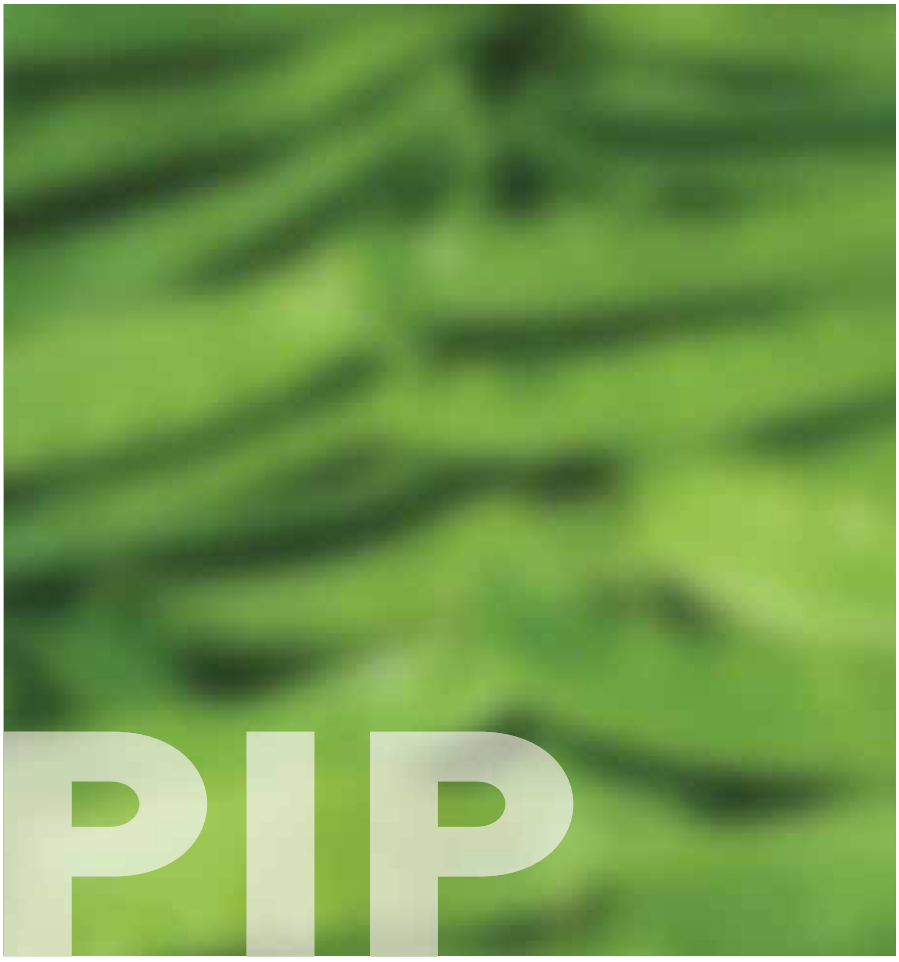

GUIDE TO GOOD CROP PROTECTION PRACTICES

FOR PAPAYA (*CARICA PAPAYA*) IN ORGANIC FARMING IN ACP COUNTRIES

COLEACP is an international network promoting sustainable horticultural trade.

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

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PIP

FOR SUSTAINABLE DEVELOPMENT OF THE ACP HORTICULTURAL INDUSTRY

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NOTICE

The Guide to Good Crop Protection Practices (organic fruit or vegetable) details all plant protection practices and recommends primarily the active substances supported by Plant Protection Products (PPP) manufacturers in the framework of EU Directive 91/414, allowed for usage by the EU Regulation 2092/91 on organic production and which must comply with European standards for pesticide residues. Currently, these active substances have not been tested by PIP in ACP countries to check their conformity with European MRLs and their efficacy. The information given on the active substances suggested is therefore changeable and will be adapted on an ongoing basis in accordance with the new information collected by PIP.

It is, of course, understood that only those products legally registered in their country of application are authorised for use. Growers must therefore check with the local regulatory authorities to see whether the product they wish to use is included on the list of registered products.

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

PIP
FOR SUSTAINABLE DEVELOPMENT OF THE ACP HORTICULTURAL INDUSTRY

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1. Main pests and diseases and importance

1.1. Extent and impact on quantity and quality of fruit produced

The main pests and diseases that will be discussed in this guide are listed below. This section presents, for each pest or disease:

- the level of economic importance generally observed in ACP countries rated on the following scale: + = low, ++ = average, +++ = high;
- the parts of the plant affected and how they are attacked;
- the resulting types of loss, all of which decrease the yield of marketable fruit and consequently end up causing a loss of financial income. The presence of pests and diseases can reduce yield and cause losses at different levels: less fruits per plant, fewer plants per hectare, smaller-sized fruits, lower quality of fruits.

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

One should check the status of quarantine organisms on the websites
http://europa.eu/legislation_summaries/food_safety/plant_health_checks/f85001_en.htm
and http://www.eppo.org/QUARANTINE/quarantine.htm since regulation can change.

INSECTS								
Importance	Organs attacked			Types of loss				
	Leaves	Fruits	Trunk	Number of plants	Number of fruits/plant	Size of fruit	Quality of fruit at maturity	Post-harvest quality of fruit
Fruit flies - *Bactrocera invadens QO* and *Ceratitis* spp. *QO*								
++		Adults lay eggs under skin of maturing fruits and larva develop into the fruit			Fruits may drop prematurely		Fruits rotten	Fruits are destroyed when infested
Papaya mealybug - *Paracoccus marginatus*								
+++	Infests the young leaves, trunks and fruits, and mostly along the veins and midrib of the older leaves				Reduced because affected trees will start to drop flowers and young fruits		Fruits are covered with sooty mould and may be deformed	Infested fruit are not acceptable for export
Thrips - *Thrips tabaci*								
Thrips tabaci vectors viruses such as the Tomato Spotted Wilt Virus which also attacks papayas.								
+	Larvae and adults feeds on young leaves flowers and young fruits						Develops a leathery, brown skin	Sold on local market instead of export

Importance	Organs attacked			Types of loss				
	Leaves	Fruits	Trunk	Number of plants	Number of fruits/plant	Size of fruit	Quality of fruit at maturity	Post-harvest quality of fruit
Whiteflies - *Aleurodicus dispersus* and *Bemisia tabaci* QO								
They are known vectors of virus diseases.								
+	Larvae and adults feed on young succulent leaves				Reduced by slowing down plant growth			

MITES								
Importance	Organs attacked			Types of loss				
	Leaves	Fruits	Trunk	Number of plants	Number of fruits/plant	Size of fruit	Quality of fruit at maturity	Post-harvest quality of fruit
Spider mites - *Tetranychus* spp. False spider mite - *Brevipalpus phoenicis* Broad mites - *Polyphagotarsonemus latus*								
++	Larvae and adults feed on these organs				When heavy infestations occur fruits can drop	Reduced size of fruits under heavy infestation	Scarred fruit	Scarred fruits are not acceptable for export

NEMATODES						
Importance	Organs attacked	Types of loss				
	Roots	Number of plants	Number of fruits/plant	Size of fruit	Quality of fruit at maturity	Post-harvest quality of fruit
Reniform nematodes - *Rotylenchulus reniformis*						
+	The vermiform immature female is the infective stage and it partly penetrates the cortex of host plant root	Under severe infestation plants may wilt and die thereby reducing plant population	Reduced by slowing tree growth	Reduced fruit size		Depending on export specifications on size fruits may not be acceptable
Root-knot nematodes - *Rotylenchulus reniformis*						
+	Juveniles (young nematodes) penetrate the root tips and occasionally invade roots in the zone of root elongation	Under severe infestation plants may wilt and die thereby reducing plant population	Reduced by slowing tree growth	Reduced fruit size		Depending on export specifications on size fruits may not be acceptable

FUNGI								
Importance	Organs attacked			Types of loss				
	Leaves	Fruits	Trunk	Number of plants	Number of fruits/plant	Size of fruit	Quality of fruit at maturity	Post-harvest quality of fruit
Ripe fruit rots - *Colletotrichum gloeosporioides* and *Phomopsis caricae-papayae*								
+++	Fungus enter and develop into leaves	Enter into immature fruit but the fungus can remain quiescent until harvest	Develop also on stems				Reduced by presence of spots. Ripened fruit can rot.	Post harvest decay of fruit and therefore the fruit are not marketable
Asperisporium spot (black speckle) - *Asperisporium caricae*								
+	Infection develop on the under side	Infection is superficial and is confined to the outer surface layer			Under heavy infection, plant growth is reduced due to drop of leaves		Spots on fruit are superficial but under heavy disease pressure can cause disfigurement of the fruits	Disfigured fruits are unfit for export
Cercospora fruit spot - *Cercospora papayae*								
+	Mycelium develop on these organs				Reduced due to defoliation		Reduced fruit quality due to black corky lesions on fruit	Affected fruits are not acceptable for export
Powdery mildew - *Oidium* spp.								
+	Young flushes are affected. Powdery fungal growth covers lower leaf surfaces	Mycelium develop on fruit surface			Reduced because under severe infection terminal shoots may be killed and the trees weakened		Reduced quality due to light grey scarred areas on fruit surface	Affected fruits are not acceptable for export
Root, collar and stem rot – *Phytophthora nicotianae* var. *parasitica*, *Phytophthora palmivora* and *Pythium* spp.								
Importance	Organs attacked			Types of loss				
	Leaves, stems, fruits, roots			Number of plants	Number of fruits/plant	Size of fruit	Quality of fruit at maturity	Post-harvest quality of fruit
++	These fungi may enter and develop in these organs			Reduced because damping-off of seedlings. Drastic reduction of plant population under severe infection	Reduced by weakening of the tree	Small and do not ripen	Fruit rot. Fruit quality reduced	Fruit rot. Not acceptable in both local and export markets

VIRAL DISEASES								
Importance	Organs attacked			Types of loss				
	Leaves	Fruits	Trunk	Number of plants	Number of fruits/plant	Size of fruit	Quality of fruit at maturity	Post-harvest quality of fruit
Ringspot potyvirus								
+++	After transmission into the plant by aphids or mechanically, viruses develop in the whole plant						Reduced by presence of green rings on ripened fruits	Infected fruits are not acceptable for export
Tomato spotted wilt tospovirus QO								
+	After transmission into the plant by thrips, viruses develop in the whole plant				May be reduced by dwarfing of plants		May cause deformation of fruit	Affected fruits are unfit for export
Bunchy top phytoplasma								
+++	After transmission into the plant by grafting or leafhoppers, phytoplasma develop in the whole plant				May be diminished by reduced growth		Fruit quality reduced	Affected fruits are not marketable for export
Mosaic potexvirus								
++	After transmission mechanically, viruses develop in the whole plant				May be diminished by reduced growth		Fruit quality reduced	Affected fruits are not marketable for export
Yellow crinkle phytoplasma								
+	After transmission into the plant by leafhoppers, phytoplasma develop in the whole plant				May be diminished by reduced growth		Fruit quality reduced	Affected fruits are not marketable for export

SNAILS								
Importance	Organs attacked			Types of loss				
	Leaves	Fruits	Trunk	Number of plants	Number of fruits/plant	Size of fruit	Quality of fruit at maturity	Post-harvest quality of fruit
Giant East African Snail – *Achatina fulica*								
+	May eat all parts of the plant			May kill the plant after stem injuries			Reduced if presence of bites	Damaged fruit is not marketable

1.2. Identification and damage

This section provides information and illustrations to help with the identification of the pests and diseases identified in 1.1.

INSECTS

Fruit flies – *Bactrocera invadens and Ceratitis* spp.

The morphology of the various fruit fly species is similar. Adult fruit flies are 4-7 mm long, brightly coloured, usually in brown-yellow patterns. The wings are spotted or banded with yellow and brown margins. The flies lay eggs under the skin of mature green and ripening fruit. Eggs are about 1 mm, white, and slender. These are laid, or inserted into fruit in groups of up to 37 eggs. Eggs hatch within 1-2 days into whitish maggots, which feed on the fruit flesh. This causes the fruit to rot. After 4-17 days the maggots leave the fruit, making holes in the skin. Then they drop to pupate in the soil. The affected part of the fruit becomes soft and colours prematurely.

Attacked fruit usually shows signs of oviposition punctures. Around these a necrosis may occur. Small holes on the fruits are visible when the maggot leaves the fruit.

Ceratitis capitata			*Bactrocera invadens*
			
Adult	Eggs	Larva	Adult

For more information on fruit flies identification one can consult the web site http://www.africamuseum.be/fruitfly/AfroAsia.htm

Papaya mealybug - *Paracoccus marginatus*

The adult female is yellow and is covered with a white waxy coating. Adult females are approximately 2.2 mm long (1/16 inch) and 1.4 mm wide. A series of short waxy caudal filaments less than 1/4 the length of the body exist around the margin. Eggs are greenish yellow and are laid in an egg sac that is three to four times the body length and entirely covered with white wax. The ovisac is developed ventrally on the adult female.

Adult males tend to be coloured pink, especially during the pre-pupal and pupal stages, but appear yellow in the first and second instar. Adult males are approximately 1.0 mm long, with an elongate oval body that is widest at the thorax (0.3 mm). Adult males have ten-segmented antennae, a distinct aedeagus, lateral pore clusters, a heavily sclerotized thorax and head, and well-developed wings.

Two characteristics that are important in distinguishing *P. marginatus* adult females from all other species of *Paracoccus* are: the presence of oral-rim tubular ducts dorsally restricted to marginal areas of the body, and the absence of pores on the hind tibiae. Adult males may be distinguished from other related species by the presence of stout fleshy setae on the antennae and the absence of fleshy setae on the legs.

The mealybugs feed on leaves, stems and fruit and even on seedlings. The result is chlorosis, plant stunting, leaf deformation, early leaf and fruit drop, a heavy buildup of honeydew, and death. Heavy infestations are capable of rendering fruit inedible due to the buildup of thick white wax. Papaya mealybug has only been recorded feeding on areas of the host plant that are above ground, namely the leaves and fruit. Heavy mealybug infestation can kill the affected plants.

Mealybugs on fruit

Thrips - *Thrips tabaci*

Whiteflies are small insects (1-3 mm long), with two pairs of wings that are held roof-like over the body. Their body and wings are covered with waxy coating. Whiteflies are yellowish white. They are often found clustered in groups on the underside of young leaves and readily fly away when disturbed.

Eggs are laid usually in arcs or circles, on the undersides of leaves, with the broad end touching the surface. Eggs are whitish in colour when first laid, but gradually turn brown.

On hatching, the first instar or crawler is flat, oval and scale-like, and is the only mobile larval stage. It moves to a suitable feeding location on the lower leaf surface where it moults and becomes sessile throughout the remaining nymphal stages. The fourth nymphal stage is termed the puparium, and is approximately 0.7 mm long.

Adults are about 1 mm long; the male is slightly smaller than the female. The body and both pairs of wings are covered with a powdery, waxy secretion, white to slightly yellowish in colour.

Feeding of whiteflies causes yellowing of infested leaves. Whiteflies excrete honeydew, a clear, sugary liquid. This honeydew covers the leaves and supports the growth of black sooty mould.

Whiteflies – *Aleurodicus dispersus* and *Bemisia tabaci*

Whiteflies are small insects (1-3 mm long), with two pairs of wings that are held roof-like over the body. Their body and wings are covered with waxy coating. Whiteflies are yellowish white. They are often found clustered in groups on the underside of young leaves and readily fly away when disturbed.

