A Training Manual for Training of Trainers on Recognition and Management of Major Arthropod pests of major vegetable s and tropical fruits

Volume 10

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Integrated Pest Management (IPM)

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Definitions

Many definitions are available in literature. The two common definitions are the following:

A) IPM means a pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible, and maintains the pest populations at levels below those causing economically unacceptable damage or loss; and

B) IPM is an ecologically based pest control strategy that relies heavily on natural mortality factors such as natural enemies and weather, and seeks out control tactics that disrupt these factors as little as possible.

Important in both definitions given above are the ecological approach of pest management and the integrated manner of applying all control techniques available. IPM seeks to help farmers become better managers, incorporate natural processes into farming, and reduce off-farm inputs, leading to a more profitable and efficient production, and to better human and environmental health. IPM relies on farmers' increased knowledge, active monitoring and analytic decision making with respect to pest management at the farm level. It preferably applies measures preventing the development of pest populations rather than those controlling pests.

Principles and options of IPM for vegetables

- Site seedbeds on land not previously under vegetable crops and, preferably, away from old fields.
- Heat soil in the seedbed; place plenty of crop trash or straw and burn for at least 30 min and after cooling, mix the soil with compost in equal proportions.
- Use certified disease-free seed of resistant/ tolerant varieties. (Always buy seed from reputable seed dealers and consult seed dealers on right choice

of varieties.)

- Dress the seed with a fungicide and an insecticide prior to sowing. (Seed treatment will protect seedlings against damping-off and early season pests. Use only registered products at the recommended rates shown on the label.)
- Mulch seedlings in the seedbed, if possible do not overwater seedlings in the seedbed; water seedlings early in the morning and thin out seedlings to avoid plant congestion in the seedbed. (Excessive watering is conducive to damping-off diseases, and extended wetness of seedlings favours development of foliar diseases.)
- Rogue out weak-looking seedlings from the seedbed.
- Prepare land well before transplanting. (Tilling and ploughing kill existing cutworms.)
- Do not transplant seedlings on land that was previously under the same type of vegetable crop. Transplant only healthy, robust seedlings on well-prepared land preferably late in the afternoon to minimise transplanting shock and desiccation.
- Avoid field operations when it is wet. (This will help prevent inadvertent spread of diseases from plant to plant and movement of infested soil within and outside the field.) .
- Keep fields free of weeds. (Weeds are potential alternative hosts of insect pests and diseases. and are nutrients competitors.)
- Ensure optimal fertilisation.
- Monitor fields regularly for pest and disease occurrence. (Early detection of pests and diseases is important. Manual collection and destruction of larvae at light infestations are useful for control of pests such as cutworms
- Scout for caterpillar presence. (Feeding damage and caterpillar excrement give an indication of their activity. Scouting can be done by walking in a zigzag pattern through the field.)
- Avoid unnecessary use of pesticides. Do not practice calendar spraying. Pesticides should be used as a last resort; use only registered products at the recommended dosage and observe pre-harvest intervals as indicated on the label. Buy pesticides from reputable dealers.
- Avoid using broad-spectrum pesticides. Whenever available, use selective pesticides such as microbial pesticides (e.g. *Bt* products) for control of caterpillars, or products which are less (or not harmful at all) to natural enemies such as neem-based products which control pests with minimal effect on their natural enemies.

- Remove crop refuse from the field immediately after harvest and dispose of volunteer plants.
- Practice crop rotation with unrelated crops; avoid overlapping crucifers between seasons.

Insect and mite pests of major vegetables

Tomato

Fruit worms (Tomato leaf miner/fruit borer, African Boll Worm)

The South American tomato moth, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae)

The South American tomato moth, *Tuta absoluta*, is a highly destructive leaf miming and fruit boring insect pest of tomato. It also attacks beans and plants in the solanaceous family (pepper, potato, eggplant and wild plants such as *Datura* and *Solanum*). The pest is endemic to countries in the Southern America and hence commonly named as the South American tomato moth.

Lifecycle

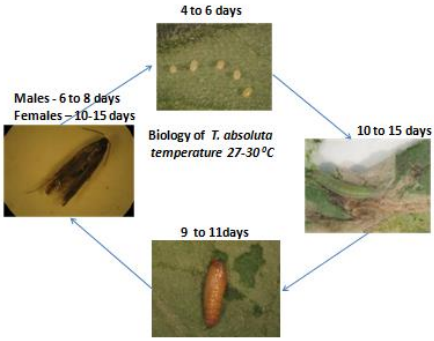
Tuta absoluta is a micro lepidopteran insect. The adults are silvery brown, 5-7 mm long. They (adults) are nocturnal and hide between leaves during the day time. Duration of the developmental cycle is temperature dependent. A generation may take 76, 40 and 24 days at 14, 20 and 27°C respectively. The minimal temperature for biological activity is 9°C. After copulation, females lay individual small (0.35 mm long) cylindrical creamy yellow eggs. Recently hatched larvae are light yellow or green and only 0.5 mm in length. As they mature, larvae develop a darker green color and a characteristic dark band posterior to the
head capsule. Four larval instars develop. Larvae do not enter diapause when food is available. Pupation may take place in the soil, on the leaf surface or within mines.

