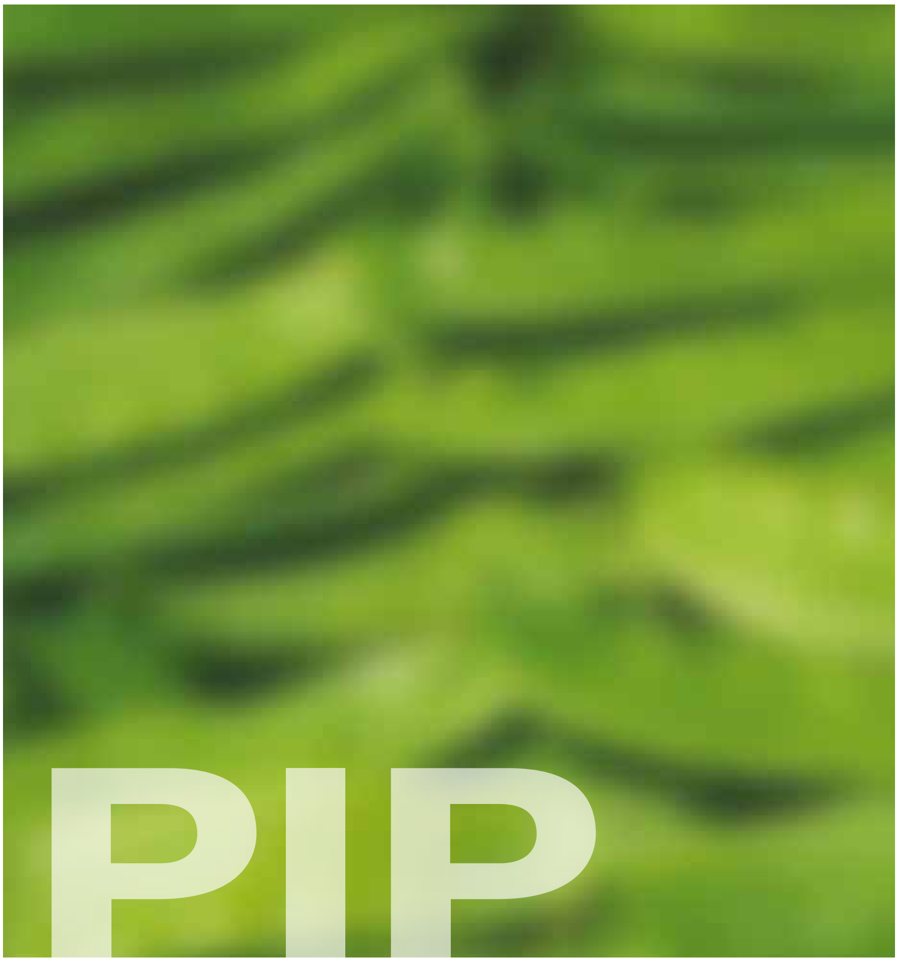

CROP PRODUCTION PROTOCOL

MANGO (*Mangifera indica*)

COLEACP is an international network promoting sustainable horticultural trade.

PIP is a European cooperation programme managed by COLEACP. It is financed by the European Development Fund and implemented at the request of the ACP (Africa, Caribbean and Pacific) Group of States.

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".

PIP

FOR SUSTAINABLE DEVELOPMENT OF THE ACP HORTICULTURAL INDUSTRY

www.coleacp.org/pip

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Disclaimer

The document « Crop Production Protocol » (Mango) describes all the agricultural practices linked with mango and suggests pest and disease control based mainly on active substances supported by the plant protection products manufacturers in European Regulation 1107/2009 and due to comply with pesticide residue limits. Most of these active substances have been tested through a field trials programme and the residue level of each active substance has been measured. The pest and disease control suggested is dynamic and will be adapted continuously, integrating all information gathered by the PIP. Each grower should select from the products listed a set of active substances that are of no concern regarding residues.

A formulation may be applied only if it is legally registered in the country of application. Growers should check with the local registration authorities wether a product they wish to use is included on the list of registered products.

The PIP's crop protocols and guides to good phytosanitary practices are regularly updated. For further information, see the PIP website www.coleacp.org/pip

PIP

FOR SUSTAINABLE DEVELOPMENT OF THE ACP HORTICULTURAL INDUSTRY

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Mangifera indica - family of the anacardiacae

1. Description

1.1. Botany

Mango trees originate from India and Burma and diversified into other areas of south-east Asia.

- In north-western India, are monoembryonic, anthracnose-susceptible varieties with skin colour that varies in intensity. The climate there is highly contrasting, hot, humid summers alternating with a dry, cold season.
- In Burma, Thailand, Indonesia and the southern part of the Indo- Chinese peninsula, are polyembryonic varieties whose having greenish skin with little colouring that are relatively resistant to anthracnose. The climate is less contrasting, and is hot and humid.

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 due to sparse flowering, and 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, cause 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 (10 to 30 m tall) evergreen tree.

It produces cluster-shaped inflorescences at the tips of branches in the peripheral area of the foliage. Inflorescences are made up of male and hermaphrodite flowers. Each inflorescence carries about 1000 flowers which, following pollination, produce a few fruits at most. The average fruit-set rates are very low, less than 1/1000. Pollination is brought about by insects (flies, thrips, etc.) but 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 higher fibre content. The flat seed is protected by a lignified kernel.

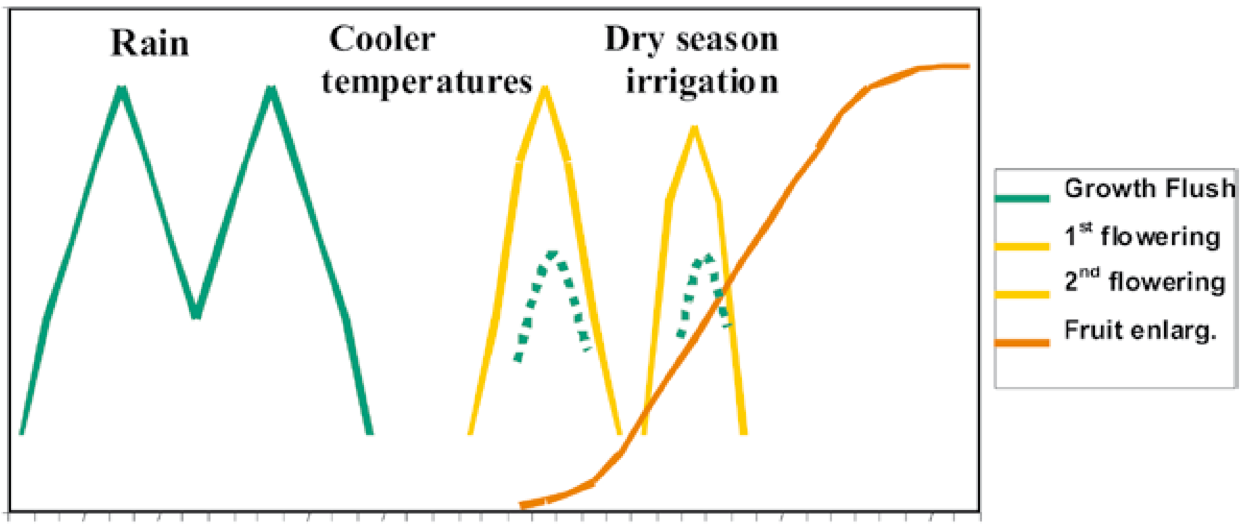
In monoembryonic varieties, the seed comprises a single zygotic embryo (arising from a single pollinisation; and the genome is always different from that of the mother plant). In polyembryonic varieties, the seed comprises one or several nucellar embryos (arising from nucellar tissue; and the genome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

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 two, sometimes three blossomings a year at intervals of 1.5 months).



Example of a phenological cycle - Reunion Island

In the table below periods of flowering and harvesting are indicated for some ACP countries

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

Légende

Fl	Flowering	Fr	Fructification
Fl	Second flowering	Fr	Starting, end or secondary fructification

Note: sometimes flowering and fructification may occur at the same time: Fl-Fr
for instance in the South of Ghana, in Kenya, and in some areas producing early Amélie in February in Burkina.

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. So-called Florida mangoes are those most frequently used for export from Latin America or Africa to Europe or North America, although imports of Pakistani mangoes to Europe have risen sharply over the past few years.

Three varieties dominate 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" - 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, grown mainly in Brazil and Mexico, South Africa and Israel. It is unusual in West Africa, where the variety Kent is preferred

➢ **Kent**:
The cultivar Kent 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 g. 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; these grow on lateritic soils 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 occurence.

➢ **Keitt**:
This cultivar originates from Florida and was introduced into Africa via the Foulaya experimental station in Guinea towards 1950, and 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 g 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. It is sometimes prone to internal physiological disorders and its skin is much more fragile than that of the Kent mango. Its late production, which was once considered an advantage, making it possible to extent the harvest period, is becoming a handicap due to parasitic attacks on the late fruit (flies, fungal diseases, bacterial blight, etc.).

Secondary cultivars

➢ **Amélie**:
This cultivar originates from the French West Indies. It was introduced into Mali in the previous century and then spread throughout western Africa. Its high susceptibility to anthracnose is such that it can be grown only in the drier zones (Sudano-Sahelian zone). The fruit is rounded and weighs between 300 and 600 g; its flesh is deep orange, smooth and pleasant. Major retailers find fault with the fact that its skin is not red coloured and with its poor storage properties. To overcome this drawback, the mangoes are often harvested early and their skin remains green when they reach the shelves. Amélie fills a limited commercial niche very early in the season, from the end of March to mid-April, when mangoes are scarce and practically none of the coloured varieties are available. Despite competition from South America, the export flow continues until the arrival of the Kent mangoes in early April.

➢ **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 and are best transported by air to minimise storage-related risks. The quantities involved are minor.

➢ **Palmer**:
This is a late variety long, and brightly coloured (reddish purplish) fruits. The flesh is yellow and firm, and 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. The fruit's elongated shape is another shortcoming as far as the retail trade is concerned. Nonetheless, it is the fifth 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 assess the development stage of the fruits correctly, and harvest them too late (inadequate length of storage). Guinea was the last country in West Africa to export it, but there it has also been replaced by Kent mangoes.

➢ **Valencia pride**:
This mid-season variety yields fairly large, elongated fruits with good taste quality and excellent appearance. It is difficult to store and 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 g), 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, for example some areas in South Africa.

➢ **Osteen**:
This mango originated in Florida from a Haden cultivar seed. It has now become the first mango grown in Europe, mainly in Spain. Highly coloured, and with interesting organoleptic qualities, it is one of the main mangoes found in European markets from September to November. Spain finds the proximity of European consumer markets a tremendous advantage, as it can pick ripe fruit that is ready to eat. But little is known about the behaviour of this variety in intertropical areas. It is mentioned here, due to its increasing importance in European markets.

Tommy Atkins – photo Henri Vannière

Kent – photo Jean-Yves Rey

Kent - photo Jean-Yves Rey

Keitt - photo Jean-Yves Rey

Amélie – photo Jean-Yves Rey

Zill – photo Gilles Delhove

Palmer -photo Jean-Yves Rey

Valencia Pride - photo Jean-Yves Rey

Améliorée du Cameroun – photo Jean-Pierre Imele

Apple mango – photo Gilles Delhove

Others pictures are available at:
www.cgste.mq/intranet/IMG/pdf/fiches_mangues_SECI.pdf
http://freshmangos.com/varieties.html

Matching production with market demand

Two varieties presently dominate the export market for mangoes: Tommy Atkins and Kent which represent more than 75% of exported volume. Tommy Atkins essentially comes from Latin America, while Kent is common in Africa and is spreading in Brazil at the request of importers who are looking for quality fruit.

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

It is interesting also to note the improved mango from Cameroon, which represents the bulk of production in Cameroon. Probably originating from South East Asia, it is a polyembryonic mango, well suited to humid areas close to the Equator, where it flowers abundantly, but it behaves quite well in dry savannas. Its main drawback is its sensitivity to physiological problems (jelly seed) and therefore its short shelf life. If the plant was produced by planting, fruit set is delayed with respect to grafting. For consumers in Central Africa, it is the best mango. This is a small mango, green-skinned with a sweet, orange coloured flesh, and pulp that not too fibrous.

Also worth mention are Ngowe in Kenya, and "Apple mango" native to Asia and widely cultivated in Tanzania and Kenya, in particular for the Middle Eastern market. It is regular and rounded in shape, not too fibrous, weighing 350-500 g, very meaty and plump.

3. The nursery

3.1. General Considerations

Various methods of propagation can be applied, including grafting and layering. In practice, only grafting is used to produce mango tree planting stock for the fruit 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 12-18 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 bags 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 these varieties 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 tends to use the seeds of one or two locally well adapted polyembryonic varieties for the purpose 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 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 extraction of the seed. The kernel is removed to avoid forcing the young root to curl when the seed germinates. Any seed with a defect – such as germination already initiated, traces of fungal attack, or presence of pests (e.g. *Cryptorhynchus mangiferae*) - must be discarded. Germination capability lasts for a limited period. A clear decrease can be observed after extracting the seed, and a nearly zero rate after one week. Sowing should be performed immediately after extraction (same day, or next morning provided the seeds are kept in a humid place).

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 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 watered abundantly 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/m^2 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

As it is impossible to conserve the seeds, sowing will always take place shortly after the extraction of seeds, at the time of the mango harvest.
Sowing can be carried out with a high-density propagator or on site in bags.
The first solution has the advantage of securing better plant homogeneity and allows sorting when transplanting. The seed is pressed down slightly into the earthy substrate and slightly covered with 2-3 cm soil. The substrate is kept moderately moist through regular watering. Germination takes between 6 and 30 days.