Eggs are laid usually in arcs or circles, on the undersides of leaves, with the broad end touching the surface. Eggs are whitish in colour when first laid, but gradually turn brown.

On hatching, the first instar or crawler is flat, oval and scale-like, and is the only mobile larval stage. It moves to a suitable feeding location on the lower leaf surface where it moults and becomes sessile throughout the remaining nymphal stages. The fourth nymphal stage is termed the puparium, and is approximately 0.7 mm long.

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Feeding of whiteflies causes yellowing of infested leaves. Whiteflies excrete honeydew, a clear, sugary liquid. This honeydew covers the leaves and supports the growth of black sooty mould.

Larva of *Aleurodicus*

Adults of *Aleurodicus*

MITES

Several species of mites damage papaya: **spider mites** (*Tetranychus* spp., *Eutetranychus* spp. and *Olygonychus gossypii*), the false spider mite (*Brevipalpus phoenicis*) and the **broad mite** (*Polyphagotarsonemus latus*) (personal communication, M. Knapp, ICIPE).

Spider mites – *Tetranychus* spp.

Spider mites spin silk threads that anchor themselves. Eggs are tiny, spherical, pale-white, and are laid on the undersides of leaves often under the webbings. They can only be seen with a magnifying lens. The larva is light green or pinkish, slightly larger than the egg and has six legs. The nymphs look similar to the adult but are smaller. They are green or red in colour and have eight legs. The adult has an oval body with 8 legs, and is very tiny (they rarely exceed a size of 0.5 mm) resembling tiny moving dots to the naked eye. The male is usually smaller than the female and have a more pointed abdomen. Spider mites are variable in colour depending on the species. Many of the species are bright red in colour; and this is the reason why spider mites are sometimes referred to as red spider mites. Others are yellowish, greenish, pinkish, orange or reddish in colour. The two-spotted spider mite has a large dark blotch on each side of the body.

Spider mites suck the plant sap, leading to poor plant growth and blemishes on the fruit. Infested leaves show yellow patches on the upper surface, particularly between main veins and midrib. Feeding by mites causes scarring and discoloration of fruit, and reduced fruit size affecting its market value. Infestations usually begin on the older leaves and then spread to the younger growth.

Generally, spider mites prefer the undersides of leaves, but in severe infestation will occur on both leaf surfaces as well as on the stems and fruits.

Adults and larvae

Symptoms in a nursery

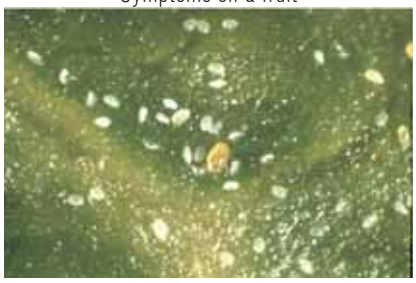
False spider mite – *Brevipalpus phoenicis*

The false spider mite usually feeds on the trunk below the level where the bottom whorl of leaves is attached. The mites move upward on the trunk and outward onto the leaves and fruit as the population increases, leaving a large, conspicuous, damaged area behind them. The affected area becomes raised and blister-like. Later the affected tissue dries up, dies and becomes discoloured, forming a large and continuous callous area, light brown and scaly and/or scabby. Damage by feeding on young papaya fruits is manifested by sunken areas. Sometimes feeding by the mite causes a copious outflow of a milky white liquid that mars the appearance of the fruits. Under heavy mite infestations, the papaya stem, which normally remains green for a long time, becomes brownish and corky in appearance, and has a spindly growth.

Broad mites – *Polyphagotarsonemus latus*

P. latus eggs are laid on the underside of leaves, tender stems, fruit, flower peduncles and flowers. Broad mites attack mainly the terminal buds; they feed on the young leaves as they emerge from the growing point. Mite feeding causes discolouration of tissue; fruit become deformed or fail to develop. Severely infested fruits fall. Leaves of attacked plants are stunted, thick and brittle, with down curled edges.

Symptoms on a fruit



Mites

Leaf damage

NEMATODES

Reniform nematodes - *Rotylenchulus reniformis*

R. reniformis is a microscopic organism only found in soils and roots. When roots are severely infested with the nematode they can appear dirty because of soil particles adhering to the gelatinous matrices of the nematodes on the surface of the root. To accurately determine its presence or association with disease symptoms the nematode has to be extracted either from the soil or roots by standard nematode extraction procedures. The identity of the extracted nematodes is confirmed by microscopic examination.

All stages of the nematode up to immature female and mature male can be extracted from soils. Root extractions will mainly provide hatched second stage juveniles from the eggs on the root surface and possibly some immature females. The sedentary mature females partly embedded in the roots and covered by gelatinous matrices are observed by staining the roots and nematodes in acid fuchsin or methyl blue and examining under a microscope.

There are no typical symptoms on the aerial parts of the infested plants. The plants manifest chlorosis of the leaves, reduced growth and yield. In nurseries, under severe infestation, seedlings are killed.

Root-knot nematodes - *Meloidogyne* spp.

There are four species of root-knot nematodes (*M. arenaria, M. hapla, M. incognita* and *M. javanica*) that are widespread in the tropics. The species important on papayas is *M. incognita* and are particularly serious in irrigated fields.
Root-knot nematodes measure about 0.5 mm to 1.5 mm in length.
Invading nematodes initiate the development of giant cells in the root tissues and galling of roots occurs.

Galls on roots

FUNGI

Anthracnose - *Colletotrichum gloeosporioides*

Symptoms on fruit appear at ripening stage. They initially appear as small, dark, circular areas, which enlarge to form circular slightly sunken lesions. The lesions can reach up to 50 mm in diameter. The margin of the lesions darkens while the centre turns brown or black. In the final stages, a mass of orange or salmon-pink spores develop on the surface of the lesions. In the middle of mature lesions fungal fruiting bodies may develop and can be observed as small, black spots. It also attacks leaves and flowers. Leaf symptoms develop as small, water-soaked, irregular lesions which enlarge and later turn brown. As the lesions mature, their centres turn greyish-white and may drop out later.

Symptoms on fruits after harvest

Wet fruit rot - *Phomopsis caricae-papayae*

The infected area is slightly depressed, soft and translucent. The fungus is rapid growing causing lesions to expand very quickly with the infected area extending to the seed cavity. The cuticle over the infected area remains intact and develops a delicate, wrinkled pattern that is parallel to the leading edge of the lesion. Black, scattered conidia usually form in the infected area after about seven days. The infected tissue is soft, mushy and wet but does not usually leak liquids. Under conditions of high humidity the infected area can become covered by white to grey mycelium. It also attacks stems causing a rot. Stem rot starts near the base or higher with well defined lesions spreading rapidly. In severe cases the disease causes death of plants.

Single lesions on papaya fruit

Asperisporium spot (black speckle) - *Asperisporium caricae*

Small black spots, 1 to 4 mm in diameter, are produced on both the fruit and mature leaves. Young leaves in the crown of the tree are not affected, but diseased mature leaves wilt and drop. Infection of the fruit is superficial, and the lesions are confined to the outer surface layer. The black lesions can appear white if hyperparasitised by fungi such as *Cephalosporium*, *Rhinotrichium gossypinum* and *Verticillium*.

Cercospora spot or black spot - *Cercospora papayae*

Fruit spots start as tiny black dots that eventually enlarge to about 3 mm in diameter. The spots are superficial, slightly raised, a result of the tissue beneath the epidermis becoming corky, and do not develop into a fruit rot. The spots are somewhat obscure on green fruits but become readily visible when the skin colour turns yellow as the fruit ripens.
Leaf spots are irregularly shaped, greyish-white in colour and 1 to 5 mm diameter. Damage to trees is usually negligible but under heavy disease pressure, leaf yellowing, necrosis and defoliation are known to occur.

Black spots

Powdery mildew – *Oidium* spp.

Light yellowish green patches on upper surface of young crown leaves. These appear water-soaked. On the lower leaf surface a white greyish powdery growth appears. The powdery growth consists of fungal mycelium and spores. Under heavy infection premature leaf fall occurs. Powdery mildew also attacks fruits. Fruit symptoms consist of circular, white patches on the fruit surface. These patches may coalesce to cover large areas of the fruit surface. As the fruit develops, the white mould disappears leaving light grey scarred areas.

O. caricae on fruit

O. caricae on leaves

Root, collar and stem rot – *Phytophthora nicotianae* var. *parasitica*, *Phytophthora palmivora* and *Pythium* spp.

In nursery beds, seedlings wilt rapidly and wither after emergence. Symptoms at this stage include blackish, water-soaked patches at the collar at the ground level. Seedlings die when necrosis has encircled the stem. This happens when the nursery has been over-watered.

In adult plants, foliage yellows and may die prematurely. Newly formed leaves after infection are small with short leaf petioles. A yellowing and collapse of older leaves which then hang limply around the trunk before falling become evident. The young crown leaves wilt and the plant may die within a few days, but often trees linger on for months in an unthrifty condition with a few, small, yellow leaves around the crown. These trees are very susceptible to drought and are easily pushed or blown over by wind. Small roots are absent and large ones show a soft, wet decay extending towards the trunk. Root rot caused by *Phytophthora palmivora* causes more rapid decline than that caused by *Pythium* spp. In fruits few seeds are set and fruits resulting from infection are small and do not ripen. Also on fruits and the fruit bearing parts of the stem dark green watery spots may appear. Fruits can be affected at any stage of development. They develop a whitish coating of fungal mycelium that contains sporangia. During hot wet weather, yellowish rings appear on immature fruit. They then shrink, become mummified and eventually drop from the affected trees.

Severe damage to papaya trees due to *Phytophthora* sp.

VIRAL DISEASES

Ringspot potyvirus

Initially, the disease appears as oil streaks on stems and petioles and as it progresses, mottling of leaves becomes evident. Severely infected plants do not flower and die young. Infected fruits develop characteristic line patterns, which form rings and remain green when fruits ripen.

Infected leaf

Virus lesion on fruit


Ringspot infection on fruit

Tomato spotted wilt tospovirus

The virus causes premature leaf loss. Other symptoms include concentric yellow or brown rings, small brown patches, large irregularly-shaped necrotic patches on leaves and fruits, necrotic sections of stems and necrotic tissue at the junction between leaf and petiole. Visual identification is not definitive.


Fruits infected with T.S.W.V.

T.S.W.V. infection on young leaves

Bunchy top phytoplasma

The newly formed leaves are small, thick, chlorotic and borne by very short rigid petioles that extend horizontally, whereas normal petioles are almost vertical. Infected fruit exhibit green areas that are paler than normal, without any latex secretion.

Mosaic potexvirus

No visible symptoms develop on the fruit. A yellow mosaic pattern develops on young leaves. Symptom expression is temperature sensitive, being most noticeable during cool months. Seedling plants develop vein clearing symptoms, and affected leaves become rugose. The systemic infection of young plants leads to a reduction of growth.

Yellow crinkle phytoplasma

The first symptom is marked yellowing of old leaves whose petioles curve downwards from the insertion point. This leads to premature leaf fall. Between the veins of the youngest leaves, thin tranlucid areas develop that can later detach from the infected plants.

SNAILS

Giant East African Snail – *Achatina fulica*

Shell size may be up to 20 cm in length and 12 cm in maximum diameter. Generally there are seven to nine whorls and rarely as many as ten whorls. *Achatina fulica* prefers environments that are rich in calcium carbonate. In these calcium-rich areas the shells of the adults tend to be thicker and opaque. Juveniles generally have a thinner, more translucent shell and are more brittle. Note that even in this post-embryonic juvenile the characteristic truncated columella is already evident. Upon emerging from its egg shell the length of the post-embryonic juvenile shell measures approximately 4 mm. Eggs are borne 30-1000 white/yellow, 4-5mm in diameter, up to 6 times a year. Dependent on the temperature, the babies will hatch in anything from 5 to 21 days.

Though shell colouration may be variable due to environmental conditions and diet, generally it is reddish-brown with light yellowish, vertical (axial) streaks. The two shell colours are not distinct from each other and are somewhat streaked or smudged in appearance. Another shell colour variation resembles a light coffee colour. The colours fade with age in the earliest whorls appearing lighter or less intense, becoming darker and more vibrant nearest the body whorl.

The body of the live animal has two pairs of tentacles, one short lower pair that are tactile and chemotactic, and one longer upper pair with eye spots at the tips. The body itself is moist, slimy and rubbery. Body colouration can be either mottled brown or more rarely a pale cream colour. The foot sole is flat, with coarse tubercles most evident laterally on the upper surface of the extended body

The outline of the shell may vary somewhat, even within the same colony, from slender to moderately obese. The broader specimens with the same number of whorls tend to be shorter in shell length. The shell is generally conically spired and distinctly narrowed but barely drawn out at the apex. The whorls are rounded with moderately impressed sutures between the whorls. The aperture is relatively short and has an ovate-lunate shape. The lip is sharp, convex, thin and evenly curved into a regular semi-ellipse. The shell surface is relatively smooth, with faint axial growth lines.

One of the most important identification features of *Achatina fulica* is the columella which truncates or ends abruptly, a feature remaining evident throughout the lifespan of the snail. The columella is generally concave; lesser concaved columella tend to be somewhat twisted. The broader shells tend to have a more concave columella. The columella and the parietal callus are white or bluish-white with no trace of pink.

Adult on young fruit

1.3. Appearance of pests and diseases in terms of phenological stage of the plant

The following table shows the stages of cultivation during which most important crop enemies are potentially present and the stages during which their presence can do the most harm. It is especially during the latter stages that they must be monitored and controlled if necessary. The purpose is to show that the presence of a pest, disease or pathogenic agent is not always harmful to the crop.

Stage	Length of stage	Fruit fly		Papaya mealybug		Thrips		White-flies		Mites		Ripe fruit rots		Black speckle		*Cercospora* spot		Powdery mildew		*Pythium* and *Phytophthora*		Nematodes		Viral and phytoplasma diseases		Snails	
Nursery	1-1.5 months																										
Vegetative growth	4 to 5 months																										
First flowering after planting	3.5 months																										
From fruit-set to harvest	6 months																										
First harvest after planting	8-9 months																										
Fruit after harvest																											

	Periods during which pest or pathogenic agent is potentially present
	Periods during which the appearance of a serious infestation can cause the greatest loss

1.4. Importance by country – periods of the year and climatic conditions favourable to crop enemies

Key :

UGA = Uganda, KEN = Kenya, GHA = Ghana, CAM = Cameroon, CAC = Caribbean countries

0 = no damage

+ = limited damage

++ = average damage: control necessary

+++ = heavy damage: control essential

X = generally limited damage but evolution of damage level over the year is not known

XX = damage can be average, but evolution of damage level over the year is not known

XXX = damage can be heavy, but evolution of damage level over the year is not known

/ = no information available

N.B. the inventory of pests and diseases has not been conducted exhaustively in all countries. The pest may be present, but has perhaps never been observed in the country on the crop, because it does not cause serious damage.

Fruit Flies - *Bactrocera invadens* and *Ceratitis* spp.

Favourable conditions : Warm, humid weather is favourable to their development. In East Africa, the common species observed on papayas are *Ceratitis rosa* and *Bactrocera invadens*.

