PIP

CROP PRODUCTION PROTOCOL
MANGO (*MANGIFERA INDICA*)

COLEACP is an international network promoting sustainable horticultural trade.

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In accordance with the Millennium Development Goals, the global objective is to: "Maintain and, if possible, increase the contribution made by export horticulture to the reduction of poverty in ACP countries".

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PIP
FOR SUSTAINABLE DEVELOPMENT OF THE ACP HORTICULTURAL INDUSTRY

Document drafted by PIP with technical collaboration of:

H. VANNIERE and J.F. VAYSSIERES from CIRAD-FLHOR, H. MARAITE from UCL phytopathology unit

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Table of contents

Mangifera Indica - family of the anacardiacae

1. Description

1.1. Botany and Description

Mango trees originate from India and Burma and thereafter diversified into other areas of south-east Asia:
- in north-western India, giving rise to monoembryonic, anthracnose- susceptible varieties whose skin colour varies in intensity. The climate there is highly contrasting with hot, humid summers that alternate with a dry, cold season;
- in Burma, Thailand, Indonesia and the southern part of the Indo- Chinese peninsula, giving rise to polyembryonic varieties whose skin is greenish with little colouring and are relatively resistant to anthracnose in a far less contrasting hot and humid climate.

These two types of mango were brought together in Florida a century ago where they produced considerable progeny either by natural or artificial hybridisation. This area is considered to be a centre of secondary diversification. Most of the varieties found on the export market are derived from these hybridisations. In the regions of origin, the primitive type habitat was tropical forests at medium elevations. In those circumstances, fruiting is erratic: sparse flowering, fungal attacks on the flowers and young fruit.

In sub-tropical areas, alternating temperatures (25 °C day/15 °C night), together with a marked dry season, are instrumental in bringing about more intense flowering. Low temperatures are the main limitation to the extension of mango growing areas beyond 36 °N and 33 ° S.

Mango Tree Morphology and Biology

Mango is a well-developed (10 to 30 m tall) evergreen tree.

It produces cluster-shaped inflorescences at the tip of the branches in the peripheral area of the foliage. They are made up of male and hermaphrodite flowers. Each inflorescence carries several 1000 flowers which, following pollination, produce a few fruits at most. The average fruit-set rates are very low, less then 1/1000. Pollination is brought about by insects - flies, thrips, etc., very rarely by bees. The fruit is a drupe. It has fairly fine skin covered with lenticels. Its colour varies depending on the variety: green, yellow, orange, reddish-purplish, sometimes alone or else in combination in the form of blushes. At maturity, the flesh turns yellowish orange. It can be firm but is most often juicy. Fibres are found in the vicinity of the stone to a greater or lesser degree according to the variety. The less evolved types that originate from India have a more pronounced turpentine taste and greater fibre content. The flat seed is protected by a lignified kernel.

In monoembryonic varieties, it comprises a single zygotic embryo (arising from a single pollination and whose genome is always different to that of the mother plant). In polyembryonic varieties, it is made of one or several nucellar embryos (arising from nucellar tissue and whose genome is always identical to that of the mother plant).

Their germination capacity lasts only a few weeks.

1.2. The Phenological Cycle - Periodic Growth

During the hot, humid season, growth is not continuous. Each growth flush is followed by a period of apparent dormancy (periodic growth). The mango tree's phenological cycle is strongly influenced by weather conditions. For mango trees to flower, there must be a marked halt in growth. This occurs as a result of a drop in average temperatures and/or a marked dry period.

In humid tropical areas, because there is no cessation of growth, the development cycle of the various architectural units of the tree cannot be synchronised. Flowering and vegetative flushes occur in succession dissynchronously which in turn accentuates the natural ability of mango to flower in quick succession (frequently 2 sometimes 3 blossomings a year at intervals of one-and-a-half months).

Rain Cooler temperatures Dry season irrigation

Growth Flush
1st flowering
2nd flowering
Fruit enlarg.
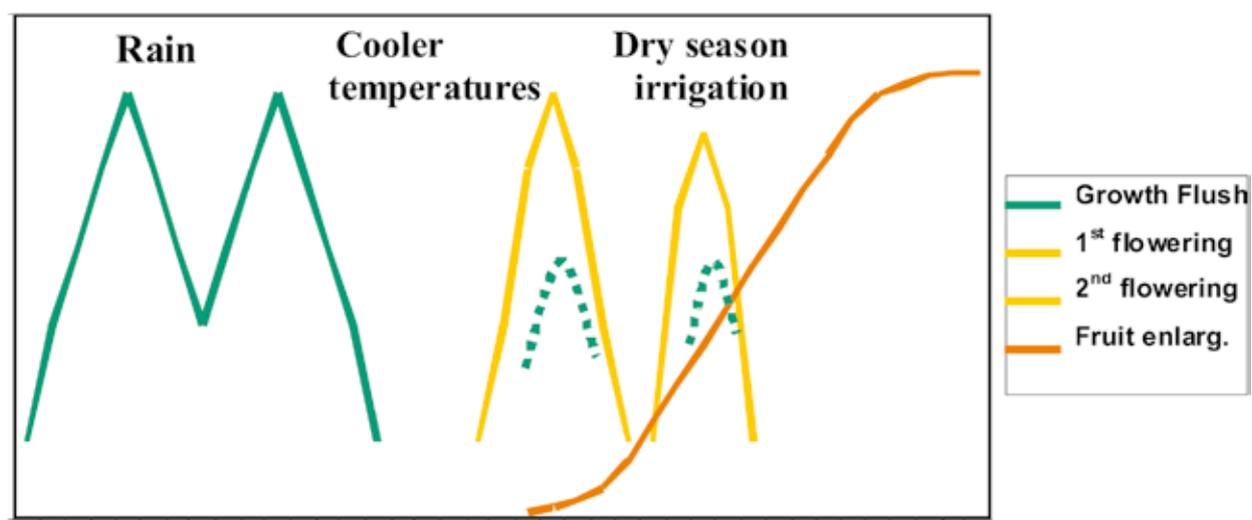
Example of a phenological cycle - Reunion Island

2. Varieties

The choice of variety arises from a compromise between the expectations of producers, distributors and consumers. It takes into account such varied features as agronomic characteristics, resistance to various pests, storage and transportation capability, sensory and visual qualities, market niche, etc.

Among the wide range of mango varieties available, very few meet all of these criteria for the export market. Most of the preferred varieties originate from Florida.

There are three leading varieties on Western markets:

➢ **Tommy Atkins**:
This early variety has a number of positive features in terms of productivity, appearance, handling and storage properties. On the other hand, its mediocre taste makes it undesirable for knowledgeable consumers and is an impediment to its future development on European markets. It is susceptible to a physiological problem referred to as " jelly seed", i.e., premature or partial ripening that causes breakdown of the flesh (jelly-like texture) in the vicinity of the stone.
This is a leading variety in the export trade mainly grown in Brazil and Mexico, South Africa and Israel. It is unusual in West Africa where the Kent variety is preferred

➢ **Kent**:
The Kent cultivar originates from Florida and was introduced into Africa via the Foulaya experimental station in Guinea around 1950. From there, it was dispersed to other stations in western and central Africa.
The fruits reach maturity in the middle of the season. They are ovate, relatively large and generally weigh between 500 and 900 grammes. The flesh is firm and has a pleasant taste. This mango matures very slowly and gradually. Fruits that are harvested close to maturity can be stored for a long time at cool temperatures. The fruit's excellent sensory qualities, the firmness of its flesh and its gradual ripening are all equally attractive features to retailers. Although it is difficult to grow, this mango is the standard in terms of quality on export markets. It depends heavily on climate and the nature of the soil. The most attractive fruits are those with a red-coloured skin and well-developed, balanced flavours that grow on lateritic soil in a dry climate on trees exposed to sunlight. In humid locations with poor exposure to sunlight, the fruits remain green at maturity. This cultivar is more susceptible to fly punctures and anthracnose attacks when conditions are conducive to their expression.

➢ **Keitt**:
This cultivar originates from Florida and was introduced into Africa via the Foulaya experimental station in Guinea towards 1950 and thereafter was dispersed over Africa much in the same way as the Kent variety.
The fruit is oval, longer and flatter lengthwise than Kent. Its weight is highly variable, ranging from 500 gr to 1 kg, which is a shortcoming for the export market. It is a late variety; the fruits are attractive with a variable blush depending on the exposure. The parts that are exposed to sunlight range from deep pink to bright red including various coppery tones. Just as with the Kent variety, the skin of fruit grown in humid situations with little exposure to sunlight does not take on a pleasant hue.
Blushing occurs at an early stage, which sometimes interferes with the correct assessment of this variety's degree of ripeness. If harvested just before the maturation process begins, it keeps well. Keitt is less susceptible to parasite attacks (fruit fly and anthracnose) than Kent.

Secondary cultivars

➢ Amélie:

This cultivar originates from the French West Indies and was introduced into Mali in the previous century and then spread throughout western Africa. Its high susceptibility to anthracnose is such that it can only be grown in the drier zones (Sudano-Sahelian zone). The fruit is rounded and weighs between 300 and 600 g and its flesh is deep orange, smooth and pleasant. Major retailers find fault with the fact that its skin is not red coloured and its poor storage properties. To overcome this drawback, the mangoes are often harvested early on and their skin remains green when they reach the shelves. Amélie fills a limited commercial niche very early on in the season from the end of March to mid-April when mangoes are scarce and practically none of the coloured varieties are available. The skin is fragile, sensitive to friction and to harm caused by ants. It reacts by forming superficial corky wheals.

➢ Zill:

Zill is the earliest of the red varieties that reaches maturity in the interval between Amélie and Kent. The skin of ripe fruit has a bright red and yellow colour. Its orange flesh has a pleasant taste much appreciated by many consumers. Once the fruit begins to ripen, it quickly reaches maturity and thereafter the quality of the flesh soon deteriorates. Because the fruit's average weight is fairly low, a very large proportion is unfit for export. Tree yield is mediocre and branches are liable to break in the event of strong winds. Small quantities of this variety continue to be exported before the Kent mango season that are preferentially transported by air so as to minimise storage- related risks. The quantities involved are minor.

➢ Palmer:

This is a late variety whose fruits are long and brightly coloured (reddish purplish). The flesh is yellow, firm and it stores very well. Yield is high but the proportion of fruits that can be exported is small (insufficient average weight). Its sap is acidic and can cause sap burn with detrimental effects on the outward appearance of the fruit. It reddens at an early stage making it difficult to determine when the fruit should be harvested. Many fruits are picked before they are ripe. The Palmer season occurs just before that of the competing Keitt variety. Finally, the fruit's elongated shape is another shortcoming as far as the retail trade is concerned. Nonetheless, it is the 5th leading variety for export.

➢ Irwin:

This is an early and highly productive variety. The fruits are small but brightly coloured, attractive and tasty. They keep adequately if they are harvested at the right stage. Some producers find it difficult to correctly assess the development stage of the fruits and harvest them too late (inadequate length of storage).

➢ Valencia pride:

This mid-season variety yields fairly large, elongated fruits with good taste quality and excellent appearance. It is difficult to store and as such must be transported by air. This variety has a niche position on the export market.

➢ Sensation:

This variety, of unknown parentage, originates from Florida. The fruit is small to medium-sized (280-340 grams), deep red in colour with a few spots of yellow. Its main quality is its relative tolerance to blackspot bacterial disease. This is a mid-season variety that is well adapted to the cooler areas of the sub-tropical zone, e.g. some areas in South Africa.

Matching production with market demand

Two varieties presently dominate the export market for mangoes: Tommy Atkins and Kent which represent more than 3/4 of volumes are exported. Tommy Atkins essentially comes from Latin America while Kent is common in Africa and spreading in Brazil at the request of importers who are looking for quality of the fruits.

The other varieties are minor and take up particular niches that have been left open: early varieties (Amélie), late varieties, consignments shipped by air deriving from quality management criteria (Valencia pride), etc.

3. The nursery

3.1. General Considerations

Various methods of propagation can be applied: seedlings, grafting, layering. In practice, only grafting is used to produce mango tree planting stock whose fruit is intended for the export market. The planting stock produced comprises two parts: the rootstock (root system) and the grafted part (the variety targeted for harvesting).

The production cycle at the nursery should last no longer than 12 to 18 months depending on the climate in the region. Beyond that time span, the planting stock would be too old and subject to trauma during transportation, rolling of the roots in the bags that could adversely affect the re-establishment and life expectancy of the trees.

3.2. Choice of Rootstock

Polyembryonic varieties should be used as rootstock as only they can provide uniform seedlings (identical genome).

There has been little investigation on rootstock selection aimed at influencing the vigour and yield of mango trees, fruit quality, resistance to soil parasites, etc. Each production region therefore tends to use the seeds of one or two locally well-adapted polyembryonic varieties for the purposes of producing rootstocks.

3.3. Choice of Seeds for Producing Rootstock

The seeds must come from identified trees that are selected as being true to type and showing no symptoms of disease or of degeneration.

3.3.1. Preparation of Seeds Prior to Sowing

The fruits should be harvested just before reaching maturity. The stones must be separated from the rest of the flesh and temporarily stored under shade on a flat, dry surface prior to the extraction of the seed whereby the kernel is removed to avoid forcing the young root to curl when the seed germinates. Any seed with a defect – germination already initiated, traces of fungal attack or presence of pests (Cryptorhynchus mangiferae) - must be discarded. Germination capability lasts for a limited amount of time, diminishing markedly within 2 weeks of extraction from the stone and down to almost nil after 4 weeks. Seeds should therefore be sowed soon after extraction.

3.3.2. Preparing the Hotbed Soil

The aim is to produce a uniform mixture that filters and adequately retains the water and nutrients.

This mixture should be made up of a base of one third of non-clayey mellow soil, one third coarse sand and one third well-decomposed organic matter. In West Africa, powdered dung collected in animal pens is an appropriate source of organic matter that is easily found in villages. It must be abundantly watered and then aerated to induce proper fermentation. The well-mixed earth should then be disinfected by solarisation under a transparent film or by treatment with dazomet at the dose of 200 g/m2 for a 30-cm layer of soil. After broadcasting the chemical on the soil mixture, the latter should be thoroughly mixed and then regularly watered. It is advisable to wait 3 weeks to 1 month before using it to fill 15-cm diameter bags, 20 - 25 cm deep.

3.3.3. Sowing

The germination capability of seeds is limited in time. The latter decreases sharply within 2 weeks of being extracted from the stone and goes down to almost nil after 4 weeks. Because it is impossible to store seeds, sowing should always be done at the time of fruit harvest, shortly after extracting the seeds. Seeds may be sowed in a germinator at a high density, or else directly into the bags.

In the first case, it is easier to ensure homogeneity of the plants by sorting them when they are first transplanted.

The seeds should be slightly pushed into the hotbed substrate and very lightly covered with 2 to 3 cm of soil. The substrate should be kept moist by regular watering without excess. Germination takes from 10 to

30 days. From the time of sowing to elongation of the tigella and emergence of the first leaves, the seedlings should be partially shaded to avoid excessive exposure to sunlight.

The shade must intercept no more than 50% of sunlight. Shade should later gradually be reduced and altogether removed at a pace appropriate to actual sun exposure conditions.

3.3.4. Transplanting

Seedlings should be transplanted when the tigella reaches a height of between 6 and 8 cm. At that stage, the root is approximately 10 cm long and should be trimmed to facilitate transplanting and encourage development of secondary roots. Bags should be of 0.04 mm-thick black polyethylene with a capacity of 3 to 5 litres. The bottom and sides of the bags should be pierced. The bags are arranged side-by-side on double lines in ditches 0.15 m deep furrows to protect them from sunlight.

Polyembryonic seeds often produce several plantlets per seed. These can be separately transplanted if proper care is taken to disassociate the coty-ledons keeping the tigella and rootlet intact. Any extra seedling should be removed to avoid twin plants developing in a single bag.

3.4. Grafting

3.4.1. Choosing Scions

The choice and condition of scions are very important. They must be cut from healthy, true-to-type trees.

Cuttings should be made when the terminal bud is rounded and swollen and bud-burst is imminent but not yet initiated. If the terminal bud does not fulfil these conditions, the leaves from the tip of the twigs can be removed along a length of some 15 cm. This causes the terminal buds to swell and they will be ready to be cut 8 to 15 days later.