3.3.4. Transplanting

Seedlings should be transplanted when the tigella reaches a height of 6-8 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 3-5 litres. The bottom and sides of the bags should be pierced. The bags are arranged side by side on double lines in 0.15 m deep furrows to protect them from sunlight.
The use of polyembryonic seeds often results in the presence of several seedlings per seed. Care should be taken always to avoid the development of twin plants in one bag by eliminating redundant plants. It is possible to transplant them separately, taking care to separate the cotyledons to keep their shoots and radicle intact. But it is preferable to use only the most vigorous plant and eliminate other weaker plants. Thinning is recommended only when there is a shortage of plants.

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.
At the time of removal the graft must be "ripe", that is to say, it loses its flexibility due to lignification of the stem. The terminal bud must be globular, swollen and ready to germinate, although without presenting early bud burst.
In the event that the terminal bud does not show these characteristics, it is advisable to pluck the ends of branches over about 15 cm. This operation will triggers the swelling of the terminal buds. These may be removed 8-15 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 cambium 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 there is close contact and a proper seal
- care must be taken to avoid drying of the tissues of rootstock or scion.

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

3.4.5. Postgrafting Care

Normally the bud bursts 15-20 days after the graft. To accelerate growth in the case of a side graft (veneer or cleft), the rootstock should be topped, but 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 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 g nitrogen diluted in 1 litre of water per bag.

3.5. Plant Protection Measures in Nurseries

Nursery-grown seedlings are liable to attack by pests and diseases. In contrast with adult plants, which to some extent are able to endure parasitic attacks, young seedlings are much more susceptible, because they have fewer reserves. 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.

For more information on these practices see Chapter 5.

See tables in Annex 1 for more details on the active substances that can be used.

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 trilobitiformis; Ceroplastes* spp.

➢ soft scale: *Icerya seychellarum; Rastrococcus invadens*..

Scales are normally controlled by natural enemies. Outbreaks of scale generally take place after insecticides are applied against other pests. Armoured scales are also noted in slow-growing trees.

Plant Protection Products: The basis for controlling hard scale is the application of white oil that smothers these insects. Scale insects are most vulnerable when the young larvae have reached the mobile stage. If necessary, the soft scale insects may be controlled chemically by spraying organophosphates, chloronicotinoids or other products (see table in Annex 1)

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 as it can destroy the shoots within a few days, even within hours. It is crucial to respond quickly.

Plant Protection Products: Preference is given to authorised synthetic pyrethroids that respect the parasitoids (e.g. deltamethrin).

3.5.1.3. Locusts

As with mango bugs, it is important to react quickly to attacks. The most effective approach is preventive treatment of locusts that congregate in the vicinity of the nursery.

Plant Protection Products: Massive use of pesticides has generated resistance. It is advisable to contact the plant protection services in each region to determine which active ingredients are effective. Biopesticides based on *Metarhizium* spp. (normally *M. anisopliae*) have proved effective against short-horned grasshoppers.

3.5.1.4. Thrips

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

S. aurantii is a tiny, highly mobile, 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 so efforts must be made to preserve the beneficial fauna.

Plant Protection Products: Spinosad has given satisfactory results in this respect on mango and citrus trees. Attention must be paid to the phenomenon of resistance as a result of repeated use of these insecticides (see Annex 1 for other pesticides).

3.5.1.5. Leaf-gall cecidomyiids: Procontarinia matteiana

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

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

Plant Protection Products: See Annex 1, Table 2.

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. Resistance to powdery mildew appears very quickly, above all with the benzimidazoles. Preference should be given to triazoles or strobins when these products are authorised.

Plant Protection Products: Contact fungicides: micronised sulfur

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.

Plant Protection Products: Contact fungicides: copper, captan, mancozeb, maneb and other fungicides (see Annex 1).

Systemic or penetrating fungicides: products belonging to different chemical families (benzimidazoles, triazoles, strobins and others, according to the legislation in force) are normally alternated to prevent the emergence of resistance.

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, from which further contamination originates.
- **leaves:** black, polyhedric 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.

Plant Protection Products: 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 plant material).

4. Orchards establishment

Orchard in Tanzania – photo Gilles Delhove

Orchard in Senegal – photo Jean-Yves Rey

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. 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 obtains 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 2-3 month period of dormancy that precedes flowering, trees optimally should be 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 to limit both 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 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 per hectare. With varieties of medium vigour, densities can be higher, 150 trees per hectare and up to 400 trees per hectare 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 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 hole measuring 50 x 50 x 50 cm is dug at the location of each plant. The earth should be mixed with 20 kg of well rotted manure incorporating 500 g superphosphate or tricalcium phosphate, 200 g potassium sulfate, and dolomite if necessary. The hole is then covered up to form a mound with the soil mixture.

Under certain conditions, structuring the soil with improving plants is recommended. Some species, including grasses such as *Bracharia*, favour soil structure up to a depth of 1 m. However, these soil-improving species exert strong competition on the crop. They are therefore introduced 2 years before the mango trees and destroyed before the trees are planted. An alternative is to destroy the improving plants initially along the rows of mango trees initially, decreasing the width of the remaining strips of grass as the mango trees develop. The choice of improving plant species depends on environmental conditions (soil, rainfall, etc.).

4.3. Plantations

4.3.1. Plantation layout

Care must be taken in staking out the plantation to ensure 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

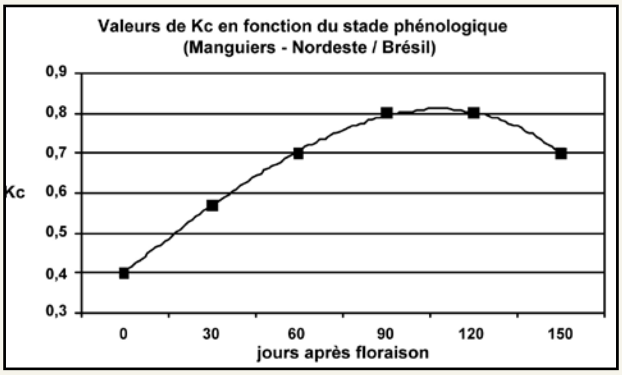
Seedlings should be planted at the beginning of the rainy season when re-establishment is easier. Each clump, with the plastic bag or pot removed, should be planted at the top of the mound. A raised basin should be formed using earth taken from the interline. Initial watering serves to compact the soil moderately and ensure close contact between the surrounding earth and the clump. After initial watering, the trees should be mulched to maintain moisture and 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 evapotranspiration (ETP), adjusted by means of a crop coefficient (K_c ; see figure) that varies according to the plant's physiological stage. Another correction must take into account the growth of trees. The needs of a young plantation are therefore significantly different from those of an adult orchard.



Example of K_c value trends in adult Tommy Atkins mango orchards in Brazil (Silva, 2000.)

In the course of a season, the water consumption of an orchard will vary greatly under the double influence of the increase in ETP and the K_c.
During the first 5 years of an orchard's life, transpiration the mango trees will evolve very quickly in relation to the evolution of the canopy. Irrigation management mainly using climate data is tricky. It is better to rely on the evolution of soil moisture using tensiometer probes placed at a depth of 20-40 cm.
The choice of technique and irrigation management must take into account the climatic demand and development of trees, the water retention capacity of the soil, irrigation system throughput and water quality. Input frequency is strongly linked to the choice of technique. The principle of drip irrigation is based on frequent but limited inputs. Proper management should result in several irrigations per day covering daily needs. With mini-sprinklers or microjets, the frequency of contributions will be lower, two to three irrigations per week covering the needs of several days.

4.4.2. Role of Various Nutrients in Fertilisation

4.4.2.1. Nitrogen

Nitrogen is a major element for the growth of trees. Due to its high solubility, it is usually applied at different times in the course of the year.
Excessive applications of nitrogen have an adverse effect on the quality of mangoes. Imbalances in the Ca/N ratio are implicated in physiological disorders grouped under the term "internal breakdown" (see Chapter 5). This is why most modern mango fertilising programmes set out to limit nitrogen inputs to 300 g N per tree per annum, except on soils that are very deficient.
It is important to avoid excessive nitrogen inputs during the phase of fruit growth by applying them mainly from harvesting to the end of vegetation.

4.4.2.2. Phosphorus

Phosphorus fosters 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 be incorporated into the base dressing.
Thereafter, phosphorus can be incorporated locally every 2 or 3 years over the surface area that mirrors each tree's canopy.
Phosphorus efficiency is hindered by a low pH and high iron level, 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 the quality and storage properties of the fruit.

4.4.2.5. Magnesium

Magnesium plays an important role in the formation of chlorophyll pigments.

Magnesium deficiencies rarely affect young leaves. The symptoms are visible mostly on older leaves of several months. They result in the discoloration of interveinal areas, which become yellowish. A green chevron is often visible at the base of the blade.

An excess of magnesium leads to a potassium/calcium imbalance. Magnesium is applied in the form of dolomite in acidic pH; magnesium sulfate in a high pH.

4.4.2.6. Boron

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

4.4.2.7. Zinc

Zinc is combined with iron and manganese to form chlorophyll.

Symptoms of zinc deficiency are seen when the new vegetative shoots appear, with the presence of small leaves that are is discoloured between the ribs. Excess phosphorus can cause zinc deficiency.

4.4.3. Mineral fertilisation

To establish a fertilisation plan, farmers need information on the levels of major mineral elements in the soil and leaves. It is also necessary to know the level of production of the orchard to evaluate the export of mineral elements from the fruit.

Leaf analyses give a good indication of the "normal" growth of the tree. Otherwise, nutrients can accumulate in the leaves due to poor development of the tree linked to other causes (lack of water, or root and vascular problems). During the first years after planting, annual inputs will be increased gradually to reach a maximum after around 10 years.

It is difficult to establish a reference manuring plan applicable to different locations.

The table below provides ranges of amounts applied in various production areas and for planting densities of between 150 and 350 trees per hectare.

FERTILISER APPLIED (Kg/ha)

Age	Nitrogen (N)	Phosphorus ($P_2 O_5$)	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; 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 according to 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

Young mango trees are sensitive to herbicides, especially position herbicides. It is best to weed manually around the plants. For the application of contact herbicides or systemic herbicides, using a protective cover is imperative to avoid the projection of spray onto the trunk or leaves. In irrigated areas, it is common to combine this with intercropping for the first years. This helps maintain the cleanliness of the young orchard and facilitates the monitoring of plants and their maintenance.

In the non-irrigated orchards of the West African savannas, light ploughing can limit the development of weeds during the rainy season. A final tillage early in the dry season helps keep the floor clean during the dry season.

5. Plant protection

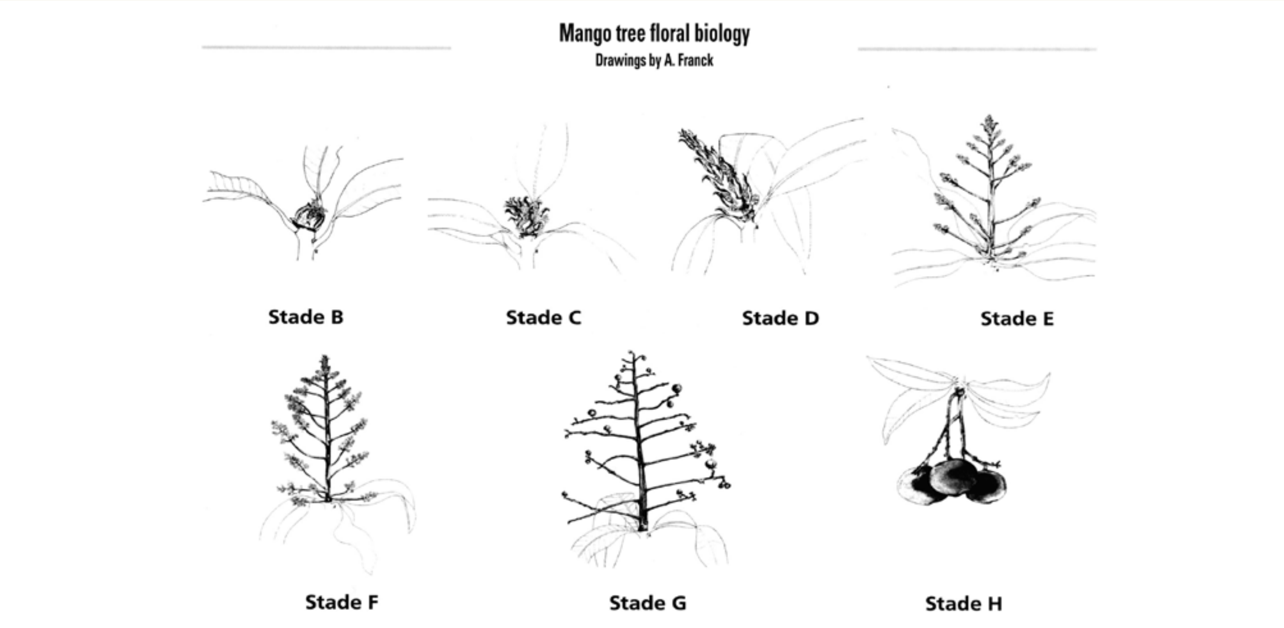
Current methods for plant protection are integrated, and are based on detailed knowledge of the orchard and close monitoring of pest development.

5.1. Steps to implement an integrated plant protection approach

WHAT TO DO?	HOW ?	WHEN ?	WHY ?
IDENTIFY	➢ Visually inspect the various organs ➢ Beat the inflorescences ➢ Set 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 be performed only when there is a real hazard for the crop, neither before nor after
CHOOSE	➢ Adjust strategy on the basis of clearly identified and assessed risk	After every inspection in the orchards	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

It is important to know exactly at which stage of the plant cycle the pest or disease is likely to appear on the crop. The figure below shows the stages of floral development.