Month	1	2	3	4	5	6	7	8	9	10	11	12
UGA	/	/	/	/	/	/	/	/	/	/	/	/
KEN	+	+	+	+	+	+	+	+	+	+	+	+
GHA	++	++	++	++	++	++	++	++	++	++	++	++
CAM	++	++	++	++	++	++	++	++	++	++	++	++
CAC	++	++	++	++	++	++	++	++	++	++	++	++

Papaya Mealybug – *Paracoccus marginatus*

Favourable conditions : Warm, dry weather conditions. The periods prior to and after the rains are the most favourable for mealybugs.

Month	1	2	3	4	5	6	7	8	9	10	11	12
UGA	/	/	/	/	/	/	/	/	/	/	/	/
KEN	/	/	/	/	/	/	/	/	/	/	/	/
GHA	/	/	/	/	/	/	/	/	/	/	/	/
CAM	/	/	/	/	/	/	/	/	/	/	/	/
CAC	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++

Thrips – *Thrips tabaci*

Favourable conditions : Hot, dry weather conditions.

Month	1	2	3	4	5	6	7	8	9	10	11	12
UGA	/	/	/	/	/	/	/	/	/	/	/	/
KEN	/	/	/	/	/	/	/	/	/	/	/	/
GHA	++	++	++	++	0	0	0	0	0	0	0	0
CAM	+	+	0	0	0	0	0	0	0	+	+	+
CAC	/	/	/	/	/	/	/	/	/	/	/	/

Whiteflies – *Aleurodicus dispersus* and *Bemisia tabaci*

Favourable conditions : Hot, dry weather conditions.

Month	1	2	3	4	5	6	7	8	9	10	11	12
UGA	/	/	/	/	/	/	/	/	/	/	/	/
KEN	/	/	/	/	/	/	/	/	/	/	/	/
GHA	++	++	++	++	0	0	0	0	++	++	++	+
CAM	+	+	0	0	0	0	0	0	0	+	+	+
CAC	/	/	/	/	/	/	/	/	/	/	/	/

Spider Mites - *Tetranychus* spp.

Favourable conditions : Hot, dry weather is conducive to the development of Tetranychus spp. They are normally less numerous after rains. They are normally active within a temperature range of 16- 37°C. Wind plays an important role in the dispersal of spider mites.

Month	1	2	3	4	5	6	7	8	9	10	11	12
UGA	/	/	/	/	/	/	/	/	/	/	/	/
KEN	+	+	+	0	0	0	+	+	+	0	0	+
GHA	++	++	++	0	0	0	0	0	0	++	++	++
CAM	+	+	0	0	0	0	0	0	0	+	+	+
CAC	+	+	+	+	+	0	0	0	0	0	0	0

Broad Mites - *Polyphagotarsonemus latus*

Favourable conditions : Development is favoured by overcast, humid weather.

Month	1	2	3	4	5	6	7	8	9	10	11	12
UGA	/	/	/	/	/	/	/	/	/	/	/	/
KEN	0	0	0	+	+	+	+	0	0	+	+	0
GHA	++	++	++	0	0	0	0	0	0	++	++	++
CAM	+	+	0	0	0	0	0	0	0	+	+	+
CAC	+	+	+	+	+	0	0	0	0	0	0	0

Nematodes - *Rotylenchulus reniformis* and *Meloidogyne* spp.

Favourable conditions : Warm soil temperatures are highly conducive to nematode development. Some plant penetration by root-knot nematodes occurs between 10 and 35°C, with the optimum at about 27°C depending on the species. No eggs are laid at temperatures lower than 14 or higher than 32°C.

Month	1	2	3	4	5	6	7	8	9	10	11	12
UGA	/	/	/	/	/	/	/	/	/	/	/	
KEN	++	++	++	++	++	++	++	++	++	++	++	++
GHA	++	++	++	++	++	++	++	++	++	++	++	++
CAM	++	++	++	++	++	++	++	++	++	++	++	++
CAC	++	++	++	++	++	++	++	++	++	++	++	++

Ripe Fruit Rots – *Colletotrichum gloeosporioides* and *Phomopsis caricae-papayae*

Favourable conditions : Water plays a central role in the contamination process, because the spores are always waterborne. In conditions of high humidity, masses of slimy spores are produced on the surface of pre-existing lesions on leaves and inflorescences, twigs, etc. Repeated precipitation and abundant dew with run-off are needed for the dissemination of spores from these organs to receptive healthy organs (inflorescences, young leaves, and fruit) in the immediate area. A high RH (≥ 95%) and temperatures at about 25°C are very favourable conditions for disease development.

Month	1	2	3	4	5	6	7	8	9	10	11	12
UGA	/	/	/	/	/	/	/	/	/	/	/	/
KEN	0	0	+	+++	+++	+++	+	0	0	+++	+++	0
GHA	0	0	+++	+++	+++	+++	+++	+++	+++	0	0	0
CAM	0	0	+++	+++	+++	+++	+++	+++	+++	0	0	0
CAC	+	+	+	+	+	+++	+++	+++	+++	+++	+++	+++

Asperisporium Spot – *Asperisporium caricae*

Favourable conditions : Cool, rainfall conditions favour disease development.

Month	1	2	3	4	5	6	7	8	9	10	11	12
UGA	/	/	/	/	/	/	/	/	/	/	/	/
KEN	0	0	+	+	+	+	+	0	0	+	+	0
GHA	/	/	/	/	/	/	/	/	/	/	/	/
CAM	/	/	/	/	/	/	/	/	/	/	/	/
CAC	/	/	/	/	/	/	/	/	/	/	/	/

Cercospora Spot – *Cercospora papayae*

Favourable conditions : Severe disease development when warm, humid, rainy weather occurs. Frequent rains or dew on the leaves coupled with temperatures ranging from 20 to 270C are the predisposing factors for disease development.

Month	1	2	3	4	5	6	7	8	9	10	11	12
UGA	/	/	/	/	/	/	/	/	/	/	/	/
KEN	0	0	+	+	+	+	+	0	0	+	+	0
GHA	0	0	+	+	+	+	+	+	+	0	0	0
CAM	0	0	+	+	+	+	+	+	+	0	0	0
CAC	/	/	/	/	/	/	/	/	/	/	/	/

Powdery Mildew – *Oidium* spp.

Favourable conditions : It is greatly influenced by plant age, humidity, and temperature. Infection can take place at RH as low as 46% though the optimum range is between 50 and 70%. Optimum temperature is 27.4%. The disease is most prevalent during dry cool seasons.

Mois	1	2	3	4	5	6	7	8	9	10	11	12
UGA	/	/	/	/	/	/	/	/	/	/	/	/
KEN	+	+	+	++	++	++	+	+	+	+	+	+
GHA	+	+	+	++	++	++	++	++	++	+	+	+
CAM	+	+	++	++	++	++	++	++	++	+	+	+
CAC	+	+	+	+	+	++	++	++	++	++	++	++

Root, Collar and Stem Rot – *Phytophthora nicotianae* var. *parasitica, Phytophthora palmivora* and *Pythium* spp.

Favourable conditions : *Phytophthora* species are favoured by high moisture content in both the atmosphere and in the soil, and warm temperatures ranging from 20 to 35°C. *Pythium* species prefer cooler soil temperatures (18 to 24°C) and high soil moisture content.

Month	1	2	3	4	5	6	7	8	9	10	11	12
UGA	/	/	/	/	/	/	/	/	/	/	/	/
KEN	+	+	+	++	++	++	+	+	+	+	+	+
GHA	+	+	+	++	++	++	++	++	++	+	+	+
CAM	+	+	++	++	++	++	++	++	++	+	+	+
CAC	+	+	+	+	+	++	++	++	++	++	++	++

Viral and phytoplasma diseases

Favourable conditions : Most importantly is the presence of virus inoculum, hosts and transmission agents. Papaya viruses are vectored by aphids (ringspot virus; papaya mosaic), leafhoppers (bunchy top phytoplasma; yellow crinkle phytoplasma), thrips (tomato spotted wilt virus) or whiteflies (mosaic). The insect vectors spread the viruses from plant to plant and from field to field. Importantly, is vector activity rather than abundance in numbers of the vectors in a crop. For all mentioned insect vectors ideal weather condition is dry season with temperatures ranging from 25 to 30°C.

Month	1	2	3	4	5	6	7	8	9	10	11	12
UGA	/	/	/	/	/	/	/	/	/	/	/	/
KEN	+	+	+	+	+	+	+	+	+	+	+	+
GHA	+	+	+	+	+	+	+	+	+	+	+	+
CAM	+	+	+	+	+	+	+	+	+	+	+	+
CAC	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++

Snails - *Achatina fulica*

Favourable conditions : *Achatina fulica* is active at night and does not like very wet conditions. It is capable of aestivating for up to three years in times of extreme drought. Wherever it occurs, it keeps to the hot lowlands and the warm temperate lower slopes of the mountains. It evidently needs a combination of a constantly high temperature, well above freezing the year round, and much humidity at least during part of the year, the drier months being spent in dormant aestivation. At the same time it is averse to sunshine, exposure to the direct rays of the sun killing it off rapidly. It spends the day buried underground.

Month	1	2	3	4	5	6	7	8	9	10	11	12
UGA	/	/	/	/	/	/	/	/	/	/	/	/
KEN	+	+	+	+	+	+	+	+	+	+	+	+
GHA	/	/	/	/	/	/	/	/	/	/	/	/
CAM	+	+	++	++	++	++	++	++	++	+	+	+
CAC	+	+	+	+	+	+	+	+	+	+	+	+

2. Main control methods

2.1. Introduction

Successful organic production requires an integrated approach to managing pests and diseases. An important part of this approach involves a number of preventative strategies that minimise the likelihood of occurrence and when infection occurs, its severity. When these measures are implemented adequately, insect pest and disease infestation will hardly reach economic thresholds.

A range of preventative measures are important to minimise susceptibility to pest and disease pressures. Some key preventative measures are as follows:

- **Location/regional occurrence** - Understanding the prevalence, timing and severity of specific pests or diseases for a given location is very important and can have a significant impact on production costs and reliability of production. One has to consider location, its microclimate and soils. An organic management plan should be developed to identify and minimise risks.
- **Surrounding land use** – Neglected orchards or poorly managed surrounding properties can be a constant source for new outbreaks of pests or diseases, and infestation of properly managed fields.
- **Variety** – Selection of plant material with resistance characteristics should be used wherever possible. Selecting varieties that are well suited to the local growing conditions will ensure healthy growth and resilience to problems.
- **Healthy trees** – Emphasis on maintaining healthy trees that are naturally able to cope with minor pest or disease problems is important. The foundation for healthy trees is a healthy soil. This is achieved by creating a biologically active soil with adequate organic matter and nutrient cycling (mulch) to balance the chemical, biological and physical condition of the soil.
- **Biodiversity** – Orchard floor management that involves a mix of plant species and mowing at the right time to encourage beneficial predators (which like flowers) while preventing high humidity under the tree. Windbreaks and shelterbelts can also be designed to encourage biodiversity.
- **Hygiene** – Vigilant and thorough orchard hygiene is very important. Removal of infected wood, fruit and other plant tissue can reduce the severity of subsequent problems.
- **Rapid decomposition** – Infected plant material – as a source of future inoculum – can be reduced by rapid decomposition assisted with mulch from the orchard floor.

As a result, when the right varieties of papaya are planted in the right location, and taken care of as above, pests and diseases will rarely pose problems. However, this does not mean that pests and diseases are neglected. Proper identification, regular monitoring and (preparation for) timely intervention are essential for a sustainable production of high quality fruit.

2.2. Pest growth cycle or disease cycle and position of control methods and factors influencing development

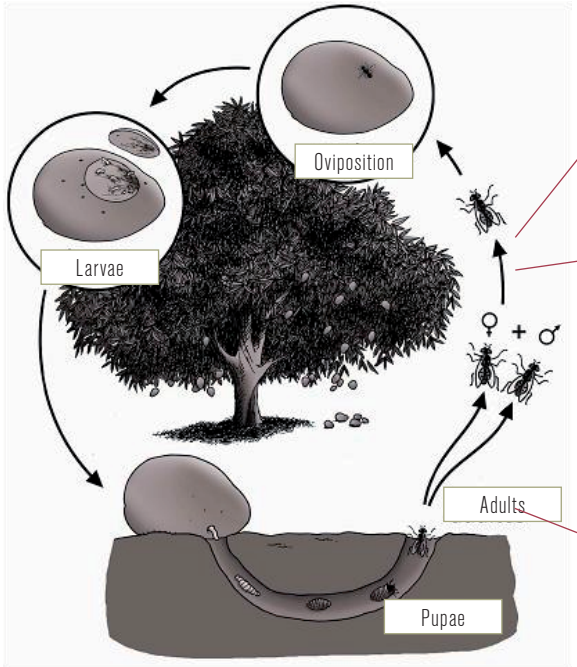
Based on the stages of development of each pest or disease, the following are the applicable control methods, as well as the effects of natural factors other than those related to climate, which are described in Part 1.4 of this guide. The control methods are then positioned in terms of the plant's development cycle.

N.B.: the illustrations of the cycles represent the different stages of development, but in no case should these illustrations be used to identify pests or diseases. For identification, please return to part 1.2 of this guide.

FRUIT FLIES – *Ceratitis* spp. and *Bactrocera* spp

Position of control methods on the growth cycle of the pest

Like all flies, fruit flies develop by complete metamorphosis. The female oviposits in clusters under the skin of fruit close to maturity. Fruit flies need protein during their egg-laying period. Larvae emerge from the eggs 2 to 5 days later. After spending some 9 to 15 days in the fruit, maggots (third larval stage), leave the fruit and become pupae in the soil. The adult flies emerge from these pupae.



The above drawing describes the lifecycle of fruit flies in mango trees which is the same as in papaya trees

Pest growth cycle or disease cycle and position of control methods and factors influencing development

In the orchard

<u>At beginning of fruit set</u>

- Fruits with dimples and oozing clear sap should be removed since it signals that a female has laid eggs. This method is more effective, although more laborious, than picking rotten fruits from the ground as by then the maggots may have left the fruits to pupate.
- Collect and remove prematurely fallen or aborted fruits. Bury them at least 50 cm deep under the soil. Better even with an addition of sufficient lime to kill the larvae.
- Trapping the flies:
    - Electronic ultraviolet light traps are very efficient and functional for an ongoing problem.
    - Traps can be used for monitoring and control of fruit flies.

- When controlling fruit flies populations with traps the density of traps needs to be high.
- Depending on the traps, the local conditions, climate, the density can reach 50 to 100 traps per ha.
- There are two main kinds of attractants:
    - Sexual attractants or parapheromones, which attract only males. Different parapheromones attract different species of fruit flies.
    - Food attractants, most often protein hydrolysate, which attract both male and female flies.
- Traps also contain an insecticide solution to kill the flies.
- Fly traps with fresh bait should be hung in the trees just above the lower leaves. Baits should be replaced 2 times a week.
- Examples of fresh baits: Pieces of ripe bananas with sugar and water or vinegar, with honey and water.

- Fruit flies are attracted to yellow surfaces. Yellow sticky traps can be used to catch fruit flies. Yellow dishes filled with soapy water can trap 10-15 fruit flies every two days.
- Special fruit fly traps are constructed in such a way that once flies have entered to take the bait, they can no longer escape.
- Scavenging poultry are an enormous help in fruit fly control.

At harvesting

- Harvest fruits early when mature on a weekly basis.
- Avoid movement of fruits from infested areas to non-infested ones.
- Practice crop and field sanitation. All the fallen and damaged ripe fruits should be collected every day and destroyed to eliminate all sources of possible breeding sites. Pick overripe fruits. These are good breeding sites for fruits flies.
- Do not put collected damaged fruits in compost heaps. Bury these at least 50 cm below the soil surface that adult flies will not be able to emerge.
- Larvae can be suffocated by soaking the infested fruits in water that is topped with a layer of kerosene for three days.
- Cook infested food and feed it to chickens and pigs.

