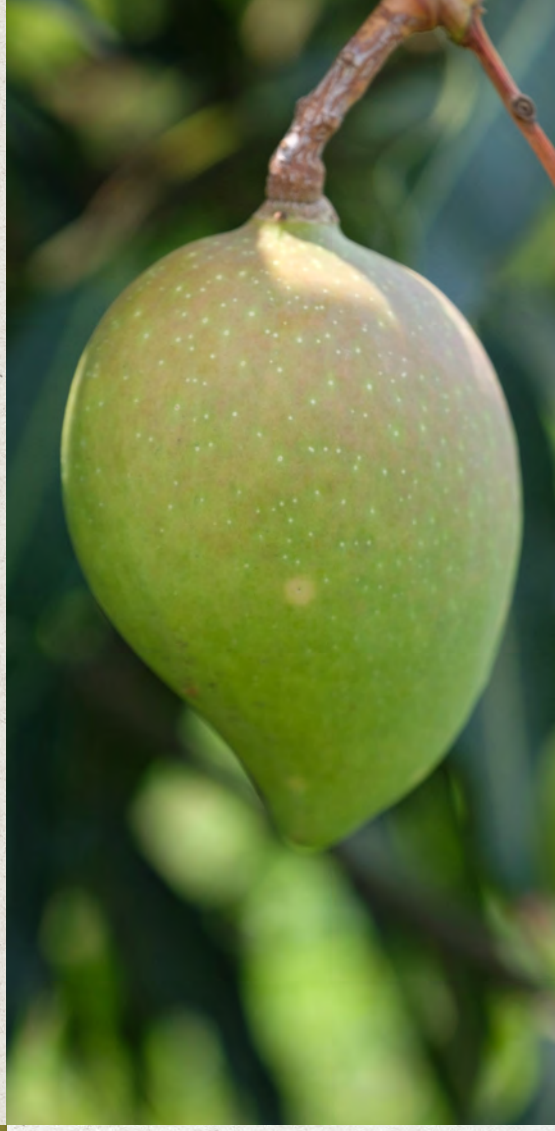
PRODUCTION GUIDE



GUIDE TO GOOD CROP PROTECTION PRACTICES

FOR MANGO IN ORGANIC FARMING

Mangifera indica

COLEACP

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COLEACP implements two intra-ACP Fit For Market programmes. The Fit For Market programme, co-funded between the EU and the AFD, now in its fifth year, aims to strengthen the competitiveness and sustainability of the African, Caribbean and Pacific (ACP) horticultural sector, primarily for the private sector. Fit For Market SPS began in January 2019 and focuses on strengthening the sanitary and phytosanitary (SPS) systems of the ACP horticultural sector, primarily for the public sector. Both programmes form part of the intra-ACP indicative programme (2014-2020) of cooperation between the EU and the OACPS.

This publication is an integral part of a COLEACP collection, which is made up of training materials, educational resources and technical documents. All of them are suited to different types of beneficiaries and educational levels found in agricultural production and sales.

This collection is available online for COLEACP members.

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Warning
The document "Guide to Good Phytosanitary Practices for organically-produced mangoes (Mangifera indica)" sets out all phytosanitary practices and advocates largely those active substances produced by manufacturers of Plant Protection Products as part of Regulation (EC) 1107/2009, authorised by Regulations (EC) 834/2007 and 889/2008 on organic production. Information provided on the active substances recommended is subject to change and will be continually updated in line with new information collected by the COLEACP.
Naturally, it should be understood that only those substances which are legally approved in the country in question are authorised for use. Consequently, every producer has the duty to check with the local regulatory authorities whether the product they wish to use appears on a list of approved products.

FIT FOR MARKET SPS FIT FOR MARKET AFD STDF

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For more information, see the programme's website:
www.coleacp.org

1. MAIN PESTS AND DISEASES AND IMPORTANCE

1.1. Extent and impact on yield and quality

The main pests and diseases addressed in this guide are listed below. In this section, the following information is given for each pest or disease:

- The level of economic significance generally observed in ACP countries according to the following scale: + = not very significant, ++ = quite significant, +++ = significant;
- The parts of the plant which are attacked and the way they are damaged;
- The types of losses caused, which ultimately lead to reductions in the yield of marketable fruit and thus financial losses. Pests and diseases can lead to reduced yield through losses at different levels: lower numbers of plants per hectare, lower numbers of fruit per plant, fruit of reduced size and fruit of lower quality.

Quarantine organisms in Europe are followed by the abbreviation "QO".

INSECTS								
Significance	Parts affected			Types of loss				
	Leaves	Fruit	Trunk	Number of plants	Number of fruits per plant	Size of fruit	Quality of fruit at maturity	Quality of fruit after harvest
Fruit flies - *Ceratitis* spp. QO, *Bactrocera* spp. QO, *Anastrepha* spp.								
+++		Adult females pierce the epidermis of the fruit and lay their eggs in the pulp. The larvae develop in the pulp			Fruit dropping		Fruit rotting	Destruction of infested fruit by the importing country
Mango stone weevil – *Sternochetus mangifereae* QO								
+++		Presence of larvae in the stone			Premature dropping of fruit in the event of serious infestation		Pulp of ripe fruit damaged	Destruction of infested fruit by the importing country
Fruit tree mealybug – *Rastrococcus invadens*								
+++	Presence of sucking larvae, mainly on the underside	Presence of larvae			Physiological disorder in the tree leading to poor or no flowering	Reduction by weakening young plants in the event of large-scale colonisation	Fruit marked by secreted honeydew on which sooty mould is likely to develop	
Other mealybugs: diaspididae and coccidae *Icerya seychellarum, Coccus mangiferae, Aulacapsis tubercularis, Pseudoaonidia tribitiformis, Ceroplastes* spp., *Protpulvinaria mangiferae, etc.*								
++	Presence of sucking larvae on the underside of leaves	Presence of sucking larvae			Reduction by weakening young plants in the event of large-scale colonisation. Risk of fruit dropping	Fruit with marks or cracks		

INSECTS (continued)								
Significance	Parts affected			Types of loss				
	Leaves	Fruit	Trunk	Number of plants	Number of fruits per plant	Size of fruit	Quality of fruit at maturity	Quality of fruit after harvest
	Thrips - *Selenothrips rubrocinctus, Scirtothrips aurantii*							
++	Presence of sucking larvae on the underside of leaves	Presence of sucking larvae on flowers and young fruit			Risk of stopping growth of fruit in the event of a serious infestation		Risk of slight deformation of fruit	
	Whiteflies - *Aleurodicus dispersus QO, Aleurocanthus woglumi*							
++	Presence of sucking larvae on the underside of leaves				Reduced by the risk of withering in the event of large-scale colonisation; blackening and possible falling of leaves		Risk of honeydew dripping onto fruit	
	Mango blossom gall midges (*Procontarinia mangiferae*) and mango leaf gall midges (*Procontarinia matteiana*)							
++	Presence of flies which bite young leaves to lay their eggs	Presence of flies which bite developing flower stalks to lay their eggs			Deformations/necrotic brown marks on inflorescences. Risk of poor flowering			
	True bugs - *Anoplocnemis curvipes, Lygus* spp., *Leptoglossus* spp.							
++	Presence of true bugs on young shoots, biting the buds. Injection of toxin into young shoots	Injection of toxin into the bacterial canker marks on fruit		Destruction of young shoots in a matter of hours				Fruit unsuitable for consumption if toxin is injected into bacterial canker marks
	Termites (microtermes)							
+ *			Crusting on trunks and lower parts of the scaffold branches	Die-back of individual tree parts, becoming gradually more widespread over several months				

* Very variable impact depending on the site and species. May lead to the orchard being completely wiped out

Acrididae							
+	Presence of desert locusts or grasshoppers which eat leaves and young shoots						

FUNGI

Significance	Parts affected			Types of loss				
	Leaves	Fruit	Trunk	Number of plants	Number of fruits per plant	Size of fruit	Quality of fruit at maturity	Quality of fruit after harvest
Anthracnose - *Colletoricum gloeosporiodes*								
+++	Fungi on the underside of the leaves	Germination of spores on unripe fruit, then the fungus becomes latent until harvest			Risk of considerable losses in the event of large-scale Infestation during flowering		Appearance of symptoms in case cases (marks on skin just prior to harvest)	Appearance of brown marks after the harvest
Powdery mildew - *Oïdium mangiferae*								
+++ *	A white powder appears on the buds, flowers and leaves, and occasionally on the fruit			Risk of premature dropping of fruit				

*Mild temperatures and humid but not excessively damp air

OTHER POST-HARVEST DISEASES

Significance	Parts affected			Types of loss				
	Leaves	Fruit	Trunk	Number of plants	Number of fruits per plant	Size of fruit	Quality of fruit at maturity	Quality of fruit after harvest
Scab - *Elsinoe mangiferae*								
+++ *	Appearance of brown or black jagged marks on leaves						Black surface lesions on the skin of the fruit forming a slightly cracked crust. Visible during the harvest	

* Hot and humid regions

Fusarium wilt - *Fusarium tupiense*								
++ *		Deformed inflorescences with very short internodes. Sterile flowers and drying out		Less fruit due to sterilisation and drying out of flowers				

* Casamance and west Africa

OTHER POST-HARVEST DISEASES

Significance	Parts affected			Types of loss				
	Leaves	Fruit	Trunk	Number of plants	Number of fruits per plant	Size of fruit	Quality of fruit at maturity	Quality of fruit after harvest
Alternaria - *Alternaria alternata*								
+++	Appearance of round, black marks on the underside of the leaves	Inflorescences attacked. Appearance of round, black surface marks around the peduncle of the fruit		Inflorescences attacked leading to a drop in the numbers of fruit produced			The marks on the fruit can grow into large, black patches, which can extend into the pulp. Peduncle rot	Damage continues after the harvest
Sigatoka - *Cercospora mangiferae*								
+++	Appearance of rot marks on leaves after the harvest							Rot can extend into the pulp of the fruit
Stemphylium - *Stemphyllium* sp.								
+++		Appearance of brown/ black concave rot marks on the fruit after the harvest						Rot can extend into the tissue of the fruit, which becomes reddish-brown.
Peduncle rot - *Lasiodiplodia* spp., *Dothiorella* spp., *Phomopsis* spp., *Pestalopsiopsis* spp.								
++		Appearance of peduncle rot on fruit and marks across the skin of the fruit after the harvest	On the trunk and branches: drying out of branches	These diseases mainly develop after the harvest				Rotting fruit
***Aspergillus* spp., *Cladosporium* spp., *Fusarium* spp., *Penicilium* spp., *Rhizopus* spp.**								
++		Various types of marks develop on the fruit after the harvest after damage because contaminated						Rotting fruit

1.2. Identification and damage

This section provides information and illustrations to help identify the main pests and diseases.

INSECTS

Fruit flies – *Ceratitis* spp., *Bactrocera* spp., *Anastrepha* spp.

The females bite into the fruit when it is still green or, more often, at the premature stage to lay their eggs. The larvae then grow inside the fruit, feeding on its flesh by digging tunnels, thus allowing fungi and bacteria to develop. They are responsible for the fruit falling from the tree prematurely. They also cause the fruit to ripen earlier, making it unsuitable for sale. For more information on identifying flies, visit https://www.africamuseum.be/fruitfly/AfroAsia.htm

Figure 1: Bactrocera dorsalis

Figure 3: Ceratitis cosyra

Figure 2: Damaged fruit

Mango stone weevil – *Sternochetus mangifereae*

The females lay their eggs on the fruit as it ripens. The larvae then dig a tunnel to the inside of the stone. When they reach adulthood, they re-emerge, damaging the ripened fruit. In the event of a severe infestation, the fruit falls prematurely. The adult remains dormant most of the year under the bark of the mango tree.

Figure 4: Adult mango stone weevil

Figure 5: Close-up of an attack on a stone

Fruit tree mealybug – *Rastrococcus invadens*

The fruit tree mealybug feeds on the leaves and fruit of the mango tree. It buries its rostrum into the plant and secretes honeydew, promoting the growth of a fungus called sooty mould, which leaves a black layer on the surface of the fruit.

Figure 6: Mealybugs on the underside of the leaves

Figure 7: Sooty mould on the upper face of leaves

Other diaspididae and coccidae
Icerya seychellarum, Coccus mangiferae, Aulacapsis tubercularis, Pseudoaonidia tribitiformis, Ceroplastes spp., *Protpulvinaria mangiferae*

In nurseries, these insects feed on new shoots, disrupting the growth of the seedlings. In orchards, they suck up the tree's sap and inject it with their toxic saliva. They can feed off the fruit and the leaves, leading to early dropping of leaves, dead branches, deformed fruits and discolouration.

Diaspididae are small (+/- 3mm long). They do not produce honeydew, but they secrete a wax which covers them in a circular or oyster shell-shaped shield. The larvae are only mobile at the start of their initial life stage. They then attach themselves to the plant permanently and remain fixed to their host when their shield is removed.

The eggs of the coccidae are sheltered under the female's shell. They emerge as flat, crawling larvae (nymphs), which look like dust on the surface of the host plant. Some species are ovoviviparous. Coccidae secrete honeydew, which attracts ants. The waxy layer which surrounds them is inextricably linked to their body, so it cannot be removed without removing the coccidae as well. Coccidae generally live between the leaves, branches and fruit throughout their life cycle.