5.3. Geographic distribution of diseases and insects

Disease	West Africa	Southern Africa and Indian Ocean	Caribbean	Ecological context conducive to strong expression
Anthracnose	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*	X		Humid tropical areas

* confirmed present in Ghana, Mali and Burkina and likely present in Côte d'Ivoire

Pest	West Africa	Southern Africa and Indian Ocean	Caribbean	Ecological context conducive to strong expression
Fruit flies *Ceratitis* spp.	X	X	X	
Fruit flies *Bactrocera* spp.	X	X		
Fruit flies *Anastrepha* spp.			X	
Mealy bugs	X			Biological control difficult in continental areas
Scales	X	X	X	
Termites	X			
Oecophylla ants	X	X		
Thrips	X	X	X	
Locusts	X			Sudano-Sahelian Zone
Gall midges	X	X		
Whiteflies	X	X		
Bugs	X	X		

5.4. Pesticide treatments

Pesticides are applied differently depending on the pest or disease.
Some pests, such as scale insects, require application of large volumes of mixture at high pressure (using a hose) to ensure the insecticide permeates the entire foliage.
In other cases, it is enough to spray fine droplets on the surface of young leaves and inflorescences (using an atomiser). The intention is to produce a dense mist and ensure that its dispersal by airflow covers the foliage and inflorescences, including the tip and base.

Before performing any treatment, it is important to define the application method, choose the equipment best suited to the situation and check its settings.
A preliminary test with 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. 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:

The product can be sprayed onto 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 of 200-1000 litres) which produces streams that disperse the active ingredient uniformly and regularly, diluted in a fluid, in the form of droplets projected by a powerful air blast onto the plants needing treatment.
- some tanks are equipped with hoses for carrying out treatments that require both high pressure and large flow rates (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 past 3 hours.
- Alternate between families of active ingredients as far as possible to avoid forming resistances.

Spraying trees:

Pesticide recommandations are commonly given in two ways:

- an amount of product to apply per hectare
- an amount of product per volume of water, with the assumption that the volume mentioned covers a hectare.

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

Calibrating the sprayer to deliver a constant quantity of water at all stages is not difficult. Backpack sprayers may be used to spray trees for insect or disease problems; these are 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 sprayer, follow these steps.

1. Pick out a row or area where the trees represent the average tree height and spacing for a fully developed orchard.
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 of the target pest.
4. After spraying the 20 litres of water, count the number of trees sprayed (let's say 12 trees).
5. Next, determine what part of a hectare was sprayed with 20 litres.

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

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

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

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

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

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 stages 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 LITRES PER HECTARE

	Surface area treated: 1 ha	**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 LITRES PER HECTARE

Doses of substance per unit surface area are the same as a treatment with 1000 litres per hectare. However, the volumes of water change and the mixture is therefore twice as concentrated.

	Surface area treated: 1 ha	**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 LITRES PER HECTARE

Doses of substance per unit surface area are the same as a treatment with 1000 litres per hectare. However, the volumes of water change and the mixture is therefore twice as diluted.

	Surface area treated: 1 ha	**Surface area treated: 1000 m²**	**Surface area treated: 100 m²**
Approved dose	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

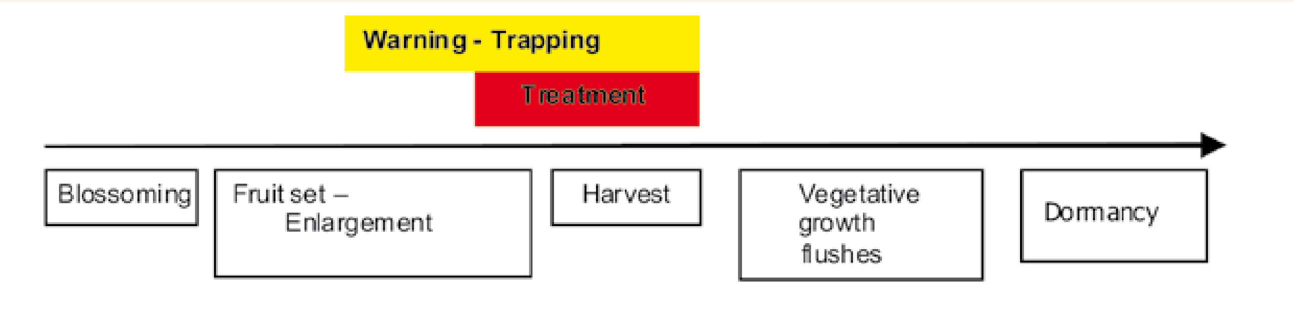
$$\text{Dose of product} = \frac{\text{Dose of active ingredient (g/ha)}}{\text{Active ingredient concentration in commercial product (g/l or g/kg)}}$$

5.5. Pests

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

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, papaya, citrus (orange, mandarin and others, particularly those with a thin peel and non-acid pulp), annona, tropical almond, etc., as well as market garden crops such as cucurbits. Host plant spectrum depends on fruit fly species and country. For more information visit www.africamuseum.be/fruitfly/AfroAsia.htm.

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 has little 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; these holes show 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 are punctured at a late stage, may still be on the tree at the time of harvesting.

Because fly populations build up over the season, 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 2-5 days later. After spending some 9-15 days in the fruit, maggots (the third larval stage), leave the fruit and become pupae in the soil. Adult flies emerge from 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 there are host plants in the vicinity with fruit that reach maturity before mangoes, the risk of mango orchard infestation is significantly increased.

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 attractant:

- sexual attractants, or parapheromones, which attract only males
- food attractants, most often protein hydrolysate, which attract both male and female flies (the majority of fruit flies caught are female and immature males).

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 choice of attractant/s 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 the ability to cause damage should be established experimentally for each growing region to determine infestation thresholds for triggering treatment see CTA and COLEACP (2007) *How to control the mango fruit fly*, http://publications.cta.int/publications/publication/1413.

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	Males of *Ceratitis capitata, C. fasciventris,* and *C. anonae*	Change attractant every month in the traps
Terpinyl	Males of *Ceratitis cosyra, C. sylvestrii, C. quinaria,* and *C.fasciventris* (AW)	
Methyl eugenol	Males of *Bactrocera invadens* and *C. bremii*	
Insecticide	**Effective on**	**Observations**
Dichlorvos	All fruit flies	Change insecticide every month
Food baits	**Effective on**	**Observations**
three components	All female of fruit flies (and sometimes males)	Change attractant every month in the traps

Prevention: The range of preventive methods for controlling fruit fly populations is limited. They apply to the plantation and its environment:

- ➢ Picking up and destroying punctured fruits that have dropped to the ground both within the orchard and in 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. Another, better technique, is to place the fruit harvested in devices called augmentoria (see example below) that prevent the exit of adult flies but allow out any parasitoids of these flies.
  - ➢ Destroying non-beneficial host plants.

Augmentorium, Photo CIRAD

Control without Plant Protection Products: Ants and other insects destroy some larvae in the fruits and pupae in the soil, but natural parasitism of flies is low. Population control can not be only based on biological control methods . Some national programmes do exist, conducted in co-operation with the International Atomic Energy Agency (IAEA), 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.

Predation of *Oecophylla longinoda* on adults of *Bactrocera invadens*
Photo Jean-François Vayssières

Adult of *Ceratitis cosyra* caught by ants
Photo Jean-François Vayssières

Predation of *Oecophylla longinoda* on larvae of fruit flies
Photo Jean-François Vayssières

Nest of *Oecophylla longinoda*
Photo Jean-François Vayssières

Plant Protection Products: Two methods of intervention 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 use, the 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 1 m² per tree). The treatment is effective for about 8 days and must be repeated following heavy rain (>25 mm). Spot applications of this type are performed using knapsack sprayers, allowing treatment just before harvest or even during the harvest as fruit can be avoided. The best known product is Success Appat (see Annex 4).

- **Generalised treatment:** an insecticide is applied to the entire surface at a rate of 800 to 1000 l of mixture per hectare in the case of an adult orchard.
  See Annex 1 on pesticides for use on mango and good agricultural practices (GAPs) tested by PIP regarding residue compliance with maximum residue limits (MRLs). Some active substances comply with EU MRLs at a 7-day pre harvest interval (PHI).

NB: Spot applications may be disappointing in some cases, for example:

➢ orchards surrounded by fruit plantations or wild fruit hedges that are themselves infested with fruit flies,

➢ very high parasitic load following inadequate prior control of the pest (e.g. many punctured fruits on the ground, no generalised treatment at the beginning of the season to avoid the early pullulation of flies).

Fruit flies consuming leaves covered with Success Appat,

Photo Jean-Yves Rey

See Annex 1

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 cases of severe attack, 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 trilobitiformis*

➢ soft scale such as *Icerya* spp, *Pseudococcus* spp, *Rastrococcus* spp. Two major mango scale pests are: *Icerya seychellarum*; *Rastrococcus invadens*.

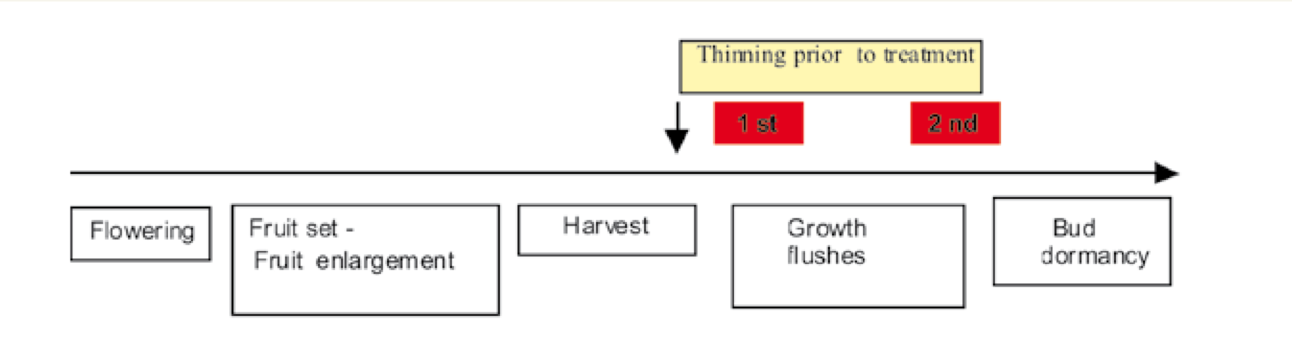
Plant Protection Products: The basis for shield scale control is by applications of white oil that acts by smothering the pests.
Scale insects are more vulnerable at the juvenile stage of development when larvae are motile. Treatment is most effective in this period.
See Annex 1.

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. Trees that suffer heavy attacks during the rainy season do not flower the following season.

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 easily identified by a "wet" area underneath the foliage and the presence of sooty mould. Inspection of the undersides of the leaves reveals 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.

Control without Plant Protection Products: Biological control can be achieved using parasitoids from Asia: *Anagyrus mangicola* and *Gyranusoïdea tebegy,* and to a lesser extent with natural, endemic parasites. Hence, care must be taken not to undertake premature generalised chemical control, which 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).

Plant Protection Products: Chemical control should be considered only once natural biological control has proved to be ineffective.
Treatments should be applied after the end of the harvests and before the emergence of new vegetative shoots so as not to jeopardise future flowering. Two treatments spaced 15 days apart are recommended in cases of heavy attack. It is possible to renew treatment 1-3 months later, at the beginning of the dry season. It is best to prune the mango tree before application to facilitate the penetration of products. The use of tractors with lances is essential to ensure that the entire canopy has been treated: both surfaces of the leaves, and the interior and the exterior of the tree.
See in Annex 1 foractive substances used and the GAPs to be respected for compliance with 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.

Plant Protection Products: use of plant protection products is difficult, so control strategies should focus on preserving the beneficial fauna, which play a very useful role. Spinosad has given very 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 three treatments per year. See Annex 1 on pesticides for use on mango and GAPs tested by PIP regarding residue compliance with EU MRLs. Some active substances comply with MRLs at a 7-day PHI.

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 five punctures per cluster are observed on 100 panicles in an orchard.

Young leaves respond to punctures by developing highly characteristic galls. 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 observed only it has occurred. The concepts of risk area or susceptibility stage (the emergence of new leafy shoots) can serve as guidelines.

Plant Protection Product: see Annex 1, which distinguishes between the two types of pest.

5.5.6. Whiteflies: *Aleurodicus dispersus*

This is a homopteran insect belonging to the family of Aleyrodidae, 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 *Encarsia haitiensis* (Hymenoptera) feed on these larvae and provide biological control.

Plant Protection Product: See Annex 1 for pesticides for use on mango and GAPs tested by PIP regarding residue compliance with EU MRLs. Some active substances comply with EU MRLs at a 7-day PHI.

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

The Mango bugs 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 - a few days or even a few hours. Quick response is essential.

Plant Protection Product: See Annex 1 for pesticides for use on mango and GAPs tested by PIP regarding residue compliance with EU MRLs. Some active substances comply with MRLs at a 7-day PHI.

Spraying of biological black soap is effective for control of this pest.

5.5.8. Locusts

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

Plant Protection Product: Usually controlled 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 resistance. It is therefore appropriate in each region to check the efficacy of active ingredients with the local plant protection services.

Control without plant protection products: biopesticides based on Metarhizium anisopliae are particularly effective.

See Annex 1 for pesticides for use on mango and GAPs tested by PIP regarding residue compliance with EU MRLs. Some active substances comply with EU MRLs at a 7-day PHI.

5.5.9. Termites

A broad range of species cause damage.

Stage of highest susceptibility: All stages.

Other host plants: Many woody and semi woody 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.

The latter type can be quite common. They are rarely attributed to the effects of underground termite attacks that destroy the root system. Making excavations near decaying mango trees makes it possible to check if termites are involved.

In general, the mosts damage to the tree is located at the base of the trunk, on the stump and on the proximal portion of the large roots. This damage is not caused by large termites (Macrotermes), which build large mounds, but by Microtermes. It is therefore unnecessary to target Macrotermes, which play an important ecological role in the functioning of the soil.