Post harvest

- It is essential to identify the fruits that bear traces of punctures. They should then be removed at the time of harvesting or during sorting operations.
- In Pacific, export fruit to New Zealand is forced through hot air at 48.5° C for 3 hours.

PAPAYA MEALYBUG – *Paracoccus marginatus*

Details on the biology and life cycle of the papaya mealybug are lacking. In general, mealybugs have piercing-sucking mouthparts and feed by inserting their mouthparts into plant tissue and sucking out sap. Females have no wings, and move by crawling short distances or by being blown in air currents. Females usually lay 100 to 600 eggs in an ovisac, although some species of mealybugs give birth to live young. Egg-laying usually occurs over the period of one to two weeks. Egg hatch occurs in about 10 days, and nymphs, or crawlers, begin to actively search for feeding sites. Female crawlers have four instars, with a generation taking approximately one month to complete, depending on the temperature. Males have five instars, the fourth of which is produced in a cocoon and referred to as the pupa. The fifth instar of the male is the only winged form of the species capable of flight. Adult females attract the males with sex pheromones. Under greenhouse conditions, reproduction occurs throughout the year, and in certain species may occur without fertilization. The papaya mealybug is polyphagous and has been recorded on over 55 host plants in more than 25 genera. Economically important host plants of the papaya mealybug include papaya, hibiscus, avocado, citrus, cotton, tomato, eggplant, peppers, beans and peas, sweet potato, mango, cherry, and pomegranate.

Position of control methods on the growth cycle of the pest

The most susceptible stages of the pest are the first stages and for adults also winged adults.

Position of control methods on the growth cycle of the crop

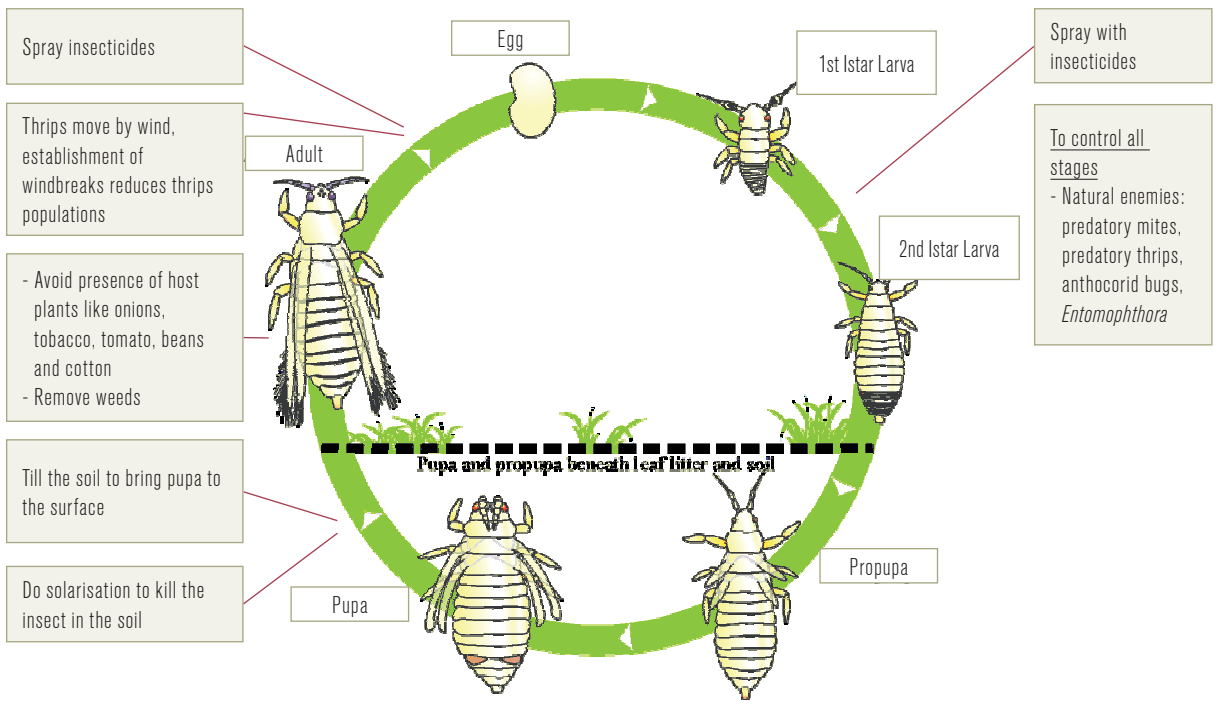
At all stages

- Remove weeds and unwanted host crops within and in the vicinity of the orchard to minimise migration of mealybugs due to their wide host range. Some wild hosts: *Mimosa pigra* (giant sensitive plant), *Parthenium hysterophorus* (Parthenium weed).
- Water properly (frequency and amount) seedlings and trees in the orchard.
- Conserve natural enemies (parasitic wasps and predators).
- Spray mineral oils or soap and water solution.
- Disturb activity of ants that attend the mealybugs.

THRIPS – *Thrips tabaci*

The female lays eggs in the leaf tissue. The first two immature stages are called larvae and are similar to adults but wingless. These are followed by two-to-three preadult instars (the prepupa and pupa) which usually have short wing pads, are inactive and do not feed. They usually pupate in the soil or under debris near host plants. Thrips have a short generation time of 2-3 weeks in warm conditions. The adult lifespan is 2 to 3 weeks. Thrips migrate actively between different hosts. Primary hosts include *Gossypium* (cotton), *Allium* (onions, garlic, leek, etc.), *Cucurbitaceae* (cucurbits), *Nicotiana tabacum* (tobacco), *Brassica oleracea var. capitata* (cabbages), *Chrysanthemum* (chrysanthemum), and *Piper nigrum* (black pepper)

Position of control methods on the growth cycle of the pest



Position of control methods on the growth cycle of the crop

In the orchard

Before orchard plantation

- Thrips move by wind, establishment of windbreaks reduces thrips populations.
- Avoid presence of host plants like cotton, tobacco, tomato etc.

At all stages

- Plants that have a natural repellent to thrips are citronella and pyrethrum. Plant these near papaya trees.
- Remove weeds to minimise migration of thrips
- Plough and harrow before transplanting and solarisation can kill pupae in the soil from previously infested crops.
- If absolutely necessary, spot spray repellent or insecticides but caution about their impact on the thrips' natural enemies.
- Natural enemies, particularly predators, are important in natural control of thrips. Main natural enemies include predatory bugs, predatory mites and predatory thrips.

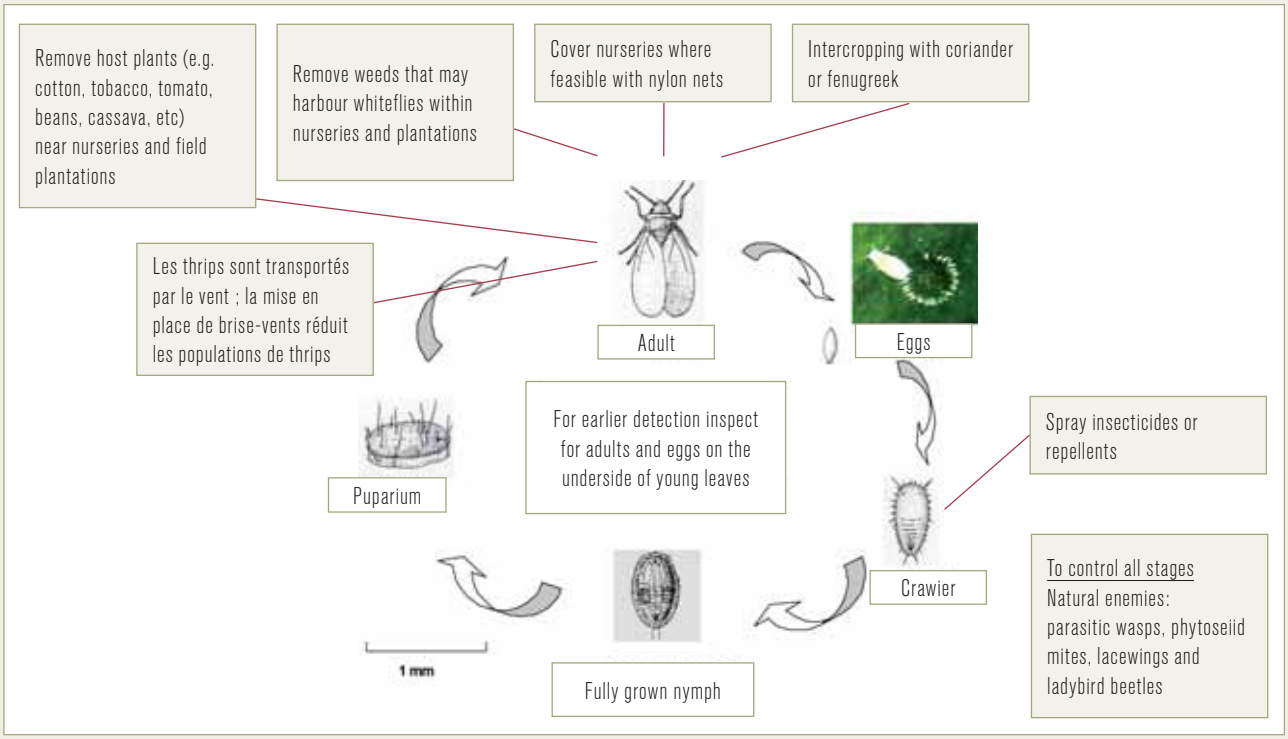
WHITEFLIES - *Aleurodicus dispersus* and *Bemisia tabaci*

Eggs are laid usually in arcs or circles, on the undersides of leaves. Hatching occurs after 5-9 days at 30°C depending on host species, temperature and humidity.

On hatching, the first instar or crawler is the only mobile larval stage. It moves to a suitable feeding location on the lower leaf surface where it moults and becomes sessile throughout the remaining nymphal stages. The first three nymphal stages last 2-4 days each (depending on temperature). The fourth nymphal stage is termed the puparium. Pupation lasts for about 6 days and within this period, the metamorphosis to adult occurs. A female may live for 60 days, although the life of the male is generally much shorter, being between 9 to 17 days.

Whiteflies are highly polyphageous insects and are recorded attacking over 300 plant species with special preference for cotton, tobacco, beans, sunflower, aubergine, tomato, citrus trees and sweet pepper.

Position of control methods on the growth cycle of the pest



Position of control methods on the growth cycle of the crop

In the nursery

- Cover nurseries where feasible with nylon nets.

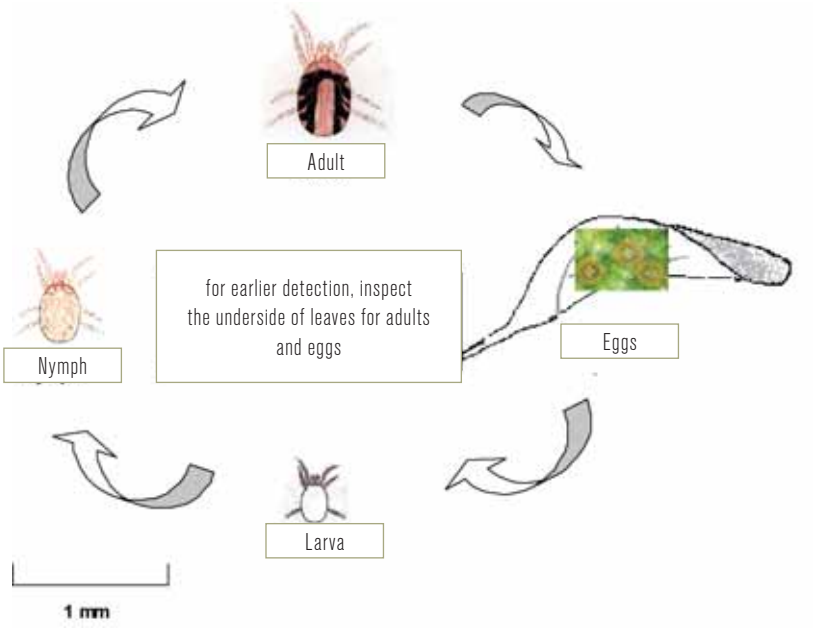
Before orchard plantation

- Whiteflies move by wind, establishment of windbreaks reduces whitefly populations.
- Avoid presence of host plants like cotton, tobacco, tomato etc.

At all stages

- Plant crops that have a natural repellent to whiteflies such as coriander and fenugreek. Plant these near papaya trees.
- Remove weeds to minimise migration of whiteflies.
- Spray neem extracts, mineral oil or soap and water solution.
- Conservation of natural enemies is important in management of whiteflies.

MITES - *Tetranychus* spp. and *Polyphagotarsonemus latus*



The lifecycle of a **spider mite** may take 10-30 days depending on temperature. It includes five stages: egg, larva (first instar) and two nymphal stages and adult. A female may lay over 100 eggs during its lifespan.

The generation time of *P. latus* is short. The developmental period from egg to adult at 25°C averages 4.1 days for both males and females. Each female lays 25 eggs.

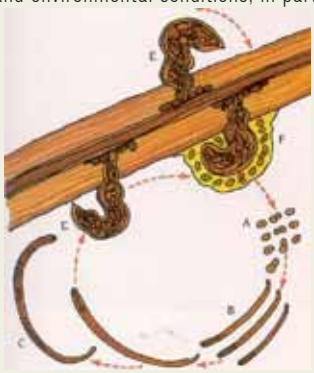
Polyphagotarsonemus latus is a broadly polyphagous species and has been found on crop species belonging to over 60 different plant families. Primary hosts include *Gossypium* (cotton), *Citrus* spp., *Capsicum frutescens* (chilli), Solanum melongena (aubergine), *Camellia sinensis* (tea), *Carica papaya* (papaya), *Corchorus* (jutes), *Cucumis sativus* (cucumber), and *Vitis vinifera* (grapevine). Wild hosts include *Datura* spp.
Mites disperses by various means. Transported by the wind. Short-distance movement may be accomplished by walking. Human transport of infested plants is another way of dispersal.
There is also evidence that *P. latus* disperses through insects living on plants. Females of *P. latus* were observed to have a phoretic relationship with *Bemisia tabaci* on *Phaseolus vulgaris* in Colombia and on watermelons in Venezuela.
In addition, the vicinity of wild or cultivated host plants also encourages infestation by mites.

Control methods

- Maintain good biological control by conserving natural enemies.
- Use sprinkler irrigation in nurseries and small trees in the orchard.
- Controlling dust, which improves predator activity, is critical for maintaining biological control when mites are a problem. Planting hedges along roads reduced dust drift onto trees. Make vehicles drive slowly in the vicinity of orchards. Wet dirt roads to prevent airborne dust.
- Spraying the underside of leaves with a forceful stream of water can reduce mite populations on small trees. Adding soap will be more effective. *[However, consult your certification body on the use of soaps]*
- To minimize initial infestation, avoid drought and other stress. Appropriate irrigation frequency and amounts will reduce the adverse impact of mite feeding.
- Good sanitation practices (i.e., elimination of favoured weed species) and removal of alternate host plants (i.e., ornamental plants and non-commercial fruit trees in orchards) that act as mite reservoirs are useful cultural control practices.
- Spay with active ingredient with miticide action.