Egg: Small (0.36 x 0.22 mm), cylindrical and creamy white to yellow or brownish. Eggs are mainly deposited on the underside of leaves.

Larva: Cream-coloured with a dark head, becoming greenish to light pink in the second to fourth instars. Length (1st instar) 0.9 mm to (4th instar) 7.5 mm. After hatching, the larva immediately penetrates the plant tissue

Pupa: Brown. May be found in or on the leaves or the soil, and occasionally on the flowers, fruits and growing points

Adult: Ten mm long, filiform antennae, silverish-grey scales, black spots on anterior wings.



Life cycle of *Tuta absoluta*

Damage and Symptoms

Infestation of tomato plants occurs throughout the entire crop cycle. Feeding damage is caused by all larval instars and throughout the whole plant. On leaves, the larvae feed on the mesophyll tissue, forming irregular leaf mines which may later become necrotic. Larvae can form extensive galleries in the stems which alter the general development of the plants. The larvae burrow into the fruit, forming galleries which represent open areas for invasion by secondary pathogens, leading to fruit rot. Damage can reach up to 100%.

Tuta absoluta damage on tomato leaf, stem and fruit

Management

The basis for sustainable management of *Tuta absoluta* is the integration of cultural, behavioral, biological and chemical control.

Cultural control

Cultural control of *Tuta absoluta* should emphasis on field prevention of infestation and hygiene. This includes:

- Use of pest-free transplants
- Removal and destruction of wild weed host plants such as *Solanum* and *Datura* and weedy crop hosts such as potato and egg plants (see pictures below)
- Selective removal and destruction of infested plant material
- Removal and destroying damage fruit from the field. Infested fruit sorted out as unmarketable should not be left around the farm. These are important source of new infestation. Keep them in a sealed plastic bag for about a month. During this period, the insects in the fruit will die and the fruits can be used for fertilizing the soil.
- Crop residue removal
- Allow a minimum of 6 weeks from crop destruction to next crop planting
  - Between planting cycles, cultivate the soil and cover with plastic mulch or
    Perform solarisation. This prevent the insect pupae from transforming to adult and hence reduce egg number or new infestation
    - Crop rotation with non-solanaceous plants

- In green house tomato production, the entrance room needs to be double door. Covering the entrance room with a black polyethylene sheet reduce the influx of the moth to the green house. Care should be taken to seal holes that can allow the moth to move to the green house.

Chemical control

Chemical control using synthetic insecticides has been the primary method to manage the pest. Organophosphate and pyrethroids were the main insecticide groups used for the control of this pest in South American countries where the pest is endemic. Due to the insect's ability to develop resistance quickly to insecticides, many of the insecticides that were used in South American countries where the pest is endemic are ineffective currently. The following insecticides are registered for the control of Tuta absoluta on tomato and som more are on pipe line for registration and use in Ethiopia. These insecticide should be used rationally by alternating application of insecticides from different classes

- Coragen 200 SC(Chlorantranliprole 200 g/L); apply at 250 ml per ha 2 to 3 times per crop growing season
- Tracer 480 SC (Spinosad); apply at 150 ml per ha 2 to 3 times per crop growing season
- Ampligo 150 ZC (Chlorantraniliprole 100 g/L + λ- cyhalothrin 50 g/L). Apply at 300 ml per ha 2 to 3 times per crop growing season
- Radiant 120 SC (Spinetoram); apply at 130 ml per ha 2 to 3 times per crop growing season

Check for other insecticides registered for use against Tuta *absoluta* in Ethiopia (List is available from the Crop protection directorate of The Ministry of Agriculture and Livestock.

Biological control

A good number of parasitoids, predators and pathogens are known to give control of the pest. Of these the predators *Nesidiocoris tenuis* and *Macrolophus pygmaeus*; and the entomopathogen *Bacillus thuringiensis* are regarded effective biological control agents to reduce the pest population and its damage. Both the predators and the pathogen are commercially available for the control of the pest in several countries.

Pheromonal control

Pheromones are used both for monitoring population for timing treatment application as well as mass trapping of males to prevent them from mating. This reduces egg load and subsequent infestation in the field. Sticky delta traps or a tray with water with the pheromone lure at the center as shown below can be used. Small food oil or soap (liquid or powder) should be added to sink the moths trapped. Otherwise, they can fly back easily. Recent studies in Meki area of Central Rift Valley region showed that a pheromone lure of 3 mg kept on the ground or crop surface allows capturing a larger size of male *Tuta absoluta*.