Conditions conducive to infestation: Termite attacks occur throughout West Africa. The phenomenon is much more marked in the Sahelian region than in the maritime area, as the trees, which are stressed due to water deficit, for example, attract termites and are less tolerant to their attacks.

Methods of observation: Identification of crusts on the trunk and scaffold branches. If there are signs that leaves are wilting and twigs are drying out, dig around the tree to identify possible underground attacks.

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 avoiding leaving large quantities of woody debris or dead trees in the orchard. Whitewashing tree trunks with milk of lime limits the activity of aerial termites.

Control without Plant Protection Products: Experiments to test the efficiency of entomopathogenic fungi such as *Metarhizium anisopliae* are currently being conducted.

Plant Protection Products: The range of active substances that can be used is limited. The fight against termites comes under the specific register of localised soil treatment. Doses are usually given in grams of active ingredient per m^2. It is preferable to carry out the treatments after harvesting to avoid any residues on fruit, and if possible just before or at the beginning of the rainy season. In Mali, for example, the treatment takes place after the last harvest at the beginning of the rainy season, then 2 months later, towards the end of the rainy season.
To ensure that the product penetrates sufficiently, it is recommended to scrape the ground slightly before applying the pesticide. This application must be made at the base of the trunk and on the ground around the trunk and be followed by abundant watering to ensure that the product penetrates well.
Termites easily detect individuals affected by either entomopathogenic organisms or pesticides, and throw them out of the colony. For pesticides, there are some exceptions to this rule: fipronil and groups comprising acetamiprid, imidacloprid and thiamethoxam. As these pesticides are not, or are poorly detected, they can reach and poison the queen after being transported though a chain.
This mode of action explains the efficacy and durability of the action of these pesticides.
See Annex 1 for active substances that can be used and the GAP to be respected for compliance with MRLs.

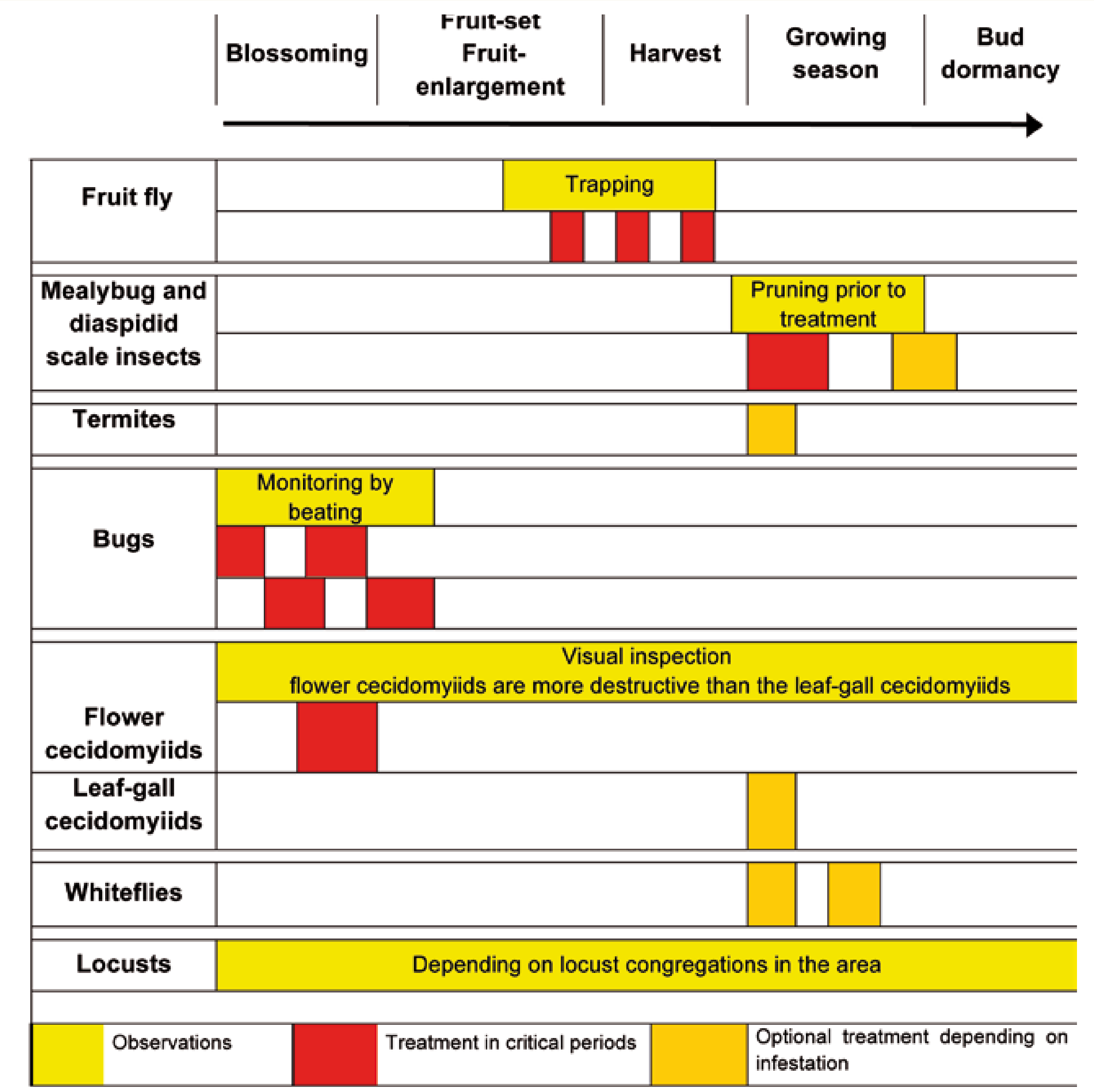
5.5.10. Mango seed weevil

The females lay their eggs at random in depressions on the surface of fruit during ripening. After hatching, the larvae make their way through the flesh to the seed that is being formed. Typically a single larva per fruit reaches the adult stage. Larval development usually takes place inside the seed, very rarely in the flesh. The adult weevils typically leave the seed 1 or 2 months after fruit fall. They damage the flesh of ripe fruit during this operation, and infested seeds may limit the reproduction of plants in nurseries and orchards. A severe infestation can cause premature fruit drop. Adult weevils are in diapause under the bark or under clumps of stone until the next flowering. During their period of activity, they move only when night falls.
These pests are quarantine pests for the EU. Among the major exporting countries of West Africa, this insect is present in some coastal countries but production areas for export are free of infestation. In this case, great care should be taken when transporting fruit and seeds from the South to the North and the seeds incinerated after use. For more information on this pest see http://etd.uovs.ac.za/cgi-bin/ETD-search/search (keywords = mango seed weevil)

Adult attacked by ants

Photo Jean-François Vayssières

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



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 affect 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. 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 in 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 (Figures2-5 in Annex 3). The following table summarises the fungi that produce post-harvest lesions on mango after incubation in the producer country or upon import to Europe, and 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.

THE PREVALENCE OF FUNGI ASSOCIATED WITH POST-HARVEST ROT ON MANGO PRODUCED IN SENEGAL JULY-SEPTEMBER 2004, ANALYSED AFTER INCUBATION AT AMBIENT TEMPERATURE IN SENEGAL OR UPON IMPORT TO EUROPE

Type of rot fungus	Relative frequency		
	in Senegal		import to Europe
	July	August and September	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 and Penicillium	-	-	+++
Fusarium	-	-	+

-: not detected; + detected on < 10% of fruit or lesions per batch; ++ detected at least one out of 10 times on 10-20% of fruit or lesions per batch; +++ detected at least once on 21-40% of fruit or lesions per batch; ++++ detected at least once on 41-80% 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 shedding of 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, such as lenticels or an injury. Its penetration will be blocked by the presence of inhibiting substances, such as 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 in 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 humidity (>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, cashew, banana, coffee, papaya, etc. A range of other species are also affected: sugar cane, alfalfa, peppers, etc. The populations of pathogen that colonise these different hosts, especially mango, are nonetheless highly heterogeneous. Differences in host range and aggressiveness, as well as sensitivity to fungicides, have 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 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 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 in 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-h 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 in 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: *A. 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* spp.
For three out of 10 batches of mango from Senegal analysed upon import, the proportion of lesions caused by *Cercospora* spp. 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 in 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 spp. were 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 in Annex 3). 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* spp., *Phoma* spp. and *Bipolaris* spp.**
These pathogens 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 (syn. *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 *Botryosphaeria* (Loculoascomycetes) 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 conidial reproduction are seen in *Lasiodiplodia, Botryodiplodia, Diplodia, Fusicoccum, Nattrassia* and *Hendersonia*. The nomenclature of several of these conidial stages, for example in *Dothiorella*, is currently being called into question, giving rise to considerable confusion in terminology and taxonomy, 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 in Annex 3). A superficial subcuticular 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 from which they 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 in 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 described 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, *L. theobromae* will be predominant over *D. dominicana* at 30°C, while the opposite is the case at temperatures ≤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 *L. 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 in Annex 3) or randomly on fruit (Figure 6B in 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, are able to survive 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. 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 marketing. The following table shows the usefulness of various protective measures, sources of inoculum and conditions for fungal infection and development.

THE MAIN FUNGI ASSOCIATED WITH POST-HARVEST ROT IN WEST AFRICA: SOURCES AND DISPERSION OF INOCULUM, CONDITIONS OF INFECTION AND DEVELOPMENT, AND USEFULLNESS OF PRETECTIVE 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-harvest	
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 the lower branches off of the ground;

Stake up lower branches to prevent fruits from touching the ground, photo Henri Vannière
- implement measures to limit fruit fly populations.
- regularly collect fruit that has dropped to the ground and bury it by covering with soil to prevent 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.

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. Use of Plant Protection Products in orchards: Preventive measures may prove inadequate for limiting the development of diseases when damp periods (rain, abundant dew) coincide with a 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 2-3 weeks subsequently as necessary, according to the staggering of flowering and the washing off of products due to rainfall.

It is 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 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 become less effective;
- spraying can have a negative impact on microflora that are enemies of agents causing post-harvest rot and paradoxically may lead to increased numbers of such agents;
- treatment of larges trees strongly increases the risk of excessive fungicide 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. Annex 1 shows which active substances may be used and describes the GAP to comply with current MRLs.
Certain active substances may be used during the harvest period when a 7-day 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 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 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 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 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 treatment. The use of benzimidazoles or strobilurins as a pre-harvest treatment risks the selection of resistant strains and thus reducing 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 section 6) 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 when quiescent infections are reactivated often inhibits them effectively, and 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 5 mins. 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 1°C. 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 . 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 insufficient and is consequently often combined with fungicide treatment..

5.6.1.6.2. Plant Protection Products used in market preparation stations:

Several types of active substance with 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);
- 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 81 g 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 a.s. per hl in Brazil, and 24.75 g a.s. per hl in Australia. In Israel, the combination of brushing under a warm water shower and soaking for 15-20 s in 22.5 g/hl prochloraz has proven to be as effective in 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 Annex 1 for active substances that may be used.

5.6.2. Powdery Mildew: *Oidium mangiferae*

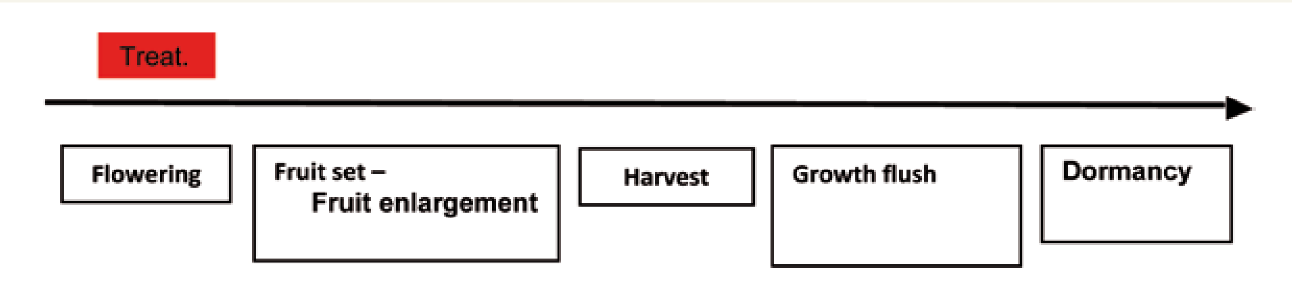
Symptoms and damage: The juvenile tissue that is attacked becomes covered with whitish mould (mycelium). The mycelium rapidly colonises the inflorescences, causing necrosis of the tissue.

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) with relative moistures as low as 20%. Such conditions often occur at the beginning of the cycle, when new leaves and new inflorescences are emerging. In the tropics, 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 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.

Plant Protection Product: 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 8-10 days, and more frequently in the case of rainfall over 25 mm. As soon as the first symptoms appear, the only way to halt disease progression is by curative treatment using systemic fungicides. The various chemical families should be used in alternation, sometimes including contact fungicid es, to avoid creating resistant strains. Micronised sulfur continues to be an economical active ingredient and is the basis for preventive treatment. See Annex 1 for other active substances.



5.6.3. Mango Scab: *Elsinoë 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 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 continue to remain superficial and do not affect the flesh. They may cover a considerable portion of the fruit.

Plant Protection Product: 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 with those used against anthracnose.
See Annex 1 for pesticides for use on mango and GAPs tested by PIP regarding residue compliance with EU MRLs. Some active substances comply with MRLs at a 7-day PHI.

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

This very serious bacterial disease is frequent in Asia, southern Africa, the Indian Ocean countries and Australia.
The bacterium can survive as an epiphyte on mango trees, and contaminated plants do not always display visible symptoms. The bacterium is transported mainly 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 cases of severe infection, canker may develop on the twigs. Foliar symptoms begin with small oily spots delineated by the limb veins. These go on to become raised black spots surrounded by a chlorotic halo. Early spots are 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 exudtes. These spots are frequently distributed in a tear stain pattern.
Contamination is always external. Tropical rainstorms are highly conducive to dispersion of the inoculum 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 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 1 month before harvest.

