo*)
Mini pak choi (*Brassica campestris* var. *chinensis*), mini cauliflower (*Brassica oleracea* var. *botrytis*), mini broccoli (Brassica oleracea var. italica), cabbage (*Brassica oleracea* var. *capitata* and var. *sabauda*)
Mini carrot (*Daucus carota*)
Mini corn and sweetcorn (*Zea mayis*)
Mini leek (*Allium porrum*)
Organic papaya (*Carica papaya*)
Watermelon (*Citrullus lanatus*) and butternut squash (*Cucurbita moschata*)
Sweet potato (*Ipomea batatas*)
Chilli pepper (*Capsicum frutescens, Capsicum annuum, Capsicum chinense*) and sweet pepper (*Capsicum annuum*)
Potato (*Solanum tuberosum*)
Tamarillo (*Solanum betaceum*)
Taro (*Colocasia esculenta*) and arrowleaf elephant ear (*Xanthosoma sagittifolium*)