3.4.2. Preparing the Rootstock

At the time of grafting, rootstocks must be at least 6 mm in diameter and 30 cm tall. They should be prepared 2 months prior to grafting by removing all the lateral branches, leaving only the main stem.

3.4.3. Appropriate Grafting Period

Appropriate grafting dates are highly dependent on the development of the rootstock and on the vegetative growth stage of the trees from which the scions are taken. Grafting is not recommended during the very hot or very rainy seasons, or during the cool season.

Best results are obtained during the seasons of highest sprouting intensity in mango trees.

3.4.4. Grafting Techniques

The aim of grafting is to bring the cambiums of the scion and the rootstock into contact so that they join. To achieve this, the following conditions must be fulfilled:

- the meristems must be active and remain so throughout the period preceding and following the graft,
- there must be sufficient area of contact,
- The binding used must ensure that there is close contact and a proper seal.

Techniques vary from one area to another. The most common are the following:
- splice grafting
- whip grafting
- side cleft grafting,
- side veneer grafting.

3.4.5. Postgrafting Care
Normally the bud bursts 15 to 20 days after the graft. To accelerate growth in the case of a side graft (veneer or cleft), the rootstock should be topped nevertheless leaving a sufficient length of stock to allow the young graft to be tutored. In windy locations, the binding should be left on until the graft point has consolidated. In the other cases, the binding should be removed when the second flush occurs.
From the time of grafting to when seedlings are marketed, the plants should be weeded, irrigated and fertilised once a week at a dose of 0.5 gr of nitrogen diluted in 1 litre of water per bag.

3.5. Plant Protection Measures in Nurseries
Nursery-grown seedlings are liable to be attacked by pests and diseases. In contrast with adult plants which to some extent are able to endure parasitic attacks, young seedlings, because they have fewer reserves, are much more susceptible. The nursery phase is an all-important one for the future plantations. Careless management can contribute to the rapid spread of pathogens and pests in new orchards.
Pesticides used in nurseries are the same as those used to protect orchards. Solutions of active ingredient are applied at similar concentrations whereas the method of application depends on the layout of seedlings in the nursery. The degree of wetting is comparatively greater (just prior to run-off point) in the case of fungicides or anti-scale insecticides, and slightly less for the other insecticides.
See appended tables for more details on pesticides for use on mango.

3.5.1. Main Pests

3.5.1.1. Scale Insects
These feed on the sap of the plant and sometimes inject toxic saliva that causes a reaction: yellowing and, in the event of severe attacks, drying out of the leaves and twigs.
There are two major categories of scale insects:
➢ Hard scale: *Coccus mangiferae; Aulacapsis tubercularis; Pseudaonidia tribitiformis; Ceroplastes* spp…
➢ Soft scale: *Icerya seychellarum; Rastrococcus invadens*..

Chemical control: The basis for controlling hard scale is to apply white oil that smothers these insects. Soft scale insects can be chemically controlled by spraying with organophosphorous, chloronicotinoides or other products (see table in Appendix).
Scale insects are most vulnerable when the young larvae have reached the motile stage.

3.5.1.2. Mango Bugs
Mango bugs such as Lygus spp. infest young shoots by biting the buds, which produces characteristic deformities. This is a formidable pest since it can destroy the shoots within a few days, indeed even within hours. It is crucial to respond quickly.

Chemical control: Insecticides in the synthetic pyrethroids family (deltamethrin, lambda-cyhalothrin etc.) are commonly and successfully used (see Appendix).

3.5.1.3. Locusts
Just as with mango bugs, it is important to react quickly to attacks. The most effective approach is to preventively treat locusts that congregate in the vicinity of the nursery.

Chemical control: Based on treatment using synthetic pyrethroids (deltamethrin, lambda-cyhalothrin, etc.), organophosphates (fenitrothion, malathion, etc.) or other insecticides such as fipronil (see Appendix). Massive use of pesticides has generated resistance. It is therefore advisable to contact the plant protection services in each region to determine which active ingredients are effective.

3.5.1.4. Thrips

Scirtothrips aurantii (citrus and mango thripsr); *Selenotrhrips rubrocinctus.*

S. aurantii is a tiny, highly motile, biting insect that attacks many different plants. On mango trees, it seeks shelter and food on the young, tender shoots. As a result, the young leaves assume a characteristic crinkled appearance. Hot, dry weather presents a high risk of pullulation. The degree of infestation can be estimated by tapping the tips of the branches over a sheet of white paper. This pest is a difficult to control chemically and hence efforts must be made to preserve the beneficial fauna.

Sspinosad has given satisfactory results in this respect on mango and/or citrus trees. Attention must be paid to the phenomenon of resistance as a result of repeated use of these insecticides (see table in Appendix for others pesticides).

3.5.1.5. Leaf-gall cecidomyiids: Procontarinia matteiana

Cecidomyiids are tiny midges (dipterans) that puncture the very young leaves so as to deposit their eggs. As the larvae develop in the limb, they cause gall to form.

Young nursery or recently planted trees must be protected. In this case, it is very difficult to set a specific threshold to trigger intervention because damage is always observed once it is done. The concepts of risk area and susceptibility stage (new leafy shoots) can serve as criteria for guiding this decision.

Chemical control: See appended table.

3.5.2. Major Diseases

3.5.2.1. Powdery Mildew: Oidium mangiferae

This fungus develops as a white mould (mycelium) on young leaves. The risk of an attack is greater during cool, slightly moist weather. Surprisingly, abundant rainfall works against the development of powdery mildew.

Chemical control: Contact fungicides: micronised sulphur
Systemic fungicides: Systemic products are effective only on very young leaves that absorb the active ingredient because they have a sufficiently large receptive surface area. Once the leaves develop a waxy, impermeable skin layer, this is no longer possible.

3.5.2.2. Anthracnose: Colletoricum gloeosporiodes

Humid conditions are conducive to attacks. As a result, small black spots edged with light green may develop on the leaves. The necrotic part of the limb disintegrates leaving a small hole.

Chemical control: Contact fungicides: Copper, captan, mancozeb, maneb and other fungicides (see table in Appendix).

3.5.2.3. Bacterial Blackspot: Xanthomonas campestris pv. mangifereindicae

Hot, humid weather is particularly favourable to bacterial blackspot. Aerosols created by tropical storms (combination of wind and rain) encourage its propagation.
Symptoms appear on:
➤ **twigs:** pustules in the shape of buttonholes wherefrom further contamination originates.
➤ **leaves:** black, polyedric spots, somewhat raised on both sides of the limb surrounded by a yellow halo. The damaged leaves may be prematurely shed.

Most of the exported varieties originating from Florida are susceptible to this disease.

Control: There is no curative treatment. Treatments with copper-based substances hinder the development of bacterial blackspot but do not stop it. The basis for controlling this disease is prevention (isolated nursery,origin of the plant material).

4. Orchards establishment

4.1. Requirements

4.1.1. Climate
To develop and bear properly, mango trees prefer a tropical climate with a marked cool and/or dry season. Flowering and therefore fruiting require drops in temperature and water deficits. Mango is intolerant to frost and its vegetative threshold is around 16°C. Furthermore, for pollination of flowers to be adequate, temperatures must not drop below 14°C during blossoming.

4.1.2. Water Requirements
The powerful root system of mango trees gets water directly from the upper level ground water. In this case, orchards need not be irrigated. But contrary to common belief, mango trees are sensitive to water deficits during the period of intense physiological activity. If the plant becomes dehydrated, photosynthesis drops dramatically. During the 2 to 3 month period of dormancy that precedes flowering, trees should be optimally supplied with water arising from rainfall, ground water uptake and irrigation. Mango tree water needs can be estimated by calculating the climatic demand. These needs vary during the course of the year and may be as high as 200 - 250 mm per month during the hottest and driest season.

4.1.3. Soil
Mango trees grow on a fairly broad variety of soils. Deep, percolating soils that have no hydromorphic drawbacks are preferable.
Undesirable soil features such as excessively high salinity or pH, scant water reserves or highly compacted soil should be avoided.

4.2. Plot Developments Prior to Planting

4.2.1. Erosion and Drainage Measures
The soil surface should be worked so as to limit erosion and allow for rapid drainage of excess water during the rainy season. Mounds and drainage ditches should be implemented before planting. Care should be taken not to disturb the pre-existing soil horizons in the area where the trees will actually be planted.

4.2.2. Windbreak Network
Protecting the orchard against wind is very useful both to limit water consumption and mechanical damage. It also helps to hinder the propagation of diseases from one plot to the next. Windbreaks (*Casuarina equisetifolia, Acacia auriculiformis*, etc.) should be established before planting the mango trees.

4.2.3. Planting Density
Appropriate planting density achieves optimal yield, ease of movement within the orchard, proper exposure to sunlight and ventilation of adult trees. Densities vary significantly. On traditional plantations that use vigorous varieties and on which canopy development is not restrained, densities tend to be lower, about 100 seedlings / hectare. With varieties of medium vigour, densities can be higher - 150 trees/ha and up to 400 trees/ha if canopy development is controlled by pruning. Very few high-density orchards exist today.

4.2.4. Soil Preparation

4.2.4.1. Mechanised mango culture
Compact soils require two subsoiling passes perpendicular to one another to be performed through a depth of 70 - 80 cm. When ploughing prior to planting, ridges should be earthed up along the planting row. Basal fertilisation and other dressings should be applied before final ploughing so they are incorporated into the soil.

4.2.4.2. Non-mechanised mango culture
A 50 cm x 50 cm x 50 cm hole is dug at each planting position. The earth should be mixed with 20 kg of well-decomposed manur adding 500 g of superphosphate or tricalcium phosphate, 200 g of potassium sulphate and if necessary some dolomite. The hole is then refilled with the soil mixture forming a mound.

4.3. Plantations

4.3.1. Plantation layout
Il Care must be taken in staking out the plantation to make sure that the lines, rows and diagonals are properly aligned. When holes are made, to maintain the benefit of a well-plotted layout, two other stakes positioned on each side of the plantation hole and aligned using a planting ruler should replace the stake that marks the position of each tree.

4.3.2. Planting
Seedlings should be planted at the beginning of the rainy season when re- establishment is easier. Each clump, with the plastic bag or pot removed, should be planted at the top of the mound. A raised basin should be formed using earth taken from the interline. Initial watering serves to moderately compact the soil and ensure close contact between the surrounding earth and the clump. After initial watering, the trees should be mulched to maintain moisture and thus encourage growth of juvenile roots.

4.4. Upkeep of the Plantation

4.4.1. Irrigation
Mango trees have relatively large water needs. Often, their powerful taproot system enables them to seek out water in the low-lying groundwater. If there is adequate water available, no irrigation is required. If not, various irrigation methods may be applied: drop irrigation, microjet, mini-sprayers, basin or furrow, etc. The two latter methods are uneconomical in terms of water consumption.
Calculation of water needs considers potential evapotransipiration (PET), adjusted by means of a crop coefficient Kc that varies according to the plant's physiological stage. It can be further adjusted to consider the development of the trees so as to differentiate between the needs of a young plantation and those of an adult orchard.
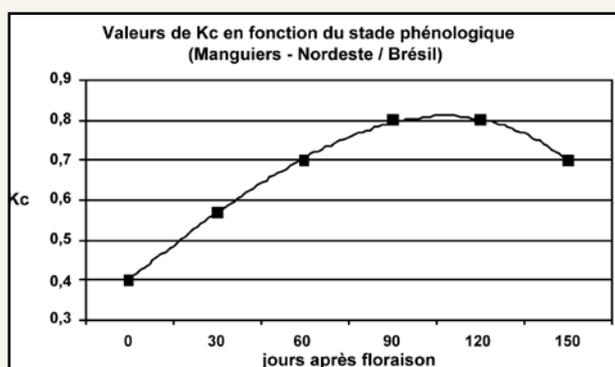
Example of Kc value trends in adult Tommy Atkins mango orchards in Brazil (Silva 2000.)

A orchard's water consumption varies enormously during the season under the dual influence of the increase in PET and of the Kc which itself can double.

Climate data is not enough to determine correct irrigation for the first 3 to 4 years after planting when the aerial parts of the trees are still underdeveloped. While needs remain limited, their volume varies considerably in proportion. In addition to considering variations in overall climatic demand as measured by PET, soil moisture in the vicinity of the seedlings should also be monitored (soil moisture from 15 to 30 cm, tensiometers, etc.) in order to determine the irrigation schedule.

The irrigation technique and schedule must consider the climatic demand and the development of the trees, the soil's water-holding capacity, the flow rate of the irrigation system and the quality of the water.

Frequency of watering is highly dependent on the choice of technique. Drop irrigation involves frequent watering but small amounts and should be scheduled to operate several times a day to adequately cover daily needs. With mini-sprayers and microjets, watering is less frequent – 2 or 3 times a week – and covers needs for several days.

4.4.2. Role of Various Nutrients in Fertilisation

4.4.2.1. Nitrogen

This is the major nutrient for tree growth. Because it is highly soluble, nitrogen is generally applied by instalments over the year.

Excess nitrogen fertilisation has adverse effects on the quality of the mangos. Imbalances in the Ca/N ratio are thought to be involved in physiological disorders grouped under the term "internal breakdown" *. Excessive nitrogen fertilisation should therefore be avoided throughout the period of fruit enlargement and should preferentially be applied from the time of harvest to the end of the growing season.

* see description in chapter on physiological diseases.

4.4.2.2. Phosphorus

Phosphorus fosters the development of the root system, floral initiation and the fruit's ability to remain attached to the tree. As phosphate fertilisers are poorly soluble, soil uptake is very slow. However, some fertilisers such as superphosphates are slightly more soluble.

This nutrient should essentially be incorporated into the base dressing.

Thereafter, phosphorus can be incorporated locally every two or three years over the surface area that mirrors each tree's canopy.

Phosphorus efficiency is hindered by a low pH and high iron rate, particularly in lateritic soils.

4.4.2.3. Potassium

Exports of potassium by fruit are considerable. This nutrient is important in terms of organoleptic quality and post-harvest storage. Potash fertiliser may be applied yearly based on the productivity level of the orchard.

4.4.2.4. Calcium

Calcium can be applied to acidic soils in the form of dolomite, natural and tricalcium phosphate or gypsum. Calcium deficiencies adversely affect quality and storage properties of the fruit.

4.4.2.5. Magnesium

Magnesium is instrumental in the formation of chlorophyll.

Magnesium deficiencies mostly affect old leaves. The intervals between the veins become yellowish and the base of the limb often has a green herringbone pattern. Excess magnesium produces a potassium/calcium imbalance. Magnesium is applied in the form of dolomite in acidic soils and magnesium sulphate in base soils.

4.4.2.6. Boron

Boron is important for pollination of the flowers and fruit growth. It is sometimes necessary to spray leaves during flowering so as to meet instantaneous boron demand.

4.4.2.7. Zinc

Zinc is involved in chlorophyll formation in combination with iron and manganese. Excess phosphorus can lead to zinc deficiencies as reflected by the emergence of smaller leaves, at the tips of new shoots, whose limb has discolouring between the veins.

4.4.3. Mineral fertilisation

To establish a manuring schedule, growers need information concerning the major mineral nutrient concentrations in the soil and leaves. In addition, knowledge of the orchard's yield is needed to estimate nutrient exports by fruit. In the first few years after planting, annual fertilisation should be gradually increased until it reaches a ceiling at the age of approximately ten years. It is difficult to establish a reference manuring plan applicable to different locations.

In the table below, we provide ranges of amounts applied in various production areas and for planting densities of between 150 and 350 trees /ha.

KILOGRAMS OF FERTILISER PER HA

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

These are indications and actual fertiliser amounts should be adjusted on the basis of soil and leaf analysis data.
Time of application and split doses of fertiliser are important and, in non- irrigated systems, should be determined on the basis of when the rainy season occurs.

Nutrient	Proportion of annual fertilisation	Method of fertilisation	Time of application
Nitrogen	50%	soil	following harvest
Nitrogen	30%	soil	flowering – fruit-set
Nitrogen	20%	soil	enlargement of fruit
Potassium	50%	soil	following harvest
Potassium	50%	soil	flowering – fruit-set
Phosphorus	100%	soil	before rainy season
Boron	100%	leaf spraying	before flowering
Zinc	100%	leaf spraying	on juvenile growth shoots

4.4.4. Weed control – Protection from fire

Juvenile mango trees are sensitive to herbicides, particularly residual herbicides. Manual weeding is preferable in the vicinity of the trees. It is essential to use a protective shield when contact or systemic herbicides are applied to prevent any spray from landing on the trunk or leaves.
Intercrops in the first few years are often grown in irrigated areas thereby controlling weeds in the young orchard and making them easier to monitor and tend to.