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

Plant Protection Products: 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.
Non-chemical control: 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 Annex 1 for pesticides for use on mango and GAPs tested by PIP regarding residue compliance with EU MRLs. Some active substances comply with MRLs at a 7-day 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 necrosis. In some cases, apparent signs are moderate whereas internal damage is considerable because the underlying flesh is vulnerable. Sunburn can cause severe economic losses. A number of simple techniques can be used to limit this type of damage. Because these methods are not more widely known, they are rarely implemented. In some cases, burning is due to an important drying up of the tree, and only watering can limit damage. But sun-burning can also occur in well irrigated orchards, especially on the part of the tree exposed to the sunset. Whitewash solution with an adjuvant adheres to the skin of fruits and protects from sunburn. Commercial products based on kaolin or calcium carbonate are available to protect from sunburn, and also have a repulsive action against fruit flies.

Leaves cut down and whitewash on fruits in Brazil, Photo Henri Vannière

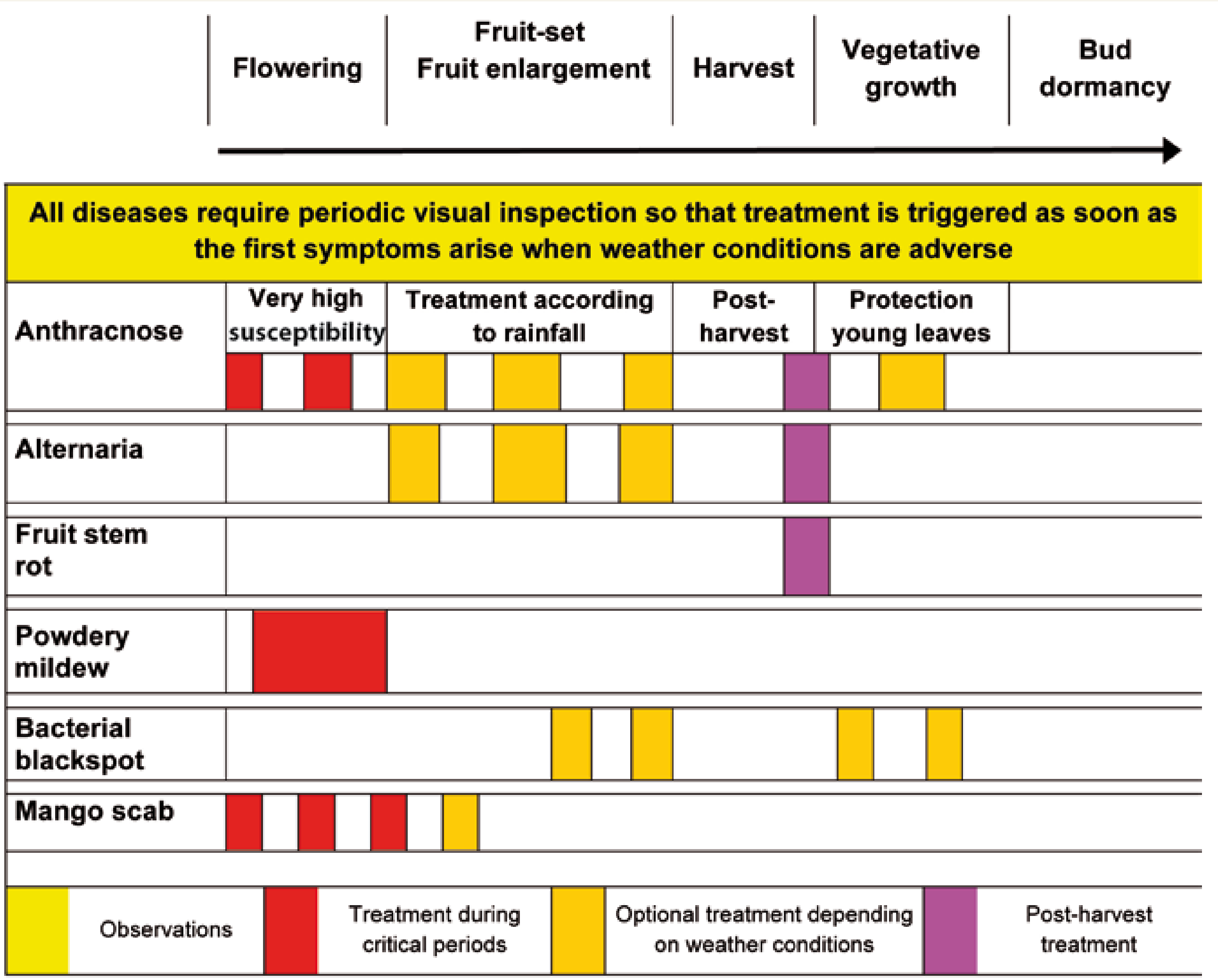
Internal breakdown

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 externally. 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 associated with varietal susceptibility:

soft nose is most often seen on cultivars Kent and Smith 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 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.

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



6. Harvesting

General considerations

For the best flavour, fruit should be picked as late as possible before the natural ripening process begins. The flowering period lasts at least 3 weeks, and up to several months in areas where the same variety has several flowering periods.
However, even in areas with only one flowering period, not all fruit on the same tree will have reached the same stage of ripeness at harvest time.

Advancing the harvest offers advantages by reducing health risks and the risk of over-ripeness on arrival, but essentially amounts to exporting a majority of unripe fruit that has not developed its optimal organoleptic qualities. At a time when countries such as Spain are making huge efforts in this area, based on short transport periods, more distant countries of origin should aim to improve the organoleptic qualities of the mangoes they export, otherwise consumers may turn to other sources.

But harvesting at average adequate ripeness imposes strict conditions:
- mastering harvest criteria, until non-destructive equipment to assess ripeness can be made available (research in progress) this requires experienced pickers,
- ensuring uniform ripeness as far as possible in fields (harvesting at intervals in the same field, very skilled pickers, etc.) and in packing stations,
- effectively managing diseases and pests,
- controlling the cold chain.

Implementation

Before harvesting the crop, it is advisable to take samples across the entire plot in order to assess the quality of the fruit:
- maturity,
- presence and extent of diseases and pests,
- presence and extent of physiological defects, physical alteration of the skin: sunburn, scratches, etc.

Plots with an excessively high rate of defects will not be authorised for export markets. It must be checked that no treatment has recently been applied that does not comply with the recommended PHI.

Harvesting requires the use of well trained staff who follow the instructions in order to:
- differentiate between fruit from different flowerings,
- select mangoes that meet the criteria defined by the packing station,
- handle fruit carefully to avoid shocks, scratches and contact with any source of contamination: leaf litter, dirty harvest crates, wet and/or sandy-gritty soil, etc.,
- manage the flow of sap and avoid staining the fruit with latex,
- sort the fruit a second time prior to transport to the packing station,
- properly arrange the fruit in transport crates.

Mangoes are selected for export by taking into account:
- physical external appearance: at least one coloured face, a well sunk stalk and rounded shoulders, no damage or scratches due to friction or spotting ...
- detection of under- or over-ripe fruit,
- detection of malformations and physiological disorders: soft nose (flexibility observed near the stylar end), sunburn, etc.
- detection of fruit fly punctures, ant bites, etc.

6.1. Cutting point

The mango is a climacteric fruit whose ripening process starts on the tree and continues after harvesting:
➢ if harvested too early, the fruit shrivels without really maturing.
➢ if harvested too late, its shelf life will be too limited to withstand transport over long distances.

Managing the cutting point is a major concern for exporters and must take into account the method of transport (plane or boat). When transported by plane, the fruit harvested can be riper, while maritime transport requires earlier harvesting.

To date, there is no reliable, non-destructive method to judge the ripeness of mangoes in the field. The determination of the cutting point is partly empirical and takes into account various criteria:
- time between flowering and harvesting,
- changes to the colour of the flesh (pale yellow),
- changes to the colour of the skin,
- fruit shape (especially the shoulders)
- presence of a bloom (whitish veil, powdery appearance) on the skin.

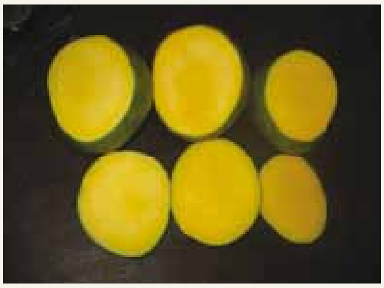
Observing the flesh colour is the most reliable characteristic. This criterion is one of the main references used by the major exporting countries. However, its destructive nature limits its use. At the beginning of harvesting, assessment of the average degree of maturity of fruit on a plot will be performed on representative samples. In addition, periodic inspections during harvesting make it possible to avoid any deviation.

The heterogeneity of the maturity of mangoes on a tree and/or orchard is a major constraint. Mastering the management of this heterogeneity is largely dependent on empiricism and the expertise of the harvesters. Each growing area has established its own references based on the above-mentioned criteria.

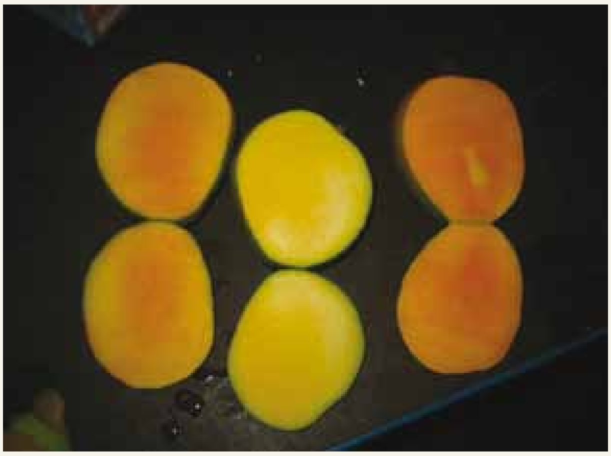
Appearance of fruit upon arrival in Europe

Below: fruit picked before it is sufficiently mature. It has a white colour over all or part of the pulp. This fruit will never achieve good organoleptic qualities. Immature fruit shrivel, especially when harvested before the rains, in the absence of irrigation. It has a low turgidity; water loss during the harvest conservation phase causes this phenomenon (right).

The fruits below are ripe



The fruits below are over-ripe compared with the control fruits



Below: fruits with internal physiological defects that were not detected during harvesting or packaging, and were then secondarily infected by fungal or bacterial rot

6.2. Precautions during harvesting

Freshly harvested mangoes exude latex that flows through the cut stalk for several minutes or even an hour after being harvested.
This latex burns the fruit's skin, which deteriorates irreversibly. Great care must be taken when handling fruit during and immediately after harvesting to avoid this type of damage. The mango stalks are not cut to the same length in all production areas. While procedures may differ at the harvest site, the goal should remain the same: to avoid contact, directly or indirectly, between the latex and the skin of the fruit.

In West Africa, the fruit is usually harvested manually, keeping a long stalk. The use of blunt harvesting tools (sticks) should be prohibited.

The Brazilian technique which uses fruit pickers, equipped with a bag or net, is considered unsuitable because of the amount of latex exuded and the size of the trees, commonly grown in free forms. In the event that the stalk breaks, latex flows out and impregnates the bag or net, burning the fruit. The spurt of sap is lower in Brazil because of the lower turgidity. Different parameters explain this different behaviour: specificity of the variety, arid climate during harvest, cultivation techniques including induced water stress before harvesting, etc.

In West Africa, because mangoes have a different behaviour, harvesters use a different technique. A blade mounted on the end of a stick is used to cut the fruit from the periphery of the tree and a partner catches them before they hit the ground. The mangoes on the inside of the tree are handpicked along with the stalk by harvesters climbing into the tree or on ladders.
Cherry pickers, the ideal tools, are too expensive.

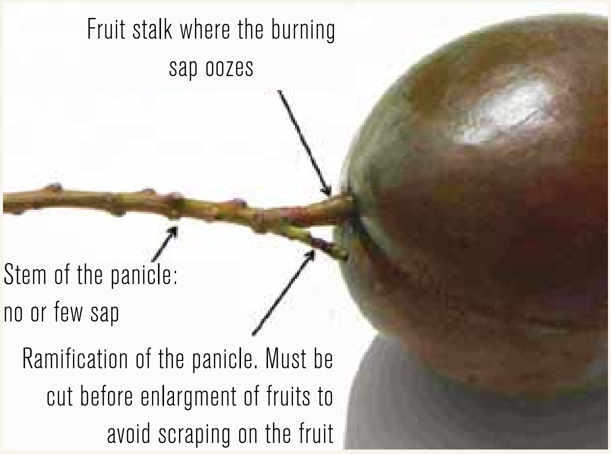
All impacts that are liable to impair conservation should be avoided during harvesting. In the orchard, all sorting operations and temporary storage of the fruit should be carried out away from direct sunlight, on clean sites to avoid soiling the mangoes with particles of earth and to prevent their contamination by pathogens present on dead leaves, twigs or inflorescences, or necrotic fruit. These aspects, which are often overlooked, are the cause of many conservation problems (fungal attacks, alterations to the flesh).

Most harvesters line crates with mango leaves to protect the fruit during transport to the packing stations. This practice should be prohibited because it contributes significantly to the spread of invasive diseases, bacterial blight in particular. The leaves of other plants can be used with the same efficiency but they do not spread mango tree diseases.

The following photographs (credit: Jean-Yves Rey) illustrate the main technical procedures that should be followed or avoided. They concern the handling of freshly harvested fruit and sap flow management. These practical recommendations are important to preserve the visual quality of mangoes and avoid any risk of secondary contamination by pathogenic flora.