Figure 8: Mealybugs on the top of a leaf

Figure 9: Mealybugs and ants on a fruit

Thrips - *Selenothrips rubrocinctus, Scirtothrips aurantii*

Thrips attack young leaves, which then curl up and fall prematurely. Unlike other species, which can also be found in orchards, *S. rubrocinctus* is only found in nurseries, attached to the bottom of the leaves. They also colonise the flowers, which they feed on and where they lay their eggs, occasionally leading to the premature loss of pollen.

Figure 10: Thrips on the underside of a leaf

Whiteflies
Aleurodicus dispersus and *Aleurocanthus woglumi*

Whiteflies feed on the sap from leaves and can cause wilting in the event of a large-scale infestation. *Aleurodicus dispersus* can be recognised by the way it lays its eggs, which are arranged in spirals on the underside of the leaves. The larvae secrete honeydew, which causes sooty mould to appear.

Figure 11: Eggs laid in a spiral

African Weaver Ants - *Oecophylla longinoda*

This species of red ant is not a major danger for mango trees because it only causes minor damage (just a few marks on the fruit) and even helps to significantly reduce attacks by pests on the mango tree (including fruit flies, mango stone weevils and mango blossom gall midges). However, fruit pickers are wary of its bite.

In general, they should be thought of as an auxiliary species rather than a pest.

Figure 12: Nest of ants

Mango blossom gall midges (*Procontarinia mangiferae*) and mango leaf gall midges (*Procontarinia matteiana*)

Gall midges are tiny flies (diptera), which bite into developing flower stalks or very young leaves in order to lay their eggs. In inflorescences, the development of maggots causes deformations or brown, necrotic marks. If flowering is poor, there may well be a high concentration of bites on the existing floral panicles, which leads to more significant harm being done. Observing the floral panicles is the only way to estimate the level of infestation. In high risk areas, as soon as five bites are observed per stalk on 100 panicles in the orchard, insecticide use should be swiftly planned. Young leaves react to bites by developing very characteristic scabs. Adult trees are not particularly disrupted. However, young trees in nurseries or newly planted trees should be protected. In this case, it is very difficult to establish an

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

Figure 13: Damage on leaves

Figure 14: Inflorescences bitten by gall midges

Figure 15: Adult procontarinia mangiferae

True bugs - *Anoplocnemis curvipes, Lygus* spp., *Leptoglossus* spp.

These pests infest new shoots by biting into the buds, leading to the characteristic deformations. Some of them bite into necroses caused by bacterial canker and inject a toxin. These pests are feared because they can destroy new shoots very quickly. This can take just a few days, or even a few hours in some cases. It is essential to react quickly in the event of an attack. In Ghana, some species inject a toxin into the bacterial canker marks on the fruits they have bitten into. As a result, they can considerably worsen the damage caused by bacterial canker and the fruit becomes entirely unsuitable for consumption.

Figure 16: Adults and larvae of Lygus spp.

Termites

There are various different types and species of termites.

It is important to distinguish between two types of symptoms.

- Visible crusting on the trunks and lower parts of the scaffold branches. These attacks are very superficial. They are often temporary and are relatively easy to combat.
- More widespread dieback of parts of the mango tree, gradually worsening over a period of several months.

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

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

Figure 17: Tunnel in a trunk created by Microtermes
(Photo: Baptiste Assié)

Figure 18: Microtermes
(Photo: Baptiste Assié)

Figure 19: Withering tree following an attack

Figure 20: Amiterme

Figure 21: Crusting on a trunk

Figure 22: damage characteristic of Amitermes observed after removing Odontoterme plaster, a few traces of which can be seen to the left of the photo.

Acrididae

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

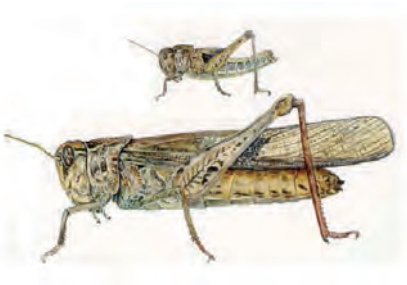

Figure 23: Acrididae

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

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Anthracnose - *Colletotrichum gloeosporioides*

Anthracnose can affect any part of the mango tree. It causes small black marks to appear on the leaves, which disrupt photosynthesis. It can also lead to the premature dropping of the fruit and the appearance of black marks on ripe fruit. After the harvest, the fruit loses its resistance and the disease develops more quickly, especially when not refrigerated.

Affected leaves have black marks (necroses), while brown marks appear on the fruit after the harvest. Another common symptom is the appearance of marks in the shape of a teardrop.

Figure 24: Damage on inflorescence

Figure 25: Marks on a leaf

Figure 26: "Teardrop" marks

Powdery mildew - *Oïdium mangiferae*

The tender parts of the plant (inflorescences and leaves) are covered in a white mycelium, leading to their necrosis. This disease can cause defoliation.

Figure 27: Leaves attacked by powdery mildew

Figure 28: Inflorescences attacked by powdery mildew

Scab - *Elsinoe mangiferae*

This disease only affects the hottest, most humid production regions. Infection requires flowing water (rainfall).

Scab appears most commonly in new orchards and nurseries. Young plant tissue is sensitive.

On the leaves, brown or black marks with pointed edges develop, growing to around 5mm in diameter. On young fruit, the marks are grey with a jagged, black border. As the fruit grows, these marks become darker and form a slightly cracked crust. The marks remain superficial and do not affect the flesh of the fruit. A significant amount of the fruit can therefore be recovered.

Figure 29: Fruit attacked by scab

Fusarium wilt - *Fusarium tupiense*

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

This disease has been observed mainly in Casamance in the south of Senegal.

Figure 30: Fusarium tupiense damage on flowers in Casamance
(photos by Gilles Renoux)

Round rot marks caused by other pathogens

Figure 31: Young lesions concentrated around the top of the fruit caused by Alternaria sp.

Figure 32: More advanced marks caused by Alternaria sp.

Figure 33: Rot marks emerging after the harvest caused by Cercospora sp.

Figure 34: Slightly concave rot marks caused by Stemphylium *sp.*

Figure 35: Apical rotting of stalk caused by Dothiorella *sp. and* Lasiodiplodia *sp.*

Figure 36: Randomly distributed marks on the skin of a fruit caused by Dothiorella *sp. and* Lasiodiplodia *sp.*

Figure 37: Rot marks developing after contamination of the peduncle during the harvest (photo on the left) or damage (photo on the right) caused by Aspergillus *sp.*

BACTERIA

Bacterial canker of mango trees - *Xanthomonas citri* pv. *mangiferaeindicae*

Bacterial canker of mango trees leads to a number of different symptoms.

On the leaves, the damage begins with small oily marks, which change into raised and pointy necrotic black marks, often contained within the boundaries of the veins of the leaf. These marks are surrounded by a lighter, oily halo on the underside and a yellow halo on the top of the leaf. Cankers become visible on the leafstalks and the main vein. Badly affected leaves fall off and long, causing defoliated branches.

On the branches and stalks, the bacteria causes raised marks, cracking and cankers. After penetrating young stems, it survives inside them during the dry season. Gum containing the bacteria oozes from the cankers, especially during the rainy season.

On the fruit, small, raised, black marks are visible, often in the shape of a teardrop. As they develop, these marks tear in a star-shape. Gum then seeps from these craters.

Figure 38: Marks on the top of a leaf caused by bacterial canker

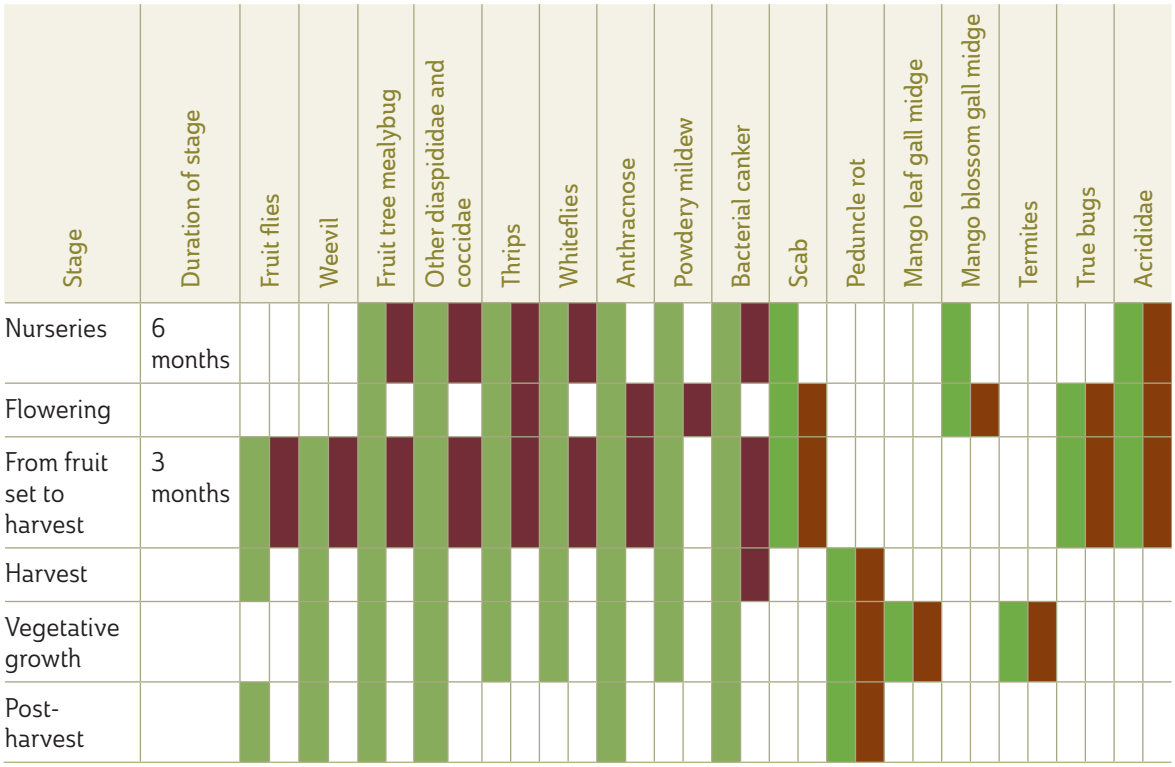
Figure 39: Damage to a branch

Figure 40: Marks on the underside of a leaf. Black marks are surrounded by a lighter, oily halo.

Figure 41: Damage on fruit.

1.3. Appearance of pests and diseases by plant phenological stage

The table below shows the phenological stages when the crop's pests and diseases may be present and the stages when their presence leads to the most significant losses. During these later stages, they need to be monitored and controlled most carefully if need be. It should be noted that the presence of a pest or disease does not always lead to damage to the crop.



1.4. Significance by country - periods of the year and favourable climatic conditions for the crop's adversaries

Legend:

BEN = Benin, BUR = Burkina Faso, CAM = Cameroon, CIV = Côte d'Ivoire, DOR = Dominican Republic, GHA = Ghana*, KEN = Kenya, MAL = Mali, SEN = Senegal**, TAN = Tanzania

* for the south of Ghana (according to the symptoms described)

** regions of Thiès and Dakar 0 = no damage

\+ not very significant damage

++ quite significant damage: checks required

+++ significant damage: checks essential

X damage generally not very significant, but the change in the significance of the damage over the year is unknown

XX damage may be quite significant, but the change in the significance of the damage over the year is unknown

XXX damage may be significant, but the change in the significance of the damage over the year is unknown
/ no information available
? the cycle of the disease and its presence on the tree outside the flowering season have not been studied.

Note: Since an exhaustive inventory of pests and diseases was not carried out for each country, it is possible that the pest is present but has never been observed on the crop in that country because it does not cause significant damage. You will note that there are no tables for true bugs, termites and acrididae, since these insects have no particular seasonal variation.

Fruit flies – *Ceratitis* spp., *Bactrocera* spp., *Anastrepha* spp.

Favourable conditions: heat and humidity

Month	1	2	3	4	5	6	7	8	9	10	11	12
BEN	+	++	+++	+++	+++	+++	++	++	+	+	+	+
BUR	++	+++	+++	+++	+++	++	++	++	+	++	+	++
DOR	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
GHA	+	+	++	+++	+++	+++	+++	+++	+	+	+	+
SEN	+	+	+	++	++	+++	+++	+++	+++	++	++	++
CIV	+	+	+++	+++	+++	+++	+++	+++	+	+	+	+
MAL	+	+	+	+++	+++	+++	+++	+++	+	+	+	+
CAM	+	+	++	+++	+++	+++	+++	+++	+	+	+	+
KEN	+++	+	+	+	+	+	+	++	++	+++	+++	+++
TAN	+++	+	+	+	+	+	+	++	++	+++	+++	+++

Mango stone weevil – *Sternochetus mangiferea*

Favourable conditions unknown

Month	1	2	3	4	5	6	7	8	9	10	11	12
BEN	++	+++	+++	+++	+++	++	+	+	+	+	+	++
BUR	+	+	+	+	0	0	0	0	+	+	+	+
DOR	X	X	X	X	X	X	X	X	X	X	X	X
GHA	+++	+++	+++	+++	+++	++	+	+	+	+	+++	+++
SEN	/	/	/	/	/	/	/	/	/	/	/	/
CIV	X	X	++	++	++	X	X	X	X	X	X	X
MAL	/	/	/	/	/	/	/	/	/	/	/	/
CAM	X	X	X	X	X	X	X	X	X	X	X	X
KEN	X	X	X	X	X	X	X	X	X	X	X	X
TAN	X	X	X	X	X	X	X	X	X	X	X	X

Fruit tree mealybug – *Rastrococcus invadens*

Favourable conditions: generally more prevalent during the dry season. The prevalence of the mango tree mealybug is falling in the savannahs of west Africa, but invasions are liable to start again at any time.