5. Plant protection

Current methods for plant protection are integrated and based on detailed knowledge of the orchard and close monitoring of parasitic developments.

5.1. Steps to be followed to implement an integrated plant protection approach

WHAT TO DO?	HOW ?	WHEN ?	WHY ?
IDENTIFY	➢ by visually inspecting the various organs ➢ by beating the inflorescences ➢ by setting up fruit fly traps	Every week from flowering to harvest Monthly From harvest to after flowering, or more often if a risk is identified	To detect diseases or pests as soon as they appear in the orchard and before any major damage is done
ESTIMATE and QUANTIFY	➢ take correct samples ➢ evaluate precisely by making counts		To obtain the information required to take decisions. Treatment should only be performed when there is a real hazard for the crop, neither before nor after
CHOOSE	➢ adjust the strategy on the basis of a clearly identified and assessed risk	Après chaque tournée d'inspection dans les vergers	To take timely steps within the framework of integrated management, using the most suitable method for controlling the disease or pest that accommodates beneficial predators and parasites

5.2. Identification of risk periods on the basis of the phenological stage
One should exactly know at which stage of the plant cycle the pest or disease likely appears on the crop. This is developed further in this document. For information below we give the stage of floral development.

Mango tree floral biology
Drawings by A. Franck

Stade B   Stade C   Stade D   Stade E

Stade F   Stade G   Stade H
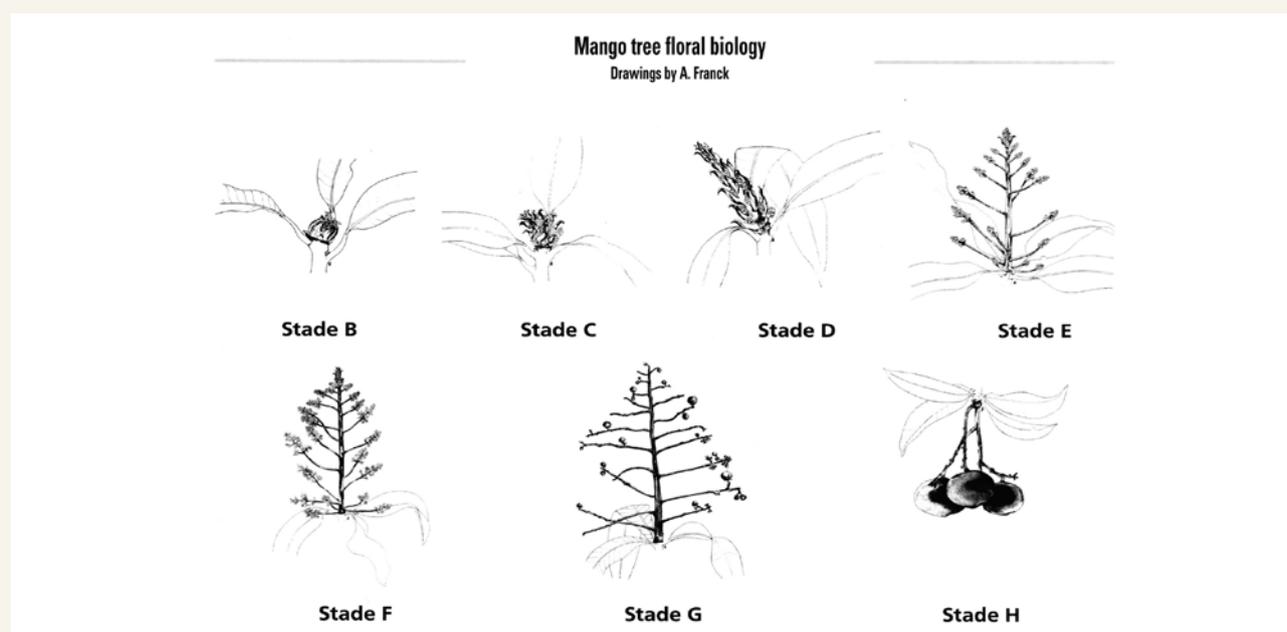
5.3. Geographic distribution of the various diseases and insects

Disease	West Africa	Southern Africa & Indian Ocean	Caribbean	Ecological context conducive to strong expression
Anthrachnose	X	X	X	All areas
Powdery mildew	X	X	X	Cool areas
Alternaria	X			Alternation of dry and slightly rainy periods
Stem-end rot	X	X	X	All areas
Bacterial black spot		X		Humid tropical areas

Pests	West Africa	Southern Africa & Indian Ocean	Caribbean	Ecological context conducive to strong expression
Fruit fly *Ceratitis* spp.	X	X	X	
Fruit fly *Bactrocera* spp.		X		
Fruit fly *Anastrepha* spp.			X	
Mealybug	X			Biological control difficult in continental areas
Diaspidid scale insects	X	X	X	
Termites	X			
Thrips	X	X	X	
Locusts	X			Sudano-Sahelian Zone
Gall midges	X	X		
Whiteflies	X	X		
Mango Bugs	X	X		

5.4. Pesticide treatments

Pesticides are applied differently depending on the pest or disease to control.

Some pests such as scale insects require application of large volumes of mixture at high pressure to ensure that the insecticides permeate the entire foliage (use of hoses).

In other cases, it is enough to spray fine droplets on the surface of young leaves and inflorescences (use of atomisers). The emphasis should be placed on producing a dense mist and ensuring that its dispersal by airflow covers the foliage and inflorescences including the tip and base.

Before performing any treatment, it is important therefore to define the application method, choose the equipment best suited to the situation and check its settings.

A preliminary test using water can be used to establish how many trees can be treated with a full tank. By combining this data with planting density, the appropriate dilution of the pesticide is determined so as to comply with the recommended per hectare dose of active ingredient.

Substances must always be applied in compliance with the dose recommended by the manufacturer as shown on the packaging or insert. This dose is not only effective, it also ensures there is no problem of phytotoxicity and innocuity of the fruit. Compatibility of the active ingredients should be checked in the case of combined mixtures.

It is essential to use scales and a measuring cup to make up the mixture in the tank.

Sprayers that can be used:

The product can be sprayed on the trees with:

• a pneumatic knapsack sprayer equipped with a centrifugal pump enabling the product to be dispersed uniformly and regularly, including on the upper parts of the trees.

• a high pressure sprayer (tractor- or trailer-mounted with a tank capacity from 200 to 1000 l) that produces streams that uniformly and regularly disperse the active ingredient diluted in a fluid, in the form of droplets that are projected by a powerful air blast on to the organs of the plants needing treatment.

• some tanks are equipped with hoses for carrying out treatments that require both high pressure and large flow rates. This equipment is recommended for treatments against mealybug.

Practical advice:

• Treatment should not be performed in high temperatures to avoid burning.

• Treatment should be performed preferably on windless days to avoid spray drift on neighbouring crops.

• Avoid treatment when weather may turn as any rainfall of 25 mm or more will wash off contact and systemic substances that have been applied in the last 3 hours.

• Alternate between families of active ingredients as far as possible to avoid forming resistances.

Spraying trees:

Pesticide recommendations commonly are given in two ways. One is an amount of product to apply per ha. Another is an amount of product per volume of water, with the assumption that the volume mentioned covers an hectare.

The recommendations for the amount of product to apply assume the trees or target crop is average size and age and the entire area is sprayed, not just a tree here and there.

The calibration of sprayer delivering a constant quantity of water at all stages of the crop is not difficult. At times, backpack sprayers are used to spray trees for insect or disease problems and this is more difficult to calibrate as the volume of water used per hectare will depend on the size (volume) of the trees and the number of trees per hectare.

For calibration of a backpack sprayers follow these steps:

1. Pick out a row or area where the trees represent the "average" tree height and spacing for an orchard which is arrived at full development.
2. Fill the sprayer with a known volume of water. (Let's assume 20 litres.)
3. Spray the trees as you would with the spray mix, trying for adequate coverage for the target pest.
4. After spraying the 20 litres of water, count the number of trees you sprayed. (Let's say you sprayed 12 trees.)
5. Next, determine what part of an hectare you sprayed with 20 litres.

$$\frac{12 \text{ trees}}{120 \text{ trees/hectare (plantation density)}} = 0.10 \text{ hectare}$$

6. Determine your litres/hectare output by dividing volume by area.

$$\frac{20 \text{ litres}}{0.10} = 200 \text{ litres/hectare}$$

7. Finally, determine how to divide the recommended quantity for the hectare application.

$$\frac{1 \text{ kg/hectare}}{200 \text{ litres/hectare}} = 5 \text{ g/l}$$

Or, for a product in "liquid" form:

$$\frac{1 \text{ l/hectare}}{200 \text{ litres/hectare}} = 5 \text{ ml/l}$$

This dilution must be maintained for the calibrated sprayer and the targeted pest at all stage of the crop in order to avoid any problem of phytotoxicity.

The tables below provide values for some common preparations of pesticide solutions

TREATMENT WITH 1000 L/HA

	Surface area treated 1 hectare	Surface area treated 1000 m²	Surface area treated 100 m²
Approved dose	Amount of substance to be diluted in 1000 litres of water	Amount of substance to be diluted in 100 litres of water	Amount of substance 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 WITH 500 L/HA

Doses of substances per unit surface area are the same as a treatment with 1000l/ha. However, the volumes of water change and the mixture is therefore twice as concentrated.

	Surface area treated 1 hectare	Surface area treated 1000 m²	Surface area treated 100 m²
Approved dose	Amount of substance to be diluted in 500 litres of water	Amount of substance to be diluted in 50 litres of water	Amount of substance 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 WITH 2000 L/HA

Doses of substances per unit surface area are the same as a treatment with 1000l/ha. However, the volumes of water change and the mixture is therefore twice as diluted.

Approved dose	Surface area treated 1 hectare	Surface area treated 1000 m²	Surface area treated 100 m²
	Amount of substance to be diluted in 2000 litres of water	Amount of substance to be diluted in 200 litres of water	Amount of substance to be diluted in 20 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

$$\text{Dose of product} = \frac{\text{Dose of active ingredient (g/ha)}}{\text{Active ingredient concentration in commercial product (g/litre or g/kg)}}$$

5.5. Pests

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

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

Varietal susceptibility: Amélie, Brooks, Davis Haden, Miami late are among the most susceptible.
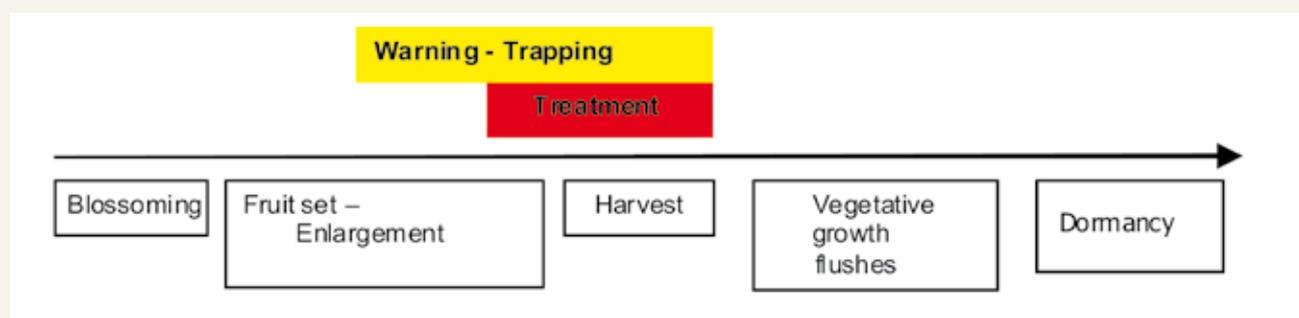
Other host plants: Many fruit trees including: guava, small fruit citrus, annona, tropical almond, etc. as well as market garden crops such as cucurbits.

Appropriate period for intervention: An insect capture system is required to establish fly population thresholds and define the most suitable method of treatment. This monitoring system should be in operation from 1 month after blossoming to the end of harvest.

Symptoms and damage: The adult female flies, whose size ranges from approximately 3.5 to 10 mm depending on the species, puncture the fruit in two ways:
- for the purpose of feeding visible as small superficial spots on the skin. This damage is of very poor economic effect for the fruit and is of little consequence.
- for the purpose of ovipositioning through a pin-sized hole in the skin of fruit before harvest that shows up as small brown spots through which there is some resin leakage.

The eggs hatch in the punctured fruit and the maggots that develop tunnel into the fruit and feed on the flesh. The damaged parts ripen very quickly. Fruits that are damaged at an early stage fall and rot on the ground. Fruits that are only slightly affected or punctured at a late stage may still be on the tree at the time of harvesting.

Because fly populations build up over the season, the late varieties are more frequently affected. When there is an abundance of other host plants in the vicinity, large fly populations may be present at the beginning of the harvesting season.

Because fruit flies are classified as "quarantine insects", no fruit containing larvae can be exported at the risk of the whole batch of mangos being turned back or destroyed by the European Plant Protection Services. It is therefore essential that fruits showing traces of punctures are identified and removed at the time of harvesting or during sorting operations.

Development cycle and conditions conducive to infestation:
After mating, the female oviposits (1 mm eggs) in clusters under the skin of fruit close to maturity. Larvae emerge from the eggs 2 to 5 days later. After spending some 9 to 15 days in the fruit, maggots, i.e., the third larval stage, leave the fruit and become pupae in the soil. The adult flies emerge from these pupae (4-5 mm) after a variable period that is highly dependent on weather conditions (temperature, rainfall / drought).
In somewhat, but not excessively moist conditions, with temperatures ranging between 25 and 30 °C, the cycle lasts between 15 and 20 days for Ceratitis capitata and up to 30 days for Ceratatis cosyra.
Ceratitis are polyphagous and multivotine (several generations per year). They migrate from one species to another depending on the season and the degree of ripeness of fruit. If host plants are to be found in the vicinity with fruit that reaches maturity before mangoes, the risk of mango orchard infestation is significantly increased.

Methods of observation - capture systems:
Trapping systems are currently generally used for monitoring fly populations rather than as a method of control. They call on two types of attractants:
• Sexual attractants, or parapheromones, which attract only males,
• Food attractants, most often protein hydrolysate, which attract both male and female flies.

These attractants have been used to develop traps to capture adult flies and evaluate levels of infestation. In addition to the attractant, the trap contains an insecticide. The actual choice of the attractant or attractants should be based on the species prevalent in the area.
Better efficiency is afforded by using the colour yellow (attractive colour) on part of the trap. The relationship between the level of infestation as provided by the traps and ability to cause damage should be experimentally established for each growing region so as to determine infestation thresholds for triggering treatment (see example below of Reunion Island).

Choice of traps: among the range of available traps, the most commonly used are the Addis, Mac Phail and Tephritrap.

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

Sexual attractants	Effective on	Observations
trimedlure	*C. fasciventris, C. anonae* male	Switch attractant every month
terpinyl	*Ceratitis cosyra, C. sylvestrii, C. quinaria, C. fasciventris* male	
methyl engenal	*Bactrocera invadens* male	
Insecticide	**Effective on**	**Observations**
ceratitis dichlorvos	Toutes les mouches	Switch insecticide every month
Food baits	**Effective on**	**Observations**
3 components	All fruit flies female	Switch food baits every month

Prevention: The range of preventive methods for limiting fruit fly populations is limited.
They apply to the plantation itself and its whole environment:
➢ picking up and destroying punctured fruit that has dropped to the ground both in the orchard itself and the nearby orchards . The fruit can be gathered and put into sealed plastic bags that are placed in full sunlight to destroy the larvae by heat.
➢ Destroying non-beneficial host plants.

Non-chemical control: Ants and other insects destroy some larvae in the fruits and pupae in the soil, but the natural parasitism of flies is low. Population control can only be based on biological control methods . Some national programmes do exist, conducted in co-operation with the IAEA (International Atomic Energy Agency, based in Vienna, Austria), which use sterile males to disrupt the reproductive cycle of flies. To be effective, such programmes must be co-ordinated and conducted over huge areas.