Good harvesting practices

The fruit stalk includes the stem of the former floral panicle and the fruit stalk in the strict sense. The latter, not the panicle, contains the burning sap. One stem can support multiple fruits.



In Brazil, harvesting of Tommy Atkins mango fruit cut into fruit hedgerows. A worker cuts the long stalks and another holds the net underneath.

Traditional fruit harvesting. The stalks are caught in the inverted V and snapped off. This tool makes it possible to reach fruit very high up in the tree. It is preferable to replace the pieces of wood with very sharp metal blades.

The fruit detached from the tree are collected in a bag before they hit the ground. Seasoned harvesters catch mangoes by hand. It is essential that the fruit does not fall on the ground.

Fruit harvested with stalks whole.

During harvesting the stalks are cut, preferably 10-15 cm long, and the mangoes are turned so that the stalk faces downwards so as not to be stained by the latex. However, when the stalks are cut in the strict sense to their final length in the field (as for almost all West African exports), there is no need to cut the stems to 10-15 cm beforehand.

The stalks will be recut to their final size in the field before transport or in the packing station (Best sap flow practices, below)

When transported over long distances or over tracks, it is strongly recommended to cut the stalks to their definitive size in the field because when a stalk breaks near the fruit during transport, all the fruit around it are burned by the sap.

Cutting stalks in the field: the fruit stalk is held with the stalk facing downwards, and the stalk is cut with pruning shears at the stem (or rachis).

After cutting the stalk, the pruning shears remain clean.

6.3. Post-harvesting

6.3.1. In the field

The stalks are quickly recut at the level of the ring (about 0.5 cm from the point of insertion in the fruit). During this operation, the mango is placed upside down to avoid contact between the latex and the skin. The fruit remain in this position until the end of the sap flow (0.5-1h). Some producers use rigid supports (metal or wooden frame supporting a wide wire mesh) to hold the fruit during this operation. This device offers the advantage of preventing the fruit from from contacting the ground. This practice is strongly recommended to avoid infestation by stalk diseases (and other types of contamination; see section 5). The fruit should then be placed in plastic boxes in two layers, ensuring that they are securely packed.

Good sap flow practices

Cutting at the fruit stalk: the stalk should be cut to this length before packing (in the field or arrival at the packing station, not during harvesting).

The fruit are then often placed, stalk pointing downwards, on clean soil until the coagulation of the sap, but it is preferable to lay the fruit on tables to prevent pathogens responsible for stalk rot from penetrating the stalks. The tables are made with wire or parallel iron rods. Such tables are increasingly used in West Africa because they make it possible to limit -if not prevent- stalk rot.

Fruit placed on the ground (to be avoided)

Cutting stalks before placing fruit on tables.

Two types of table

Once the latex has coagulated, the fruit are crated. At this point the fruit must be free of grit or any other element that can damage the skin during transport. In rainy weather, fruit placed on the floor should be washed before crating.

Fruit in a crate awaiting packing in readiness for export by plane

6.3.2. Transport from the orchard to the packing station, grading

The fruit must be transported as quickly as possible. Upon reception, the fruit will be placed in the shade in identified batches of the same origin. It is preferable to perform the definitive grading a few hours after the arrival of mangoes at the station. This allows the emergence of some defects caused during harvesting or transport. The accepted fruit is then weighed.

6.3.3. Packing at the station

Packing stations must be light, airy premises that are spacious enough to carry out all packing operations. The fruit will be stored there by homogeneous batch (origin, variety) before being removed one by one.

The equipment at the packing station must be in good working order and clean: washing tanks, tables for sorting and packing coated with a layer of foam, if possible a mechanical grader and a treatment bath. It is necessary to ensure that the water used is of high quality and sufficient to perform all the washing and cleaning operations involving the fruit with clean water.

The staff must be trained in advance, respect hygiene instructions, and perform the tasks rigorously. All persons handling fruit must have short nails so as not to damage the mangoes.

All packing operations include at least the following:

- prewashing of fruit in a tank with water regularly replaced
- hand washing with clean water that is regularly replaced
- cleaning with clean sponges
- wiping
- sorting to remove any fruit that does not meet export criteria, with particular attention to fly stings (quarantine pest)
- grading (see Annex for the references for the fruit size/weight)
- crating
- weighing and weight adjustment (usually of each box)
- storage
- palletising
- storage in a cold room.

Packing in the station

In small stations, the fruit are prewashed in simple tanks. It is preferable to have two tanks: one for the prewash, the second for the actual washing.

(Photo - Michel Gbonamou)

In larger stations, the fruit are poured into reception tanks and then transported by a mechanical conveyor autoloader.

At the end of the first prewash, if not previously cut, the stalks are cut mechanically flush to the fruit and the fruit are immersed in a second tank to coagulate the sap (Brazil).
Whatever the technique, the water must be replaced regularly, particularly when stalks are cut in the station.

In modern packing lines the fruit are not washed but are showered under high pressure.

After soaking, fruit are brushed to remove impurities located on their surface.

On this model of a Tourangelle brushing machine, above the brushes with hard short bristles there is a polisher with long, flexible bristles that dries the fruit and makes them shine.

6.3.3.1. Control of fungal diseases, heat treatments

There are methods of controlling fruit flies and fungal diseases arising from conservation (anthracnose, stalk rot, *Alternaria*, etc.) that can be implemented during the packing process in the station.

Soaking the fruit in hot water to prevent fungal diseases or fruit flies should be performed on clean fruit. The sap adhering to the skin may cause burns under the effect of heat.

6.3.3.1.1. Treatments against fungal diseases

It is important to remember that fungal and bacterial diseases thrive on injuries to the fruit. While fruit that are visibly injured are removed during packing, micro-injuries are not always detectable, as well as "inevitable injuries" such as the cutting of the stalk.

Basic precautions during harvesting, the cutting of the stalk, handling and transport to the packing station are the first measures to be taken in the fight against post-harvest diseases.

The basic principle is to combine a thermal treatment (immersion of fruit in a hot water bath or washing with a hot water shower) with the application of a fungicide (bath or spray).

Familiarity with the nature of the fungi to be controlled is imperative in order to implement a suitable protocol. All fungal diseases are not due to anthracnose. The precise definition of the temperature of the water, dipping or spraying, duration of treatment are all parameters that vary depending on the problem. For example, some agents of the parasitic complex causing stalk diseases (*L. theobromae* and *D. dominicana*) are destroyed only at temperatures of about 55-56 °C, which is at the limit of what fruit can withstand. Depending on the nature of the pathogen, the nature of the fungicide will be different. For more details on the protocols see section 5.

The photos in A show that visual symptoms (necrotic spots) do not make it easy to distinguish between these diseases; only laboratory tests provide an accurate diagnosis.

Soaking against fungal diseases: tank for soaking fruit in hot water containing a fungicide. The solution reaches about half-way up the fruit, which is moved through the tank by rotating rollers. This bath can be replaced by showers and vigorous brushing. The hotter the water, the shorter the procedure (10 min in the case of the bath used with this machine).
(Photo - Jean-Yves Rey)

When the fruit are dipped in fungicides and waxed, drying is then performed with fans pulsating ambient or hot air depending on the natural climatic conditions.
(Photo - Jean-Yves Rey)

6.3.3.1.2. Treatments against fruit flies

Different countries, including the USA, require that mangoes exported on their territory are routinely treated against fruit flies. European countries do not have this requirement.

It is possible to destroy fly eggs and larvae in fruit by subjecting it to heat treatment (hot water bath).

The most widely used technique is to separate the mangoes into two categories according to their weight: more or less than 450 g. Batches of uniform size are immersed in a hot water bath at 46.1° C for 75 min for smaller fruit and 90 min for larger fruit. It takes more or less the same time for the water temperature to rise and cool. This heat treatment is therefore a long and expensive operation.

Other techniques exist using vapour flows, developed in New Zealand.

All these methods are cumbersome to implement and are costly. They are accessible only to structures handling high volumes of mangoes (several tens or even hundreds of tonnes per day).

Dipping to destroy the larvae of fruit flies before shipping fruit to the USA. The cages are lowered gradually into pools. This takes several hours in view of the warming phase, the soaking phase at a constant temperature, and the cooling phase.
(Photo - Jean-Yves Rey)

6.3.3.1.3. Waxing

The use of heat treatments has an adverse effect on the appearance of the skin. Applying wax followed by polishing can give a shiny appearance to mangoes. The waxes used may be produced from either natural or synthetic products.

Currently (September 2012) the additives authorised for use on fresh mangoes in Europe are:

E 473 - 474	Sucrose esters of fatty acids - sucroglycerides	Fresh fruit, surface treatment
E 905	Microcrystalline wax	Surface treatment on mangoes and other fruit
E 912	Esters of montan acid	Surface treatment on mangoes and other fruit
E 914	Oxidised polyethylene wax	Surface treatment on mangoes and other fruit

Beeswax (E 901), carnauba wax (E 903) and shellac (E 904) will be allowed on mangoes from late 2012 with implementation beginning in 2013.

The regulatory developments can be monitored at: https://webgate.ec.europa.eu/sanco_foods/main/?event=category.view&identifier=50

Over and above the aesthetic aspect, these products play a role in gas exchange. The film created by the application of a wax makes it possible to create a chamber around each fruit in which the composition ($O2/CO2$ ratio) of the atmosphere is changed with respect to the ambient atmosphere. These coating techniques are being studied further to determine their effects on the evolution of the external colour and the improvement the shelf life of mangoes.

6.3.3.2. Sorting and grading

The sorting should be done on a long mat by very competent staff. This is the critical phase of packing as far as quality is concerned. Sorters will remove all fruit with unacceptable defects, including damage or presence of insects, especially quarantine pests (fruit flies), fungal and bacterial diseases, insufficient or excessive maturity, injuries to and defects of the skin, sunburn, deformations, etc. Physiological defects are not easy to detect, mainly to the touch. See also http://www.cop-horti.net/IMG/pdf/Pages_de_21135_-_PDMAS_-_guide_pages_21_a_30.pdf.

Various models of grader are used, depending on the speed of the packing station. Rotary graders can handle 500-800 tonnes per harvest depending on the organisation of the station, while mechanical or electronic graders make it possible to condition 2,000-5,000 tonnes per year or more, depending on the daily working time. The accuracy of online graders is much better than that of rotary graders, which nevertheless are excellent equipment, durable and cheap, for novice exporters.

The quantities of mangoes packed every day depend as much on the competence of the personnel and organisation of the work as on the speed of the grader.


Sorting (Photo - Jean-Yves Rey)

Cup grader (Photo - Jean-Yves Rey)

6.3.4. Crating and palletising

After sorting and grading, the fruit are arranged according to grade in boxes of 4 or 5 kg (containing 6-12 fruits depending on their size).
The fruit are laid down, and sometimes protected from each other using tissue paper or polystyrene tubes to avoid injury during transport. The boxes are placed on pallets with angle protections and horizontal strapping:
- maritime transport to ISO (1.2 x 1 m), these pallets are often more robust;
- transport by plane (1 x 1 m).

As soon as the pallet is put together, the boxes are marked individually with the reference of the variety, size and packing station. Each pallet is identified by a code referring to the order number and origin of the batch or batches of fruit that constitute it. These references are recorded in an inventory used for the traceability system.
For exports to certain destinations such as the EU, wooden pallets must be disinfected prior to shipment in accordance with the regulations in force (steam).


Crating of graded fruit and finalisation of preparation (labelling, marking, traceability). (Photo - Jean-Yves Rey)


Box gluing machine (Brazil). Various African stations use this material instead of manually assembled boxes (saving cardboard, increased strength, etc.) (Photo - Jean-Yves Rey)

Pallet assembly (Photo - Jean-Yves Rey)

Pallets (Photo - Jean-Yves Rey)

6.3.5 Cold Storage – the Cold Chain

From harvesting to crating, all mango handling procedures are performed at ambient temperature (20-30°C). The action of lower temperatures has a very favourable effect on shelf life within limits that must be familiar to exporters.
Mangoes cannot withstand low temperatures. Temperatures below 10°C are often the cause of physiological damage (brown spotting of the skin, flesh browning, etc.).
This means that mangoes are ideally stored at temperatures between 8 and 12 °C. This depends on the variety and the degree of ripeness of the fruit (the most mature withstand temperatures a little lower). A period of 24 h between harvesting and placing in cold storage is believed to promote the fruit's resistance to cold.

With palletisation, the volume of fruit to be cooled is significant. Heat exchange is difficult for the fruit placed in a central position in the palette.
Several techniques exist to quickly bring down the temperature of mangoes:
- Hydrocooling -immersing the fruit for a few moments in a cold water bath just before the end of packing and crating. This technique, which involves wetting the fruit, is not always compatible with the other interventions. It requires a system of effective drying.
- Forced ventilation, which involves injecting a powerful flow of cold air through all the boxes of the pallet to cool the mangoes rapidly. This technique is most commonly used by large packing stations.

When pallets are cooled to the core, they are placed in a cold room at a temperature of 10-12°C. The humidity is maintained at 90% and the air is replaced to prevent an increase in CO2 and ethylene.

Prior pre-cooling can be beneficial when packing stations are distant from the final destination. It is also believed to reduce the incidence of post-harvest fungal diseases.

Container awaiting loading. When stations are far from the port, the containers must be connected to a power supply during the static phases. During transport, an electric generator (at the top and at the front of the container) supplies the cooling system with electricity during transport
(Photo - Michel Gbonamou)

Full containers must be connected to a power supply during the static phases. (packing stations, railway stations, ports): photograph shows Ferkessédougou fruit terminal.

6.3.6. Transport

Before loading, the fruit must undergo the custom control formalities and plant protection formalities.

Mango are transported in two ways:
- by plane
- by boat.

In the case of air transport, contrary to popular belief relating to the speed of this type of transport, it is necessary to follow the basic principles for storage to avoid compromising the quality of the fruit.