Month	1	2	3	4	5	6	7	8	9	10	11	12
BEN	+	+	+	0	0	0	0	0	0	0	+	+
BUR	++	++	+	+	+	+	+	+	+	+	+	++
DOR	0	0	0	0	0	0	0	0	0	0	0	0
GHA	+	+	+	+	+	+	+	+	+	+	+	+
SEN	+	+	+	+	+	+	+	+	+	+	+	+
CIV	+	+	+	+	+	+	+	+	+	+	+	+
MAL	+	+	+	+	+	+	+	+	+	+	+	+
CAM	/	/	/	/	/	/	/	/	/	/	/	/
KEN	/	/	/	/	/	/	/	/	/	/	/	/
TAN	/	/	/	/	/	/	/	/	/	/	/	/

Other mealybugs: Diaspididae and coccidae - *Icerya seychellarum, Coccus mangiferae, Aulacapsis tuberculatis, Pseudoaonidia tribitiformis, Ceratoplastes* spp., *Protpulvinaria mangiferae*

Favourable conditions: generally more prevalent during the hot and dry season.

Month	1	2	3	4	5	6	7	8	9	10	11	12
BEN	+	+	+	+	0	0	0	0	0	0	+	+
BUR	0	0	+	+	+	+	+	+	+	+	0	0
DOR	X	X	X	X	X	X	X	X	X	X	X	X
GHA	X	X	X	X	X	X	X	X	X	X	X	X
SEN	X	X	X	X	X	X	X	X	X	X	X	X
CIV	X	X	X	X	X	X	X	X	X	X	X	X
MAL	X	X	X	X	X	X	X	X	X	X	X	X
CAM	X	X	X	X	X	X	X	X	X	X	X	X
KEN	X	X	X	X	X	X	X	X	X	X	X	X
TAN	X	X	X	X	X	X	X	X	X	X	X	X

Thrips - *Selenothrips rubrocinctus, Scirtothrips aurantii*

Favourable conditions: generally more prevalent during the hot and dry season.

Month	1	2	3	4	5	6	7	8	9	10	11	12
GHA	+++	+++	+++	++	+	+	+	+	+	++	++	++
BUR	++	++	++	++	+	+	+	+	+	++	++	++
SEN	++	++	++	++	++	++	+	+	+	+	+	+
BEN	++	++	++	+	0	0	0	0	0	0	+	++
DOR	+	+	+	+	+	+	+	+	+	+	+	+
CIV	++	++	++	++	+	+	+	+	+	++	++	++
MAL	++	++	++	++	+	+	+	+	+	++	++	++
CAM	++	++	++	++	+	+	+	+	+	++	++	++
KEN	+	+	+	+	++	++	++	++	++	+	+	+
TAN	+	+	+	+	++	++	++	++	++	+	+	+

Whiteflies - *Aleurodicus dispersus* and *Aleurocanthus woglumi*

Favourable conditions: generally more prevalent during the long dry seasons. Precipitation harms their development.

Month	1	2	3	4	5	6	7	8	9	10	11	12
GHA	++	++	+++	++	+	+	+	+	+	++	++	++
BUR	++	++	++	+++	++	+	+	+	+	+	+	++
BEN	++	++	+	+	0	0	0	0	+	+	+	++
DOR	X	X	X	X	X	X	X	X	X	X	X	X
SEN	X	X	X	X	X	X	X	X	X	X	X	X
CIV	X	X	X	X	X	X	X	X	X	X	X	X
MAL	/	/	/	/	/	/	/	/	/	/	/	/
CAM	X	X	X	X	X	X	X	X	X	X	X	X
KEN	X	X	X	X	X	X	X	X	X	X	X	X
TAN	/	/	/	/	/	/	/	/	/	/	/	/

Mango blossom gall midges - *Procontarinia mangiferae*

Results have shown that P. mangiferae is present in mango orchards throughout the year, but that there is some seasonal variability. Its population density is highest during the flowering period (from June to October) (Amouroux 2013).

Month	1	2	3	4	5	6	7	8	9	10	11	12
REU	+	+	+	+	+	+++	+++	+++	+++	+++	+	+

Anthracnose - *Colletotrichum gloeosporioides* and other fungal diseases (*Alternaria* sp., etc.)

Favourable conditions: water plays a key role in the contamination process since spores are always transported by water. In the event of high humidity levels, a mass of sticky spores appear on the surface of pre-existing marks on the leaves, inflorescences, branches, and so on. Significant rainfall, or possibly heavy dew run-off, is needed to spread these spores to healthy surrounding host organs (inflorescences, young leaves and fruit). High humidity levels (≥ 95%) and temperatures between 10°C and 30°C (ideally +/- 25°C) after rainfall are very favourable conditions for the germination of spores and the formation of appressoria (latent form).

The table below shows the periods of the year and favourable weather conditions for anthracnose and fungal diseases such as alternaria, scab, sigatoka, stemphylium, *aspergillus, cladosporium, fusarium, penicilium and rhizopus*. It should be noted that these fungal diseases mainly develop between flowering and harvest.

Month	1	2	3	4	5	6	7	8	9	10	11	12
GHA	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
BUR	++	+	+	++	++	++	++	++	++	++	++	++
SEN	++	+++	+++	+++	+++	+++	+++	+++	+++	+++	++	++
BEN	++	++	++	+++	+++	+++	+++	+++	+++	++	++	++
DOR	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
CIV	++	+	+	+++	+++	+++	+++	++	++	++	++	++
MAL	++	+	+	++	+++	+++	+++	+++	++	++	++	++
CAM	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
KEN	+++	+++	+++	+++	+++	++	++	++	++	+++	+++	+++
TAN	+++	+++	+++	+++	+++	++	++	++	++	+++	+++	+++

Powdery mildew - *Oïdium mangiferae*

Favourable conditions: the damage caused by this disease can be particularly serious when temperatures are mild and humidity levels are reasonable but not excessive (no precipitation). High temperatures and significant precipitation hinder the germination of spores. The conidia are transported by the wind. They germinate at temperatures between 9°C and 32°C (ideally 23°C) with humidity levels of just 20%. These weather conditions are usually present at the start of the cycle when new leaves and flowers are appearing. In the tropics, cooler regions at altitude or bordering the ocean are more affected by this diseases than hot and humid coastal areas.

Month	1	2	3	4	5	6	7	8	9	10	11	12
GHA	+	+	+	0	0	0	0	0	0	0	0	+
BUR	+	+	+	0	0	0	0	0	0	0	0	+
BEN	++	++	++	+	+	+	+	+	+	+	+	++
DOR	++	++	++	++	++	++	++	++	++	++	++	++
SEN	++	++	++	++	++	+	0	0	0	0	0	++
CIV	+	+	+	0	0	0	0	0	0	0	0	+
MAL	+	+	+	0	0	0	0	0	0	0	0	+
CAM	++	++	++	++	++	++	++	++	++	++	++	++
KEN	++	++	++	++	++	++	++	++	++	++	++	++
TAN	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX

Fusarium wilt: *Fusarium tupiense*

This disease has been observed on inflorescences in Casamance (Senegal) but the cycle of the disease and the length of time it stays on the tree outside the flowering period have not been studied (indicated by a ? in the table).

Month	1	2	3	4	5	6	7	8	9	10	11	12
SEN	++	++	?	?	?	?	?	?	?	?	?	++

Peduncle rot: *Dothiorella* spp., *Lasiodiplodia* spp., *Phomopsis* spp.

These diseases caused by Botryosphaeriaceae mainly attack the fruit after the harvest and lead to the branches, and sometimes the entire tree, drying out, especially if it has undergone a period of stress. If peduncle rot is only detected after the harvest, the disease stays in the tree permanently. These fungi are both saprophytic and pathogenic for mango trees.

Month	1	2	3	4	5	6	7	8	9	10	11	12
GHA	++	++	++	++	++	++	++	++	++	++	++	++
BUR	++	++	++	++	++	++	++	++	++	++	++	++
SEN	++	++	++	++	++	++	++	++	++	++	++	++
BEN	++	++	++	++	++	++	++	++	++	++	++	++
DOR	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
CIV	++	++	++	++	++	++	++	++	++	++	++	++
MAL	++	++	++	++	++	++	++	++	++	++	++	++
CAM	?	?	?	?	?	?	?	?	?	?	?	?
KEN	?	?	?	?	?	?	?	?	?	?	?	?
TAN	?	?	?	?	?	?	?	?	?	?	?	?

Bacterial canker - *Xanthomonas citri* pv. *mangiferaeindicae*

Favourable conditions: bacteria survive in lesions of various organs of the plant: leaves, branches, fruit, etc. During rainfall, they are secreted in the resin which oozes from the cankers and can then infest other organs. When rain is combined with strong winds, the bacteria can be transported to other mango trees.
When the rainy season starts during the harvesting period - which is the case for most of west Africa - it is usually the later fruit that are attacked. The infestation of trees continues throughout the rainy season and the start of the dry season.

Month	1	2	3	4	5	6	7	8	9	10	11	12
GHA	++	++	++	+++	+++	+++	+++	+++	+++	+++	++	++
BUR	++	++	++	+++	+++	+++	+++	+++	+++	+++	++	++
DOR	/	/	/	/	/	/	/	/	/	/	/	/
SEN	/	/	/	/	/	/	/	/	/	/	/	/
CIV	++	++	++	+++	+++	+++	+++	+++	+++	+++	++	++
MAL	++	++	++	+++	+++	+++	+++	+++	+++	+++	++	++
CAM	/	/	/	/	/	/	/	/	/	/	/	/
KEN	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
TAN	/	/	/	/	/	/	/	/	/	/	/	/

2. MAIN CONTROL METHODS

2.1. Introduction

Successful organic farming relies on the implementation of an integrated approach to combat pests and diseases based largely on a collection of fundamental preventative strategies for reducing the likelihood and seriousness of any attacks. When these measures are correctly applied, diseases and insect infestations only very rarely reach the economic thresholds set out.

Various preventative measures need to be implemented to mitigate the impact of infestations and diseases. The following sections outline the most important measures.

- Identification by region - the prevalence, periods and seriousness of specific diseases or infestations for a given region is extremely important information because these factors can have a considerable impact on production costs and reliability. Drawing up an organic production management plan can help reduce the risks identified. Organic mango farming may prove difficult in areas with a humid climate during the fruiting period.
- The management of adjacent land - abandoned orchards or poorly maintained land can be breeding grounds for diseases or infestations.
- The choice of rootstocks and varieties grown - these choices should focus as far as possible on plants renowned for their resistance. Selecting varieties suited to local growing conditions will ensure the successful development of plants able to resist any infection.
- Maintenance of healthy trees - emphasis should be placed on maintaining healthy trees which are naturally able to resist minor diseases or infestations. Healthy trees are a sign of healthy soil, which is a soil that is biologically active containing the necessary organic matter and with a nutrient cycle able to counterbalance the physical, biological and chemical characteristics of the soil.
- Pruning trees - pruning which ensures good ventilation and a sufficient level of internal light (but not too much so that the fruit is burnt) can help significantly to reduce the emergence of diseases and guarantee that the fruit has attractive colouring.
- Promoting biodiversity - the ground of the orchard must be mown in good time and various species should be planted to attract and retain useful organisms. Windbreaks and shelterbelts can also be designed so as to promote biodiversity.
- Maintenance - vigilant and diligent maintenance of the orchard is essential. Removing infected wood, fruit and plant tissue can reduce the seriousness of subsequent infections. Severing and burning contaminated parts of a tree can significantly reduce infestations in the case of bacterial canker or fusarium wilt, for instance.

- Quick decomposition - the amount of infected plant material representing a future source of inoculum can be reduced through quick decomposition, which can be encouraged by covering the orchard floor with mulch.

Suitable identification methods, regular monitoring and timely intervention are key elements to effectively combating pests and diseases.

2.2. Preventative measures and quality of plants in nurseries

Various pests and diseases are spread by human activities. These pests and diseases are spread in two stages: (i) the pest or disease is introduced to a healthy area (production country or region), then (ii) it is spread with the production area.

A pest or disease is almost always introduced into a healthy area through human activity, such as transporting infested plant material, importing fruit or pallets containing larvae and/or spores, etc. This is not always directly related to horticultural activities and may be due to insects being transported on a plane, ship or container, for instance.

Pathogens spread through production areas at differing speeds and in different ways depending on the pathogen in question and the environmental conditions: insects flying from one orchard to another, spores or bacteria transported by the wind, use of infested plant material, etc. Although it is difficult to prevent flying insects or spores from getting into the orchard, it is essential to use healthy plant material. With this in mind, nurseries play a key role. In some countries, nurseries are deemed a commonplace practice not requiring any technical knowledge. Plants derived from seeds of unknown origin sown in plastic sacks into a substrate which is not disinfected are sold grafted or as they are. These plants are the sources of diseases, which are either on the plants or in the substrates used in the nurseries.

In some countries, nurseries are governed by strict regulations and are subject to regular checks. Nursery owners have a high level of technical expertise and make a significant contribution to improving the general health of orchards by producing healthy plants and using varieties and rootstocks which are suited to the environment and resistant or tolerant to soil diseases (e.g. rootstocks tolerant to salt in certain countries). In any case, using rootstocks of a known and established origin can help to create orchards with homogeneous trees.