Tuta absoluta moth on delta sticky trap (left) and water tray trap (right)

The African bollworm *Helicoverpa armwera* (Hubner) (Lepidoptera: Noctuidae)

The African bollworm attacks a variety of food and cash crops. The adult of the African bollworm is a stout moth, about 6-18 mm long with a wingspan of 16-18 mm. Colour varies from dull yellow or olive grey to brown, with little distinctive marking**.**

Biology

Moths are active at night and lay 500-3000 tiny, round, yellowish eggs, which darken before the larvae hatch. Female moths are attracted to tomato plants in the flowering and fruiting stages. Eggs are normally laid near or on flowers or small fruits, usually on the outer section of the plant. Young larvae are

generally yellowish-white to reddish-brown in colour. They have a black head and several rows of black tubercles, each with two bristles along their backs that give them a spotted appearance. Soon after hatching the larvae move to green tomatoes, where they bore deeply into the fruit**).** The fully-grown larvae are about 40 mm long. They vary in colour from almost black, brown or green to pale yellow or pink and they are characterised by lengthwise alternating light and dark coloured stripes, with a typical light stripe along each side of their bodies**.** The fully-grown larvae drop from the plant and burrow into the soil to pupate. The pupa is light brown in colour. Adults emerge in 1-2 weeks, mate and can begin to lay eggs 48 hours after emergence.

Damage

Caterpillars of the African bollworm feed on leaves, flowers and fruit. Caterpillars feeding on flowers and fruits cause the main damage. When flower buds are attacked, flower abortion occurs. Caterpillars prefer green fruit and seldom enter ripe fruit**.** They usually bore from the stem end, causing extensive fruit damage and promoting decay caused by secondary infections**.**

Tomato fruit damaged by ABW (left and center) and fruit decay due to secondary infection by pathogen following ABW attack

Management

Detection

- Early detection of the eggs or the caterpillars before they bore into the fruits is important. Once the caterpillars have entered the fruit they are well protected and have already caused damage. Early detection can be achieved by scouting the crop regularly.

Cultural control

- Tilling and ploughing old tomato fields expose pupae which are killed through exposure to the sun and natural enemies. Hand picking and destruction of eggs is feasible at low infestations.
- Using trap crops such as cucumber reportedly reduces the severity of attacks on tomatoes. Maize and sorghum have been recommended as trap crops to divert the African bollworm from cotton elsewhere and pepper in Ethiopia.

- Destruction of weeds which may harbour developing larvae is important for preventing fruitworm infestations.

Host Plant Resistance

- Fruit tworms resistant varieties which include African bollworm and Potato tuber moth have been identified at the melkassa center of the Ethiopian Institute of Agricultural research. One of these varieties, " Melkasalsa" is under production.



Chemical control

If the infestation is severe, pesticides may be needed. A considerable number of insecticides are reported to afford good control of fruitworms (e.g. pyrethroids). However, selective pesticides, which preserve natural enemies, are preferred. For example, pesticides based on the pathogen *Bacillus thuringiensis*, or some 'plant-based pesticides such as neem products can be used, with minimal detrimental effect on natural enemies. It has been determined from studies made at Melkassa Agricultural research Center on critical period of fruit worms damage that insecticide application should be made only twice, once at early fruiting and once at maturity.

The insecticides Agro-thoate 40% EC (common name dimethoate), Aim10% EC (common name alpha cypermethrin), Amsac 150 SC (Indoxacarb), Delros 2.5 EC (common name Deltmethrin), Diamog 40% Ec (common name dimethoate), Hondize 60% EC (Diazinon), Rider 5 EC (common name Lambda cyhalothrin), Saron (common name Lambda cyhalothrin) are registered for the control of African bollworm on tomato in Ethiopia until March 2018. Latest list of registered insecticides for ABW control can be obtained from the Plant protection directorate of the Ministry of Agriculture and Livestock.

Spider mites Tetranychus spp. (Acarina: Tetranychidae)

Spider mites are the most important non-insect arthropod pests of tomatoes. They are more prevalent and inflict heavy damage in tomato produced under irrigation in the hotter seasons.

Description and biology

Spider mites are tiny; they rarely exceed a size of 0.5 mm. They are oval in shape with arched

back and have eight legs, with the exception of the larval stage, which has six legs**.**

Spider mites are normally active within a temperature range of 16-37 oC. They flourish at relatively low humidities. A new generation will develop every 10-13 days in a temperature range of 24 to 26 oC. The lifespan of a spider mite is 13-32 days. It includes five stages: egg, larva (first instar), and two nymphal stages (second and third instars), and adult. A female may layover 100 eggs during its lifespan on leaves, stems or fruits. Several species of spider mites affect tomato of these three are known to be important in Africa. These include the tobacco spider mite, *Tetranychus evansi Baker* & Pritchard, the two-spotted spider mite, *T. utricae* Koch, and the common red spider mite *T. cinnabarinus* (Boisduval)

Spider mites spin silk threads that anchor themselves and their eggs to the plant. This silk protects them from some of their enemies and even from pesticide applications.