Chemical control: There are two methods of intervention that are used depending on the level of infestation as determined by the capture system, and on the parasitic load deriving from the orchard environment. Prior to being used, their mode of application should be validated for the particular growing area.

➢ **Spot application:** A food attractant (protein hydrolysate) is associated with an insecticide. The mixture is applied as large droplets on a limited portion of the foliage that does not bear fruit (approximately one square metre/tree). The treatment is effective for about eight days and must be repeated following heavy rain (> 25 mm). Spot applications of this type are performed using knapsack sprayers allowing treatment just before harvesting or even during the harvest as fruit can be avoided.

In large orchards, air blast spraying using trailer - or tractor-mounted systems can be used to spray a single side of a limited number of tree rows (1 out of 3 or 4 rows).

➢ **Generalised treatment:** An insecticide is applied to the entire surface at a rate of 800 to 1000 l of mixture / ha in the case of an adult orchard. See appended tables on pesticides for use on mango and GAPs tested by PIP regarding residues compliance with EU MRLs. Some active substances comply with EU MRLs at a 7 days PHI (= Pre harvest interval).

NB: Spot applications are disappointing in some cases:
➢ Orchards that are surrounded by fruit plantations which are infested by themselves with flies
➢ Very high parasitic load following inadequate prior control of the pest (many punctured fruits on the ground, no generalised treatment at the beginning of the season to avoid the early pullulation of flies, etc).

By way of example, threshold values used on Reunion Island to define the type and date of treatment (tropical environment, fruit growing: citrus and mango prevalent)

Level of infestation	Weekly reading no. of flies / trap	Type of treatment
Nil to low	Less than 25	No treatment
medium	from 25 to 120	Spot application
high	More than 120	Overall treatment

See appended table of active ingredients.

5.5.2. Scale insects

These are homopteran insects of the biting, sap-feeding type. Scale insects feed on the sap of the plant and sometimes inject toxic saliva that produces a reaction: the leaves yellow and, in case of severe attacks, whole branches may turn white and dry out.

They can be classified into two major categories:

➤ Hard scale such as diaspidid species and some lecanids. Some of the major pests of this type are: *Coccus mangiferae*; *Aulacapsis tubercularis*; *Lepidosaphes gloverii*; *Pseudaonidia tribitiformis*...

➤ Soft scale such as *Icerya* sp., *Pseudococcus* sp., *Rastrococcus* sp..
Two major mango scale pests are: Icerya seychellarum; *Rastrococcus invadens*.

Chemical control: The basis for shield scale control is by applications of white oil that acts by smothering the pests.
Soft scale insects can be chemically controlled by organophosphate-based spraying and others pesticides. See appended table.
Scale insects are more vulnerable at the juvenile stage of development when larvae are motile. Treatment is most effective in this period.
See appended table of active substances.

5.5.3. Mango mealybug: *Rastrococcus invadens*

Highest stage of susceptibility: Colonisation of new growth shoots, followed by development and pullulation during the entire period of intense physiological activity, from flowering to harvest.

Other host plants: Many fruit trees including citrus, guava, breadnut, papaya and ornamental plants such as: frangipani, rose bushes, some ficus, crotons, etc.

Appropriate period for intervention: Following harvest and after an eventual thinning, before new growth shoots emerge
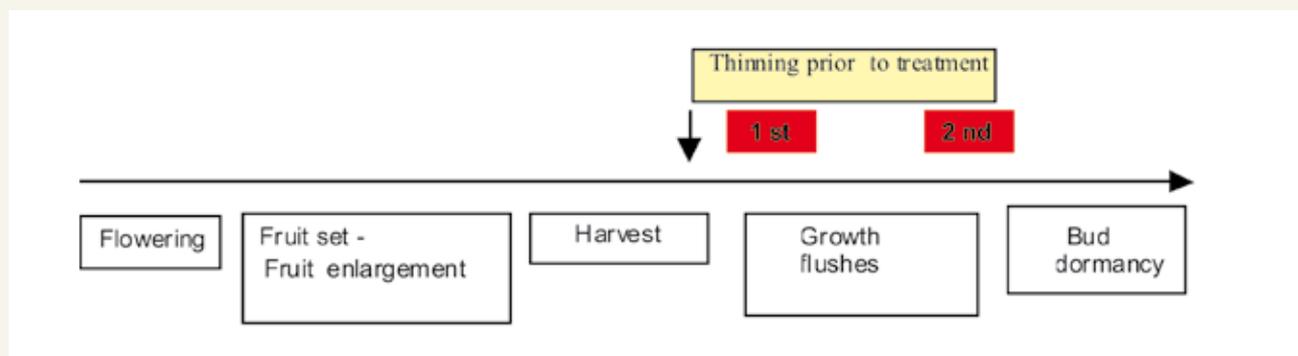
Symptoms and damage: Mealybugs may go unnoticed during their first stages of development. During the mango tree growing season and with the development of scale insect populations, exudation of honeydew is seen. Honeydew exudation is sufficient to be referred to as "rain" covering the surface of the lower leaves. Subsequently, a fungus develops on the honeydew forming a superficial black, opaque layer called sooty mould, which interferes with tree photosynthesis. Blossoming and yield are very adversely affected.

Importance of the pest depending on the growing area:

Conditions conducive to infestation: Mealybugs originate from Asia and were accidentally introduced into West Africa without their associated natural parasites and have therefore pullulated. Because there is initially no natural parasitism, they cause extensive damage every time a new area is affected. The introduction of beneficial parasites in maritime regions provides excellent biological control of the pest. In the continental regions, parasitoid populations tend to decrease significantly when temperatures drop during the harmattan season. When temperatures go up again, mealybug populations develop far more rapidly than those of their parasites. Damage is initially very visible but later stabilises as parasitic control increases.

Methods of observation: The first indication in contaminated areas is the presence of numerous mango trees covered with sooty mould. The contaminated trees are easy to be identified: a "wet" area underneath the foliage, presence of sooty mould. Inspection of the underside of the leaves shows up the mealybugs with their characteristic fluff.

Prevention: Foreign pests are often accidentally introduced via seaports. Trucks and vans actively contribute to the spread of mealybugs. Steps should be taken to avoid vehicles being parked beneath trees in infested areas and, conversely, to avoid parking vehicles that come from infested areas underneath mango trees in unaffected areas

Biological control: Biological control can be achieved using parasitoids that come from Asia: Anagyrus mangicola and Geranusodea tebegy and to a lesser extent with natural, endemic parasites. Hence, care must be taken not to prematurely undertake generalised chemical control that would destroy the parasitic entomofauna. While biological control has yielded excellent results in maritime regions, it does not appear to be as effective in continental conditions (Sahelian zone).

Chemical control: Chemical control should only be considered once natural biological control has proved to be ineffective.
Treatment should be performed after harvesting and before new sprouting so as to avoid adverse effects on impending blossoming.
In the case of partial control, treatment may be repeated 1 to 3 months later at the beginning of the dry season.
It is advisable to prune the mango trees before applying treatment so that the pesticide penetrates adequately.
To adequately drench the entire foliage of trees (both sides of leaves, the outside and inside of the tree), tractors must be equipped with hoses. Various active ingredients such as acephate, chlorpyriphos-ethyl, etc., are currently being experimented in West Africa. Results are still partial and may change in the near future. At the beginning of the 2000's, the best results were obtained using chlorpyriphos-ethyl in Ivory Coast.
See appended table of active substances and GAPs in respect to comply with EU MRLs.

5.5.4. Thrips

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

S. aurantii is a minute biting insect that is highly motile and attacks a broad range of plants. On mango trees, it seeks shelter and food on the young sap- rich shoots. Young leaves (less than 3 cm in diameter) become covered with a corky film. In the event of a severe attack, the fruit ceases to enlarge and drops off the tree. Pullulation is more likely during hot, dry weather. Populations can be estimated by regularly beating the tips of branches over a sheet of white paper.

Chemical control is difficult , and hence control strategy should focus on preserving the beneficial fauna that play a very useful role. In this context, spinosad has given satisfactory results for mango and citrus. Repeated use of an active ingredient can lead to creating resistance. As a result, growers should regularly switch chemical family and perform no more than 3 treatments per year. See appended tables on pesticides for use on mango and GAPs tested by PIP regarding residues compliance with EU MRLs. Some active substances comply with EU MRLs at a 7 days PHI (= Pre harvest interval).

5.5.5. Flower (*Erosomya mangiferae*) and leaf-gall (*Procontarinia matteiana*) cecidomyiids

Cecidomyiids are tiny midges (dipterans) that puncture the developing floral clusters or the very young leaves to lay their eggs. When the maggots develop on inflorescences, they cause deformities or necrotic brown spots. If blossoming is not abundant, bites may be concentrated on the few floral panicles and have a more marked damaging effect. The only way to assess the level of infestation is to observe the floral panicles. In risk areas, chemical control should rapidly be considered as soon as 5 punctures per cluster are observed on 100 panicles in an orchard.
Young leaves respond to punctures by developing highly characteristic gall. There is little disruption to the functioning of adult trees. However, juvenile

nursery or newly planted trees need protection. In this case, it is difficult to set out a threshold for treatment because damage is always observed after it has occurred. The concepts of risk area or susceptibility stage (the emergence of new leafy shoots) can serve as guidelines.

Chemical control: see appended table of active ingredients, distinguishing between the two types of pests.

5.5.6. Whiteflies: *Aleurodicus dispersus*

This is a homopteran insect belonging to the family of Aleyrodidae that is commonly called the spiralling whitefly because it typically lays its eggs in a spiral on the underside of the limb. This polyphagous pest attacks a broad range of plant species, both cultivated and wild. Besides mango trees, it attacks other fruit tree species: avocado, African pear, and to a lesser extent, a number of citrus trees such as pomelos. The adult female oviposits on the underside of the limb of young mature leaves. Some 8 days later, this produces larvae that complete their development cycle within 25-30 days. Rainfall has an adverse effect on the survival and development of the eggs and larvae. Honeydew secretion by the larvae is apparent from the development of sooty mould on the upper surface of the leaves. This honeydew severely impairs the physiology of mango trees. Pullulation is most likely during prolonged dry seasons. Parasitoids such as Encarcia hatiensis (Hymenoptera) feed on these larvae and provide biological control.

Chemical control: See appended tables on pesticides for use on mango and GAPs tested by PIP regarding residues compliance with EU MRLs. Some active substances comply with EU MRLs at a 7 days PHI.

5.5.7. Mango Bugs: *Anoplocnemis curvipes*, *Lygus* spp.

They infest young shoots by biting the buds leading to characteristic deformities. This is a formidable pest as it can destroy the young shoots within a very short time, i.e., a few days or even a few hours. Quick response is essential.

Chemical control: See appended tables on pesticides for use on mango and GAPs tested by PIP regarding residues compliance with EU MRLs. Some active substances comply with EU MRLs at a 7 days PHI.

5.5.8. Locusts

Locust attacks can be highly damaging for seedlings in nurseries or orchards. Young locusts are gregarious but not mobile. At this stage, locusts begin to damage extensively. Therefore, at this development stage, chemical control is the easiest and most effective. Application must not be limited to a surface but to the entire growing area.

Chemical control: Usually control using treatments based on synthetic pyrethrins (deltamethrin, lambda-cyhalothrin) organophosphates (fenitrothion, malathion) or other insecticides such as fipronil. Use of pesticides on a massive scale has brought about resistances. It is therefore appropriate in each region to check the efficacy of active ingredients with the local plant protection services.

See appended tables on pesticides for use on mango and GAPs tested by PIP regarding residues compliance with EU MRLs. Some active substances comply with EU MRLs at a 7 days PHI.

5.5.9. Termites
a broad range of species

Stage of highest susceptibility: all stages

Other host plants: many wooden and semi-wooden plants

Appropriate period for intervention: There is no particular stage at which treatments should be applied. Preferably these should be performed just after harvest so as to minimise the side-effects of pesticides on the quality of fruit.

Symptoms and damage: There are two types of symptoms:
➢ Visible crust-like spots on the trunks and lower parts of the leader branches. These attacks tend to be very superficial, temporary and are fairly easy to combat.
➢ Initially localised and then gradually generalised wilting of the mango trees over a period of months. These fairly common occurrences are rarely attributed to the effects of underground attacks of termites on the root system. This can easily be investigated by digging the ground close to the wilting mango trees

Conditions conducive to infestation: Termite attacks occur all over West Africa. They are far more marked in the Sahelian region than the maritime region since trees that undergo stress, for instance a water deficit, presumably attract the termites and are less resistant to the attack.

Methods of observation: Detection of crust-like spots on the trunks and leaders. Searching for nests in the orchard particularly close to the trees that give signs of decay. Examination of a root profile to see whether termites are involved.

Prevention: termites are part of the biotic community in orchards. Their activity is useful in breaking down wooden debris. Termites can be discouraged from forming too many colonies by not leaving large quantities of woody degrees or dead trees in the orchard. Whitewashing the tree trunks with milk of lime limits the activity of aerial termites.

Biological control: Experimentation to test the efficiency of entomopatho- genic fungi such as *Metarhizium anisopliae* is currently being conducted.

Chemical control: There is a limited range of available active substances. Termite control is performed specifically through localised treatment of the soil. Doses are given in grammes of active ingredient per square metre. Treatments should preferably be performed after harvesting to avoid residues on fruits. For instance in Mali apply pesticides after last harvesting at the beginning of rainy season and then two month later, at the end of the rainy season.

The substance should be applied close to the termite nest and should be positioned to mirror the foliage of the affected trees. Proper penetration of the substance is achieved by superficially raking the soil and application just before the rainy season.

Fipronil is considered to be the most effective active ingredient. It acts in two ways:
• directly by ingestion,
• indirectly from termite to termite by contact between impregnated termites.

Because it is odourless and has delayed action, it is carried into termite colonies without any difficulty. These modes of action explain why it is effective and has lasting action.

See appended table of active substances and GAPs in respect of compliance with EU MRLs.

SUMMARY TABLE OF PERIODS OF OBSERVATION AND TREATMENT FOR THE CONTROL OF MAJOR MANGO PESTS (WITH REFERENCE TO THE PHENOLOGICAL CYCLE)

	Blossoming	Fruit-set Fruit-enlargement	Harvest	Growing season	Bud dormancy
Fruit fly		Trapping			
Mealybug and diaspidid scale insects				Pruning prior to treatment	
Termites					
Bugs	Monitoring by beating				
Flower cecidomyiids	Visual inspection — flower cecidomyiids are more destructive than the leaf-gall cecidomyiids				
Leaf-gall cecidomyiids					
Whiteflies					
Locusts	Depending on locust congregations in the area				

Legend: Observations — Treatment in critical periods — Optional treatment depending on infestation

5.6. Fungal Diseases

5.6.1. Fungal diseases that develop in the orchard but that are known primarily for causing post-harvest rot

A single pathogen can damage the plant at different stages of its life cycle and on different organs. As a general rule, young tissue is extremely sensitive, which explains the high level of damage seen on young leaves, young shoots, inflorescences and very small fruit. The differentiation of tissues goes hand in hand with greater resistance to infections.

At the end of its cycle, fruit close to maturity or already mature becomes particularly vulnerable again. Moreover, upon senescence of the tissue and during the conservation of fruit, certain quiescent infections present in earlier stages can be reactivated, causing dieback of branches and fruit rot, sometimes even well after the time of infection.

Certain very widespread and dreaded diseases, such as anthracnose, are often thought to be present based on an approximate and rushed identification process. On fruit, anthracnose causes rot that initially appears as black spots (Figure 1 – annex 3). However, not all black spots visible on the epidermis necessarily indicate an attack of anthracnose. Other fungi or pathogenic bacteria and other physical alterations can cause similar symptoms (Figures 2 to 5 – annex 3). The following table summarising the fungi that produce post-harvest lesions on mango after incubation in the producer country or upon import to Europe reveals important differences in prevalence. There is consequently a real need to attach greater importance to the crucial role of the identification of pathogens prior to the development of disease control strategies.