Prevention is the least costly and most ecological method because it does not involve any treatment.

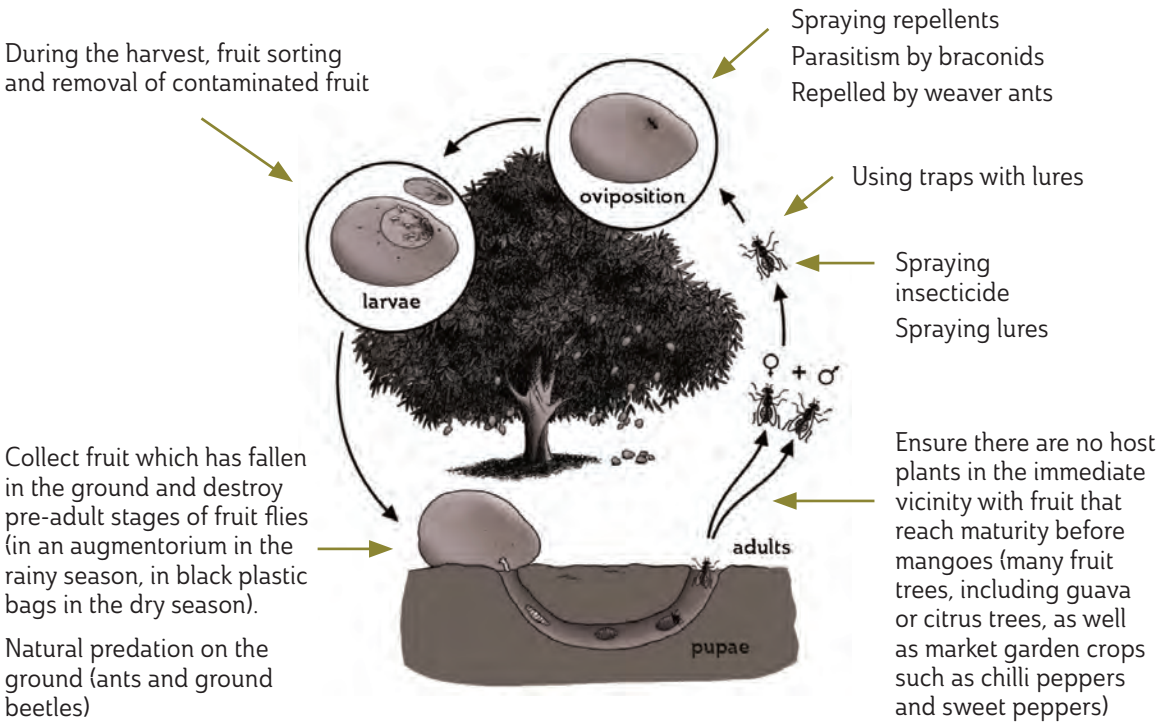
2.3. Cycle of pest or disease; positioning of control methods and factors influencing its development

This section sets out the methods of control to be applied depending on the development stage of each pest or disease and the effect of natural factors other than the weather (addressed in section 1.4). Thereafter, the positioning of methods of control with regard to the plant's development cycle is set out.

Important: the illustrations of the life cycles show different development stages but they should in no event be used as tools to identify pests or diseases. For identification, please refer to section 1.2.

FRUIT FLIES
Ceratitis spp., *Bactrocera* spp., *Anastrepha* spp.

Positioning of control methods in relation to the pests' development cycle



The female lays her eggs in bunches underneath the skin of a nearly ripe fruit. The eggs hatch from 2 to 5 days later. After spending between 9 and 15 days inside, the maggots (third larval stage) leave the fruit, transform into pupae on the ground and then become adult flies.

Positioning of control methods in relation to the development cycle of the plant

In orchards

Good orchard maintenance is essential for combating fruit flies, regardless of the species.

As the fruit begins to form

- Mangoes with dimples and those oozing clear sap should be removed, as these are signs that eggs are present. Although it is more laborious, this method is more effective that collecting rotten fruit which has fallen on the ground, since the maggots may have already left the fruit and transformed into pupae when this fruit is collected.
- Catching flies:
  - Traps can be used to monitor and eliminate fruit flies.
  - The mass trapping method requires a high concentration of traps. This should be differentiated from detection trapping, which involves a maximum of two traps per hectare (Vayssières and Sinzogan, 2008b).
  - Mass trapping can involve between 50 and 100 traps per hectare depending on the type of trap, the local conditions and the climate.
  - There are two main types of lure:
    - sex-based lures, or parapheramones, which only attract males (the species attracted differs depending on the type of parapheramone used);
    - food-based lures, usually protein hydrolysates, which attract both males and females.
  - The traps also contain an insecticide authorised in organic farming, which kills the flies.
  - Traps with fresh bait must be hung on low branches which can be reached from the ground. The bait must be replaced twice a week.
  - Examples of fresh bait: pieces of ripe banana soaked in a mixture of sugar and water, sugar and vinegar or water and honey.
  - Detection trapping of fruit flies can be used to calculate the abundance of adult flies per hectare. Detection trapping is a tool which can help you decide (i) when to use phytosanitary treatment and (ii) whether the treatment is cost-effective. The Economic Damage Threshold will have already been determined.
  - There are also methyl eugenol-based traps, which only capture males of the Bactrocera species.

- The main integrated methods of control used by the *West African Fruit Fly Initiative* (WAFFI) in Benin and some other countries in west Africa include three main parts:

  1. Preventative measures (harvest and destruction of bitten fruit);
  2. IPM measures using spot treatments;
  3. Organic control measures using weaver ants and parasitoids. All these measures are compatible and work well together.

During the harvest

- Pick fruit at the ripe green stage, when it is unlikely to be infested.
- Avoid transporting fruit from infested areas to non-infested areas.
- Clean the orchard. All fallen and damaged ripe fruit must be collected each day and destroyed to remove any potential reproduction sites.
- Do not throw damaged fruit onto compost heaps. Bury them in the ground 50cm or so deep so that any adult flies are not able to come up to the surface.
- Put fruit collected from the ground into an 'augmentorium'. This device is a tent-like structure which prevents a repeat infestation by a new generation of adult flies which emerge in the augmentorium, while a net with a specific size mesh is placed over the roof to allow the flies parasitoids to escape.

After the harvest

Heat treatment may be applied to eliminate the flies at different stages in the fruit. The fruit must be immersed in hot water (46.1°C) for 75 to 90 minutes depending on its size, ripeness and variety. This treatment type is not necessarily cost-effective and heat can also alter the quality of the fruit. Special attention should be given to the smallest fruit, which is the most sensitive to heat treatment. In order to limit the potential impact of heat treatment as much as possible, trials should be carried out in advance to adjust the settings of the treatment (time and temperature).

- It is vital to identify fruit with bite marks so that it can be eliminated during the harvest or sorting.

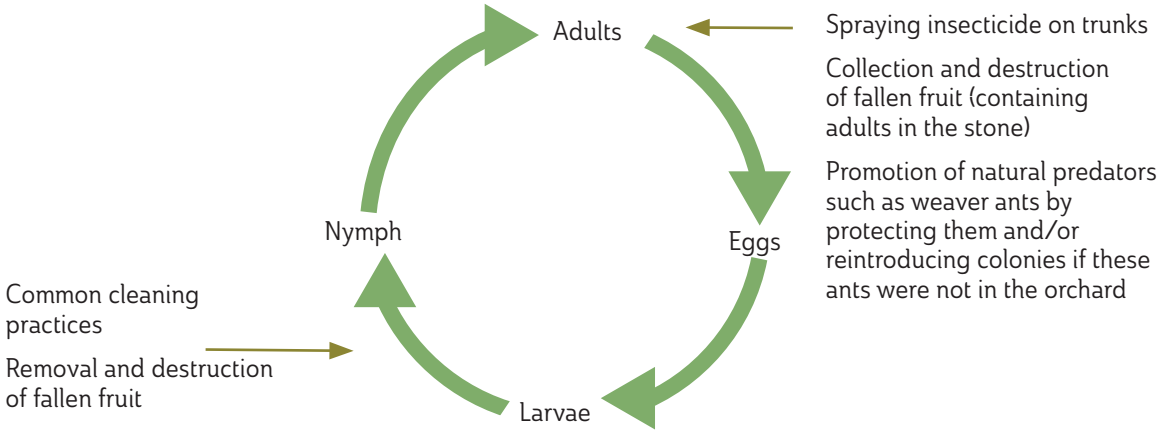
For more information on fruit flies, visit: https://afrifly.wordpress.com/

MANGO STONE WEEVIL
Sternochetus mangiferae

Positioning of control methods in relation to the pests' development cycle

The females lay their eggs randomly in recesses on the surface of the fruit as it ripens. After hatching, the larvae make their way through the flesh to the stone, which is still being formed. In general, one larva reaches adulthood per fruit. Larval development usually takes place inside the stone and very rarely in the flesh of the fruit.

Adult weevils usually leave the stone one or two months after the fruit drops from the tree.



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

Adult weevils remain in diapause under bark or rocks until the next flowering. When active, they only move around at night.

Positioning of control methods in relation to the development cycle of the plant

In orchards

At all stages

- To ensure that non-infested orchards remain healthy, it is important to check that no mango which may contain a weevil in its stone is introduced to the orchard or nearby areas. Strict application of this safety measure will considerably reduce risks of infestation. It is also advisable to remove any wild mango trees located in the immediate proximity of the production site.

- Harvesting and destroying fruit bitten by weevils combined with the use of weaver ants considerably reduces the impact of the mango stone weevil on mango production.

Before flowering

- During diapause, adult weevils are at rest under the bark of the tree and are very vulnerable. Eliminating them while they are under the bark before the tree flowers helps to prevent infestation.

During the harvest

- Infested fruit is very difficult to detect because the damage caused is not visible from the outside. Sorting the fruit is therefore impossible.
- Cleaning the orchards and removing any fallen fruit and stones requires considerable manual labour, as does the complete removal and destruction of fruit collected from the ground. This method has proven to be only partially effective in eliminating weevils.
- The fruit and stones on the ground in orchards affected by weevils must be destroyed correctly.
- When fruit is transported from infested areas to healthy areas, especially for processing, it is important to burn all stones after using the pulp. Never transport stones from infested areas to be sown in nurseries.

FRUIT TREE MEALYBUG
Rastrococcus invadens

The mango tree mealybug is seen as one of the biggest threats to mango trees in certain production areas in west Africa.

Its life cycle is split into three main stages: eggs, nymphs and adult insects. Trees are colonised by initial stage mobile larvae, which are transported by the wind from one tree to another and from one orchard to the next. Unlike diaspididae, these mealybugs can move around the plant at every stage of their development because they retain the ability to remove their rostrum from the place it is attached and bury it elsewhere.

The main methods of control used in nurseries and orchards are as follows:

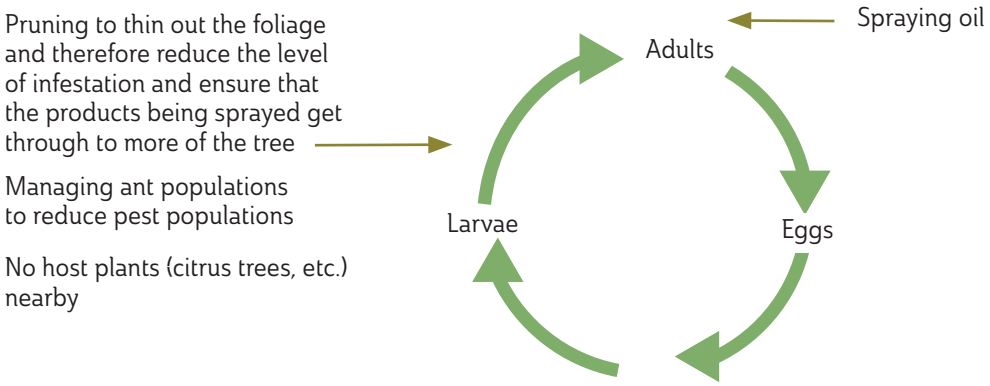
- This mealybug arrived in the coastal areas of the Gulf of Guinea without any natural predators and invaded all the mango trees in those regions. The IITA (International Institute of Tropical Agriculture) whose biological control laboratory is based in Cotonou, Benin, introduced hymenoptera from India, which are parasites of *R. invadens* (*Gyranusoidea tebygi Noyes* and *Anagyrus mangicola Noyes*). These parasitoids helped to control the mealybug very effectively in all coastal and wetland areas. In areas of dry savannah, controlling this pest has been more piecemeal and less effective (Conakry and surrounding area, Korhogo area in Côte d'Ivoire, Sikasso area in Mali, etc.) but, in organic farming, the use of natural predators remains the best approach for large-scale control.