NEMATODES - *Rotylenchulus reniformis* and *Meloidogyne* spp.

R.reniformis has four juvenile stages, an immature female and mature female/male stages. Mature females lay single-celled eggs (Life cycle diagram: A), which develop into the first stage juveniles that moult into the second-stage juvenile before emerging from the egg. Further moults occur producing the third and fourth juvenile stages (Life cycle diagram: B, C, D), all of them retaining the cuticles of the previous stages. None of these juvenile stages are parasitic and they do not feed on the plant roots. The final moult produces an immature vermiform female or male. *R. reniformis* has both males and females but is also known to reproduce parthenogenetically. Males are not parasitic. The vermiform immature female is the infective stage and it partly penetrates the cortex of host plant root. A permanent feeding site in the root endodermis is developed at the head of the nematode and it becomes sedentary. The posterior body of the female remains protruding from the root and swells as the nematode reaches maturity producing a very characteristic kidney or reniform shape (Life cycle diagram: E). The swollen females lay eggs into a gelatinous matrix, which covers the body on the surface of the root (Life cycle diagram: F). The life cycle from egg to egg can be as short as 3 weeks and is affected by the host and environmental conditions, in particular temperature.



A): Eggs; (B,C,D): Juvenile nematodes; (E): Female nematodes reniform in shape; (F): A gelatinous matrix covering the body of a swollen female laying eggs

There are four species of **root-knot nematodes** *(M. arenaria, M. hapla, M. incognita and M. javanica)* that are widespread in the tropics. The species important on papayas is *M. incognita* and are particularly serious in irrigated fields. Important environmental factors that influence development of *Meloidogyne* spp. are moist soils and relatively warm temperatures. Under average conditions a female produces 300 to 800 eggs. A new generation can arise within 25 days, but under less favourable conditions, the time may be prolonged to 30 to 40 days. Juveniles (young nematodes) penetrate the root tips and occasionally invade roots in the zone of root elongation. Invaded nematodes initiate the development of giant cells in the root tissues and galling of roots occurs. They are spread by transplanting infested seedlings, or from soil washed down slopes or sticking to farm implements and farm workers. They may also be spread by irrigation water.

The presence of wild or cultivated host plants within or in the vicinity of the orchard, accidental or intentional of movement of infested soil (on footwear or farm implements) into the orchard may aggravate nematode infestation.

Position of control methods on the growth cycle of the crop

In the nursery

• Eliminate nematodes from seed beds and potting soil.

In the orchard

Before plantation:

- Rotation of crops.
- Deep ploughing followed by dry fallows.
- Soil solarisation.

At plantation:

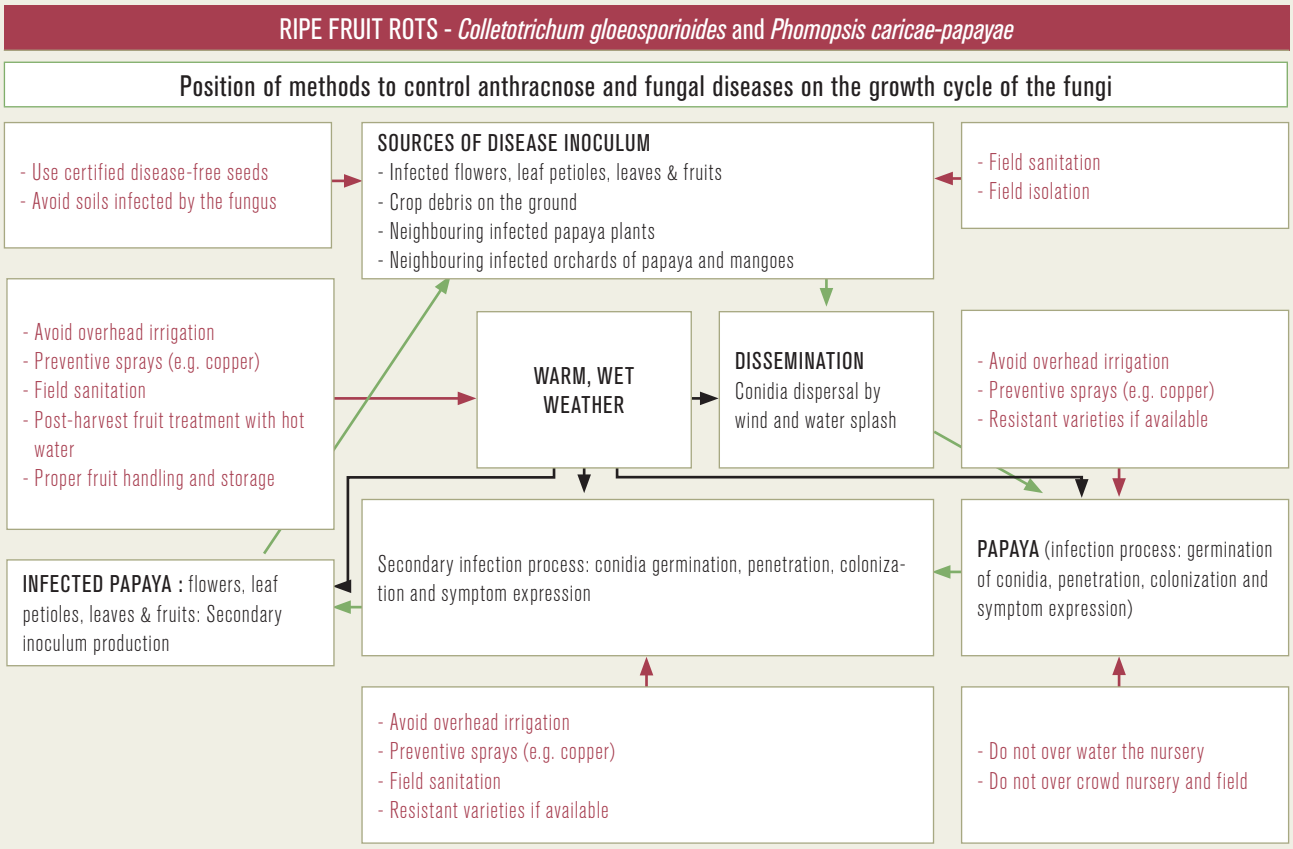
- Use of nematode-free planting material.
- Do not replant in areas previously under nematode infestation.
- Amending soil by adding organic matter not only improves the soil water holding capacity and nutrients, but can reduce nematode pest damage by increasing the activity of soil microorganisms antagonistic to nematodes, and by production of decomposition products which can be nematicidal.
- Amending soil with neem cake powder. *[It must be noted that according to EU Regulations for Organic Agriculture (EEC) 2092/91 the application of neem preparations is restricted and only allowed for the production of seeds and seedlings. Consult your certification body on up-dates].*
- Application of sawdust and chicken manure improves crop nutrition and has a side benefit of controlling root knot nematodes.

At all stages:

- Biological control using pathogenic fungus *Paecilomyces lilacinus.*
- Different cover crops reduce the presence of the nematodes: *Crotalaria juncea* (Sunnhemp), *Lolium multiflorum, Triticum aestivum, Indigofera spicata, Sinapis alba* (yellow mustard), *Tagetes erecta* (Marigold) and *Glycine javanica.*

After last harvesting:

- Post harvest destruction/removal of infested crop residues.



Interventions depicted in red

Position of methods to control anthracnose and fungal diseases on the growth cycle of the crop

Nursery

- Use certified disease-free seeds.
- Do not have a nursery site where it was previously under papaya and particularly a site which had problems with these diseases.
- Do not over crowd the nursery beds.
- Do not over water the nursery beds.

When transplanting into the orchard

- Do not transplant where papaya was previously grown.
- Transplant only healthy, vigorous seedlings.
- Transplant in the field at the recommended spacing.
- Avoid overhead irrigation.

For upkeep of the orchard

- It is also very important to balance soil nutrients especially nitrogen; apply composted manures.
- Clean orchards weed-free, and collect and destroy affected fruits.

Before flowering

- Dispose of dead crop residues and old fruit away from trees before bloom.

At beginning of fruit set

- Collect regularly and burn necrotised or dead organs scattered on the ground (remains of inflorescences, dry branches, dead leaves, including bedding leaves, etc.).
- Regularly collect fruit that has dropped to the ground, bury it by covering with soil to prevent the dispersion of spores by wind, water splash or insects.

At harvest and post-harvest

- Keep fruit out of contact with the ground, particularly with sandy, abrasive soils and mud during the rainy season.
- Fruits should be handled carefully during and after harvest. Very small injuries caused to the epidermis of the fruit during harvesting, market preparation and transport can favour the reactivation of quiescent infections or direct infection by spores present on the fruit during the rainy season.
- At grading, attention should be paid to remove the infected fruit.
- Keeping fruit dry and cool can aid in minimising losses from post-harvest decays until sold. Post harvest temperature is especially critical to anthracnose development. Cool fruit to 5°C as soon as possible after harvest. Delays of longer than 6 hours before cooling and higher air temperatures during these delays will result in increased post harvest fruit decay. Cooling fruit promptly is of increasing importance as the season progresses because fruit ripens faster as it increases in maturity. Avoid storage temperatures below 5°C because chilling injury may occur.
- Ripe fruit rots can be prevented by placing fruit in hot water (49°C for 20 min or 42°C or 30 min). Another method is to spray fruit with hot water at 54°C for 3 minutes. [It should be noted that fungicide baths used in conventional papaya plantations are not permitted in organic production].

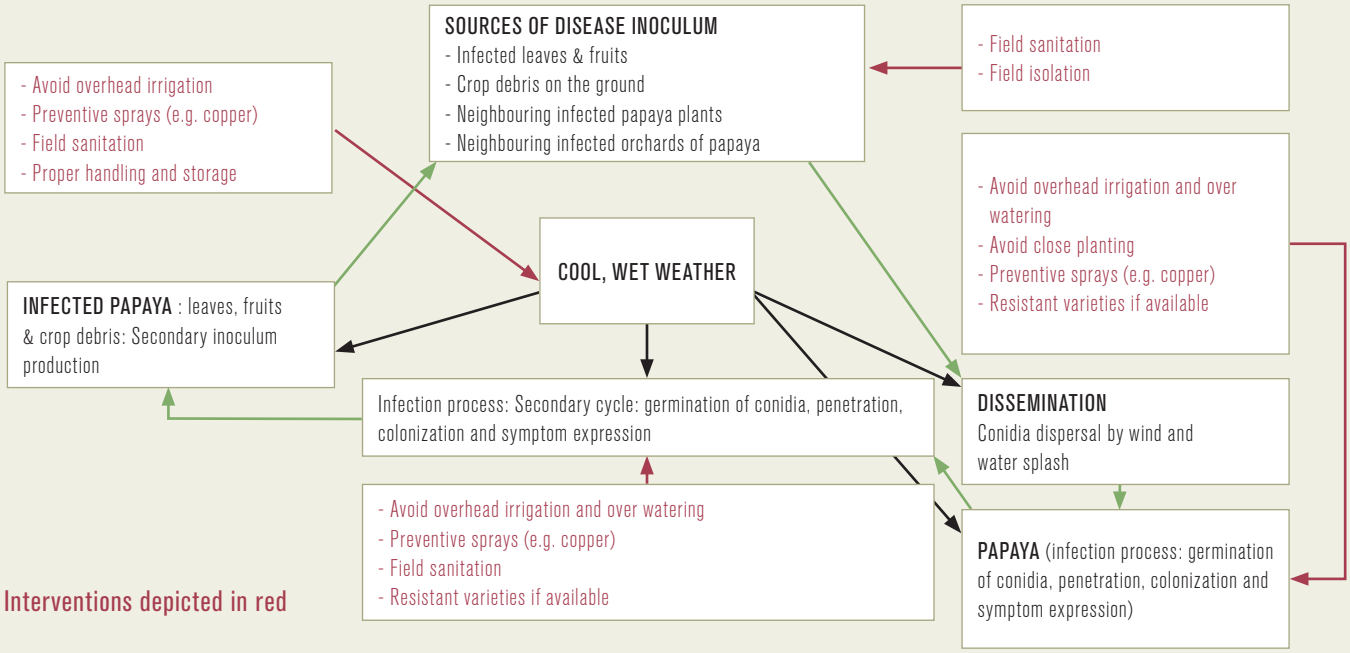
Throughout the year, and more frequently during flowering and during the rainy season:

- Copper treatment can prevent infection by the fungus.

ASPERISPORIUM SPOT – *Asperisporium caricae*

The primary source of inoculum is infected older leaves. Spores of the pathogen are spread by wind and also within the plant (old leaves to fruit) by water splash. Its host range is restricted to papaya.

Position of control methods on the growth cycle of the fungus



Interventions depicted in red

Position of control methods on the growth cycle of the crop

<u>At all stages</u>

- Remove sprouts. This is generally done 30 days after transplanting.

<u>When planting the orchard</u>

- Proper land preparation and orchard management might limit the infection.
- Plant only disease-free plants.
- Avoid close planting.
- Avoid overhead irrigation and over-watering.

<u>Post-harvest Control</u>

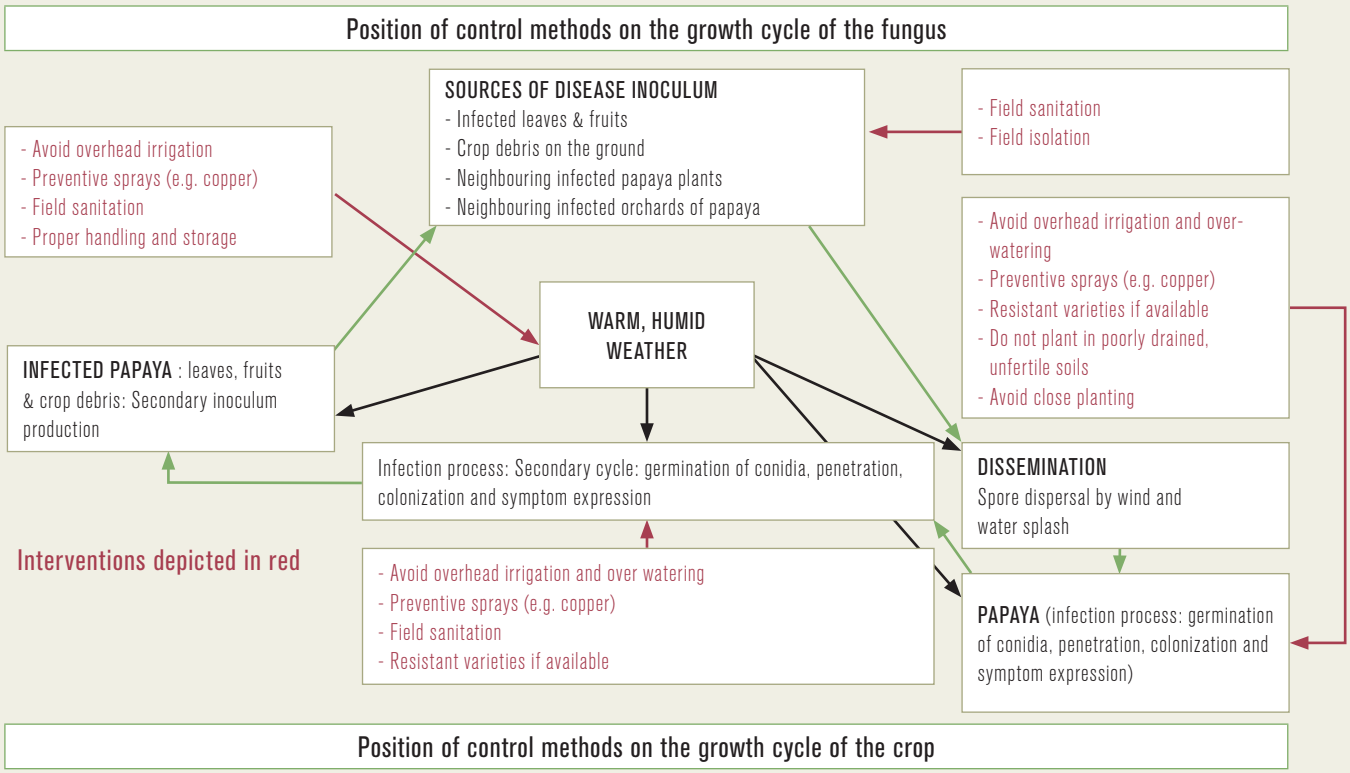
- Handle fruits with care.
- Store only dry, healthy, mature, blemish-free produce, and store fruit in a clean, dry, well-ventilated area.
- If diseased material has been stored previously, first sweep the area very well.
- Place fruits in cool (5°C) storage as soon as possible after harvest.