SUMMARY TABLE OF THE PREVALENCE OF FUNGI BETWEEN JULY AND SEPTEMBER 2004 ASSOCIATED WITH POST-HARVEST ROT ON MANGO 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 in		upon import to Europe
	July	August and September	from July to September
Isolated spots			
Alternaria	+ +	-	+ + + +
Cercospora	-	-	+ + + +
Colletotrichum	-	+ + + +	-
Curvularia	+	-	-
Drechslera	+	+	-
Phoma	+	+ +	-
Stemphylium	+	-	+ + + +
Unidentified	+ + +	+ + + +	-
Peduncular (stem end) rot			
Dothiorella	+	-	+ + + +
Lasiodiplodia	+	+	-
Pestalotiopsis	-	-	+
Phomopsis	-	-	+ +
Various spots with saprophytes:			
Aspergillus	+ +	-	+ +
Cladosporium & Penicillium	-	-	+ + +
Fusarium	-	-	+

-: not detected; + detected on < 10% of fruit or lesions per batch; + + detected at least one out of 10 times 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 spots analysed on 10 batches of mango upon import, total 128, variation of 8 to 18 depending on batch.

5.6.1.1. Anthracnose: Colletotrichum gloeosporioides

Symptoms and damage:

On leaves, the symptoms are characteristic. They show up as small, irregular brown spots, which necrotise in their centre. The spots can become coalescent, giving rise to larger necrotic areas, > 1 cm in diameter, also irregular in shape. In some cases, the necrotised part can drop off. The leaf then takes on a perforated appearance with central infections or a broken-up appearance with lateral infections.

Young shoots can be infected in conditions favourable to infestation and subsequently die back.

On inflorescences, symptoms include brown spots on the flower stalk and flowers, early necrosis of buds and mummification of very young fruit immediately after the petals have dropped.

Severe infestations during flowering can considerably diminish production potential by causing blossom dropping and the very young fruit shedding. On the surface of fruit, the infection cycle includes the germination of a spore followed by the formation of an external appressorium, which will germinate shortly afterwards. The resulting hypha will penetrate the top layers of the cuticle and epidermis without using pre-existing orifices, e.g. the lenticels or an injury. Its penetration will be blocked by the presence of inhibiting substances, i.e. resorcinol, found in immature fruit. The appressoria undergoing germination will remain quiescent until harvest. The symptoms appear as epidermal spots sometimes shortly before harvest, but more often afterwards, during conservation. These spots frequently form a characteristic pattern known as 'tear stain' (Figure 1 – annex 3). They can become coalescent, creating wider spots. At a more advanced stage, the rot can gradually extend to the flesh. In the final phase, orange- to pink-coloured spore formations can be seen in the middle of the black spots.

Conditions favourable to infestation: Water plays a central role in the contamination process, because the spores are always waterborne. In conditions of high humidity, masses of slimy spores are produced on the surface of pre-existing lesions on leaves and inflorescences, twigs, etc. Repeated precipitation and possibly abundant dew with run-off are needed for the dissemination of spores from these organs to receptive healthy organs (inflorescences, young leaves, and fruit) in the immediate area. After a rainfall, a high hygrometry (> 95%) and temperatures between 10 and 30°C (with temperatures at about 25°C being optimal) are very favourable conditions for spore germination and the formation of appressoria (quiescent form). The contamination of the surface of fruit through run-off of spore-containing suspensions results in the 'tear-stain' shape.

Sensitive cultivation stages: Young leaves, inflorescences and very young fruit are particularly sensitive. The same is true for fruit after harvesting. Very small injuries caused to the epidermis of the fruit during harvesting, market preparation and transport can favour the reactivation of quiescent infections or direct infection by spores present on the fruit during the rainy season.

Other host plants: Many fruit species are attacked by Colletotrichum gloeosporioides: avocado, citrus fruit, cashew, banana, coffee tree, papaya, etc. A whole range of other species can also be affected: sugar cane, alfalfa, peppers, etc. The populations of pathogens that colonise these different hosts, especially mango, are nonetheless highly heterogeneous. Differences in host range and aggressiveness, as well as sensitivity to fungicides, have also been detected.

5.6.1.2. Round rot spots caused by other pathogens on mango

A wide range of pathogenic fungi on mango leaves or branches can lead to quiescent infections on fruit. These infections will show up after harvest sooner or later as spots of rot often distributed randomly on the surface of the mango fruit. The spots can easily be confused with those caused by anthracnose.

Alternaria blight: Alternaria alternata

Symptoms and damage:

On leaves, a large number of small, round, black spots, measuring 1-3 mm in diameter, are scattered evenly across the leaf blade. The symptoms are more evident on the under side of the leaves than on the upper side. Attacks of inflorescences, 2-3 weeks following the opening of the buds, result in a significant decline in fruit setting. Small lesions can also form on **twigs**.

On fruit, the mycelium resulting from the germination of spores penetrates the lenticels and colonises the tissue through an intercellular invasion. It becomes quiescent before symptoms emerge. On ripe fruit, the mycelium resumes its growth, which leads to the formation of small, round, superficial black spots that develop around the lenticels. The spots are often concentrated in the peduncular region owing to the abundance of lenticels in this part

of the fruit (Figure 2 – annex 3). The spots can grow, forming large black areas and spreading into the pulp. Alternaria lesions on fruit are generally smaller, darker and firmer than those caused by anthracnose. The centre of the lesions subsides slightly and, in high humidity, can become covered with brownish to olive green-coloured spores.

In some situations, the infection of inflorescences can spread

endophytically to the peduncle and the fruit. It remains quiescent until maturity and then appears through the development of peduncular rot.

Conditions favourable to infestation: Fruit infestations originate mainly in infected leaves and inflorescences, as well as senescent leaves and twigs that have dropped to the ground. The spores formed on these sources are transported to the fruit by the wind or by rain or abundant dew. To become established, a quiescent infection requires a relative humidity of 80% during a 350-hour period. The intensity of damage increases when high humidity is maintained for longer periods. Long periods of humidity, as well as very dense vegetation that retains humidity, consequently favour the disease. These factors as well as the difference in quantity of spores can explain significant differences in the severity of attacks for orchards in the same region. Alternaria was one of the principal causes of rot on mango in Mali in 2004. For two out of 10 batches of mango harvested between July and September 2004 in Senegal, analysed upon their arrival and distribution in Europe, at least 50% of spots were due to Alternaria.

Sensitive cultivation stages: Fruit can be infected throughout the development period provided the conditions are favourable.

Other host plants: Alternaria alternata is associated with lesions on many plants and often also appears as a secondary coloniser of lesions produced by other causes. The pathogenicity and the parasitic specialisation of this species have not yet been documented at length.

Cercosporiosis: *Cercospora* sp.
For three out of 10 batches of mango from Senegal analysed upon import, the proportion of lesions caused by Cercospora sp. was in excess of 33%. The small black lesions caused by this fungus rarely reach 1 cm in diameter. Confined initially to the fruit's peel, the rot can subsequently spread to the pulp, causing the surface to hollow out slightly (Figure 3 – annex 3). In scientific literature, C. mangiferae is described as a leaf pathogen but is rarely referred to as causing rot on fruit.

Gray leaf spot: *Stemphylium* spp.
Stemphylium sp. has been identified as the cause of nearly 30% of lesions analysed upon the arrival of mangoes in Europe or during the conservation of fruit produced between June and September 2004 in Senegal. For four out of 10 batches, the presence of *Stemphylium* exceeded 75%. The lesions are generally < 1.5cm in diameter, round and dark brown to black (Figure 4). The epidermis tends to sink in. A cross-section shows that infected tissues are brownish-red and retain their consistency. In spite of being observed regularly and sometimes even frequently on fruit, a possible pre-harvest parasitic phase of *Stemphylium* has not been documented to date. The storage of fruit in a controlled atmosphere of 13°C can favour the development of rot caused by S. *vesicarium*.

Drechslera sp., _Phoma_ sp. and _Bipolaris_ sp.
have been isolated sporadically. Lesions develop on mangoes conserved after harvest in Senegal. They are sometimes reported as leaf pathogens on mango.

5.6.1.3. Peduncular rot associated with the genera Lasiodiplodia, Dothiorella, Phomopsis, and Pestalopsiopsis
Several fungi are associated with post-harvest rot that develops on fruit from the peduncle end.
Lasiodiplodia theobromae (syns. *Botryodiplodia theobromae, Diplodia natalensis*) causes rotting of fruit, stems and branches of many plants in tropical regions. This species is often considered to be a weakness pathogen or an injury coloniser. It is characterised by the formation of bicellular brownish spores in pycnidia emerging from colonised tissues. Dothiorella dominicana and other species of *Dothiorella* are often seen on fruit from subtropical regions or areas of higher elevation in tropical regions.
The name *Dothiorella* applies to a stage of asexual reproduction characterised by the formation of numerous slimy conidia in *pycnidia*. Rain is favourable to the dispersion of the conidia, as with *Colletotrichum*. The genus *loculoascomycete Botryosphaeria* has been recognised as the sexual stage for certain taxa of Dothiorella. The *pseudoperithecia* of this stage form gradually on branches, shoots, inflorescences or leaves colonised by these fungi and contribute to their survival during the dry season. Ascospores are often ejected after fruit has been dampened by brief rainfalls or abundant dew and are then scattered by the wind.

Various other types of conidian reproduction such as *Lasiodiplodia, Botryodiplodia, Diplodia, Fusicoccum, Nattrassia* and *Hendersonia* are also related to Botryosphaeria sexual reproduction. The nomenclature of several of these conidian stages, of which *Dothiorella*, is currently being called into question, giving rise to considerable confusion and synonymity, particularly for mango. Precise identification is important, however, since differences in development and in the pathogenicity of these different species must be taken into account to ensure optimal protection of fruit.

Phomopsis mangiferae presents similarities with Dothiorella but no sexual stage is known to date.

Pestalopsiopsis mangiferae produces very dark, slimy conidia in fructifications similar to those of *Colletotrichum*. They are also dispersed by rain.

The evolution of symptoms on fruit varies according to the fungus in question. *Dothiorella* spp. and *Lasiodiplodia theobromae* cause diffuse, translucent, aqueous spots that radiate out from the peduncle in irregular projections (Figure 5A – annex 3). A superficial, sub-cuticular necrosis appears, before spreading to and causing rapid rot of the pulp.

Phomopsis mangiferae and *Pestalopsiopsis mangiferae* cause dark- coloured lesions that progress more slowly from the peduncle.

Sensitive stages and conditions favourable to infestation: Several of the fungi responsible for peduncular rot can colonise mango tree branches and cause them to die back, sometimes preceded by the formation of lesions or cankers. The buds can be infected before opening. Certain fungi in this group also colonise branches as endophytes without initially causing external symptoms. Such colonisation can extend to inflorescences and from there reach the fruit peduncle several weeks after flowering. Infections remain quiescent until the fruit reaches maturity.

The peduncle can also be infected directly at harvest, in particular from a contamination of an injury by conidia formed abundantly on plant debris scattered over or worked into the ground and on fruit not harvested and left to rot. Attacks by *Lasiodiplodia* are thus more frequent on fruit harvested near ground level.

Spots caused by fungi associated with stem rot can also develop at random on other locations on the fruit during conservation (Figure 5B – annex 3) or produce 'tear stains'. These result from the reactivation of quiescent infections by conidia and/or ascospores during fruit formation, in conditions similar to those explained for anthracnose or alternaria blight, or from the contamination of micro-injuries in the epidermis during the handling of harvesting and market preparation.

The formation of rot depends on post-harvest conservation temperatures. Rot becomes visible 3-7 days after harvest at 25°C and 10–20 days after harvest at 13°C. In cases of mixed infection, Lasiodiplodia theobromae will be predominant over D. dominicana at 30°C, while the opposite is the case at temperatures of ≤ 25°C. Between 13 and 18°C, D. dominicana can be inhibited by certain strains of *C. gloeosporioides*.

Other host plants: Certain agents of peduncular rot are specific to mango (*D. dominicana, Pestalotiopsis mangiferae*, etc), while others such as Lasiodiplodia theobromae multiply on various hosts. Precise identification of the fungus responsible for peduncular rot observed in an orchard is important for determining the source of the infection.

5.6.1.4. Other post-harvest rot

Various types of spots develop on fruit after harvest as a result of contamination of injuries by saprophytic fungi found on plant debris: *Aspergillus, Cladosporium, Fusarium, Penicillium, Rhizopus,* etc. Spots develop from the peduncle (Figure 6A –annex 3) or randomly on fruit (Figure 6B – annex 3), depending on the location of the contamination. They can resemble those resulting from the reactivation of quiescent infections of pathogenic fungi. A certain level of humidity is needed for these fungi to produce spores. The spores of most such fungi are formed on slightly damp debris. They are often dry, show a certain capacity for surviving in the soil and are dispersed with dust by the wind.

5.6.1.5. Protection of orchards

The protection of mango orchards against agents causing post-harvest rot must be approached comprehensively, from the planting of the orchard up to harvest. Preventive measures and phytosanitary maintenance are valuable for promoting the general health of trees, reducing the duration of conditions of high humidity conducive to infections, and diminishing the quantity of inoculum present during sensitive cultivation stages. Pre- harvest fungicidal treatments must be well thought out, to provide specific protection, only as necessary, in conditions very favourable to infection by certain fungi. Used alone, they rarely guarantee satisfactory sanitation. Careful harvesting limits the risk of injuries and their subsequent contamination, as well as the reactivation of quiescent infections that have taken hold during the development of fruit. Post-harvest treatments inactivate quiescent infections and prevent their development during the marketing process. The following summary table shows the usefulness of various protective measures, sources of inoculum and conditions for fungal infection and development.

SUMMARY TABLE OF THE MAIN FUNGI ASSOCIATED WITH POST-HARVEST ROT IN WEST AFRICA: SOURCES AND DISPERSION OF THE INOCULUM, CONDITIONS OF INFECTION AND DEVELOPMENT, AND USEFULNESS OF PROTECTIVE MEASURES

Fungus	Source of inoculum			Dispersion		Quiescente infection			Developement		Usefulness of protective measures				
	leaves	flowers, branches	debris, soil, fruit	rain	wind	external	internal	at harvest	< 24°C	>24°C		In the orchard		post-havest	
Alternaria	++	++	++	++	+++	+++	+	+	++	+	+++	+	++	+++	+++
Cercospora	++	?	?	++	++	+++	-	?	?	?	+++	?	++	?	++
Colletotrichum	++	++	+	+++		+++	-	+	+	+++	+++	+	++	+++	+++
Stemphylium	?	?	+	?	?	+++	-	+ ?	+++	?	+++	?	++	?	++
Dothiorella	+	+++	+++	+++	+	++	+++	+++	+++	++	+++	-	+++	++	+++
Lasiodiplodia	-	++	+++	+++	?	+	+++	+++	+	+++	+++	-	+++	+	+++
Aspergillus	-	-	+++	-	+++	-	-	+++	++	++	++	-	+++	++	++
Cladosporium, Penicillium	-	-	+++	-	+++	-	-	+++	++	++	++	-	+++	++	++
Fusarium	-	-	+++	++	+	-	-	+++	++	++	++	-	+++	?	++

-: not applicable; +: slightly applicable; + + : somewhat applicable; + + + : very important; ? relation unknown.

5.6.1.5.1 Preventive measures can considerably reduce the danger of contamination:

When planting the orchard:
• select young plants from nurseries where plants are kept completely disease-free;
• plant trees with sufficient spacing to encourage air circulation.

For upkeep of the orchard:
• prune excessive branches to increase air circulation in the foliage and avoid overcrowding;
• limit the height of the mango trees through pruning so that phytosanitary treatments reach all foliage.

Before flowering:
• eliminate through pruning all dead or partially necrotised parts, which can later become sources of contamination.

After flowering:
• collect regularly and burn necrotised or dead organs scattered on the ground (remains of inflorescences, dry branches, dead leaves, including bedding leaves, etc.);
• stake up lower branches to keep fruit off the ground;
• implement measures to limit fruit fly populations (see 5.5.1.)
• regularly collect fruit that has dropped to the ground, bury it by covering with soil to prevent the dispersion of spores by wind or insects.

At harvest:
• handle the mangoes carefully to prevent injuries;
• keep fruit out of contact with the ground, particularly with sandy, abrasive soils and mud during the rainy season;
• manage sap flow by positioning the fruit on props that are easy to clean (see point 6.3.1.).