- The main aim is therefore to promote the development of parasitoids, which involves, for instance, not using insecticides which are more harmful to auxiliary species than to mealybugs. Indeed, treatments involving general insecticides would lead to short and medium-term spreads of mealybugs, whose numbers would no longer be controlled by their natural enemies. If fruit tree mealybugs are detected on neighbouring host plants, spray them regularly with a (sufficiently powerful) jet of water to knock the insects off the plants. They then become potential prey for predators on the ground, making it harder for them to climb back up the plant. Fruit tree mealybugs that are sprayed off plants are also fertile ground for the development of fungal parasites.
- Getting rid of fruit tree mealybugs by hand or with brushes helps to reduce existing colonies on the infested plant because removed mealybugs secrete a chemical substance which warns remaining mealybugs of the danger and encourages them to leave the plant by detaching themselves.
- It is also advisable to prune the parts of the tree which have been colonised. The aim of this measure is to reduce the number of infected sites and the size of subsequent colonies.
- Ensure there are no host plants nearby. Mealybugs can survive on different hosts, including cashew trees, guava trees and various natural or cultivated species. However, mango trees remain their main host and it is rare to see mango tree mealybugs support themselves on other species of fruit trees if there are no infested mango trees nearby.

OTHER MEALYBUGS: DIASPIDIDAE and COCCIDAE

Icerya seychellarum, Coccus mangiferae, Aulacapsis tuberculatis, Pseudoaonidia tribitiformis, Ceratoplastes spp., *Protpulvinaria mangiferae*

Positioning of control methods in relation to the pests' development cycle



The eggs are very difficult to detect because they are laid under the shell of the adult female. After hatching, the larvae crawl out from under the shell to look for food.

Most mealybugs are controlled naturally by parasitoids or predators like ladybirds. Mealybugs tend to spread after insecticides are used which have a greater impact on auxiliary species than on the mealybugs or following disruptions to the physiological metabolism of the mango trees.

Positioning of control methods in relation to the development cycle of the plant

In orchards

At all stages

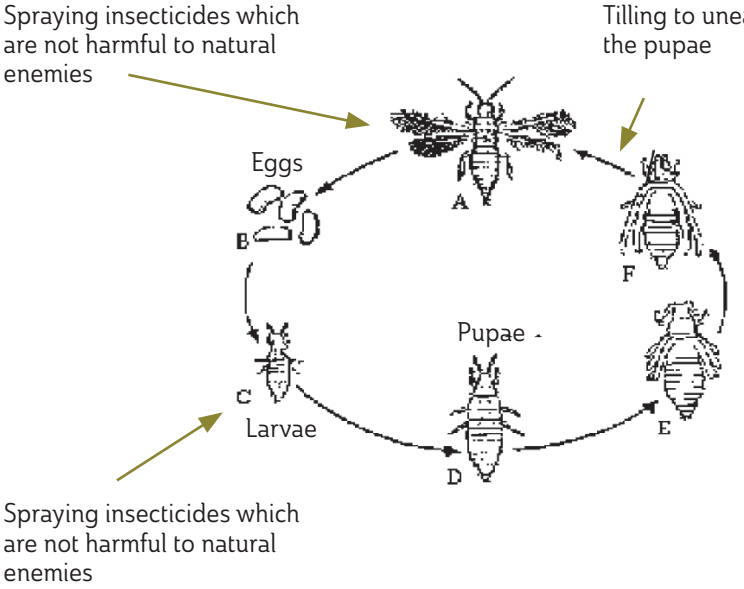
- Protect the natural enemies of mealybugs by avoiding the use of insecticides which affect the parasitoids or predators. The spread of these pests is especially significant after insecticide treatments to which the parasitoids or predators, such as ladybirds, are much more sensitive than the mealybugs, which are protected by their wax or shield. These milder insecticides therefore encourage these spreads by killing the parasitoids but not the mealybugs.
- Ensure there are no host plants (citrus trees, etc.) nearby.
- Some species (e.g.: *Coccus sp.*) are protected by ants. Controlling populations of red ants (e.g. *Solenopsis* spp.) helps to eliminate these pests.

After the harvest

- Pruning helps to thin out the foliage and therefore reduces the level of infestation and ensures that the products being sprayed get through to more of the tree.

THRIPS
Selenothrips rubrocinctus, Scirtothrips aurantii

Positioning of control methods in relation to the pests' development cycle



Control at every stage

Avoid having host plants nearby including avocado trees, citrus fruit trees, cashew trees, cacao trees, palm trees and guava trees.

Allow light through by pruning

Installing windbreaks helps to reduce numbers of thrips, which move by being transported by the wind

Attract natural enemies and help their populations to grow (predator thrips, plant bugs, anthocoridae and *entomophtora*)

The females lay their eggs in incisions made to the underside of the leaves and cover them with a fluid. Nymphs emerge around 12 days later and reach adulthood in two weeks.

Positioning of control methods in relation to the development cycle of the plant

In orchards

Before planting fruit trees

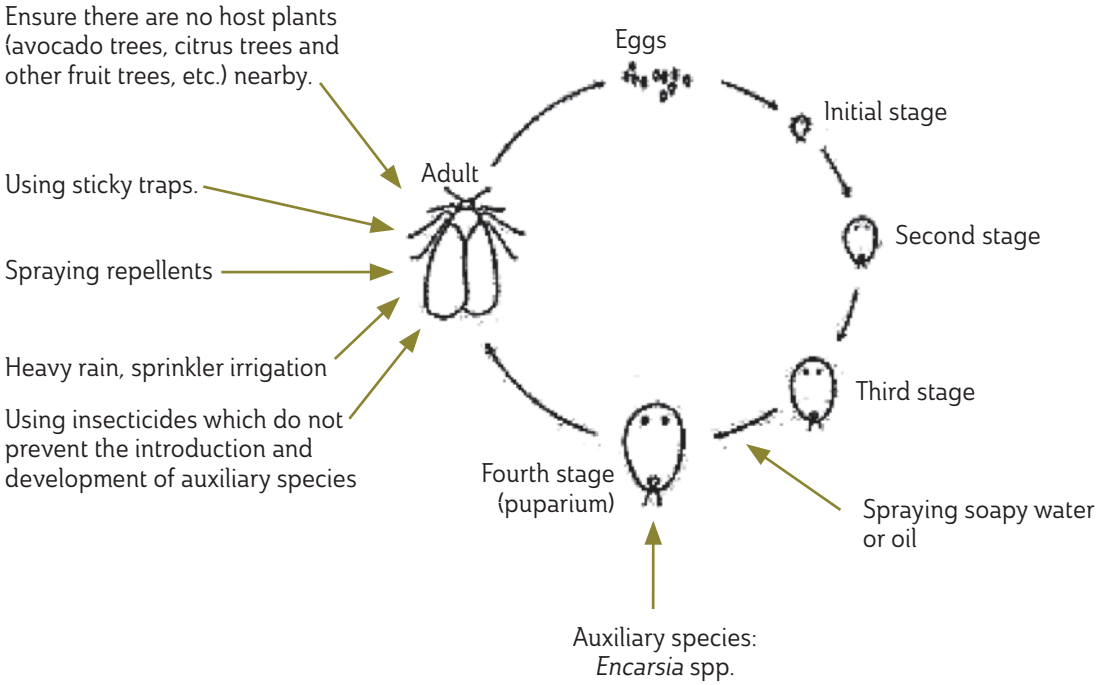
- Given that thrips are transported by the wind, installing a windbreak helps to reduce their populations.
- Ensure there are no host plants in the vicinity (avocado trees, citrus trees, cashew trees, cacao trees, palm trees, guava trees, etc.)

At all stages

- Larvae and adult thrips are sensitive to light. Pruning helps to let more light through to the rest of the tree.
- If required, insecticides which are non-toxic to their natural predators can be sprayed.
- Sulphur treatments help to repel thrips. However, in hot and dry conditions, sulphur can damage the tree's flowers.

WHITEFLIES
Aleurodicus dispersus and *Aleurocanthus woglumi*

Positioning of control methods in relation to the pests' development cycle



Positioning of control methods in relation to the development cycle of the plant

In orchards

At all stages

- Ensure there are no host plants (avocado trees, citrus tree, other fruit trees, etc.) nearby.
- Plant marigolds (*Tagetes* spp.), which are used as repellents.
- Spray insecticides, soapy water or oil in the event of a serious infestation.
- Combine crops which are sensitive to whiteflies with others that are resistant to them in order to increase the diversity of helpful insects.
- Sticky, yellow traps can be used to catch a large number of whiteflies. Their concentration must be evaluated and adjusted according to local conditions. They are simple to make - just apply a sticky substance to a piece of yellow plastic, since the colour yellow attracts flies. The sticky substance used can be a fatty material or resin from certain species of pine trees. The fatty material must not melt in the sun or be black to ensure that the yellow plastic is not covered up. It must not be edible, or animals may lick it. For vertical traps, the plastic can be held in place between poles and the sticky substance can be coated on both sides. When the trap is used to protect seedlings, it can be placed horizontally on the surface of the plants or tied around the small branches planted at each end of the seedlings. The size and shape of the

plastic used is insignificant. Vertical traps are usually between 0.5m and 1m tall and between 0.7m and 1.5m wide and are placed around 50cm above the ground. Horizontal traps can be much smaller. Vertical traps must be placed around the mango trees. If there are enough of them, they should be placed alongside each other to prevent insects coming from neighbouring mango trees or other plants from passing in between them. They are particularly useful when placed in the direction of the prevailing wind so that the insects are caught before reaching the trees. Some growers also use mobile traps.

AFRICAN WEAVER ANTS
Oecophylla longinoda

These ants are also natural predators of various mango tree pests. They feed on other insects such as fruit flies (especially larvae), drosophila and other diptera, phytophagous plant bugs, adult weevils, termites, other ant species, whiteflies and mealybugs (coccidae and diaspididae). They also try to chase away ants which protect fruit tree mealybugs. More importantly, weaver ants have a repellent effect on female fruit flies, leading them to take evasive action, thus significantly reducing the damage to the fruit. Mango trees hosting weaver ants undergo fewer fruit fly attacks than those without these ants. However, they inflict painful bites on fruit pickers. Techniques tested by the WAFFI project help to prevent this problem: leaving food at the base of the tree (e.g. chicken intestines), spraying the tree with water, coating hands and feet with ash before climbing up the mango tree, and so on. Weaver ants are present in orchards throughout the year.

Positioning of control methods in relation to the development cycle of the plant

To take advantage of the beneficial effect of these insects while mitigating the negative aspects, measures can be taken to control the ant colonies before the harvest:

- Carefully remove or move their nest using mechanical tools;
- Prevent them from accessing the trees:
  - by cutting back and pruning, or even removing parasite plants and any climbing plant or epiphyte connecting the tree to the ground;
  - by applying a suitable fatty material.

Mango blossom gall midges (*Procontarinia mangiferae*) and mango leaf gall midges (*Procontarinia matteiana*)

Positioning of control methods in relation to the pests' development cycle

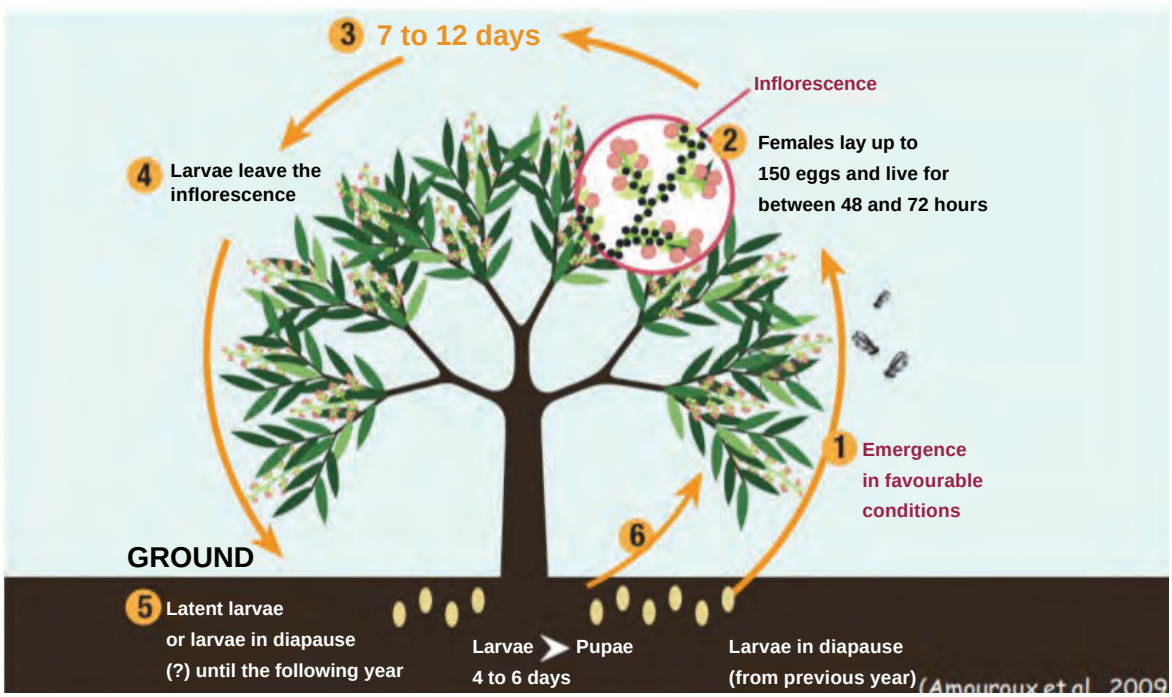


Figure 42: Life cycle of gall midges (Amouroux et al., 2009)

The life cycle of the insect lasts between 14 and 25 days in total and is shown in the diagram above. It consists of two main phases: an airborne phase and an underground phase.

Controlling these diptera with strategic chemical treatment is ineffective and difficult due to the successive generations produced during flowering and the fact that the larvae are protected inside the tissue of the mango. It is therefore advisable to apply treatments to the entire orchard. Collecting and destroying the attacked tree parts has also been suggested (Amouroux, 2013).