<u>After harvesting in the field</u>

- Remove infected plant debris from the field and remove plant residues after harvest.

CERCOSPORA SPOT – *Cercospora papayae*

The primary inoculum comes from the leaves that are present on the plants. The fungus attacks plants that are not properly managed.



When planting the orchard

- Proper land preparation and orchard management might limit the infection.
- Plant only disease-free plants.
- Do not plant in poorly drained, unfertile soils.
- Avoid close planting.
- Avoid overhead irrigation and over-watering.

Post-harvest Control

- Handle fruits with care.
- Store only dry, healthy, mature, blemish-free produce, and store fruit in a clean, dry, well-ventilated area.
- If diseased material has been stored previously, first sweep the area very well.
- Place fruits in cool (5°C) storage as soon as possible after harvest.

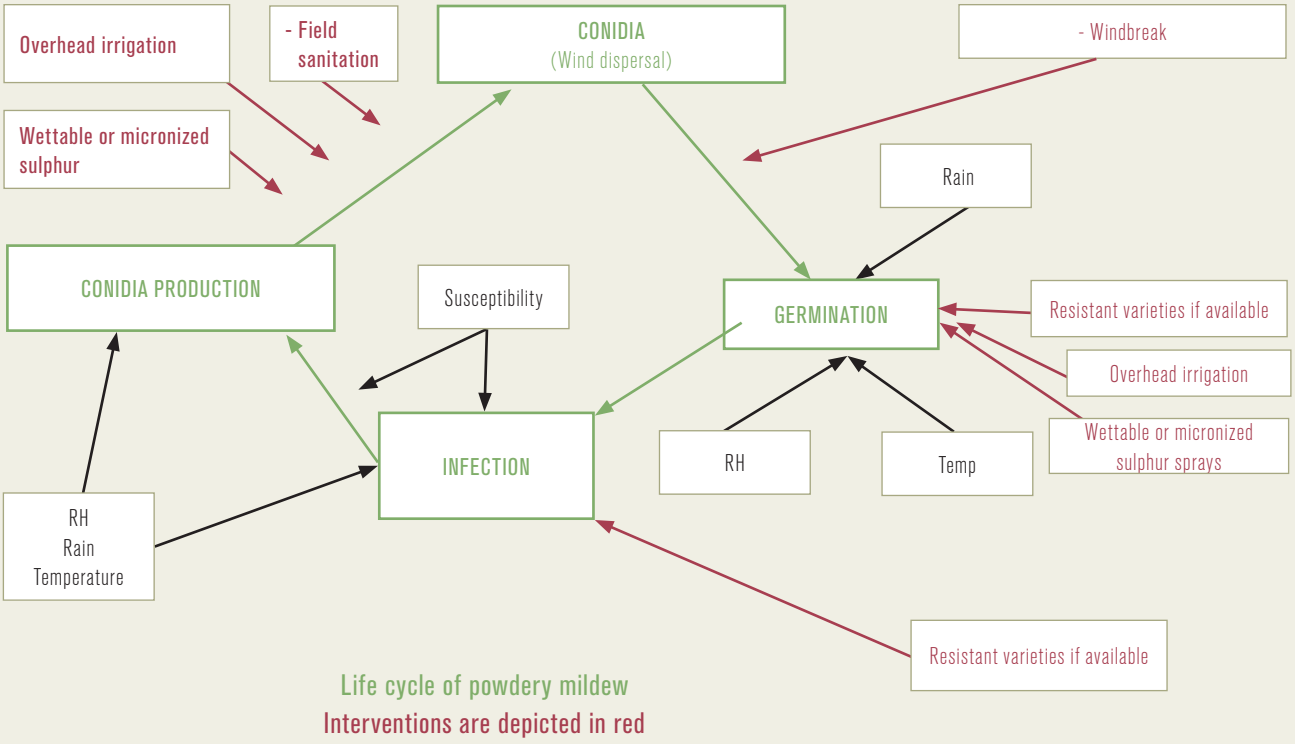
After harvesting in the field

- Remove infected plant debris from the field and remove plant residues after harvest.

POWDERY MILDEW – *Oidium* spp.

Oidium caricae is restricted to papaya. Other powdery mildew species (*Sphaerotheca humili, Ovulariopsis papayae* and *Oidiopsis taurica*) have been reported on papaya. *O. taurica* has a wide host range including beans, cucumber, eggplant, pepper and tomato.

Position of control methods on the growth cycle of the fungus



Life cycle of powdery mildew
Interventions are depicted in red

Position of control methods on the growth cycle of the crop

At all stages

- Apply overhead irrigation in nursery and small trees if symptoms of the disease are observed.
- Collect and destroy crop debris.
- Irrigate regularly to avoid drought stress.
- Keep fields weed-free.
- A good windbreak reduces dispersal of inoculum.
- Sprays of wettable sulphur (micronized sulphur) could provide good control.

ROOT, COLLAR AND STEM ROT – *Phytophthora nicotianae* var. *parasitica, Phytophthora palmivora* and *Pythium* spp.

The pathogens causing root, collar and stem rot are soil-inhabitants. Papaya residues left in the soil harbour these pathogens and they survive in the soil for long periods in the absence of suitable host plants. Spores of these pathogens are spread by surface water and in case of *Phytophthora* spp. also by rain splash.

Position of control methods on the growth cycle of the crop

Nursery

- Choose suitable areas (area not previously under papaya; area not prone to flooding; area that is well drained).
- Avoid dense planting.
- Avoid over watering.
- Remove infected seedlings from the nursery.

When planting the orchard

- Do not transplant in areas that were previously under papaya.
- Do not transplant in areas that were previously had incidence of the disease.
- Proper land preparation and orchard management might limit the infection.
- Plant only disease-free plants.
- Do not plant in poorly drained, unfertile soils.
- Avoid close planting.
- Avoid over-watering.

Orchard

- Avoid over-watering.
- Uproot and burn diseased trees.
- Practise crop rotation: Hosts include tobacco, capsicum, sweet potato, eggplant, pineapple and tomato. Non-hosts are maize, groundnuts, soybeans and sugarcane.

Post-harvest Control

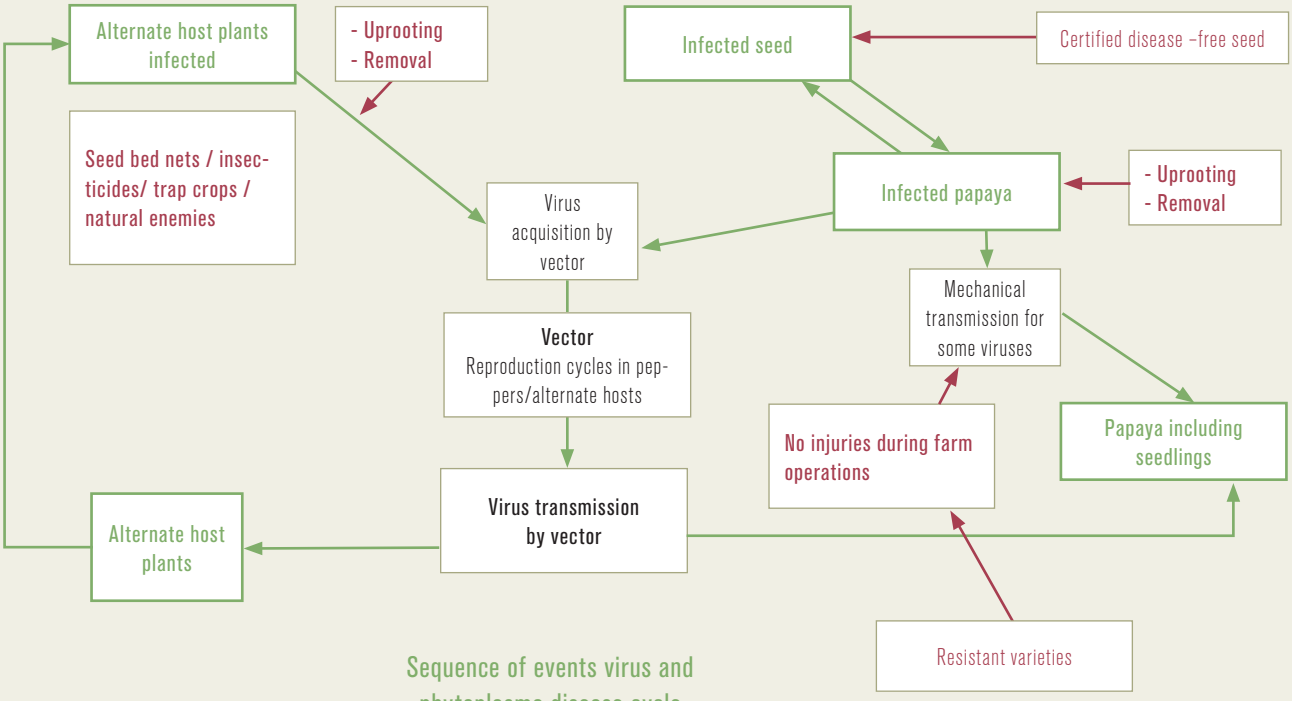
- Handle fruits with care.
- Store only dry, healthy, mature, blemish-free produce, and store fruit in a clean, dry, well-ventilated area.
- If diseased material has been stored previously, first sweep the area very well.
- Place fruits in cool (5°C) storage as soon as possible after harvest.

VIRAL AND PHYTOPLASMA DISEASES

Most importantly is the presence of inoculum, host plants and transmission agents. The insect vectors spread the pathogen from plant to plant and from field to field. Importantly, is vector activity rather than abundance in numbers of the vectors in a crop.
Ringspot potyvirus is spread by aphids *(Aphis gossypii* and *Myzus persicae)* and it is also mechanically transmitted. Members of *Cucurbitaceae* are hosts to papaya ringspot virus.
Tomato spotted wilt tospovirus has a huge host range and is transmitted by thrips mostly *Thrips tabaci.*
Bunchy top phytoplasma is transmitted by leafhoppers *(Empoasca papaya* and *E. stevensis)* and grafting.
Mosaic potexvirus is transmitted mechanically and by aphids.
Yellow crinkle phytoplasma is transmitted by the brown leafhopper *Orosius argentatus.*

For all mentioned insect vectors ideal weather condition is dry season with temperatures ranging from 25 to 30°C. Intervention should be directed at elimination sources of infection and virus vectors.

Position of control methods on the growth cycle of the vector and the virus



Sequence of events virus and phytoplasma disease cycle
Interventions depicted in red

Position of control methods on the growth cycle of the crop

At all stages
- Keep fields weed-free.
- Control disease vectors (aphids, leafhoppers, thrips, whiteflies).
- Avoid injury to plants during field operations.
- Conserve natural enemies.
- Uproot and remove affected plants.
- Spray insecticides.

After harvesting
- Remove infected plant debris from the field and remove plant residues after harvest.

GIANT EAST AFRICAN SNAIL – *Achatina fulica*

Adult size is reached in about six months; after which growth slows but does not ever cease. Life expectancy is commonly five or six years in captivity, but the snails may live for up to ten years. They are active at night and spend the day buried underground.

It is capable of aestivating for up to three years in times of extreme drought, sealing itself into its shell by secretion of a calcerous compound that dries on contact with the air. This is impermeable; the snail will not lose any water during this period.

The number of eggs per clutch averages around 200. A snail may lay 5-6 clutches per year with a hatching viability of about 90%. Dependent on the temperature, the babies will hatch in anything from 5 to 21 days.

Achatina fulica are slightly more sensitive to wet environments than other African snails and will die if maintained in conditions that are too wet. They prefer calcium-rich environments. They are averse to sunshine, exposure to the direct rays of the sun killing them off rapidly.

It has a remarkably broad host range that includes bananas, beans, breadfruit, brinjal, cabbage, cacao, cauliflower, coffee and cucurbits. As with all mollusks, they enjoy the yeast in beer.

Control methods

- Practise good field sanitation.
- Hand collection (in some countries they constitute a food source and even exported as a food delicacy to Europe. Also in some European countries snails are kept as pets).
- In East Africa, sprinkling their habitats and / or around crop base with table salt in dry seasons, has proven effective in their control.
- Food baits (e.g. over-ripe papaya fruit pieces). However, these baits should be daily removed from orchards and destroyed.
- Brewers' waste in water containers is effective trap. They are attracted by the yeast and they get drowned when going for the 'brew'.

2.3. Cultivar susceptibility to diseases

- No commercial varieties, except for transgenic, have been reported resistant to papaya ringspot virus or bunchy top phytoplasma. Transgenic varieties are not permitted in organic production.
- Varieties 'Sunrise Solo', and 'Kapoho Solo' are reported to be very susceptible to Asperisporium black spot.
- In Hawaii, 'Waimanalo-23', 'Waimanalo-24', 'Line 8' and 'Line 40' are reported resistant to *Phytophthora palmivora.* 'Kapoho Solo' and '45-T22' are moderately resistant, and 'Higgins'is susceptible to *P. palmivora*.
- In relation to anthracnose, variety 'Honey Gold' is reported tolerant in South Africa while 'Santa Cruz Grant' is rated as highly resistant in Trinidad and Tobago and 'Solo NO 8' very susceptible wherever it is grown.
- Variety 'Cariflora' is reported tolerant to papaya ringspot virus in Florida (USA).

2.4. Cultivar susceptibility to diseases

In organic agriculture, one of the most important goals is the achievement of healthy plants by encouraging an ecological balance between pests and beneficial species. Plenty of natural enemies are present in the environment and their presence should be encouraged by providing conducive habitat (flowers, humidity).

Listed below are some of biological agents commercially available in Kenya:
Aphidius transcapicus
Beauveria bassiana
Bacillus thuringiensis
Trichogrammatoidea lutea
Diglyphus isaea
Amblyseius californicus
Orius jeanneli
Encarsia formosa
Phytoseiulus persimilis
Trichoderma asperellum
Trichoderma spp.
Paecilomyces lilacinus
Pochonia chlamydosporia

2.4.1. FRUIT FLIES

Fruit flies have several predators. Braconid wasps are egg parasites. Ants and ground beetles feed on the maggots present on the ground. Spiders, different flies and birds eat the adult flies.