Throughout the year, and more frequently during flowering and setting periods coinciding with the rainy season:
• perform simple epidemiological monitoring: observe the mango trees' phenological stages, keep climatic records, take note of the appearance of symptoms and evaluate the level of contamination on new shoots, leaves and inflorescences.

5.6.1.5.2. Pre-harvest chemical measures can be taken in the orchard if preventive measures regularly prove inadequate for limiting the development of one or another disease when damp periods (rain, abundant dew) coincide with a very sensitive growth stage, such as flowering or setting. Treatment time is determined by the point at which the damp period coincides with the sensitive stage. Most existing active substances act through contact and have only a limited curative effect. Given its absence of active metabolism, moreover, the quiescent mycelium is not very sensitive to fungicide applications.

Treatments must therefore be programmed preventively at variable intervals:
• every 10 days, just before and during flowering;
• every 2 to 3 weeks subsequently as necessary, according to the staggering of flowering and the washing off of products due to rainfall.

It is nevertheless important to keep in mind that:
- spraying is only partially effective because of the difficulty of treating all foliage completely and the washing off of products during the rainy season, which is favourable to infections;
- special protective equipment is required to reduce the risk of contaminating the applicators when spraying products;
- sprayings not conform to the GAP can lead to overrun of the MRL, thus making export impossible;
- repeated spraying can lead to the development of strains that are resistant to the products applied, and to those using the same mode of action. This can make treatments less effective sooner or later;
- spraying can have a negative impact on microflora that are enemies of agents causing post-harvest rot and paradoxically lead to increasing numbers of such agents;
- treatment of big trees strongly increases the risk of excessive use and of environmental contamination.

Systematic treatments must be avoided. A warning system based on the duration of wetting and the temperature during the sensitive stages has been effective in reducing the number of treatments in Australia.

 To treat an adult orchard, the volumes of solution used add up to some 1000 l / ha. The annexed tables show which active substances may be used and describe the Good Agricultural Practices (GAP) to be observed to comply with current European MRLs.

Certain active substances may be used during the harvest period when a seven-day pre-harvest interval (PHI) is observed.

Fungi differ in their sensitivity to various fungicides (see the following table of sensitivity to fungicides). Products must consequently be chosen in terms of the prevalence of the problems identified in the orchard.

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

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

0: no sensitivity; + slight sensitivity; ++ average sensitivity; +++ high sensitivity; / no information
* existence of resistant strains
Examples of active substances:
1. benomyl, carbendazim, thiabendazole, thiophanate-methyl
2. imazalil, prochloraz
3. azoxystrobin, pyraclostrobin, trifloxystrobin, kresoxim-methyl
4. captan
5. mancozeb, maneb

Alternaria is not sensitive to benzimidazoles (thiophanate-methyl, benomyl) or strobilurins. Some control can be obtained in pre-harvest with captan- or dithiocarbamate-based (mancozeb, maneb) spraying.

Colletotrichum is intrinsically highly sensitive to benzimidazoles, which are consequently often recommended in pre-harvest treatment. Effectiveness in the orchard is nevertheless irregular, which can be attributed to the local prevalence of resistant strains or to poor identification of the fungi present. Captan- or dithiocarbamate-based spraying (mancozeb, maneb) offers some protection, but is nevertheless inferior to the protection offered by benzimidazoles in cases involving strains still sensitive to these products. Pre-harvest benzimidazole-based treatments offer better control of peduncular rot caused by Lasiodiplodia than captan- or mancozeb-based treatments. Sprayings of copper oxychloride are sometimes recommended to prevent peduncular rot. On culture medium, Dothiorella are rather sensitive to benzimidazoles and strobilurins but there are no data available on the effectiveness of products based on these substances. The same is true for *Cercospora* and *Stemphylium*.

When choosing products for pre-harvest treatments, it is important to take into consideration possible post-harvest treatments and the relevance of using fungicides with different modes of action for both types of treatments. Indeed, the use of benzimidazoles or strobilurins as a pre-harvest treatment risks leading to the selection of resistant strains and thus lowering the effectiveness of these fungicides during post-harvest use. Given the greater efficacy and facility of post-harvest use, it is therefore best to reserve exclusively for post-harvest treatments the fungicides that are very effective but carry the risk of developing resistant strains.

5.6.1.6. Post-harvest treatments

As a general rule, post-harvest treatments applied in market preparation stations offer better effectiveness than pre-harvest spraying of fungicides. Washing with warm water (see 6.3.3.1.1.) and the application of wax can inactivate and limit the subsequent development of many quiescent infections. The post-harvest application of fungicides allows uniform treatment of fruit as well as more accurate estimation and better regularity of residue levels. The presence of the fungicide at the time quiescent infections are reactivated often inhibits them effectively. The presence of the fungicide also protects injuries from invasion by saprophytes, even with relatively low concentrations of active substances.

5.6.1.6.1. Heat treatments using warm water are curative treatments used exclusively in market preparation stations. This technique requires a high level of technical capacity. The fruit is plunged into a warm water bath for five minutes. Regulation of the temperature throughout the bath, especially at the start, and the duration of the immersion period must be strictly controlled. The temperature determined for a given variety (51°C for Kent) must not vary by more than one degree. Temperatures are always between 50°C, the lower limit of effectiveness, and 55°C, above which the fruit will be damaged. Fruit must be handled with extreme care both in the field and in the market preparation station, because heat treatment will accentuate the slightest lesion on the epidermis. This is particularly the case for regions with sandy soil. Heat treatment inactivates a large proportion of superficial quiescent infections of Colletotrichum, Alternaria and Dothiorella. Its efficacy can be increased through the addition of sodium hypochlorite or calcium hypochlorite and the application of wax (carnauba wax, guar gum, acrylic resin, polyethylene emulsion, etc.). The latter can delay maturation and consequently the reactivation of quiescent infections.

In cases where infection is likely or where the peduncle is already infected, heat treatment is nevertheless insufficient and is consequently often combined with chemical treatment.

5.6.1.6.2. Chemical treatment in market preparation stations

Several types of active substances having preventive and curative properties have produced significant results for controlling anthracnose and other agents of post-harvest rot:

• benomyl (benzimidazole) has been used widely. As from 2003, benomyl is no longer authorised in Europe, but its use is not banned in many countries, among them the West African countries;

• thiabendazole (benzimidazoles);

• imazalil and prochloraz (imidazoles);

• azoxystrobin (strobilurin).

For the control of anthracnose, the results obtained with imazalil and especially thiabendazole are inferior to those obtained with the other fungicides mentioned. In practice, they are used very little.

Currently, prochloraz is considered the most effective active substance, especially when used in combination with a warm water heat treatment. In South Africa, prochloraz is used to treat mango for export at a concentration of 81g of active substance per hectolitre. The concentration is halved for mango sold on the local market. Prochloraz is recommended in post-harvest treatment at a concentration of 49.5 g of active substance per hl in Brazil, and 24.75 g of a.s. per hl in Australia. In Israel, the combination of brushing under a warm water shower and soaking for 15 to 20 seconds in 22.5 g/hl of prochloraz has proven to be as effective at controlling Alternaria as spraying with 90 g/hl. This active substance is not registered in the ACP countries for use on mango. A harmonised European MRL of 5 mg/kg was established for use on mango, effective 01/08/2003. See annexed table of active substances that may be used.

5.6.2. Powdery Mildew: *Oidium mangiferae*

Symptoms and damage: The juvenile tissue that is attacked becomes covered with whitish mould (mycelium). The mycelium rapidly colonises the inflorescences causing necrosis of the tissue.

Stages of highest susceptibility: Very young leaves and inflorescences are the most susceptible.

Conditions conducive to infestation: The disease may be particularly severe when temperatures are mild and the air is moist but not excessively (no rain). High temperatures and heavy rain prevent proper germination of spores. The conidia are carried by the wind. They germinate at temperatures ranging from 9 to 32 °C (optimal temperature 23 °C) and relative moistures of as little as 20%. These temperature and relative moisture conditions often occur at the beginning of the cycle when new leaves and, moreover, new inflorescences are emerging. In the tropics, the cool areas at higher elevations are more severely affected by the disease than the coastal areas that are hot and humid.

Appropriate period of intervention: In areas where the disease is expressed, treatment is aimed at protecting flowers that represent the production potential. This treatment must occur at an early stage before full blossoming as soon as any modification in the colour of the floral clusters is observed.

Chemical control: In conditions that are conducive to expression of the disease, treatment should be performed preventively on healthy flowers using contact fungicides. Contact fungicides are washed off by rain.
Applications must be repeated every 8 to 10 days and more frequently in the case of rainfall in excess of 25 mm. As soon as the first symptoms appear, the only way to halt the disease's progression is by curative treatment using systemic fungicides. The various chemical families should be used in alternation, sometimes including contact fungicides, to avoid creating resistant strains. Micronised sulphur continues to be an economical active ingredient and is the basis for preventive treatment. See appended tables of other active substances.
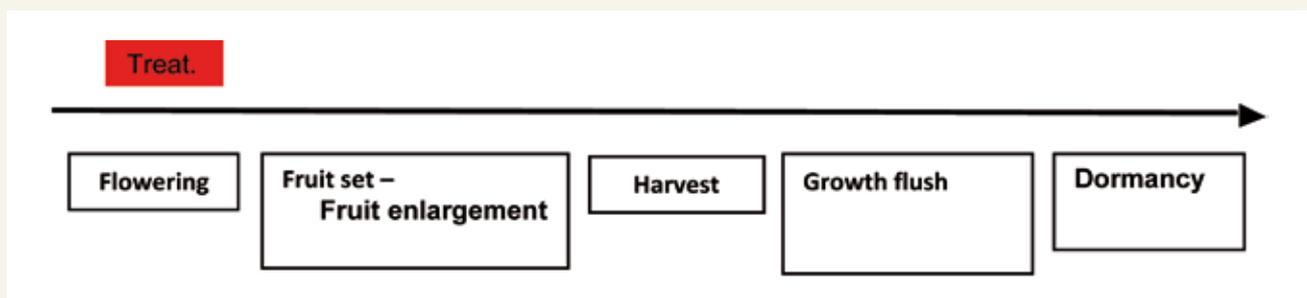
5.6.3. Mango Scab: *Elsinoe mangiferae*

This disease affects only the hotter and more humid growing areas. For infection to occur, there must be free water (rain).

Symptoms and damage: Scab is more particularly apparent in young orchards and nurseries. Juvenile tissue is susceptible.
On leaves, brownish to black spots of geometric shapes develop and reach a diameter of approximately 5 mm.

Young fruit displays grey lesions bordered by an uneven black edge. As the fruit enlarges, these lesions grow darker and form slightly crackly crusts. The lesions continued to remain superficial and do not affect the flesh. They may cover a considerable portion of the fruit.

Chemical control: Fungicides are sprayed when new growth shoots or floral buds emerge and on the young fruit, and are effective in controlling the disease. The doses applied are comparable to those used against anthracnose.

See appended tables on pesticides for use on mango and GAPs tested by PIP regarding residues compliance with EU MRLs. Some active substances comply with EU MRLs at a 7 days PHI.

5.6.4. Bacterial Blackspot: *Xanthomonas campestris* pv. *mangiferaeindicae*

This very serious bacterial disease is frequent in Asia, southern Africa, the Indian Ocean and Australia.
The bacterium can survive as an epiphyte on mango trees and contaminated plants do not always display visible symptoms. The bacterium is mainly carried by rainwater but also mechanically during tilling operations. Internal tissues are contaminated via natural openings (stomata, lenticels) or wounds.

Symptoms and damage: Symptoms are most frequently observed on the leaves and fruit and occasionally on the floral organs. In the most susceptible varieties and in the case of severe infection, canker may develop on the twigs. Foliar symptoms begin with small oily spots delineated by the limb veins. They go on to become raised black spots surrounded by a chlorotic halo. In the beginning, the size of the spots is small but they may coalesce and form extensive necrotic areas. After a few months, the lesions dry out and are discoloured becoming brownish to ash grey. In the case of a severe attack, leaves may be shed.
On the fruit, the first symptoms are the formation of small spots centred on the lenticels. These spots break up and form star shapes from which an infectious resin exudates. These spots are frequently distributed in a tearstain pattern.
Contamination is always external. Tropical rainstorms are highly conducive to the dispersion of the inoculum at distances beyond the borders of the

plantation. Very young leaves are not susceptible because the stomata are not yet functional. However, they become susceptible as soon as the limb broadens and the symptoms appear when leaves become erect. As they age, leaves become increasingly less susceptible. Conversely, fruit becomes more susceptible with time and reaches a peak of susceptibility approximately one month before harvest.

Host plants: Several plants in the Anacardiaceae family carry the disease:cashew (India), Peruvian (California) pepper tree.

The **chemical control is difficult**. Copper-based spray mixtures reduce the level of the inoculum as long as there are no lesions. These treatments are not curative but are very useful immediately following a tropical rainstorm and during the rainy season. They act simultaneously against bacterial blackspot and anthracnose.
Control of bacterial blackspot should be based on prevention and primarily on the production of healthy planting material. This implies abiding by quarantine rules when planting material from contaminated regions is brought in.
Orchard layout should consider protection from wind by establishing an appropriate windbreak network. Parasitic loads can be reduced by rapidly removing the affected organs (twigs and fruit) and burning them.
See appended tables on pesticides for use on mango and GAPs tested by PIP regarding residues compliance with EU MRLs. Some active substances comply with EU MRLs at a 7 days PHI.

5.6.5. Physiological Diseases
Sunburn
In dry savannah areas, fruit on trees that suffer stress and are exposed to the setting sun exhibit epidermal symptoms ranging from light-coloured spots to areas of actual necrosis. In some cases, apparent signs are moderate while internal damage is considerable because the underlying flesh is vulnerable. Sunburn can cause severe economic loss. A number of simple techniques can be used to limit this type of damage. Because these methods are not known, they are rarely implemented.

Internal breakdown
Mangoes may develop physiological disorders that have not so far been attributed to any particular pathogen. These are referred to under the generic term "internal breakdown" and are not always visible from the outside. These disorders appear in various forms: soft nose, jelly seed, spongy tissue, etc. and severely impair fruit quality. Internal breakdown gives rise to softening of the flesh in localised areas, sometimes along with an alteration in colour of the matching epidermis. Voids may form in the affected parts and vascular tissue may become brown. Occasionally, cavities surrounded by necrotic tissue may appear in the flesh just below the stem attachment. If the phenomenon is intense, the flesh ferments and gives off an unpleasant odour. The various symptoms are often found to be associated with varietal susceptibility:
Soft nose is most often seen on the "Kent" and "Smith" cultivars and far less on "Keitt". It sometimes coincides with roots sprouting into the flesh. Jelly seed and cavitation are more frequent in "Tommy Atkins".
The reasons for these disorders are poorly known. Apart from the varietal factor – with greater susceptibility among varieties of Indian origin or their hybrids – a calcium nutrition imbalance may be involved. When mango groves are grown on land that encloses former livestock corrals, the incidence of internal breakdown is significantly higher on the former corrals indicating that a nutrition imbalance is indeed involved where not only calcium but also excess nitrogen may be responsible. Other environmental factors, such as a moist microclimate, are also conducive to the expression of these disorders.

SUMMARY TABLE OF PERIODS OF OBSERVATION AND TREATMENT FOR CONTROLLING MAJOR MANGO DISEASES
(WITH REFERENCE TO THE PHENOLOGICAL CYCLE)

	Flowering	Fruit-set Fruit enlargement	Harvest	Vegetative growth	Bud dormancy

All diseases require periodic visual inspection so that treatment is triggered as soon as the first symptoms arise when weather conditions are adverse

Anthracnose	Very high susceptibili	Treatment according to rainfall	Post-harvest	Protection young leaves	
Alternaria					
Fruit stem rot					
Powdery mildew					
Bacterial blackspot					
Mango scab					

Observations	Treatment during critical periods	Optional treatment depending on weather conditions	Post-harvest treatment

6. Harvesting

6.1. Readiness for Picking

Mango is a climacteric fruit whose process of ripening begins on the tree and continues after harvest:

➤ if picked too early, the fruit becomes wrinkled without truly ripening

➤ if picked too late, it does not store for long enough to tolerate transportation over large distances.