Strategies combining alternative control methods not involving pesticides may also be carried out, such as:

- Placing straw-mulching on the ground which serves as a physical barrier against larvae and thus breaks this pest's life cycle.
- Synchronising the flowering of different mango trees in the same plot in order to reduce the trees' window of sensitivity to these pests.

The adults are able to travel large distances. It is therefore important to design a control strategy on a larger scale than a single orchard in order to prevent colonisation by insects from neighbouring orchards (Criq, 2018).

TRUE BUGS

Anoplocnemis curvipes, Lygus spp., *Leptoglossus* spp.

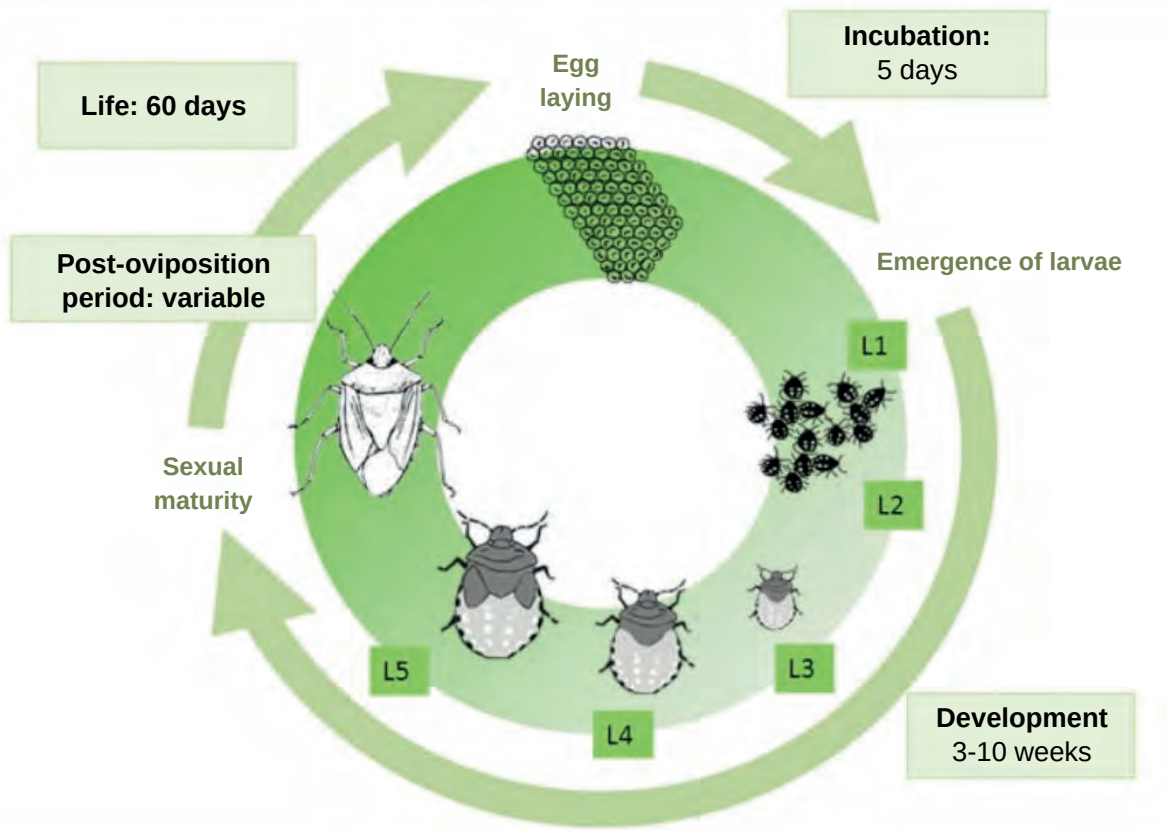


Figure 43: Life cycle of Nezara viridula. J. Poidatz (Koppert)

There are various species of true bugs. Some gregarious species coming from crops other than mangoes can land in a mango grove and cause a second infection in bacterial cankers.

Positioning of control methods

- Check plants' health quality
- Encourage natural enemies
- Use auxiliary species
- Use reasonable chemical protection

TERMITES

Since the life cycle of termites mainly takes place in the soil, it is hard to detect them before they attack the roots and trunk of mango trees. These insects tend to be in areas containing dead wood. Small openings or channels created by other insects on mango trees and weak or damaged plants can also allow them to access the trees.

To date, there is no effective organic method for combating termites. However, measures can be implemented to prevent attacks.

Preventative measures (Kengap Horticulture, 2011):

- Avoid damaging trees, which could give termites access to the plants
- Clean areas of damage to the trees to limit any further damage which could be caused by microcerotermes
- Ensure that trees are healthy and do not suffer from water stress
- Smear the trunk in lime milk or blanc arboricole to make termite attacks easier to detect
- Spread neem cake to repel termites

ACRIDIDAE

There are several groups of acrididae. Some of them are gregarious and can invade orchards en masse. They are usually controlled during their juvenile stages at egg-laying sites, which are often hundreds of kilometres away from the orchards affected, by organisations specialising in combating acrididae. Other species are sedentary and reproduce in the wilderness before invading orchards and other crops. Acrididae are now controlled on a large scale with biopesticides, particularly entomopathogenic fungi of the genus *Metarhizium,* specifically *Metarhizium acridum.*

Post-harvest rot - Anthracnose (*Colletotrichum gloeosporioides*) and other causative agents

Mango groves should be protected by a comprehensive approach, encompassing all stages from planting to harvest. Preventative measures and phytosanitary maintenance play an important role in maintaining the general health of the trees, reducing the periods of high humidity which can lead to infections and reducing the quantity of inoculum present during sensitive development stages of mango trees. Fungicide treatments after the harvest must be applied with care in order to provide specific protection, only where necessary and in the event of conditions particularly favourable to the appearance of certain fungi. When used in isolation, they rarely guarantee a satisfactory level of protection. Careful harvesting can limit the risks of damage and further contamination, as well as the risk of reactivating latent infections which emerged during the ripening of the fruit. Post-harvest treatments can deactivate latent infections and prevent them from developing during the marketing process. The summary table below shows the level of effectiveness of various protective measures, sources of inoculum and conditions favourable to the appearance and development of fungi.

SUMMARY TABLE OF THE MAIN FUNGI RESPONSIBLE FOR POST-HARVEST ROT IN WEST AFRICA: SOURCES AND SPREAD OF INOCULUM, CONDITIONS WHICH PROMOTE INFECTION AND THEIR DEVELOPMENT, AND THE EFFECTIVENESS OF PROTECTIVE MEASURES

Fungus	Source of inoculum			Spread		Latent infection			Develop-ment		Effectiveness of protective measures			
											In orchards			After the harvest
	Leaves	Flowers, branches	Debris, ground, fruit	Precipitation	Wind	external	internal	During the harvest	< 24°C	> 24°C	Preventative	Phytosanitary products	Diligent harvesting	Hot water
Alternaria	++	++	++	++	+++	+++	+	+	++	+	+++	+	++	+++
Cercospora	++	?	?	++	++	+++	-	?	?	?	+++	?	++	?
Colletotrichum	++	++	+	+++		+++	-	+	+	+++	+++	+	++	+++
Stemphylium	?	?	+	?	?	+++	-	+ ?	+++	?	+++	?	++	?
Dothiorella	+	+++	+++	+++	+	++	+++	+++	+++	++	+++	-	+++	++
Lasiodiplodia	-	++	+++	+++	?	+	+++	+++	+	+++	+++	-	+++	+
Aspergillus	-	-	+++	-	+++	-	-	+++	++	++	++	-	+++	++
Cladosporium, Penicillium	-	-	+++	-	+++	-	-	+++	++	++	++	-	+++	++
Fusarium	-	-	+++	++	+	-	-	+++	++	++	++	-	+++	?

-: not applicable; +: not very significant; ++: quite significant; +++: very significant; ? Unknown link.

Preventative measures can significantly reduce the risk of contamination.

When planting the mango grove:

- Select young plants from nurseries, which are free from disease;
- Leave enough space between the plants to allow air to circulate.

For maintenance of the orchard:

- Prune superfluous branches to provide better aeration of the foliage and avoid excessive volume;
- Limit the height of the mango trees by pruning so that the phytosanitary treatments have an effect on the entire foliage.

Before flowering:

- Remove dead or partially necrotic parts by pruning - these are potential sources of further contamination.

After flowering:

- Regularly collect and burn dead or necrotic tree parts, which are on the ground (remains of inflorescences, dry branches, dead leaves, including leaves of young plants, etc.);
- Support low branches to prevent the fruit from touching the ground;
- Take steps to reduce populations of fruit flies;
- Regularly collect fruit which has fallen on the ground and cover it with earth in order to prevent spores being spread by the wind or insects.

During the harvest:

- Handle mangoes with care to avoid damaging them;
- Prevent the fruit from coming into contact with the ground, especially sandy, abrasive and muddy ground (during the rainy season);
- Solve the problem of dripping sap by placing the fruit on stands that are easy to clean.

Throughout the year, and more frequently during periods of flowering and fruit formation which coincide with the rainy season:

- Conduct a simple epidemiological survey: monitor the phenological stages of the mango trees, keep weather logs, note the appearance of symptoms and assess the degree of contamination of young shoots, leaves and inflorescences.

ANTHRACNOSE
Colletoricum gloeosporiodes

How does *Colletoricum gloeosporiodes* develop on the plant?

Spores form on branches and dead leaves and are spread by water.

On the surface of the fruit, the infection takes place when a spore germinates, followed by the formation of an external appressorium that germinates shortly after. The resulting hypha crosses through the upper layers of the cuticle and epidermis without going through existing orifices such as the lenticel or lesions. Inhibiting substances in unripe fruit, including resorcinol, hinders its progress. Appressoria in the process of germination remain latent until the harvest. Symptoms appear in the form of marks on the skin of the fruit either just before harvest or more generally just after, during the preservation stage.

The surface of fruit contaminated by droplets transporting spores is manifested as marks in the shape of tear drops.

Positioning of control methods in relation to the development cycle of the plant

In nurseries

- In regions with a dry season less than two to four months before flowering, only non-sensitive varieties should be selected. Atmospheric pressure also needs to be taken into account in coastal areas which have a long season with no rain but high humidity.
- The resistance of the seeds taken from nurseries unaffected by anthracnose must be strengthened before planting. Hardening the plants involves placing them in conditions which are gradually more and more similar to those in the field (e.g. gradually exposing them to more light).

In orchards

- Avoid having host plants near the plantation, including citrus fruit trees, banana trees, papaya trees, avocado trees, coffee plants and cashew trees.
- Good ventilation through the orchard plays a critical role in combating anthracnose. Dead leaves and branches should therefore be pruned regularly. A good balance of nutrients is also very important, especially nitrogen.
- Ensure effective pruning from the end of the harvest so that the orchard's soil is exposed to sunlight.

Before flowering

- Flowering is a very sensitive stage. Therefore, it is essential to prune all parts affected (necrotised) by anthracnose.

As the fruit begins to form

- Cleaning the mango grove: collect all fallen fruit so that they do not rot on the ground.

After the harvest

- Handle the fruit carefully during and after the harvest. Even the slightest damage to the epidermis during the harvest, packaging or transport stages can reactivate latent infections or can even cause a new infection by spores deposited on the fruit during the rainy season.
- Separate infected mangoes from healthy ones when sorting the fruit.
- Keeping mangoes at a suitable temperature can help reduce losses caused by rotting after harvest.
- Hot water treatment is a very technical operation which can only be carried out in packaging facilities. The fruit should be handled extremely carefully, both at the harvest site and the packaging facility, since this type of treatment can aggravate even the slightest existing epidermal lesion. This is particularly the case for regions with sandy soil. Heat treatment deactivates most superficial latent infections caused by *Colletotrichum, Alternaria* and *Dothiorella*. This process can be consolidated by the addition of sodium hypochlorite or calcium hypochlorite, and the application of wax (carnauba wax, guar gum, acrylic resin, polyethylene emulsion, etc.), which helps to

slow down the ripening of the fruit and thus the reactivation of any latent infections. Nevertheless, it is insufficient if infection risks are high or the peduncle is already infected.

- Immersing freshly picked fruit into water at a temperature between 50°C and 55°C, depending on the variety, for five to ten minutes, reduces the risk of anthracnose and apical rotting of the stalk. A shower at higher temperatures (> 60°C) can also be used for a shorter time combined with hard brushing.
- The water temperature in the tank must be consistent. It must be carefully monitored to ensure the fruit is not damaged.
- This treatment is a very delicate operation, which may alter the quality of the fruit if not carried out correctly.