- **Description of braconid wasps:**

Adult wasps are tiny, about 2.5 mm in size, slender black or brown with threadlike waists.
Female wasps lay eggs into the eggs of hosts' pests.

- **Conservation**

Adult braconids feed on nectar, honeydew, or pollen before laying eggs. Dill, yarrow, zinnia, clover, alfalfa, parsley, cosmos, sunflower, and marigold are flowering crops that attract the native braconid populations and provide good habitats for them.

2.4.2. THRIPS

Natural enemies, particularly predators, are important in natural control of thrips. Main natural enemies include predatory bugs (*Orius* spp. and *Anthocoris* spp.), predatory mites and predatory thrips.

The naturally occurring predaceous thrips, *Franklinothrips orizabensis* and *F. vespiformis* are an important biological control agent that responds in large numbers to the presence of thrips populations.
The larval stage of this predator is easily identified by the red band on the abdomen. The adult thrips is black in colour, has a thin waist and legs which have white bands and is an ant mimic.

2.4.3. MEALYBUGS

Predators such as *Nephus bilucemarius, Scymnus taiwanus, Hyperaspis silvestrii, Cryptolaemus montrouzieri* and *Curinus coeruleus* provide some level of control. A biological control program using parasitic wasps (*Anagyrus loecki, Pseudleptomastix mexicana* and *Acerophagous papayae)* has been successfully implemented in Florida, Caribbean Islands, countries in South America, Guam and Palau. Currently it is being implemented in the Hawaiian Islands and Tinian in the Mariana Islands.

2.4.4. MITES

A number of natural enemies (predators) are known to feed on spider mites. These include predatory mites, small staphylinid beetles, ladybird beetles, lacewings, predatory thrips, anthocorid bugs, mirid bugs, and cecidomyiid and syrphid flies.

Predaceous mites include Amblyseius *(Neoseiulus) californicus, Euseius hibisci, Galendromus annectens,* and *G. helveolus*. Black hunter thrips *(Leptothrips mali),* sixspotted thrips *(Scolothrips sexmaculatus),* brown lacewings *(Hemerobius* spp.) and green lacewings *(Chrysopa and Chrysoperla* spp.), a predatory midge *(Feltiella sp., Cecidomyiidae),* a rove beetle *(Oligota oviformis, Staphylinidae),* and the spider mite destroyer lady beetle (*Stethorus picipes)* are other common predators.

Ladybird beetles: They lay yellow to orange in colour eggs. The eggs are elongated and are laid in groups on the underside of leaves near aphid colonies. Newly hatched larvae are soft-bodied and usually long and thin in shape. Their colour varies from black to dark brown with various types of markings. They are less than 4 mm long. Adults are oval to hemispherical and strongly convex with short legs and short antennae. Most species are brightly coloured. When disturbed, some of them emit a strong smelling yellow liquid as a protection against other predators. Their colours vary from red, orange, steel blue, yellow-brown, or yellow elytra, frequently spotted or striped with black. They feed on pollen, nectar, water, and honeydew but aphids or other prey are necessary for egg production.
• Conservation
Ladybird beetles are found in most agricultural and garden habitats. These beetles are attracted by the flowers of the *Cruciferae* and *Compositae* family. Planting these flowers around the fields or even within the fields will attract the beetles. Their presence indicates that natural biological control is occurring. It is important to maintain habitats planted with several flowering crops. These give the ladybird beetles varied food sources. When food is not available, they tend to eat each other.

Lacewings: The wings of the adults are greenish (green lacewings - *Chrysopa* and *Chrysoperla* spp.) or brownish (brown lacewings - *Hemerobius* spp.) and all are semi-transparent. The eggs are laid at the end of tiny stalks, usually on foliage. The larvae have long, sickle-shaped mouth parts. The pupae are whitish and spherical and can be confused with spider mite egg sacs. Conservation of these and other natural enemies is important in management of whiteflies (refer to conservation of ladybird beetles).

2.4.5. WHITEFLIES

Whiteflies are attacked mainly by parasitic wasps *(Eretmocerus spp. and Encarsia* spp.) and predators such as phytoseiid mites *(Amblyseius spp.* and *Typhlodromus* spp.), lacewings *(Chrysopa* spp.) and ladybird beetles. Conservation of these and other natural enemies is important in management of whiteflies (refer to conservation of ladybird beetles).

3. Crop monitoring and intervention thresholds

Usually, when sufficient measures are employed, pest and disease outbreaks are avoided. Even when a pest has been identified, it is recommended to look first at control measures to lessen its population density. One can look at cultural practices (e.g. removal of weeds); physical control (e.g. handpicking), use of baits, before taking recourse to plant protection products, be they commercial or home made. Any commercial grower should be prepared to intervene and does so based on observations or monitoring of the crop.

The following is a monitoring guideline for papaya

Pest or disease monitored	When ?	Frequency	Where ?	How ?	Sampling
Fruit flies	First flowering, fruit development to end harvest	Weekly	Traps under the shade of the canopy	Traps (pheromone or food attractant)	4 traps per ha
Mealybugs	Nursery and orchard	Weekly	Young leaves; along veins and mid-rib of older leaves and young fruit	Check visually for mealybugs and honeydew	10 random trees per ha
Thrips	During hot, dry weather. Seedlings and mature plants	Weekly	Inflorescences; underside of young leaves; infested leaves have a silvery sheen and fruit show surface speckling	Tapping branches over a white sheet and,yellow sticky traps	10 random trees per ha
Whiteflies	During hot, dry weather	Weekly	Lower surface of young leaves	Check visually for eggs and adults, and for presence of honeydew	10 random trees per ha
Mites	During dry periods and when leaves are bronze	Weekly	Concentrate on trees near dirt roads	Randomly pick leaves of different ages	10 random trees per ha
Nematodes	Nursery and orchard	Weekly	Unthrifty seedlings; stunted and yellowing plants, and roots	Check for galling of roots and soil analysis	General field inspection
Anthracnose	When warm and humid	Weekly	Flowers, fruits and leaves	Check for pink sporulation on fruit surface	10 random trees per ha
Asperisporium spot	When cool and wet	Weekly	Lower surface of older leaves and fruit	Check for black spots on lower leaf surfaces and on fruit	10 random trees per ha
Cercospora spot	During rainy season.	Weekly	Leaves, fruits, stems	Fruit spotting. Grey mycelium in centre of lesions. Dead areas on leaves.	10 random trees per ha
Powdery Mildew	Seedlings and mature plants	Weekly	Inflorescences and leaves	Check visually for white powdery growth on lower leaf surface	10 random trees per ha

Root, collar and stem rot	Nursery and orchard	Weekly	Seedlings, leaves, stems and fruit	Check for damping-off; yellowing and shedding of leaves; softening and rotting of stems at soil level, and fruit rot covered with whitish mycelial growth	General field inspection
Viral diseases	During hot, dry periods. Seedlings and mature plants	Weekly	Leaves, stems and fruit	Mosaic patterns on leaves, leaf deformation; streaks on leaf petioles and stems; fruit spotting, and presence of insect vectors	10 random trees per ha
Giant East African snail	Nursery and orchard	Weekly	Leaves and fruit	Check their habitats and under rotten mass of papaya used as baits	General field inspection

The person monitoring will soon recognise in which parts of the farm a problem tends to appear first. That area acts for early warning. It is recommended to implement prevention measures more strictly in that part of the farm to delay the infestation.

Threshold levels:

In general, threshold levels are established taking into consideration the species of pest and the local conditions. It means that from one country to another, even from one production site to another threshold levels will be different. In most of Africa, threshold values have not yet been established. Nevertheless, careful monitoring is still recommended as pest population dynamics need to be monitored. It is very valuable to know and analyse the evolution of the pressure and to take action when a sudden increase in number is noted.

The frequency of monitoring should be increased when there are favourable conditions for the development of the pest or disease (e.g. warm, humid weather for fungal diseases).
The operator in charge of monitoring should be the same one for each monitoring visit. Ideally, monitoring forms should be filled in as this allows the pest and disease management to be evaluated after the season.

Critical periods for pest management are at flower induction, 3 to 4 weeks after flowering and then every 3 weeks.

Effective monitoring should be done in relation with the characteristics of particular pests or diseases.

For fruit flies, the EU regulation 2092/91 on organic agriculture allows the usage of parapheromones for the monitoring of fruit flies. However, food attractants are still the most common monitoring tools.
Trapping techniques can be utilized to reduce natural pesticide use by improving timing of sprays as a result of better monitoring of pest populations.

4. Active substances and treatment recommendations

Hereafter a list of the plant protection products allowed for usage by the EU regulation 2092/91 on organic agriculture is given which can be recommended on papaya trees. Prior to any usage, the producer should check with his/her certification body that such usage is allowed.

A distinction is done between the active ingredients from commercial products and the active ingredients from farm-made products. For some type of product the recommended GAP that allows conformity with European Regulation on residues is given. The proposed period of spraying is highlighted in the tables with green colour.

Very often, organic farmers in ACP countries use farm-made botanical extracts of which the exact concentration in active ingredients is not known, and likely fluctuates considerably. In most of the cases, the active ingredients of plant extracts are degrading very quickly. This has the advantage that they do not leave residues. The Post Harvest Interval (PHI) is then set at the minimum (2 days) and residues are hardly a problem even when a Maximum Residue Level (MRL) is set at Limit of Quantitation (LOQ).

The recommended usage for the following natural plant protection products are based on producers' experience, organic resource centres and other literature available, but very often it is difficult to get well documented scientific results of trials specific to papaya production.

Indications how to prepare the farm-made products are given after the tables of products.

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

Strategy : Apply treatments when fruit fly population grow up. .

Active substance	Recommanded GAP				Proposed application period					
	Dose g/ha	Number of applications	Interval between applications in days	PHI in day	Nursery	Vegetative growth	Blossoming	Fruit set to enlargement	Harvest	Fruit Post-harvest
Commercial products										
Azadirachtin	30	/	/	2						
Deltamethrin	Only for traps using specific lures for *Batrocera* spp. and *Ceratitis* spp.									
Lambda-cyhalothrin	Only for traps using specific lures for *Batrocera* spp. and *Ceratitis* spp.									
Spinosad	Only for spot treatments									
Plant extracts or "farm-made" concoctions										
Pyrethrum bait (1+2)	-	3 metres intervals	Replacing weekly	/						
Vinegar bait	-	3 metres intervals	Replacing weekly	/						

/elements of the recommended GAP not available; - not applicable

Active substance	Recommanded GAP				Proposed application period					
	Dose g/ha	Number of applications	Interval between applications in days	PHI in day	Nursery	Vegetative growth	Blossoming	Fruit set to enlargement	Harvest	Fruit Post-harvest
Fatty acids of potassium salt	8-10 g/l	/	/	/			■	■		
Ginger extracts	8-10 g/l	/	/	/			■	■		
Garlic extracts	/	/	/	/			■	■		
Chilli extracts	/	/	/	/			■	■		

Papaya mealybug – *Paracoccus marginatus*

Strategy : Apply products when population are not controlled by biological agents.

Commercial products										
Mineral oil*	1-2%	/	/	7	■	■	■	■	■	

* Consult certification body.

/ elements of the recommended GAP not available

- Soap and water solution is reported to control also mealybugs. [*Consult your certification body before using soap*]

Thrips – *Thrips tabaci*

Strategy : Treatments target adult and nymph stages only in affected trees. Spot spraying is essential to avoid harming beneficial insects.

Commercial products										
Active substance	Recommanded GAP				Proposed application period					
	Dose g/ha	Number of applications	Interval between applications in days	PHI in day	Nursery	Vegetative growth	Blossoming	Fruit set to enlargement	Harvest	Fruit Post-harvest
Pyrethrin	10	/	5-10	2	■	■	■	■	■	
Azadiractin	30	/	/	2	■	■	■	■	■	
Plant extracts or "farm-made" concoctions										
Fatty acids of potassium salt	Soap solution 1-2 %	/	/	2	■	■	■	■	■	
Potassium soap	/	/	2 x/week	/	■	■	■	■	■	
Ginger – Garlic - Chili extract	/	/	/	/	■	■	■	■	■	
*Tephrosia vogelii** (Fish bean plant)	/	/	3	3	■	■	■	■	■	
Azadirachta indica (Neem)	/	/	/	/	■	■	■	■	■	
Andrographis paniculata	/	/	/	/	■	■	■	■	■	
*Derris elliptica**	/	/	/	/	■	■	■	■	■	

/ elements of the recommended GAP not available

* Approval by certification body is required.

Whiteflies – *Aleurodicus disperses et Bemisia tabaci*

Strategy : When monitoring indicates that pressure is high, it is recommended to use spot treatments.

Commercial products

Active substance	Recommanded GAP				Proposed application period					
	Dose g/ha	Number of applications	Interval between applications in days	PHI in day	Nursery	Vegetative growth	Blossoming	Fruit set to enlargement	Harvest	Fruit Post-harvest
Azadiractin*	30	/	5-10	2	■	■				
Mineral oil*	/	/	/	7	■	■				
Soap solution*	1 à 2%	/	/	2	■	■				
Plant extracts or "farm-made" concoctions										
Neem tree seed extracts*	/	/	/	/	■	■				

/ elements of the recommended GAP not available

* Approval by certification body is required.

Mites – *Tetranychus* spp. and *Polyphagotarsonemus latus*

Strategy : Treatments target adult and nymph stages in affected trees only. Spot spraying is essential to protect beneficial insect populations. No registered commercial products for mite control in organic culture are available.

Plant extracts or "farm-made" concoctions

Active substance	Recommanded GAP				Proposed application period					
	Dose g/ha	Number of applications	Interval between applications in days	PHI in day	Nursery	Vegetative growth	Blossoming	Fruit set to enlargement	Harvest	Fruit Post-harvest
Potassium soap	/	/	14	2	■	■	■	■	■	

/ elements of the recommended GAP not available

Wettable or micronized sulphur can reduce mite populations. However, sulphur can also kill predatory mites and under temperatures of over 25°C can burn the foliage. [*Consult your certification body on the use of sulphur in organic production*].

Nematodes

Strategy : Products should usually be applied before planting.

Commercial products

Active substance	Recommanded GAP				Proposed application period					
	Dose g/ha	Number of applications	Interval between applications in days	PHI in day	Nursery	Vegetative growth	Blossoming	Fruit set to enlargement	Harvest	Fruit Post-harvest
Azadiractin	30	/	/	2	■	■				
Paecilomyces lilacinus	*	/	/	/	■	■				

Plant extracts or "farm-made" concoctions										
Active substance	Recommanded GAP				Proposed application period					
	Dose g/ha	Number of applications	Interval between applications in days	PHI in day	Nursery	Vegetative growth	Blossoming	Fruit set to enlargement	Harvest	Fruit Post-harvest
Marigold (*Tagetes* spp.)	/	/	/	/						

* Depends on concentration of spores per gram of commercial product

/ elements of the recommended GAP not available

Anthracnose - *Colletotrichum gloeosporioides*										
Strategy : The action is mostly preventive as mainly contact fungicides are used.										
Commercial products										
Active substance	Recommanded GAP				Proposed application period					
	Dose g/ha	Number of applications	Interval between applications in days	PHI in day	Nursery	Vegetative growth	Blossoming	Fruit set to enlargement	Harvest	Fruit Post-harvest
Azadirachtin	30	/	/	2						
Copper fungicide*	1000	3	21 days	7-12						

/ elements of the recommended GAP not available

Asperisporium black spot – *Asperisporium caricae*										
Strategy : The action is mostly preventive as mainly contact fungicides are used.										
Commercial products										
Active substance	Recommanded GAP				Proposed application period					
	Dose g/ha	Number of applications	Interval between applications in days	PHI in day	Nursery	Vegetative growth	Blossoming	Fruit set to enlargement	Harvest	Fruit Post-harvest
Copper fungicide*	2500	2	7 – 14 days	7-12						

* Its need has to be approved by the certification body, as it is restricted. The maximum quantity which may be used each year per ha shall be calculated by subtracting the quantities actually used in the 4 preceding years from, respectively, 36, 34, 32 and 30 kg copper for the years 2007, 2008, 2009 and 2010 and following years. It also must be noted that according to EU Regulation (EEC) 2092/91 for Organic Agriculture any use of copper preparations has to be approved by the certification body. In case copper preparations have to be applied it is recommended to use preparations which contain less copper (e.g. tribasic copper sulphate, copper hydroxide) and therefore reduce the accumulation of copper in the soil.