Evaluating readiness for picking is a major preoccupation for exporters and must consider the mode of transportation: air or sea. For air transport, riper fruit can be picked while transportation by sea requires earlier harvesting. Today there is no reliable, non-destructive method for assessing the degree of ripeness in mangoes in the field. Determining readiness for picking remains partially empirical and must consider various criteria:

- Interval between flowering and harvesting,
- Colouring of the flesh (pale yellow colour),
- Colouring of the epidermis,
- Shape of the fruit (in particular shoulders)
- Presence of blush on the skin.

The most reliable criterion is observation of flesh colour. Because this is destructive, it can only be used to assess an average degree of maturity for fruit in a plot. Periodic inspections during harvesting are also a means for avoiding mistaken assessment of maturity.

However, differentiating between fruit that is ripe from fruit that is not remains largely a matter of rule-of-thumb and know-how on the pickers. Each growing area has its own benchmark and calls on all or part of the criteria mentioned above.

6.2. The Harvest

• Degree of ripeness,

• Presence and extent of diseases and pests,

• Presence and extent of physiological defects, skin blemishes: sun burn, scratches, etc.

For export markets, plots with high rates of defects should be set aside. As regards on treatment, checks should be made to ensure that preharvest waiting periods (PHP) are respected.

Harvesting requires properly trained personnel who follow instructions concerning:

• the differentiation between fruit arising from different flowering periods,

• the selection of mangoes that fulfil the criteria set out by the packaging plant,

• careful handling of the fruit avoiding impact, scratches and contact with any source of contamination: dead leaf litter, soiled harvesting crates, moist and/or sandy-gravelly soil, etc.

• careful management of sap exudation and avoiding soiling the fruit with resin,

• re-sorting of fruit before dispatching it to the packaging plant,

• careful placement the fruit in the crates. The criteria for choosing mangoes for export are:

• The outer appearance: at least one coloured side, depressed stem and rounded shoulders, no wounds, scratches due to friction or spots of various types.

• Screening for deformities and internal breakdown disorders: soft nose (softness noticeable close to the stylar part), sunburn, etc.

• Fly punctures, ant bites, etc.

Fruit should be picked by hand leaving a long stem without using sharp tools (poles). A picking bag should be used to harvest the mangoes located at the tip of the branches that are difficult to reach. Any impact during picking could impair storage properties and therefore should be avoided.

In the orchard, any sorting and temporary storage operations should be done in a clean place sheltered from the sun. Care should be taken to avoid soiling the mangoes with earth particles or encouraging contamination by pathogens from dead leaves or debris of necrotic twigs and inflorescences. These often-neglected precautions are the cause of many problems during storage (fungal attacks, spoilage of flesh).

6.3. Post-harvest

6.3.1. Field Operations

Fruit stems should quickly be cut back to the oval base (approximately half a centimetre from the insertion point in the fruit). During this operation, it is advisable to place the mango head downwards to avoid any contact between the resin and the epidermis. Fruit should be left in this position until sap has drained out (half-an-hour to one hour). Some growers use rigid metal or wooden frames over which loose-webbed mesh is stretched to hold the fruit during this operation. This has the additional benefit of avoiding any contact between the fruit and the ground. The fruit is then placed in a plastic crate on two layers with care being taken to ensure a snug fit.

6.3.2. Transportation from the Orchard to the Packaging Plant, Acceptance

6.3.2. Transportation from the Orchard to the Packaging Plant, Acceptance: Fruit should rapidly be dispatched to the packaging plant where it should be placed in the shade by batch of same origin. Final acceptance should be conducted several hours after reception so that a number of defects that are caused during harvesting or transportation can be detected. The accepted fruit is then weighed.

6.3.3. Packaging

All packaging operations should be conducted in well-lit, well-ventilated and sufficiently spacious premises. Fruit should be stored by uniform batch (origin, variety) before being handled again one by one. The plant should have well-kept, clean equipment: sinks, foam-covered sorting and packaging tables and possibly a mechanical sizer and dipping tank. Personnel should be previously trained. They should follow instructions pertaining to cleanliness and stringently carry out their tasks. People handling mangoes should always have their nails cut short so as to avoid injuring them. Packaging operations must minimally include the following steps:

- Preliminary washing of fruit with regularly renewed water,
- Manual rinsing in clean water,
- Cleaning with clean sponges,
- Drying,
- Sorting to remove fruit that does not comply with export criteria paying special attention to fly punctures (quarantine insect),
- Sizing (see appended references for size/weight of fruit),
- Placing in cartons,
- Generally, weighing and adjustment of carton weight,
- Sticker placement,
- Palletisation,
- Placement in cold storage.

6.3.3.1. Fungal Disease Control - Heat Treatment

A number of methods for controlling fruit flies and fungal diseases during storage (anthracnose, stem-end rot, alternaria, etc.) can be applied during the packaging process at the plant.

6.3.3.1.1. Treatment against Fungal Disease

The basic principle consists in combining heat treatment (immersion of fruit into a hot bath or washing under a hot jet) with fungicide application (by dipping or spraying). It is essential to clearly identify the nature of the targeted fungus or funguses so as to implement an appropriate protocol. The exact temperature of the water, type of soaking or spraying, length of treatment, etc. are all parameters that depend on the actual problem that needs to be solved. Additionally, the type of the fungicide used will differ depending on the nature of the pathogen. For more details concerning these protocols refer to the chapter on fungal diseases.

6.3.3.1.2. Treatment against Fruit Flies

Only the United States require that imported mangoes be systematically treated against fruit flies. European countries do not have this requirement. It is worth noting that fruit fly eggs and larvae in the fruit can be destroyed by means of heat treatment. In a hot water bath at 46.1 °C for respectively 75 minutes for the smaller fruit and 90 minutes for the larger ones.
Other methods have been developed in New Zealand that call on pressurised steam cleaning. All of these methods are cumbersome and costly. They can only be considered by large scale operations that process large quantities of mangoes (several dozen or even hundred tonnes per day).

6.3.3.1.3. Wax Coating

Heat treatment has an adverse effect on skin appearance. By applying wax on the mangoes and then polishing them, a shiny finish is restored.
The waxes used are produced from synthetic substances such as polyethylene or else from natural waxes such as Carnauba wax.
In addition to the aesthetic considerations, waxing also influences gaseous exchange. The application of a layer of wax on the fruit forms a film that produces a closed atmosphere and with an altered composition (O_2/CO_2 ratio) compared to the ambient environment. These coating techniques are being further investigated to determine what their effects are on mango skin colouring and improved storage properties.

6.3.4. Packing in Cartons and Palletisation

Once they have been sorted and sized, similar sized fruits are placed in cartons containing 4 or 5 kilogrammes (6-12 fruits depending on their size). The fruits are laid on their side and sometimes protected from one another by tissue paper or polystyrene wrap so as to avoid injury during transportation.
The cartons are stacked on pallets fitted with corner struts and horizontally banded:
- for transportation by sea, according to ISO standards (1.2 x 1 m) which are generally the stronger pallets;
- for transportation by air, 1 m x 1 m.
As soon as a palette is made up, the cartons should be individually marked: with reference to the variety, size, packing house, etc. Each pallet is identified by a code that bears an order number and a reference to the origin of the batch or batches of fruit that it comprises. These references are recorded in an inventory system that is used for the purposes of traceability.

6.3.5. Cold Storage - The Cold Chain

During operations from harvest to packing in cartons, the mangoes are always handled at ambient temperature ranging from 20 to 30 °C. Lower temperatures have a very beneficial effect on length of storage within limits which are very important to be aware of.

Mangoes are intolerant to excessively low temperatures. Temperatures of less than 10 °C are often the cause of physiological damage (brown pitting on the epidermis, browning of flesh, etc).
Storage temperatures must therefore range from 10 to 12 °C. This depends on the variety and ripeness of the fruit (riper fruit is tolerant to somewhat lower temperatures). Once the fruit has been palletised, the volume to be cooled is very significant. The fruit located in the middle of the pallet is not readily accessible to heat exchange.

There are several techniques for rapidly bringing down the temperature of mangoes:

- hydrocooling, which consists in immersing the fruit for a few seconds in a cold-water dip just before final packaging and placement into cartons. This technique wets the fruit and is sometimes incompatible with other operations. It requires an efficient system for drying the mangoes.
- forced ventilation, which consists in passing a cold air blast through all the cartons on the pallet to rapidly cool the mangoes. This technique tends to be used by large packing houses.

Once the pallets have been cooled to the centre, they are placed in a refrigerated facility with a temperature of between 10 and 12 °C. Relative moisture is maintained at 90% and the air is renewed so as to avoid raising the CO_2 and ethylene concentrations.

6.3.6. Transportation

Before being loaded, the fruit undergoes inspection formalities conducted by the customs and plant protection services. Mangoes may be exported it in two ways:

▪ By air,

▪ By sea.

In the first case, because the fruit is very rapidly dispatched by air, no special storage precautions need to be taken. When bringing the fruit from cold storage to the aircraft, care should be taken to avoid exposing the fruit to high temperatures (trucks queuing in full sunlight) or extended periods at ambient temperature.

In the second case, cold chain requirements may require specific measures to be taken between the packing house and the European importer premises. In most cases, the pallets are placed in refrigerated containers that are carried in succession by a truck, a ship, and then again a truck. This sequence of transportation operations requires 1 to 3 weeks depending on the distance from the growing area.

Throughout this phase, care must be taken to ensure that temperature, relative moisture and atmospheric conditions remain stable and are in line with storage requirements:

▪ Temperature ranging from 10 to 12 °C (continuously recorded data in each container).

▪ Relative moisture maintained at approximately 90% and always below 95%

▪ air renewal to avoid increasing the CO_2 and ethylene concentrations. For temperatures in the region of 10 °C, hourly production of CO_2 ranges between 12 and 16 ml/kg and that of ethylene between 0.1 and 0.5 ml/kg. The CO_2 concentration should never be more than 8% failing which irreversible damage is caused. It should preferably be maintained close to 1%.

Ethylene concentrations in the region of 100 ppm accelerate the ripening process. This is why the air in the containers must be continually renewed so that CO_2 and ethylene concentrations do not rise excessively. Continuous ventilation at an hourly rate that depends on the volume of the container normally meets these requirements. The exporter should specify temperature, relative moisture and ventilation values to the shipper. Containers equipped with on-board recorders enable the temperature values to be monitored and sometimes relative moisture values, but not often atmospheric composition.

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Annex 1: known registrations in ACP countries and efficacy of active substance

Tables below give known registrations in ACP countries. Efficacy given are based on existing registrations, documents on mango production and information from pesticides companies.

TABLE 1: REGISTRATION IN ACP COUNTRIES IN NOVEMBER 2011

Active substance or biocontrol agent	Countries						
	CILSS countries	Côte d'Ivoire	Ghana	Cameroon	Kenya	Tanzania	Jamaica
Acetamiprid						Horticultural crops	
Azoxystrobine							
Bifenthrin						Horticultural crops	
Captan							
Chlorpyrifos-ethyl	X	X				Horticultural crops	
Copper							X
Deltamethrin		Fruit trees			Fruit trees	Horticultural crops	Fruit trees
Fenitrothion					X		Fruit trees
Fipronil						Horticultural crops	
Mineral oil							Fruit trees
Imazalil		Fruit trees					
Imidacloprid						Horticultural crops	
Lambda-cyalothrin							
Malathion						Horticultural crops	X
Mancozeb			X		Fruit trees	Horticultural crops	X
Maneb							
Prochloraze							
Propiconazole						Horticultural crops	
Sulfur							
Spinosad	X		X				
Thiabendazole							
Thiacloprid						Horticultural crops	
Thiamethoxam	X					Horticultural crops	Fruit trees
Thiophanate-methyl					X		
Trifloxystrobine							

X means that registration is specific to mango

Remarks : a) list of registered products in Cameroon does not specify neither crop nor target

b) in Tanzania, horticultural crops include vegetables and fruits

TABLE 2: EFFICACY OF SOME ACTIVE SUBSTANCES OR BIOCONTROL AGENTS

A : INSECTICIDES

Active substances or biocontrol agents	Pests								
	Fruit flies	Mealybugs	Scales	Termites	Thrips	Cecidomyiids	Whiteflies	Bugs	Acrididae
Acetamiprid		X		X	X		X		
Bifenthrin	X			X			X	X	X
Chlorpyrifos-ethyl		X		X					
Deltamethrin	X				X		X	X	X
Fénitrothion	X								X
Fipronil				X					X
Imidacloprid	X	X		X	X	X	X		
Lambda-cyhalothrin	X				X		X	X	X
Malathion	X	X			X			X	X
Mineral oil			X						
Spinosad	X				X			X	
Thiaclopride	X				X		X		
Thiamethoxam	X	X			X		X		

B : FUNGICIDES

Active substances	Diseases					
	Anthracnose	Alternaria	Pedincular rots	Powdery mildew	Scab	Bacteria
Azoxystrobine	X					
Captan	X	X				
Copper	X		X		X	X
Imazalil	X	X	X			
Mancozeb	X				X	
Maneb	X	X			X	
Prochloraze	X	X	X			
Propiconazole	X					
Sulfur				X		
Thiabendazole			X			
Thiophanate-methyl	X			X		
Trifloxystrobine	X					

Annex 2: Regulations and pesticides residues

Residues trials, financed by PIP, have been undertaken in Senegal and Mali in 2004 and 2005. Tables below give the synthesis of the results and advices on the use of active substances.

The PHIs (Pre-harvest interval) are indicated for:

- Compliance with the European Maximum Residue Limits (MRLs) currently in force on spinach including amaranthus spinach (on products exported into the EU).
- Compliance with the CODEX MRL (for products sold in the countries where the CODEX MRLs are relevant).
- Special private standards, who allow to cultivate only without any quantifiable residues i.e. with "O" residues taking into account European LOQ.

Any change in one or more elements of these GAPs (increase in the doses, frequency of application and number of applications, last application before harvest not respecting the recommended pre-harvest interval) can result in residues in excess of the MRL in force. These GAPs does not represent a treatment calendar to be applied as such. In practice, the frequency of treatments must take into account the severity of attacks and the real risks of local damage.

Note on the status of active substances in EU

Before a Plant Protection Product can be marketed in EU, its active substance must be approved by the European Commission. Regulation (EC) 1107/2009 (replacing former "Directive 91/414/EEC") came into force on 14th June 2011. By 25th May 2011 the Commission adopted the Implementing Regulation (EU) N° 540/2011 as regards the list of approved active substances. These Regulations and all other related Regulations can be accessed using the search facility on the following: http://ec.europa.eu/food/plant/protection/evaluation/index_en.htm

It should be noted that if an active substance is not registered in the EU it can still be used in the ACP countries in food items exported to Europe, provided the residue complies with the EU MRL.

Note on MRLs:

The quantities of pesticide residues found in food must be safe for consumers and remain as low as possible.
The maximum residue limit (MRL) is the maximum concentration of pesticide residue legally permitted in or on food or feed.

MRLs in the EU
Pursuant to Regulation (EC) No 396/2005 harmonized Community MRLs have been established.

The European Commission (EC) sets MRLs applying to foodstuffs marketed in the territories of the EU countries, either produced in the EU or in third countries.

Annex I to the Regulation contains the list of crops (Regulation (EC) 178/2006) on which MRLs are assigned, Annexes II and III contain the MRLs: temporary MRLs can be found in Annex III, final MRLs in Annex II. Substances for which an MRL is not required are listed in Annex IV (Regulation (EC) 149/2008). When there is no specific MRL for a substance / crop a default MRL, usually set at 0.01 mg/kg, is applied.

When establishing an MRL, the EU takes into account the Codex MRL if it is set for the same agricultural practices and it passes the dietary risk assessment. Where appropriate Codex MRLs exist, the import tolerance will be set at this level.

EU harmonized MRLs came into force on 1 September 2008 and are published in the MRL database on the website of the Commission http://ec.europa.eu/sanco_pesticides/public/index.cfm

See also the leaflet "New rules on pesticide residues in food"
http://ec.europa.eu/food/plant/protection/pesticides/explanation_pesticide_residues.pdf

How are MRLs applied and monitored in EU?