Varieties resistant or tolerant to anthracnose

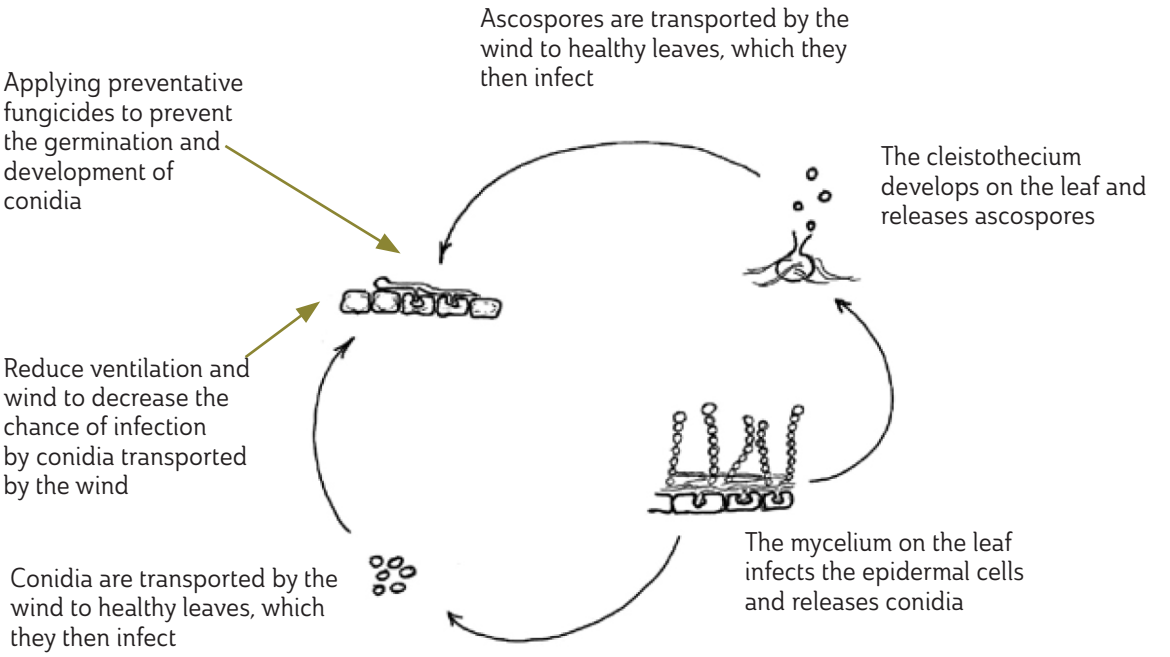
Cultivar	Resistance or tolerance
	Anthracnose
Amélie	
Haden	
Keitt	Relatively resistant
Kent	
Palmer	
Sensation	Relatively resistant
Tommy Atkins	Relatively resistant

FUSARIUM WILT

Little is known about the epidemiological cycles of fungi responsible for fusarium wilt. Climatic and agronomic factors have a significant impact on their development, but they differ from one species to another.

POWDERY MILDEW
Oidium mangiferae

Positioning of control methods in relation to the development cycle of the fungus



Positioning of control methods in relation to the development cycle of the plant

In orchards

During the plant's sensitive development stage (see 1.3)

- Apply preventative fungicides when conditions favour powdery mildew infections.
- Sulphur treatment is recommended. Apply before flowering and during the entire risk period. In the event of high temperatures and low humidity, do not treat the plant during the peak flowering period to avoid burning the flowers.
- Reduce ventilation and wind to decrease the chance of infection by conidia transported by the wind.

BACTERIAL CANKER OF MANGO TREES
Xanthomonas citri pv. *mangiferaeindicae*

Positioning of control methods in relation to the development cycle of the plant

Combating bacterial canker involves a collection of preventative and curative measures.

Preventative measures

- Prevent infested plant material from entering unaffected countries (particularly grafts, cuttings and plants) and, more generally, from being transported from infested areas to healthy areas.
- If an infection is suspected, carry out surveys to find out whether the disease is present in the country and, if it is, what the distribution and frequency is in the areas affected.
- When it is not widespread, remove and burn all trees affected.
- Check nurseries, which are the main source of the spread of the disease in previously unaffected areas.

Curative measures

- Only treatments using copper-based products are effective against this disease. In organic farming, it is important to comply with the annual limits (6kg of copper per year).
- Copper-based products are contact fungicides and bactericides. Therefore, it is necessary to treat the entirety of the tree and the fruit. The layout of the orchards should therefore be planned accordingly: good ventilation, suitable densities, tree heights limited so they can be reached by treatment equipment, etc.
- Treatment should be carried out during the wet season to protect the vegetative parts of the tree, then during the pre-flowering period, and finally from the flowering stage to the harvest as the fruit develops. In practice, this means that the trees will be treated at least once a month.
- Adopting workarounds: use less sensitive varieties, production outside risk periods, etc.

2.4. Value and use of natural enemies

One of the main objectives of organic farming is to obtain healthy plants by promoting a biological balance between harmful and useful species. There are various types of auxiliary species which can help combat pests:

- Predators, which feed on their prey;
- Parasitoids, which develop inside eggs, larvae or adults;
- Fungi, nematodes, bacteria and other entomopathogenic micro-organisms.

Some auxiliary species are naturally present in the environment. Others have been imported from the pests' region of origin (coevolution).

FRUIT FLIES

Fruit flies have natural agents of control in the form of predators and parasitoids. There are several different groups of predators, such as arachnids (Arachnida: *Salticida*e), weaver ants (Hymenoptera: *Formicidae*), ground beetles (Coleoptera: *Carabidae*), etc. Braconidae (Hymenoptera: *Braconidae)* are parasites on eggs and larvae, while the ants and beetles feed on the maggots which emerge from the fruit and turn into pupae on the ground.

Description of braconidae

Adult braconidae are very small (+/- 2.5mm) and are black or brown.

The females lay their eggs inside the fruit flies' eggs and/or larvae.

Conservation

Adult braconidae feed on nectar, honeydew and pollen before laying their eggs. Dill, yarrow, zinnia, clover, alfalfa, parsley, cosmos, sunflowers and marigolds are some of the flowering plants which attract local populations of braconidae and create suitable habitats for these species.

MANGO STONE WEEVIL

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

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

FRUIT TREE MEALYBUG

Introducing helpful parasites (*Anagyrus mangicola* and *Gyranusoidea tebygi*) into west Africa is an excellent method of biological control against this pest, especially in coastal regions. Originally introduced by researchers at the International Institute of Tropical Agriculture (IITA) in Benin, these parasitoids are currently present in all areas affected by mealybugs. However, their effectiveness varies depending on the climate.

The fruit tree mealybug's main natural predator is the ladybird. Producers can increase ladybird populations by improving their habitat.

Description of ladybirds

The female lays its eggs, the colour of which varies from yellow to orange, on the underside of the leaves. Larvae are grey, black and orange and are under 4mm.

Adult ladybirds have very rounded, oval or hemispherical bodies and are usually brightly coloured, ranging from red to orange, to brownish-yellow, to yellow through to steel blue. They often have black spots or lines with short legs and antennae. Some species secrete a strong smelling yellow liquid when they feel threatened.

Adults feed on pollen, nectar, honeydew and aphids or other prey for the production of eggs.

Conservation

Ladybirds are present in most agricultural habitats and gardens. They prefer flowers from the brassicaceae and asteraceae families. Simply planting these around the edges of the orchard (or even within it) is enough to attract them. Maintaining the diversity of flowering plants in their habitats is important because it guarantees the ladybirds a range of food sources. If there is a shortage of food, they tend to attack other ladybirds.

Apart from the mango tree mealybug *R. invadens*, almost all fruit tree mealybugs, diaspididae and whiteflies are controlled naturally by natural enemies (predators and/or parasitoids). However, some insects can protect others. This is the case for weaver ants, which, despite predating some mango tree pests (fruit flies, mango stone weevils, etc.), protect a species of mealybug that does not cause damage but makes the fruit unsuitable for export.

WHITEFLIES

Parasitoids such as *Encarcia haitiensis* feed on whitefly larvae and provide organic control.

ACRIDIDAE

Acrididae are now controlled on a large scale with biopesticides, particularly entomopathogenic fungi of the genus *Metarhizium,* specifically *Metarhizium acridum.*

3. MONITORING THE PHYTOSANITARY CONDITION OF THE CROP AND INTERVENTION THRESHOLDS

Good agricultural practices are essential disease prevention measures.

When a pest is identified, it is advisable to initially opt for control measures aimed at reducing the density of its population. Several options are available before using phytosanitary products such as plant extracts (neem extract spray, etc.), including: agricultural practices (removing weeds, etc.), direct control (manual removal, etc.), using bait or other craft-based solutions (spraying soapy water, etc.). Most phytosanitary products are not selective and can also harm useful species.

Regular monitoring is therefore necessary to prevent any infestation or infection requiring the spraying of the entire orchard.

Some measures for preventing/controlling mango tree diseases and pests are shown in the table below.

Disease or pest being tackled	When?	How often?	Where?	How?	Sampling
Fruit flies	2 months after flowering	Weekly	Traps in the shade	Traps (pheramones or food-based lures)	Concentrations to be determined based on the local conditions, species, etc.
Mango stone weevil	Before and after the harvest	Monthly	Inflorescences Maturing fruit Fruit	Visual checks Split open the seed	10 trees per hectare
Fruit tree mealybug	At all stages	Monthly	Leaves Inflorescences	Visual checks	10 marked trees per block (1 hectare)
Diaspididae and coccidae		Monthly	Young branches and young leaves	Remove the leaves which have reached an intermediate stage	10 marked trees per block (1 hectare)
Thrips	Nurseries Orchard	Monthly	Inflorescences Underside of leaves	Tap the end of the branches above a white sheet Sticky yellow traps	10 marked trees per block (1 hectare)
Whiteflies	At every stage in the orchard	Weekly	Traps around the mango trees in the direction of the prevailing wind Fruit	Sticky yellow traps Mobile traps	10 marked trees per block (1 hectare)

Anthracnose	Before and after the harvest	Weekly	Flowers Fruit	- Regular pruning of branches, dead leaves and infected parts	10 marked trees per block (1 hectare)
Powdery mildew	Before flowering	Weekly	Inflorescences	Visual checks	10 marked trees per block (1 hectare)
Bacterial canker	Nurseries Orchard	Weekly during the rainy season, monthly thereafter	Grafts Cuttings Plants Leaves Fruit	Visual checks	10 marked trees per block (1 hectare)
Fusarium wilt	During flowering	Weekly	Inflorescences	Visual checks	General in the event of risks
Scab	Nurseries Orchard	Weekly from fruit-set	Fruit-set	Visual checks	10 marked trees per block (1 hectare)
Mango blossom gall midge	During flowering				
True bugs	As the fruit grows	While doing other checks	Fruit or leaves	Visual checks or threshing	10 marked trees per block (1 hectare)
Termites	Orchard during vegetative growth	Check for plaster during general inspections; Dig around the base of the trunk if infestation suspected	Trunks and base of trunks	Visual	General in risk areas
Acrididae	Monitoring, especially during risk periods In orchards and surroundings	Regularly	Young mango or citrus tree orchards, nurseries and surrounding wild vegetation	Visual checks: presence of young larvae on surrounding trees or natural vegetation	General

Intervention thresholds:

As a general rule, intervention thresholds are determined according to the species of pest and the local conditions, which means there are variations between different countries and even different production sites. They have not yet been determined for west Africa.

Nevertheless, meticulous checks are important to monitor the development of pest populations and intervene in the event of sudden increases.

It is advisable to increase the frequency of checks when conditions are favourable for the development of pests. Each check must be carried out by the same inspector, who then fills in an inspection form for every inspection.

Controlling the development of pest populations is particularly important during the floral induction period, three or four weeks after flowering, and then every three weeks thereafter.

Effective control measures must be based on the specific nature of the insects or diseases in question.

With regard to fruit flies, European Regulation 2092/91 on organic farming authorises the use of parapheromones. However, food-based lures remain the most commonly used method.

Capture techniques ensure more effective monitoring of pest populations, which helps to reduce the use of biopesticides by choosing the optimal moment to apply them.

For more information on trapping fruit flies, see the following guide [in French] "Comment lutter contre les mouches des fruits infestant les mangues" jointly published by the CTA and the COLEACP/PIP in 2007 (Collection Guides pratiques du CTA, N° 14) and the WAFFI document [in French] "Piégeage de détection des mouches des fruits: Fiche n°3" (Vayssières et Sinzogan, 2008).

4. ACTIVE SUBSTANCES AND RECOMMENDED TREATMENTS

The list below sets out the phytosanitary products which are authorised by European Regulation 2092/91 on organic farming and which may be used for mango production. Before using any product, the producer must check with its own certification body that the product is authorised for use.

A distinction is made between active substances in commercial products and those contained in traditional artisanal products. For each type of active substance, the suggested application periods are highlighted in the table in brown.

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

Farmers in ACP countries often adopt organic production methods using plant extracts that are manufactured on a small scale such that the active substance content is unknown. In most cases, these active substances degrade very quickly and do not leave any residue behind.

Our recommendations on the use of the phytosanitary products listed below is based on the experience of producers, information collected by biological resource centres and other available documents. However, it is difficult to obtain scientific results specifically for mango production.

For traditionally-made artisanal products, guidance on their preparation is provided following these tables.

Fruit flies – *Ceratitis* spp., *Bactrocera* spp., *Anastrepha* spp.

Strategy: when monitoring indicates that the pressure is high, it is advisable to opt for local treatments (or spot treatments) rather than general treatments. Local treatments are carried out using food-based lures and by spraying areas with no fruit.