Cercospora spot – *Cercospora papayae*

Strategy : The action is mostly preventive as mainly contact fungicides are used.

Active substance	Recommanded GAP				Proposed application period					
	Dose g/ha	Number of applications	Interval between applications in days	PHI in day	Nursery	Vegetative growth	Blossoming	Fruit set to enlargement	Harvest	Fruit Post-harvest
Commercial products										
Copper fungicide*	1000	3	21 days	7-12						

* Its need has to be approved by the certification body, as it is restricted. The maximum quantity which may be used each year per ha shall be calculated by subtracting the quantities actually used in the 4 preceding years from, respectively, 36, 34, 32 and 30 kg copper for the years 2007, 2008, 2009 and 2010 and following years.

Powdery mildew – *Oidium* spp.

Strategy : In areas where the disease is expressed, treatment is aimed at protecting flowers that represent the production potential. This treatment must occur at an early stage before full blossoming as soon as any modification in the colour of the floral clusters is observed.
Micronised sulphur continues to be an economical active ingredient and is the basis for preventive. However, caution is necessary as sulphur is detrimental to predatory mites and also it can scorch the foliage under temperatures above 25°C.

Active substance	Recommanded GAP				Proposed application period					
	Dose g/ha	Number of applications	Interval between applications in days	PHI in day	Nursery	Vegetative growth	Blossoming	Fruit set to enlargement	Harvest	Fruit Post-harvest
Commercial products										
Sulphur (micronised) *	/	/	/	2						
Fatty acids of potassium salts	/	/	/	2						
Horticultural oils	/	/	/	2						
Plant extracts or "farm-made" concoctions										
Wood ash	/	/	/	/						
Neem	/	/	/	/						
Cow, goat sheep urine	/	/	/	/						

/ elements of the recommended GAP not available

* Consult certification body

Phytophthora spp. and *Pythium* spp.										
Strategy : Copper based fungicide treatments at the very beginning of first symptoms can reduce fruit rots.										
Active substance	Recommanded GAP				Proposed application period					
	Dose g/ha	Number of applications	Interval between applications in days	PHI in day	Nursery	Vegetative growth	Blossoming	Fruit set to enlargement	Harvest	Fruit Post-harvest
Commercial products										
Copper fungicide*	1000	3	21 days	7-12						

* Its need has to be approved by the certification body, as it is restricted. The maximum quantity which may be used each year per ha shall be calculated by subtracting the quantities actually used in the 4 preceding years from, respectively, 36, 34, 32 and 30 kg copper for the years 2007, 2008, 2009 and 2010 and following years.

Viral diseases
Strategy : Only insect vector control is applicable. Once plants are infected there is no cure. Information on active substances and treatment recommendation for control of insect vectors is given under the individual insect vectors.

Giant East African snail – *Achatina fulica*										
Strategy : Food baits.										
Active substance	Recommanded GAP				Proposed application period					
	Dose g/ha	Number of applications	Interval between applications in days	PHI in day	Nursery	Vegetative growth	Blossoming	Fruit set to enlargement	Harvest	Fruit Post-harvest
Commercial products										
Metaldehyde powder 50% bait concentrate*	15 g in 454 g cornmeal flour	/	/	/						

* Consult certification body

/ elements of the recommended GAP not available

Preparation and direction for use of "farm-made" concoctions:

Fruit fly traps

Traps for fruit flies typically contain baits with a mixture of protein and sugar. Fruit flies need protein during their egg laying period. The traps are constructed is such a way that once the flies enter, they no longer can escape. Traps with bait should be hanged in the orchard 6-8 weeks before the fruit ripens. Catches should be monitored regularly and baits changed, especially after rains. Hang baits on the west side of the trees, as fruit flies prefer to concentrate in the evenings on that side.

Constructing fruit fly traps

1. Take a 2 litre plastic water bottle with a screw-on top. Cut two or more holes of a diameter of 0.5 cm, about 4 fingers high from the bottom in the side of the container.

2. Cut off the top of a plastic water bottle leaving 3-4 cm of the large bottle width intact. Invert this so the mouth is now facing inside the bottle. Add the bait in the bottle until just below the holes. Flies will enter through the inverted bottle mouth.

Pyrethrum bait

- 1 litre of water, ½ cup cow urine, 1 ½ teaspoons vanilla essence, 100g sugar, 10g pyrethrum. All ingredients are well mixed. Traps holding 50 cc are hung throughout the orchard.

Vinegar bait

- Take 1 cup of vinegar, 2 cups of water, 1 tablespoon of honey and shake well. Fill the trap to just below the holes with this mixture and hang the bottle about 5 feet high. Fruit flies enter the bottle and fall into the attractant.

Fatty acids of potassium salts:

This is an active ingredient present in soft soap. Take only the soft soap used for washing dishes and not washing powders since these can harm plants. Be careful with soap as it can be phytotoxic when too concentrated. Try on a few trees before larger scale treatment.

Ginger, garlic, and chilli extracts:

Soak 50 g of peeled garlic overnight in 10 ml mineral oil. Combine garlic, 25 g of green chillies, and 25 g of ginger. Add 50 ml of water to the mixture. Grind them. Add 3 litres of water. The taste of garlic may remain for some time with the fruit so it is better not to spray near harvest time.

Garlic oil spray

Chop finely 100 g of garlic. Soak the chopped garlic in mineral oil for a day. Add 1/2 litre and 10 ml of soap. Dilute filtrate with 10 litres of water. Constantly shake the container or stir the extract while in the process of the application to prevent oil from separating.

Chilli spray:

Boil 90 g of ripe pods or 100 g of chilli seeds in water for 15-20 minutes. Take the pot from the fire and add 3 litres of water. Cool and strain. Add 30 grams of soft soap. Stir well and strain.

Extracts of marigold (*Tagetes* spp.)

Crush large quantities of fresh flowers (roots and leaves can be added) and put this in water. Leave this for 5 to 7 days while stirring daily. Filter the mixture using a cloth. Dilute the mixture and add liquid soap (use soft soap used for washing dishes and not washing powders since these can harm plants). Preventative this should be applied once a week.

Tephrosia vogelii

Leaves from *T. vogelii* contain at least 4 insecticidal components, collectively known as rotenoids. Mature leaves may contain 80-90% rotenoids. Roots also contain rotenoids. Precautions should be taken while preparing the concoction, as it can irritate human skin. When eating fish poisoned with *Tephrosia*, people can get sick. The spray may also cause some dizziness to the user. Cattle deaths have been reported as a result of drinking water of poisoned fish ponds. In organic production, the use of rotenone is permitted as an insecticide under European Union Regulation 2092/91, amended by 1488/97, Annex II (B). Based on a study that links rotenone to Parkinson's Disease, the UK Soil Association put a temporary ban on its use, pending further investigations.

1 litre of fresh *Tephrosia vogelii* leaves are pounded and soaked in 1 litre of water and left overnight. The spray is effective against ants, termites, aphids and many other insects. Application should be on the spot. It is possible to bait ants with a sugar solution with Tephrosia leaf powder, which kills ants. Care should be taken that no other mammals eat the bait.
Rotenone is rapidly broken down by sunlight which means that evening application provides the best results. Degradation in 24 to 48 hours, no risk of residues.

Use of neem *(Azadirachta indica)* extracts for spot spraying treatments. The effective ingredients are present in all parts of the tree but are most highly concentrated in the seeds. The insect controlling substances are primarily azadirachtin A and B. In addition, neem contains a number of other

substances such as Salannin and Meliantriol, which have primarily repellent effects, and Nimbin/Nimbidin, which seem to have antiviral effects. Some substances support each other, thus creating synergistic effects.
When harvesting neem seeds, care must be taken that the fruit colour is neither greenish-yellow nor brownish-yellow but plain absolute yellow. Greenish yellow fruits are not fully mature and are low in azadirachtin content. For the collection of the fruits, spread a plastic or cloth under the tree. Thus they do not come in contact with the soil and the danger of fungus attack and aflatoxin development is reduced. After collection, the fruit pulp should be removed. The seeds are then dried for one day in the sun, and the following three days in the shade, during which they are regularly stirred. Neem seeds should be dried well so that they do not produce the toxic aflatoxins which impair their pest control properties and which are highly toxic to humans. Operators should wash hands after handling neem seeds. Stored neem kernels should be kept in well aerated containers or jute bags to prevent mould, which would reduce effectiveness and produces the highly toxin aflatoxin.

Seeds between 3 and 9 months after harvest have the highest quantity of azadirachtin.

Characteristics

- Only seeds which are green inside have a high azadirachtin content. If they are brown inside, they should be discarded.
- The pulp of the fruits has no insect control properties and should be removed.
- Azadirachtin is highly sensitive to ultraviolet light. Therefore spraying in the evening is highly recommended. Spraying also should be done immediately after the preparation is prepared.
- Degradation in 24 hours, no risk of residues.

Dosage recommendations:

- For seeds: per ha, about 30 g of azadirachtin is required. In neem seeds, contents between 2 and 9 mg/g can be found. (= 5 to 10 kg of seeds/ha)
- For usage of pounded neem leaves: concentration 100g/L.
- The solution should be left for decantation for one night, then filtered and spot sprayed on targeted pest.

Andrographis paniculata

Mix 2 kg of fresh plant material of *Andrographis paniculata* with 250 ml of water and grind it well. Add 2 litre of cow urine and 10 g of crushed dried chilli fruits. Add 10 litres of water and leave the solution for a few hours. Filter the solution and it is ready for spraying.

Derris eliptica

Wash fresh roots of *Derris eliptica* (oil tree) and cut them into short 5 cm lengths. Add small amounts of water and pound the roots until they are finely shredded. Filter the solution. Dilute with soap and water at a ratio of 1 part soap: 4 parts root solution: 225 parts water. Apply immediately.

Cow urine

1 part cow (goat, sheep) urine is mixed with 2 parts water. (Urine from animals with a vegetarian diet is preferred above urine based on meat diet as the last one results in a higher concentration of urea as well as other substances which can have a detrimental effect). A dilution of 1:1 is suggested as undiluted urine causes slight phytotoxicity.

Wood ash

A heaped tablespoon of wood ash is stirred vigorously into one litre of water and left to stand over for one night, then strained and mixed with a cup of sour milk or buttermilk. Before spraying, this mixture is diluted three times with water. Always try out on a few trees the strength of dilution to find the most effective dilution as it differs per crop.

5. Existing registrations

As the market of approved pesticides for ACP organic producers is very small, plant protection products specific to organic papaya are rarely developed. Even when an organic pesticide is registered in the producing country, it is for general use, and there are no specific recommendations for papaya.

Registration of active ingredients is not required for the "farm concoctions" made out of plant extracts. In all the ACP countries researched, there is no legislation for such products. It is not written that it is allowed to use them either, they are just not mentioned and accepted as long as they don't leave residues.

Registration in Uganda

Data not available

Registration of insecticides and fungicides in Cameroon

Active substance	Type of registration	Targeted pests and diseases											
		Fruit flies	Mealybugs	Thrips	Whiteflies	Nematodes	Mites	Anthracnose	Asperisporium black spot	Cercospora spot	Powdery mildew	Root, collar and stem rot	Snails
Azadirachtin	Horticultural crops	X		X				X					
Copper oxide	Horticultural crops							X				X	

In order to be allowed to use a pesticide registered for another crop, there should be an application for extension of usage (from major to minor usage).

Registration of insecticides and fungicides in Jamaica

Active substance	Type of registration	Targeted pests and diseases											
		Fruit flies	Mealybugs	Thrips	Whiteflies	Nematodes	Mites	Anthracnose	Asperisporium black spot	Cercospora spot	Powdery mildew	Root, collar and stem rot	Snails
Azadirachtin	Papaya	X		X	X								
Copper hydroxide	Papaya							X					
Copper sulphate pentahydrate	Papaya										X	X	
Mineral oil	Fruit trees		X		X		X						
Metaldehyde	Fruit trees												X

Registration of insecticides and fungicides in Kenya

Active substance	Type of registration	Targeted pests and diseases											
		Fruit flies	Mealybugs	Thrips	Whiteflies	Nematodes	Mites	Anthracnose	Asperisporium black spot	Cercospora spot	Powdery mildew	Root, collar and stem rot	Snails
Azadirachtin	Horticultural crops	X		X	X	X							
Deltamethrin	Fruit trees	X		X	X								
Pyrethrin	Fruit trees			X	X								
Sulphur	Fruit trees and horticultural crops						X				X		
Copper oxychloride	Horticultural crops							X	X	X		X	
Copper hydroxide	Horticultural crops							X	X	X		X	
Mineral oil	Horticultural crops		X	X	X								

Registration of insecticides and fungicides in Ghana

Active substance	Type of registration	Targeted pests and diseases											
		Fruit flies	Mealybugs	Thrips	Whiteflies	Nematodes	Mites	Anthracnose	Asperisporium black spot	Cercospora spot	Powdery mildew	Root, collar and stem rot	Snails
Azadirachtin	Under consideration	X		X	X			X					
Copper hydroxide	Cocoa, under consideration							X					
Copper oxychloride	Cocoa, under consideration							X					
Copper oxide	Cocoa, coffee under consideration							X					
Sulphur	Under consideration										X		
Lambda-cyhalothrin	Vegetables	X											
Deltamethrin	Various	X		X	X								

In order to be allowed to use a pesticide registered for another crop, there should be an application for extension of usage (from major to minor usage).

Existing registration of insecticides and fungicides in EU and USA

Active substance	Type of registration	Targeted pests and diseases											
		Fruit flies	Mealybugs	Thrips	Whiteflies	Nematodes	Mites	Anthracnose	Asperisporium black spot	Cercospora spot	Powdery mildew	Root, collar and stem rot	Snails
Azadirachtin[1]	EU	X		X		X							
Pyrethrins[1]	EU			X									
Fatty acids of potassium salt	EU			X							X		
Copper hydroxide1	EU/USA												
Copper sulphate1	EU/USA												
Horticultural oils	EU/USA		X										
Sulphur	EU/USA												
Pyrethroids[1] (only deltamethrin or lambda-cyhalothrin)	EU	X		X									

[1] Need to be recognized by the inspection body or inspection authority.

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- http://www.spc.int/lrd/index2.php?option=com_docman&task=doc_view&gid=94&Itemid=66

CROP PRODUCTION PROTOCOLS

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

GUIDES TO GOOD PLANT PROTECTION PRACTICES

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

PIP
FOR SUSTAINABLE DEVELOPMENT OF THE ACP HORTICULTURAL INDUSTRY

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