- Operators, traders and importers are responsible for food safety, and therefore for compliance with MRLs.
- The Member State authorities are responsible for monitoring and enforcement of MRLs.
- To ensure the effective and uniform application of these limits, the Commission has established a multiannual Community monitoring program, defining for each Member State the main combinations of crops and pesticides to be monitored and the minimum number of samples to be taken. Member States must report results to the Commission, which published an annual report. At present the reports are published by the European Food Safety Authority (EFSA) http://www.efsa.europa.eu/en/scdocs.htm
- In case of detection of pesticide residue levels posing a risk to consumers, information is transmitted through the Rapid Alert System for Food and Feed (RASFF) and appropriate measures are taken to protect the consumer. The database is accessible on http://ec.europa.eu/food/food/rapidalert/rasff_portal_database_en.htm and RASFF publishes an annual report http://ec.europa.eu/food/food/rapidalert/index_en.htm.
- PIP monthly updates on its website a summary of RASFF notification for fruit and vegetable imports from ACP countries.

MRLs in ACP countries

ACP countries don't have set their own MRLs therefore they usually admit Codex LMRs for foodstuffs marketed in their country.
The Codex Alimentarius Commission was established in 1961 by the Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) with the objective to develop an international food code and food standards. Membership of the Codex Alimentarius Commission is open to all Member Nations and Associate Members of FAO and WHO. More than 180 countries and the European Community are members of the Codex Alimentarius Commission.

The Joint FAO/WHO Meetings on Pesticide Residues (JMPR) is not officially part of the Codex Alimentarius Commission structure, but provide independent scientific expert advice to the Commission and its specialist Committee on Pesticide Residues for the establishment of Codex Maximum Residue Limits, Codex MRLs for pesticides which are recognized by most of the member countries and widely used, especially by countries that have no own system for evaluating and setting MRLs.

The Codex MRL database can be found on the web site: http://www.codexalimentarius.net/pestres/data/index.html?lang=en.

TABLE 1: STATUS OF ACTIVE SUBSTANCES AND BIOCONTROL AGENTS IN THE EU REGULATION 1107/2009 ; EU AND CODEX MRLS IN OCTOBER 2011 AND GAPS TESTED FOR INSECTICIDES

Caution: The information contained in this table is subject to change by future directives of the Commission of the European Communities or Codex decisions.

| Active substance | EU regulation | | Codex MRL | Recommended GAP | | | PHI in days | | |
	Status regulation 1107/2009	MRL		Dose g a.s./ha	Number applications	Interval between applications in days	EU MRL	Codex MRL	LOQ
Acetamiprid	Approved	0.01**	/	50 on termites	2	60	174 days results for 4 applications : last application on termites 233 days before harvest and last application on scales and mealybugs 174 days before harvest		
				75 on scales and mealybugs	2	30			
Bifenthrin	Not approved	0.3	/	120 on termites	2	60	233	//	233
				50 on fruit flies	2	10	7	//	> 21
Chlorpyrifos-ethyl	Approved	0.05**	/	1000 on termites	2	60	174 days results for 4 applications : last application on termites 233 days before harvest and last application on scales and mealybugs 174 days before harvest		
				1000 on scales and mealybugs	2	30			
Deltamethrin	Approved	0.05**	0.05 stone fruits	2	10	7	7	7	/
Fipronil	Approved	0.005**	/	1250 on termites	2	60	233		
Imidacloprid	Approved	0.2	0.2	105 on termites	2	60	174 days results for 4 applications : last application on termites 233 days before harvest and last application on scales and mealybugs 174 days before harvest		
				210 on scales and mealybugs	2	30			
				100 on fruit flies	2	10	> 21	> 21	> 21
Lambda-cyhalothrin	Approved	0.2	/	25 on fruit flies	2	10	7	//	> 21
Malathion	Approved	0.02**	/	1000 on fruit flies	2	10	7	//	7
Spinosad	Approved	0.02**	0.2 stone fruits	1 l of commercial product at 0.24 g/l per ha with spot applications	2	10	7	7	7
Thiacloprid	Approved	0,02**	0,5 stone fruits	90 on fruit flies	2	10	21	7	> 21

Active substance	EU regulation		Codex MRL	Recommended GAP			PHI in days		
	Status regulation 1107/2009	MRL		Dose g a.s./ha	Number applications	Interval between applications in days	EU MRL	Codex MRL	LOQ
Thia-methoxam	Approved	0,5	/	200 on termites	2	60	174 days results for 4 applications : last application on termites 233 days before harvest and last application on scales and mealybugs 174 days before harvest		
				200 on scales and mealybugs	2	30			
				50 on fruit flies	2	10	7	//	7

Approved : active ingredient approved for use in EU countries
Not approved : active ingredient not authorized in EU countries but usable in countries out of EU if the EU LMR are respected for the imported products in EU.
/ = for this active substance, Codex doesn't give a value
// data not available or not possible to calculate
** = LOQ
In yellow = GAP validated by PIP residues trials (Senegal and Mali in 2004/2005)

TABLE 2: STATUS OF ACTIVE SUBSTANCES AND BIOCONTROL AGENTS IN THE EU REGULATION 1107/2009 ; EU AND CODEX MRLS IN OCTOBER 2011 AND GAPS TESTED FOR FUNGICIDES

Caution: The information contained in this table is subject to change by future directives of the Commission of the European Communities or Codex decisions.

Active substance	EU regulation		Codex MRL	Recommended GAP			PHI in days		
	Status regulation 1107/2009	MRL		Dose g a.s./ha	Number applications	Interval between applications in days	EU MRL	Codex MRL	LOQ
Azoxystrobine	Approved	0.7	2 stone fruits	100	2	14	7	7	21
Captan	Approved	2	/	200	2	14	7	//	>21
Copper	Approved	20	/	5000	2	14	7	//	>21
Fludioxonil	Approved	0.05**	5 stone fruits	30 per 100 l water	n.a.	n.a.	Post-harvest		
Imazalil	Approved	0.05**	/	50 per 100 l water	n.a.	n.a.	Post-harvest		
Mancozeb	Approved	2	2	1600	2	14	7	7	>21
Maneb	Approved	2	2	1600	2	14	7	7	>21

Active substance	EU regulation		Codex MRL	Recommended GAP					
	Status regulation 1107/2009	MRL		Dose g a.s./ha	Number applications	Interval between applications in days	PHI in days		
							EU MRL	Codex MRL	LOQ
Prochloraze	Approved	5	7 tropical fruits with inedible peel	25 per 100 l water	n.a.	n.a.	Post-harvest		
Propiconazole	Approved	0.05**	/	50	2	14	7	//	7
Thiabendazole	Approved	5	5	50 per 100 l water	n.a.	n.a.	Post-harvest		
Thiophanate-methyl	Approved	1	/	700	2	14	7	//	>21
Trifloxystrobine	Approved	0.5	3 stone fruits	250	2	14	7	7	>21

Approved : active ingredient approved for use in EU countries
Not approved : active ingredient not authorized in EU countries but usable in countries out of EU if the EU LMR are respected for the imported products in EU.
/ = for this active substance, Codex doesn't give a value
// data not available or not possible to calculate
** = LOQ
In yellow = GAP validated by PIP residues trials (Senegal and Mali in 2004/2005)
n.a. = not applicable

TABLE 3: SOURCES OF GAP VALIDATED BY PIP TRIALS AND INDICATED IN PREVIOUS PAGES:

Active subsance	Commercial product tested	Manufacturer	Trials	
			Year	Country
Insecticides				
Acetamiprid	Mospilan 200 SP	Nisso	2004	Mali
Bifenthrin	Talstar 100 EC	FMC	2004/2005	Senegal Mali
Chlorpyrifos-ethyl	Dursban 4	Dow AgroSciences	2004	Senegal
Fipronil	Regent 5 G	BASF	2004	Mali
Imidacloprid	Confidor 350 SC Confidor 200 OD	Bayer CropScience	2004/2005	Senegal Mali
Lambda-cyalothrin	Karaté Max 2.5 WG	Syngenta	2004/2005	Senegal Mali
Malathion	Callimal 500 EC	Calliope	2004/2005	Senegal Mali
Spinosad	Success Appat	Dow AgroSciences	2004/2005	Senegal Mali
Thiacloprid + deltamethrin	Proteus 170 OD	Bayer CropScience	2004/2005	Senegal Mali
Thiamethoxam	Actara 25 WG	Syngenta	2004/2005	Senegal Mali
Fungicides				
Azoxystrobine	Ortiva 250 SC	Syngenta	2004	Mali
Captan	Captan 80 WG	Arysta LifeScience	2004/2005	Senegal Mali
Copper	Callicuivre 50 WP	Caffaro	2004	Senegal

Active subsance	Commercial product tested	Manufacturer	Trials	
			Year	Country
Fludioxonyl	Savior 200 SC	Syngenta	2004	Senegal
Imazalil	Sulima 75 SP	Arysta LifeScience	2004	Senegal
Mancozeb	Dithane M45 WP	Dow AgroSciences	2004/2005	Senegal Mali
Maneb	Triamangol 80 WP	Cerex Agri	2004	Senegal
Prochloraze	Sportak 45%	BASF	2004	Senegal
Propiconazole	Tilt 250 EC	Syngenta	2004	Senegal
Thiabendazole	Tecto 500 SC	Syngenta	2004	Senegal
Thiophanate-methyl	Topsin M50 SC	Nisso	2004/2005	Senegal Mali
Trifloxystrobine	Flint 50 WG	Bayer CropScience	2004/2005	Senegal Mali

Note : GAPs indicated in previous pages are those corresponding to the PPPs listed above. User of this information should check if the product used is equivalent (same concentration and same type of formulation) to the reference product. If it is not the case, the indicated GAP could not be adequate.

DOSES AND MODE OF APPLICATION FOR PESTICIDES NOT SPRAYED

TO CONTROL TERMITES				
Active substance	Trade name	Dose s.a./ha	Dose commercial product	Mode of application
Acetamiprid	Mospilan 20 SP	50 g	3 g/50 l water/tree	To apply the 50 litres f mixture (water + product) on the ground under all the crown (approximately 50 m^2)
Chlopyriphos-ethyl	Dursban 4	1000 g	20 ml/50 l water/tree	To apply the 50 litres f mixture (water + product) on the ground under all the crown (approximately 50 m^2)
Imidacloprid	Confidor 350 SC	105 g	2,4 ml/50 l water/tree	To apply the 50 litres f mixture (water + product) on the ground under all the crown (approximately 50 m^2)
Bifenthrin	Talstar 100 EC	120 g	12 ml/50 l water/tree	To apply the 50 litres f mixture (water + product) on the ground under all the crown (approximately 50 m^2)
Fipronil	Regent 5 G	1250 g	250 g/tree	To apply the granules on the ground under all the crown (approximately 50 m^2)
Thiamethoxam	Actara 25 WG	200 g	8 g/50 l water/tree	To apply the 50 litres f mixture (water + product) on the ground under all the crown (approximately 50 m^2)
TO CONTROL MEALYBUGS AND SCALES				
Imidacloprid	Confidor 350 SC	210 g	4,8 ml/5 l water/tree	To apply the 50 liters of mixture on ground around the base of the tree
Thiamethoxam	Actara 25 WG	200 g	8g/5 l water/tree	To apply the 50 liters of mixture on ground around the base of the tree

Annex 3 – 1: pictures of post-harvest diseases on fruits

A. (Photo P.M. Diédhiou)

B. (Photo FUSAGx)

Figure 1. Spots of anthracnose caused by *Colletotrichum* sp.
A: Round-shaped spots randomly located. B: Tear-stain symptoms

A

B

C

(Photos P. Gerbaud, identification Clinique des plantes, CORDER)

(Photo P.M. Diédhiou)

Figure 2. Black spots appearing after harvesting and caused by *Alternaria* sp.
A and B: Young lesions concentrated in the stem-end zone. C: More advanced spots.

Photos P. Gerbaud, identification Clinique des plantes, CORDER)

Figure 3. Post harvest spots of rot associated with *Cercospora* sp.

(Photos P. Gerbaud, identification Clinique des plantes, CORDER)

Figure 4. Spots of rot slightly concaves and associated with *Stemphylium* sp.

A. (Photo P.M. Diédhiou)

B. (Photos P. Gerbaud, identification Clinique des plantes, CORDER)

Figure 5. Rot associated with Dothiorella and Lasiodiplodia sp.
A: Stem-end rot; B: Diffuse spots developing randomly on the surface of a fruit.

A. (Photo P.M. Diédhiou)

B. (Photo P.M Diédhiou)

Figure 6. Stem-end rot developing from an infection of the stem-end at harvesting (A) or from an injury to the skin (B) and caused by *Aspergillus* sp.

Annex 3 – 2: pictures of diseases in the orchards

Scab

Symptoms on fruit

Xanthomonas

Symptoms on fruit

Anthracnose

Symptoms on a panicle

Symptoms at the basis of a panicle

Symptoms on a leaf

Oidium

Symptoms on panicles

Symptoms on leaves

Annex 3 – 3: pictures of pests

Fruit flies

Ceratitis sp.

Symptoms on a fruit

Eggs

Bactrocera invadens

Larva

Rastrococcus invadens

Larvae

Sooty mould on upper surface of a leaf
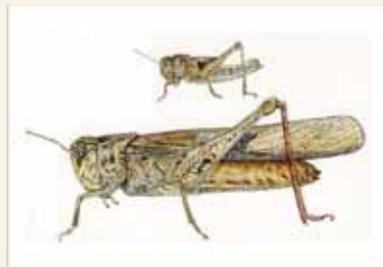Larvae on underside of leaves

Scales

Larvae

Anoplocnemis

Adult

Lygus spp.

Adult and larvae

Locusts

Oedaleus senegalenis

Thrips
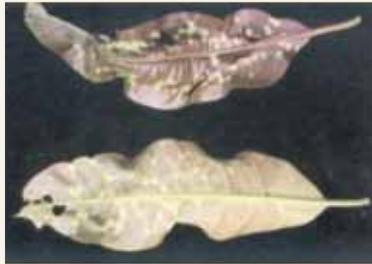

Scirtothrips

Selenothrips

Foliar damage

Symptoms on young fruits

Cecidomyiids

Erosomyia adult

Foliar damage

Aleurodicus dispersus

Larvae

Adults

Termites

Crusting on a trunk

Decaying trees

CROP PRODUCTION PROTOCOLS

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

GUIDES TO GOOD PLANT PROTECTION PRACTICES

Amaranth (*Amaranthus* spp.)
Baby carrot (*Daucus carota*)
Baby and sweet corn (*Zea mayis*)
Baby Leek (*Allium porrum*)
Baby pak choy (*Brassica campestris* var. *chinensis*), baby cauliflower (*Brassica oleracea* var. *botrytis*), baby broccoli and sprouting broccoli
(*Brassica oleracea* var. *italica*) *and head cabbages* (*Brassica oleracea var. capitata* and *var. sabauda*)
Banana (*Musa* spp. – plantain (*matoke*), apple banana, red banana, baby banana and other ethnics bananas)
Cassava (*Manihot esculenta*)
Chillies (*Capsicum frutescens, Capsicum annuum, Capsicum chinense*) and sweet peppers (*Capsicum annuum*)
Citrus (*Citrus* sp.)
Coconut (*Cocus nucifera*)
Cucumber (*Cucumis sativus*), zucchini and pattypan (*Cucurbita pepo*) and other cucurbitaceae with edible peel of the genus *Momordica, Benincasa, Luffa, Lagenaria, Trichosanthes, Sechium* and *Coccinia*
Dasheen (*Colocasia esculenta*) and macabo (*Xanthosoma sagittifolium*)
Eggplants (*Solanum melongena, Solanum aethiopicum, Solanum macrocarpon*)
Garlic, onions, shallots (*Allium sativum, Allium cepa, Allium ascalonicum*)
Ginger (*Zingiber officinale*)
Guava (*Psidium catteyanum*)
Lettuce *(Lactuca sativa*), spinach (*Spinacia oleracea* and *Basella alba*), leafy brassica (*Brassica* spp.)
Lychee (*Litchi chinensis*)
Melon (*Cucumis melo*)
Organic Avocado (*Persea americana*)
Organic Mango (*Mangifera indica*)
Organic Papaya (*Carica papaya*)
Organic Pineapple (*Ananas comosus*)
Potato (*Solanum tuberosum*)
Sweet potato (*Ipomea batatas*)
Tamarillo (*Solanum betaceum*)
Water melon (*Citrullus lanatus*) and butternut (*Cucurbita moschata*)
Yam (*Dioscorea* spp.)