Particular attention must be paid to avoiding:
- exposure of fruit to high temperatures, which can happen in closed lorries, exposed to direct sunlight, while waiting for loading
- breaking the cold chain, exposing the fruit to ambient conditions - whenever the fruit leave a cold room, they are quickly covered with condensation, especially in a humid climate or maritime region; this condensation water can have disastrous effects by soaking cartons and favouring the development of diseases.

With maritime transport, pallets are placed in refrigerated containers successively transported by lorry, boat, and then again by lorry, before reaching the final importer in Europe. This succession of transport operations requires 1-4 weeks depending on the remoteness of the production site. The cold chain must be respected at each point in the logistics process.

Throughout the period of refrigerated transport, the physiological activity of the fruit is slowed down, but gas exchange continues. For temperatures near 10°C, CO_2 is produced at a rate of 12 and 16 ml/kg per hour, and ethylene at a rate of between 0.1 and 0.5 µl/kg. In a closed chamber, in the absence of ventilation, the concentration of these gases can increase substantially.

The CO_2 concentrations in the container should never exceed 8% or they risk irreversible damage. It is best to keep close to 1%.

It is known that ethylene contents of around 100 ppm accelerate the ripening process.

For these reasons, continuous ventilation, with an hourly flow corresponding to the volume of the container, makes it possible to maintain a suitable atmosphere.

In the case of maritime transport, throughout the transportation phase by boat or truck, the conditions of temperature, humidity and atmospheric composition must remain stable and consistent with the needs of storage:

- temperature between 8 and 10°C (data continuously recorded in each container).
- humidity maintained at about 90% without reaching 95%
- air replaced to avoid an increase in CO_2 content and ethylene.

Before loading a container, the flaps must be checked to ensure that the ventilation is operational.

Indications of temperature, humidity and ventilation are specified to the carrier by the exporter. On-board recorders make it possible to check the proper application of these instructions for temperature, sometimes humidity, but very rarely the composition of the atmosphere.

Given the overall duration of transport, disruptions to the cold chain have even more adverse effects in the case of maritime transport compared with air transport.

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

The tables below give known registrations in ACP countries. Efficacies given are based on existing registrations, documents on mango production and information from pesticide companies.

TABLE 1.1: KNOWN REGISTRATIONS IN ACP COUNTRIES (EXCLUDING CSP COUNTRIES, SEE TABLE 1.2) IN JANUARY 2013

Active substance or biological agent	Country					
	Côte d'Ivoire	Ghana	Cameroon	Kenya	Tanzania*	Jamaica
Acetamiprid					Horticultural crops	
Azoxystrobine	X					
Bifenthrin					Horticultural crops	
Bupirimate				Fruit trees		
Captan						
Carbendazim				X		
Chlorpyrifos-ethyl	X				Horticultural crops	
Copper	X					X
Cymoxanil				Fruit trees		
Cypermethrin	Fruit trees		Fruit trees			
Deltamethrin	X		Fruit trees	Fruit trees	Horticultural crops	Fruit trees
Diazinon				Fruit trees		
Dimethoate			Fruit trees	Fruit trees		
Fenitrothion				X		Fruit trees
Fenthion				Fruit trees		
Fipronil					Horticultural crops	
Imazalil	Fruit trees					
Imidacloprid					Horticultural crops	
Iprodione	Fruit trees					
Lambda-cyalothrin						
Malathion				Fruit trees	Horticultural crops	X
Mancozeb		X	Fruit trees	Fruit trees	Horticultural crops	X
Maneb			Fruit trees			
Metalaxyl-m	X	Fruit trees				
Prochloraze	X					
Propiconazole					Horticultural crops	
Propineb				Fruit trees		
Sulfur						

Active substance or biological agent	Country					
	Côte d'Ivoire	Ghana	Cameroon	Kenya	Tanzania*	Jamaica
Spinosad	X	X				
Thiabendazole						
Thiacloprid	X				Horticultural crops	
Thiamethoxam					Horticultural crops	Fruit trees
Thiophanate-methyl				X		
Triadimefon				X		
Trifloxystrobine						
White oil						Fruit trees

X: registration is specific to mango
* In Tanzania, horticultural crops include vegetables and fruits

TABLE1.2: REGISTRATION BY COMITE SAHÉLIEN DES PESTICIDES (CSP) FOR CILSS COUNTRIES (BURKINA FASO, CAPO VERDE, GAMBIA, GUINEA-BISSAU, MALI, MAURITANIA, NIGER, SENEGAL, CHAD) IN OCTOBER 2012 FOR USE ON MANGO

Active substance	Use
Abamectin	fruit crops: insects/acaridae
Acetamiprid + cypermethrin	all crops: insects and greenhouse whitefly
Chlopyrifos-ethyl	mango: mealybugs, termites all crops: soil insects, ants, grasshoppers, termites
Deltamethrin (+ methyl-eugenol)	all crops: bait for fruit flies
Spinosad	Mango: fruit flies
Thiamethoxam	mango: mealybugs

TABLE 1.3: EFFICACY OF SOME ACTIVE SUBSTANCES OR BIOCONTROL AGENTS

A: INSECTICIDES

Active substance or biocontrol agent	Pest									
	Fruit flies	Mealy bugs	Scales	Termites	Thrips	Cecidomyiids	Whiteflies	Bugs	Weevil	Acrididae
Abamectin					X					
Acetamiprid		X		X	X		X			
Bifenthrin	X			X			X	X		X
Chlorpyrifos-ethyl		X		X						X
Cypermethrin							X			
Deltamethrin	X				X		X	X		X
Fenitrothion	X									X
Fipronil				X						X
Imidacloprid	X	X		X	X	X	X			
Kaolin	X				X					
Lambda-cyhalothrin	X				X		X	X		X
Malathion	X	X			X			X		X
Spinosad	X				X			X		
Thiacloprid	X				X		X			
Thiamethoxam	X	X	X	X	X		X		X	
White oil			X							

B: FUNGICIDES

Active substance or biocontrol agent	Diseases					
	Anthracnose	Alternaria	Stem-end rot	Powdery mildew	Scab	Bacterial canker
Azoxystrobine	X					
Captan	X	X				
Copper	X		X		X	X
Imazalil	X	X	X			
Mancozeb	X				X	
Maneb	X	X			X	
Metalaxyl-m	X					
Prochloraze	X	X	X			
Propiconazole	X					
Sulfur				X		
Thiabendazole			X			
Thiophanate-methyl	X			X		
Trifloxystrobine	X					

Annex 2: Regulations and pesticides residues

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

Pre-harvest intervals (PHI) 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, which allow cultivation only without any quantifiable residues, i.e. with "0" residues taking into account European limit of quantification (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 do 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 14 June 2011. By 25 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 at European Commission > Food >Plant > Pesticides: 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 maximum residue limit:

The quantities of pesticide residues found in food must be safe for consumers and remain as low as possible.
The 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 harmonised Community MRLs have been established.

The 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 harmonised 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 EC Factsheet (208) *New rules on pesticides residue in food*,
http://ec.europa.eu/food/plant/protection/pesticides/explanation_pesticide_residues.pdf

How are MRLs applied and monitored in the 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 notifications for fruit and vegetable imports from ACP countries.

MRLs in ACP countries

ACP countries do not have set their own MRLs, therefore they usually admit Codex MRLs for foodstuffs marketed in their country.
The Codex Alimentarius Commission was established in 1961 by the Food and 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) are 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 recognised 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 at: http://www.codexalimentarius.net/pestres/data/index.html?lang=en.

TABLE 2.1: STATUS OF ACTIVE SUBSTANCES AND BIOCONTROL AGENTS IN THE EU REGULATION 1107/2009 ; EU AND CODEX MRLS IN JANUARY 2013 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					
	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
Acetamiprid	Approved	0.01**	/	50 on termites	2	60	174 days results for four 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	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 four 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 four 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	0.2	25 on fruit flies	2	10	7	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					
	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
Thiameth-oxam	Approved	0.5	1	200 on termites	2	60	174 days results for four 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	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 2.2: STATUS OF ACTIVE SUBSTANCES AND BIOCONTROL AGENTS IN THE EU REGULATION 1107/2009 ; EU AND CODEX MRLS IN OCTOBER 2012 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					
	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
Azoxystrobine	Approved	0.7	0.7	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
Prochloraze	Approved	5	7 tropical fruits with inedible peel	25 per 100 l water	n.a.	n.a.	Post-harvest		

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

Active substance	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-cyhalothrin	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
Fludioxonyl	Savior 200 SC	Syngenta	2004	Senegal

Active substance	Commercial product tested	Manufacturer	Trials	
			Year	Country
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
Prochloraz	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

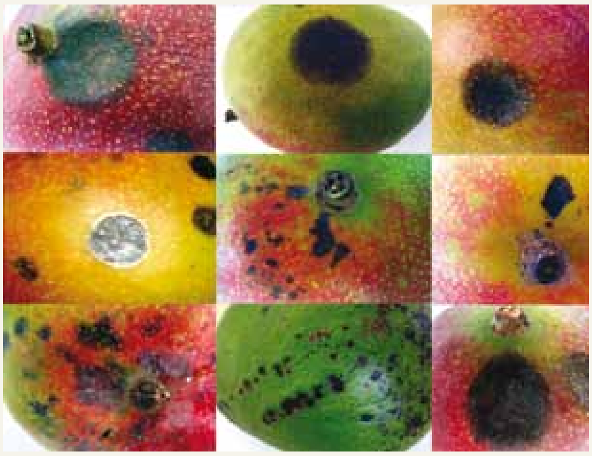
Note: GAPs indicated in previous pages are those corresponding to the plant protection products listed above. Users of this information should check if the product used is equivalent (same concentration and same type of formulation) to the reference product. If it is not the case, the indicated GAP may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

TABLE 2.4: 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	Apply 50 litres of mixture (water+product) on the ground under all the crown (approximately 50 m^2)
Chlorpyrifos-ethyl	Dursban 4	1000 g	20 ml/50 l water/tree	Apply 50 litres of 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	Apply 50 litres of 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	Apply 50 litres of mixture (water+product) on the ground under all the crown (approximately 50 m^2)
Fipronil	Regent 5 G	1250 g	250 g/tree	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	Apply 50 litres of 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	Apply 50 litres of mixture on the ground around the base of the tree
Thiamethoxam	Actara 25 WG	200 g	8g/5 l water/tree	Apply 50 litres of mixture on the ground around the base of the tree

Annex 3 (a) Photographs of of post-harvest diseases on mango fruits

The images below demonstrate that spots on mango fruit are not necessarily caused by anthracnose.



None of the mango fruits below is attacked by anthracnose due to *Colletotrichum gloeosporioides*.

Photos P. Gerbeau (composition H. Vannière)

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 A et B P. Gerbaud, identification Clinique des plantes, CORDER)

(Photo H. Vannière)

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 concave 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)

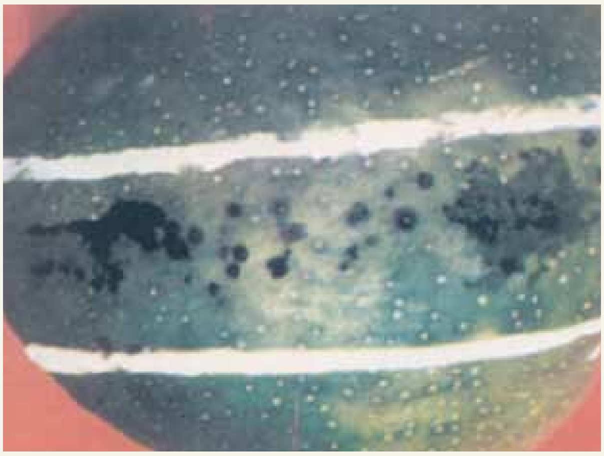
Figure 6. Stem-end rot developing from an infection of the stem-end at harvesting (A) or from an injury to the skin (B) and caused by *Aspergillus* sp.

Annex 3 (b) Photographs of diseases in mango orchards

Scab

Symptoms on fruit

Xanthomonas



Symptoms on fruit

Symptoms on a panicle

(Photo Jean-Yves Rey)

Symptoms at the base of a panicle

Symptoms on leaves (Photo Henri Vannière)

Oidium

Symptoms on panicles

(Photo Henri Vannière)

Symptoms on leaves

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

Spots on the upper face of a leaf

Symptoms on a branch

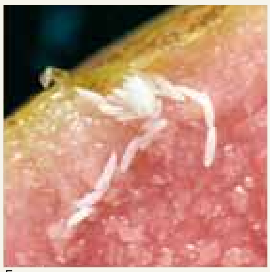
Spots on the the under side of a leaf

Symptoms on a fruit

Annex 3 (c) Photographs of mango pests

Fruit flies


Ceratitis sp.


Eggs


Larva



Bactrocera invadens (Photos Gilles Delhove)


Symptoms on a fruit

Rastrococcus invadens


Larvae on the underleaf

(Photo Jean-Yves Rey)


Sooty mould on the upper face of leaves

(Photo Jean-Yves Rey)

Scales


Larvae

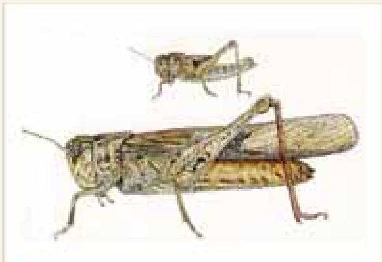
Anoplocnemis


Adult

Lygus spp.