Commercial products

Active substance	Comments	Suggested application period						
		Nurseries	Flowering	Fruit-set to enlargement of fruit	Maturity/Harvest	Growth period	Bud dormancy	Fruit after harvest
Azadirachtin				■	■			
Deltamethrin	Only for traps using bait specifically for *Batrocera* sp. and *Ceratitis* sp.			■	■			
Lambda-cyhalothrin	Only for traps using bait specifically for *Batrocera* sp. and *Ceratitis* sp.			■	■			
Spinosad	Only for use in localised or strip treatments			■	■			
Kaolin	See manufacturer's instructions							

Plant extracts or mixtures prepared on-site

Active substance	Suggested application period						
	Nurseries	Flowering	Fruit-set to enlargement of fruit	Maturity/Harvest	Growth period	Bud dormancy	Fruit after harvest
Potassium salts of fatty acids*			■	■			
Ginger extract*			■	■			
Garlic extract*			■	■			
Chilli pepper extract*			■	■			

*Local effectiveness to be confirmed

Mango stone weevil - *Sternochetus mangiferae*

Strategy: this insect is very difficult to monitor because it feeds inside the stones. Spraying can target adults during diapause on the trunks after the harvest or may be carried out on the flowers just after flowering.

Commercial products

Active substance	Suggested application period						
	Nurseries	Flowering	Fruit-set to enlargement of fruit	Harvest	Growth period	Bud dormancy	Fruit after harvest
Azadirachtin							

Mineral oils can be used to spray on the trunks while the adults are in diapause, but prior approval from the certification authority is required.

Mealybugs - *Rastrococcus invadens*

Strategy: an insecticide should only be used when natural biological control has proven ineffective. Pruning should be carried out before any treatment.

TO CONTROL MEALYBUGS DIRECTLY

Commercial products

Active substance	Suggested application period						
	Nurseries	Flowering	Fruit-set to enlargement of fruit	Harvest	Growth period	Bud dormancy	Fruit after harvest
Azadirachtin	■					■	

Plant extracts or mixtures prepared on-site

Active substance	Suggested application period						
	Nurseries	Flowering	Fruit-set to enlargement of fruit	Harvest	Growth period	Bud dormancy	Fruit after harvest
Papaya leaf extract*						■	
Chilli pepper extract*						■	

TO CONTROL ANTS

Plant extracts or mixtures prepared on-site

Active substance	Suggested application period						
	Nurseries	Flowering	Fruit-set to enlargement of fruit	Harvest	Growth period	Bud dormancy	Fruit after harvest
Marigold extract (Tagetes spp.)*					■	■	
Citrus oils*					■	■	
Garlic extract*					■	■	

*Local effectiveness to be confirmed

Other mealybugs: diaspididae and coccidae

Strategy: apply white oil to suffocate the insects

TO CONTROL MEALYBUGS DIRECTLY

Commercial products

Active substance	Comments	Suggested application period						
		Nurseries	Flowering	Fruit-set to enlargement of fruit	Harvest	Growth period	Bud dormancy	Fruit after harvest
Azadirachtin				■		■		
Horticultural oils*	1-2% solution			■		■		

Plant extracts or mixtures prepared on-site

Active substance	Comments	Suggested application period						
		Nurseries	Flowering	Fruit-set to enlargement of fruit	Harvest	Growth period	Bud dormancy	Fruit after harvest
Potassium salts of fatty acids**	1-2% solution	■		■	■			

TO CONTROL ANTS

Plant extracts or mixtures prepared on-site

Active substance	Suggested application period						
	Nurseries	Flowering	Fruit-set to enlargement of fruit	Harvest	Growth period	Bud dormancy	Fruit after harvest
Marigold extract (*Tagetes* spp.)*	■	■	■				
Citrus oils*	■	■	■				
Garlic extract*	■	■	■				

* horticultural oils are concentrated and must be mixed with water. Before carrying out a large-scale treatment, it is advisable to test the concentration on a few trees because young leaves can be very sensitive to sprayed horticultural oils. Treatments should not be carried out during flowering and the growth of vegetative shoots. Treat with a 2% solution to combat insects and acarids. Apply subsequent treatments after intervals of at least six months. After the mineral oil treatment, use a high pressure water jet to remove the dead mealybugs from the tree. It is important to remove dead mealybugs from trees to protect against their shield acting as new mealybug "hatcheries". To remove live mealybugs, a powerful jet of water can be used to pull them off the bark.

** local effectiveness to be confirmed

Thrips

Strategy: treatments target nymph and adult stages

Commercial products

Active substance	Suggested application period						
	Nurseries	Flowering	Fruit-set to enlargement of fruit	Harvest	Growth period	Bud dormancy	Fruit after harvest
Pyrethrin*							

Plant extracts or mixtures prepared on-site

Active substance		Suggested application period						
	Comments	Nurseries	Flowering	Fruit-set to enlargement of fruit	Harvest	Growth period	Bud dormancy	Fruit after harvest
Potassium salts of fatty acids*	1-2% solution							
Lemongrass extract (*Cymbopogon* sp.)*								
Garlic extract*								

*Local effectiveness to be confirmed. Soap spray kills thrips (treatment must be repeated twice in one week). Lemongrass, garlic and pyrethrum are natural repellents for thrips.

Whiteflies

Strategy: treatments target nymph and adult stages

Commercial products

Active substance	Suggested application period						
	Nurseries	Flowering	Fruit-set to enlargement of fruit	Harvest	Growth period	Bud dormancy	Fruit after harvest
Azadirachtin		■	■	■	■		

Plant extracts or mixtures prepared on-site

Active substance	Comments	Suggested application period						
		Nurseries	Flowering	Fruit-set to enlargement of fruit	Harvest	Growth period	Bud dormancy	Fruit after harvest
Potassium salts of fatty acids*	1-2% solution		■	■	■	■		
Garlic extract			■	■		■		

* Mild soap (e.g. potassium salts of fatty acids) can be used to reduce whitefly numbers without having any side effects on their natural enemies. The eggs are resistant to this type of treatment. Only adults, nymphs and pupae are killed (although effectiveness is lower for pupae).

Anthracnose - *Colletotrichum gloeosporioides*

Strategy: measures are mainly preventative given that it is largely contact fungicides which are used.

Commercial products

Active substance	Suggested application period						
	Nurseries	Flowering	Fruit-set to enlargement of fruit	Harvest	Growth period	Bud dormancy	Fruit after harvest
Copper-based compounds		■	■				
Potassium bicarbonate		■	■				

Note:
It has been noted that in Australia, a mixture of Casuarina leaves can help to reduce the effects of anthracnose and black marks.

Powdery mildew

Strategy: in regions where the disease is present, the treatment should aim to protect the flowers, since they contain the production potential. This treatment must be carried out at an early stage before full flowering, as soon as the slightest change in colour of the flowers is observed.

Contact fungicides are washed off by rain. Applications must be repeated every 8 to 10 days and more often in the event of more than 25mm of rainfall.

Micronised sulphur is still a cost-effective active substance. It forms the basis of the preventative treatment.

Commercial products

Active substance	Suggested application period						
	Nurseries	Flowering	Fruit-set to enlargement of fruit	Harvest	Growth period	Bud dormancy	Fruit after harvest
(Micronised) sulphur							
Potassium salts of fatty acids							
Horticultural oils							

Note: it has been noted that in Australia, a mixture of Casuarina leaves can help to reduce the effects of anthracnose and black marks.

Bacterial canker of mango trees - *Xanthomonas citri pv. mangiferaeindicae*

Strategy: measures are mainly preventative given that it is largely contact bactericides which are used.

Commercial products

Active substance	Suggested application period						
	Nurseries	Flowering	Fruit-set to enlargement of fruit	Harvest	Growth period	Bud dormancy	Fruit after harvest
Copper-based compounds							

Preparation and recommendation for using traditional artisanal products:

Neem extract (*Azadirachta indica*): for direct spray treatments. The active ingredients are present in all parts of the tree, but the seeds contain a particularly high concentration. The main substances with insecticidal properties are azadirachtin A and B. Neem also contains other useful substances for combating insects such as salannin and meliantrol, which tend to have a repellent effect, and nimbin/ nimbidin, which appear to have an antiviral effect.

Neem seeds need to be dried to prevent the development of aflatoxins, which weaken the seeds' insecticidal properties and are highly toxic to humans. The harvested seeds should not be greenish yellow (at this stage they are not entirely mature and only contain low amounts of azadirachtin) or brownish yellow. They must be completely yellow. When harvesting, a plastic or fabric sheet should be laid on the ground under the tree to prevent the fruit coming into contact with the ground, thus reducing the risk of fungal infection and aflatoxin development. After the harvest, the pulp is removed so that only the seeds remain. These are then dried in the sun for one day, then placed in the shade for a further three days. They should be mixed regularly while drying. They are then stored in containers or jute bags that are sufficiently ventilated to prevent mould forming, which reduces their effectiveness and causes highly toxic aflatoxins to appear.

The highest concentrations of azadirachtin are found in seeds harvested between three and nine months. The germination of seeds reduces one month after the harvest and if exposed to temperatures above 45°C.

Characteristics:

- Only seeds which are green on the inside have high azadirachtin content. Seeds which are brown on the inside should be removed.
- The pulp of the fruit does not have insecticidal properties and should be disposed of.
- Azadirachtin is very sensitive to ultraviolet (UV) radiation. It is therefore highly advisable to spray it during the evening. The mixture should also be used as soon as it is ready.
- There is no risk of residue because it degrades in just 24 hours.

Recommended doses:

- Seeds: around 30g of azadirachtin per hectare, i.e. 5 to 10kg of seeds per hectare (Seeds' azadirachtin content = 2-9mg/g).
- Crushed leaves: 100 g/L.
- Let the solution settle for 24 hours, then spray it on the affected areas immediately after filtering.

Potassium salts of fatty acids: active substance in soft soap.

Only use soft soap used for washing dishes, not detergents, which can damage the plants. Soft soap must be used with care: if it is too concentrated, it becomes phytotoxic. It is advisable to carry out an initial trial on a few trees before carrying out a large-scale treatment.

Ginger, garlic and red chilli pepper extract: soak 50g of peeled garlic in 10ml mineral oil overnight. Add 25g of unripe red chilli peppers and 25g of ginger. Add 50ml of water and grind the mixture together. Add 3 litres of water. The plants treated retain a garlic flavour for one month after the application. As a result, it is advisable to avoid treatments close to the harvest period.

Papaya leaf extract: soak 4kg of crushed papaya leaves in 15 litres of water overnight. Sieve and spray the mixture onto the infected areas.

Red chilli pepper extract: boil 90g of ripe red chilli pepper or 100g of seeds in water for 15-20 minutes. Take off the boil and add 3 litres of water. Leave to cool and then filter. Add 30g of soft soap. Mix well, then filter.

Marigold extract (*Tagetes* spp.): crush a large quantity of fresh flowers (possibly with roots and leaves) soak in water for between 5 and 7 days. Stir daily. Filter the mixture through fabric. Dilute and add liquid soap (soft soap used for washing dishes, not detergents, which can damage the plants). Apply as a preventative measure once a week.

Citrus oils: soak citrus fruit zest in an equivalent volume of water for 10-15 days. Adding garlic tea or bell pepper tea increases the effectiveness of the treatment. This mixture is also effective against acarids and whiteflies. However, it also kills helpful insects, so should only be used if strictly necessary. It can also be phytotoxic.

Garlic oil: soak 100g of finely chopped garlic in mineral oil for 24 hours. Add half a litre and 10ml of soap. Dilute in 10 litres of water and filter.

Shake or stir the mixture continuously during application to maintain the oily consistency.

5. SPECTRUM OF ACTIVITIES OF ACTIVE SUBSTANCES AND BIOLOGICAL AGENTS

The market for organic producers in ACP countries is still very recent and very small. This is why specific organic protection products for mangoes are rarely developed.

The spectrum of activities of the active substances/biological agents set out below is derived from existing authorisations, various publications on mango production, information from companies manufacturing phytosanitary products and trials organised by the COLEACP. Given the changes to phytosanitary regulations and standards governing the use of plant protection products, it is essential to check whether these products are indeed authorised in the producer country. Authorisation of active substances is not required for local concoctions made using plant extracts because there is no legislation for these products in ACP countries.

TABLE OF VARIOUS ACTIVE SUBSTANCES OR BIOLOGICAL AGENTS USED IN ORGANIC FARMING:

Active substances or Biological agents	Anthracnose	Fungi causing peduncle rot	Scab	Bacterial canker	Waxy-shell mealybug	Soft-bodied mealybug	Fruit flies	Thrips	True bugs	Mango stone weevil	Whiteflies	Powdery mildew	Acrididae
MINERAL SUBSTANCES													
Copper	X	X	X	X									
Potassium salts of fatty acids				X			X	X			X	X	
White oil					X	X							
Horticultural oils						X						X	
Potassium bicarbonate	X												
Micronised sulphur												X	
Spinosad (0.24 g/l)							X						
PLANT EXTRACTS													
Azadirachtin					X	X	X*			X	X		
Purified orange extract							X						
Ginger extract				X			X						
Garlic extract				X			X	X			X		
Chilli pepper extract				X	X		X						
Papaya leaf extract					X								
Lemongrass extract								X					
Marigold extract				X									
Other essential oils (citrus, thyme, etc.)	X	X											
LIVING ORGANISMS													
Microbial biopesticides (e.g. *Bacillus* spp.)	X*	X*	X	X									
Entomopathogenic fungi (*Metarhizium* spp.)								X					X
Parasitoids					X	X	X						
Predators					X	X	X	X		X	X		
Beauveria bassiana							X*						

*effectiveness proven by field trials conducted by the COLEACP

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COLEACP

TECHNICAL ITINERARIES

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

GUIDES TO GOOD PHYTOSANITARY PRACTICES

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

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