Adult and larvae

Locusts


Oedaleus senegalenis

Thrips


Scirtothrips


Selenothrips


Foliar damage


Symptoms on young fruits

Cecidomyiids


Erosomyia adult


Symptoms on a panicle (Photo Henri Vannière)


Symptoms on a leaf (Photo Henri Vannière)

Aleurodicus dispersus


Larvae


Adults

Termites

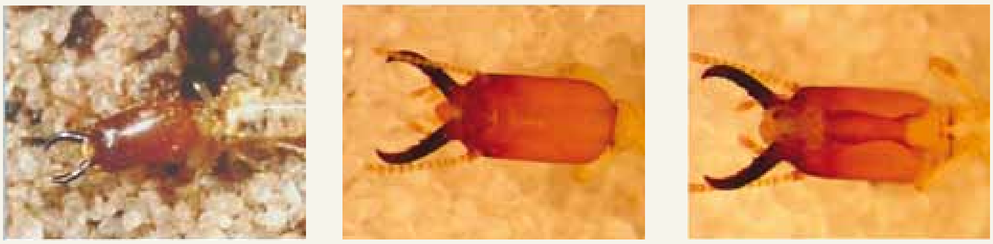

Decaying trees


Crusting on a trunk

Microcerotermes build tunnel-shaped galleries on the trunk and enter into injuries or withered stumps of branches, where they increase necrosis. This damage usually involves isolated branches.

Tunnel on a tree trunk (Photo Baptiste Assié)

Withered stump of a branch (Photo Baptiste Assié)



Microcerotermes soldiers (Photo Baptiste Assié)

On the other hand, *Amitermes* can be considered the most dangerous termites for the mango tree (usually *A. evuncifer*). They settle at the base of the trunk, at the collar or below ground level, usually under the mounds of *Odontotermes,* whose damage they will exacerbate.

Amitermes soldiers (Photo Baptiste Assié)

Typical damage of *Amitermes* covering the equally typical damage of *Odontotermes*. On the right side of the photo the blackish appearance of the injury is the harvesting ground of the *Amitermes*. On the left side we can make out an injury that is lighter and not quite as deep. This a former injury caused by *Odontotermes* (Photo Baptiste Assié)

Symptom of weevil damage on fruit. Some varieties are hardly damaged as the larva does not reach the kernel (here cv. Julie in Guadeloupe). For other varieties, damage may not be easily seen on the fruit, but the larva is in the kernel.

(Photo Jean-Yves Rey)

Internal damage (Photo Jean-François Vayssières)

Adult (Photo Jean-François Vayssières)

Annex 4

CONTROLING FRUIT FLY IN WEST AFRICA

PRACTICE N°4

FRUIT FLY CONTROL THROUGH SPOT TREATMENTS WITH «SUCCESS APPAT»

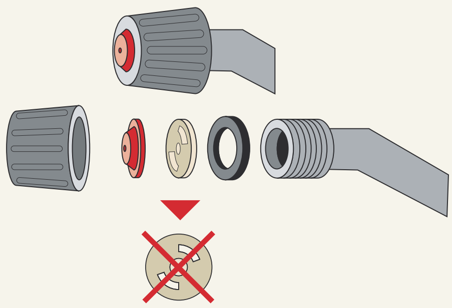
- SUCCESS APPAT is approved on mangoes by the Sahelian Pesticide Committee (CSP).
- This product is authorised in organic production in Europe.
- It contains an attractant and an insecticide (Spinosad).
- **It attracts and kills female fruit flies that cause damages to mangoes.**

ATTENTION: attractants with methyl-eugenol including nutmeg attract only male flies that do not cause damages to the fruit

APPLICATION AND PROTECTION EQUIPMENT

1

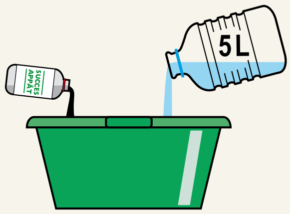
SPRAYER PREPARATION



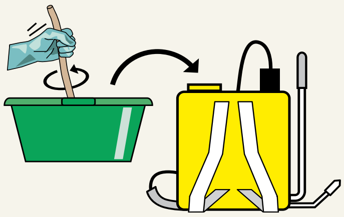
For spray flow with large droplets remove the part that creates turbulence or use an adapted nozzle

THE STANDARD RECOMMENDED DOSE PER HECTARE (2 ACRES) IS 1L OF SUCCESS APPAT, DILLUTED IN 5L OF WATER

Shake well before using

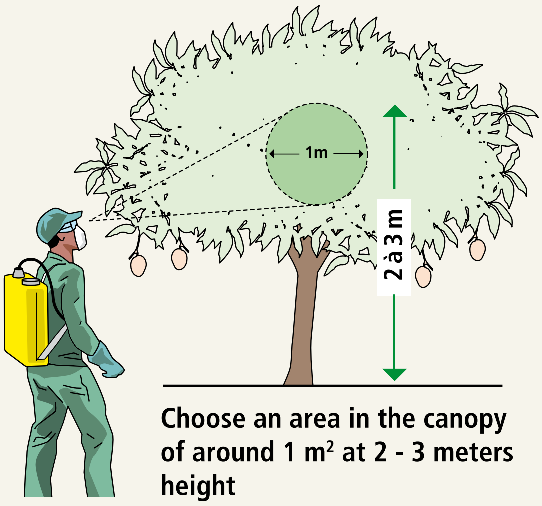


Pour 1 measure of SUCCESS APPAT for 5 measures of clear water



Mix well, fill the sprayer and use immediately

HOW TO APPLY : THE SPOT APPLICATION METHOD



Choose an area in the canopy of around 1 m² at 2 - 3 meters height

Spray with circular movements, penetrating into the foliage.

Wet the leaves until dripping but avoid that the product drips to the ground

Treated spot

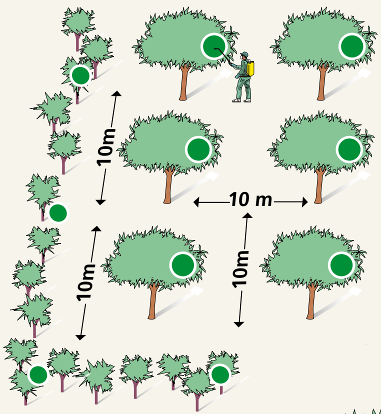
Always spray with the wind in your back
but never when the wind is strong or during rain

Do not spray the fruit

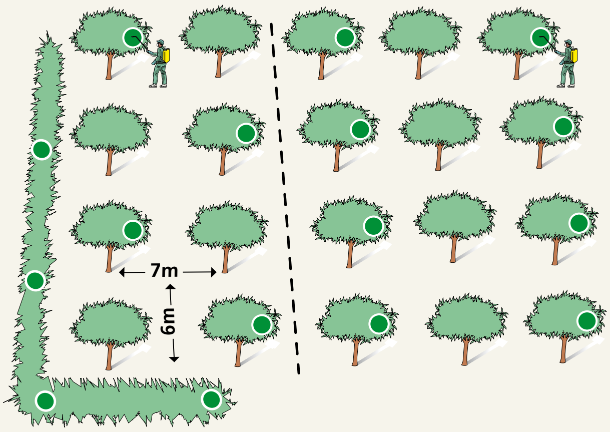
Do not spray under the leaves

TREATMENT COVER AREA

Treat all trees in orchards with 100 - 150 trees per hectare (50-75 / acre)

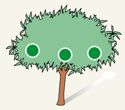


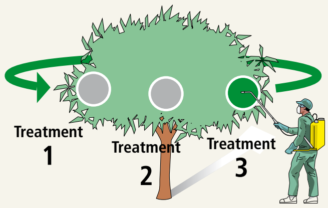
Treat surrounding vegetation every 10 meters



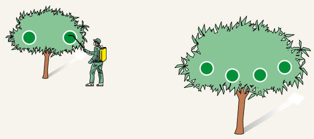
Treat every other tree or line in orchards with more than 150 trees per hectare (+75 / acre)

In sparesely planted orchards with large trees apply 2 to 4 spots per tree





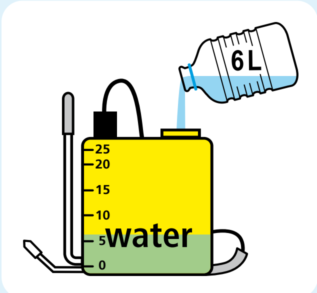
Avoid spraying the same branches between treatments

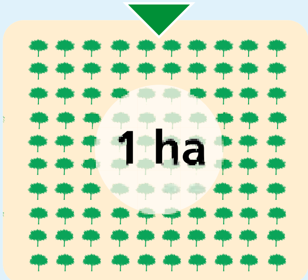


3

BEFORE APPLICATION IT IS STRONGLY RECOMMENDED TO CONDUCT A TEST WITH WATER. FOR 1 HECTARE :

Fill the knapsack with
6 liters of water (no product)

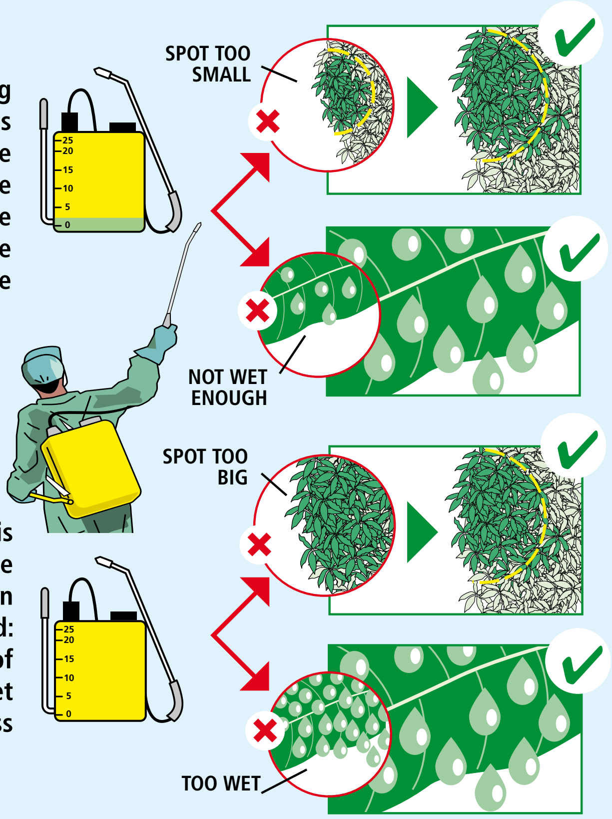




Treat 1 hectare
(see «How to apply»)

If after spraying the area there is water left in the knapsack: increase the size of the spots or wet the foliage more

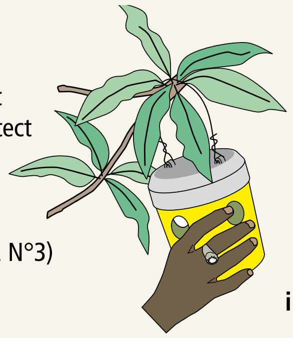
If the knapsack is empty before the area has been fully treated: reduce the size of the spots or wet the foliage less



WHEN TO START TREATMENTS ?

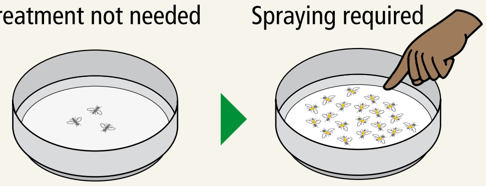
Set up traps at fruit setting stage to detect fruit fly presence

(see also PRACTICE N°3)



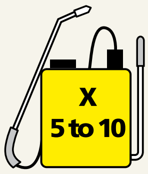
Count the number of trapped flies each week :

Treatment not needed — Spraying required



Start treatments as soon as you notice significant increase in numbers of flies trapped : usually 8 -10 weeks before fruit maturity

REPEAT TREATMENT EVERY 7 DAYS AND CONTINUE AS LONG AS THERE IS FRUIT ON THE TREES AND THE NUMBERS OF FLIES TRAPPED REMAIN HIGH



Average 5 - 10 treatments per season will be necessary

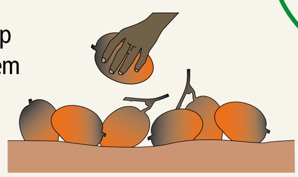
Anticipate next treatment after each heavy rainfall

Spray just after picking to respect a minimum 3 day waiting period before next harvest

4

TREATMENTS ARE ONLY EFFECTIVE IN A WELL KEPT PLANTATION !

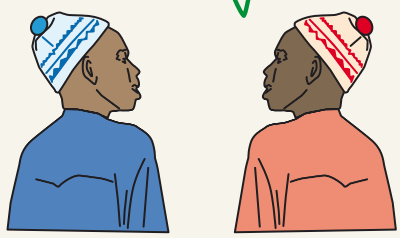
Before each treatment pick-up all fallen fruit and destroy them by burrying, burning or solar heating



ACT TOGETHER TO SUCCEED !

We all have to spray our orchards, otherwise there will be as many flies as before

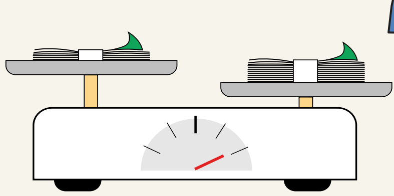
OK, I will spray my trees and tell others



COSTS AND BEFEFITS FOR THE GROWERS*

COSTS

10 L of SUCCESS APPAT, per hectare and per season + spraying equipment + labour



BENEFITS

Up to 80% reduction in harvest losses caused by fruit flies

* costs and benefits can vary according to local conditions

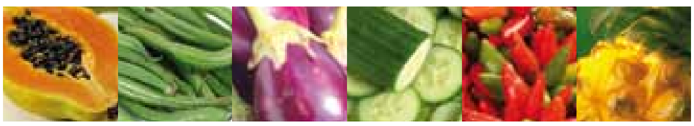
IITA — cirad LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT — AG MARKETS PDMAS — COLEACP — EDES — PIP

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 (*Ipomoea batatas*)
Tamarillo (*Solanum betaceum*)
Water melon (*Citrullus lanatus*) and butternut (*Cucurbita moschata*)
Yam (*Dioscorea* spp.)



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