Spider mites are most numerous in hot, dry weather. Their populations normally decline after rain. Wind plays an important role in the dispersal of spider mites. Thus, other crops, wild plants or weeds can serve as a source of infestation. They can also be dispersed on clothing and implements.

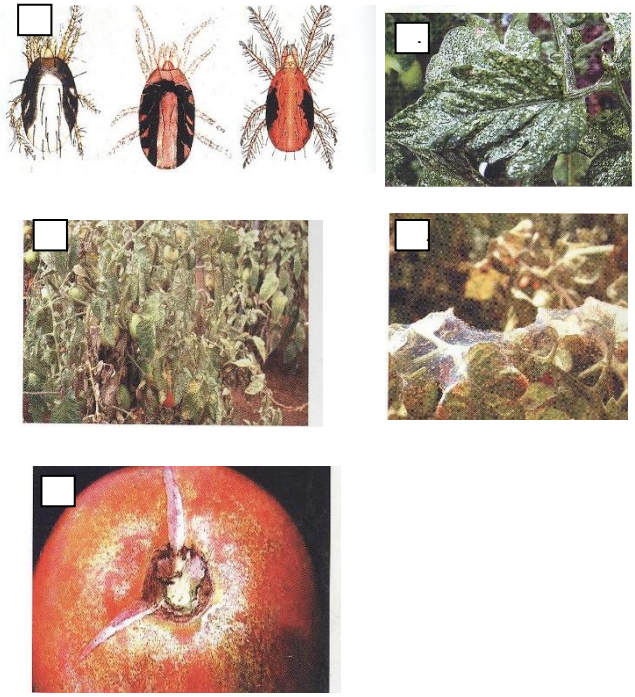
Damage

Infested leaves first show a white to yellow speckling and then turn pale or bronzed, as the infestation becomes heavy **(**Spider mites prefer the lower surface of the leaves, but in severe infestations will occur on both leaf surfaces as well as on the stems and fruits. Under heavy infestation the plant can be completely covered with webbing**.** High spider mite infestations cause defoliation, which leads to production of smaller and lighter fruits with lower

percentage of soluble solids and a lower content of ascorbic acid (vitamin C). Spider mite attack may also cause speckling of the fruits**.**

Managements

- Before applying any control measures, regular inspections should be done to determine the presence and level of infestation of spider mites.
- Spider mites rapidly develop resistance to pesticides, particularly when they are used for several consecutive seasons. When spraying, rotation of acaricides with different chemical composition is essential to avoid or delay development of resistance.
- The indiscriminate use of broad-spectrum insecticides eliminates natural enemies. Their use may lead to mite outbreaks. To keep populations of spider mites at a low level, the use of broad-spectrum insecticides, especially pyrethroids, should be avoided as much as possible and plants should be irrigated regularly.
- The pesticides Awash (common nameAbamectin), Oscar 20% EC (common name Tebufenpyrad) and Oberon speed SC 240 (common name Abamectin + Spiromesifen) are registered for mite control until March 2018. As indicated for the other pests, list of pesticides registered are updated regularly and can be obtained from the Plant protection directorate of the Ministry of Agriculture and Livestock
- To minimize the risk of infestation, keep the field free of weeds, remove and burn or compost crop residues immediately after harvest, and avoid planting next to an infested field.
- Several species of predatory mites are known from eastern and southern Africa which capable of controlling infestations provided they are not disturbed by the severe use of broad-spectrum insecticides and the crop is irrigated properly.



a. Spider mites; b. Leaf damage caused by spider mites; c. Tomato plant damaged by spider mites; d. Tomato plants with a high infestation of spider mites; e. Spider mite damage on tomato fruit

The tobacco whitefly, *Bemisia tabaci*

Bemisia tabaci is native to the Indian subcontinent but is nowadays widely distributed, and occurs outdoors in all tropical and subtropical countries of the world.

Description and biology

Whitefly adults resemble very small moths. They have a coating of white, powdery wax on the body and wings**.** Eggs are elliptical, about 0.2-0.3 mm long, attached vertically to the leaf surface by a short stalk, which is inserted into the leaf tissue. They are normally laid in an arc or circle comprising 20-40 eggs on the underside of young leaves. The

first juvenile stage crawls on the leaf surface for some time before settling and fixes itself on the lower surface 1-2 days after hatching. It then starts sucking and excretes tiny wax filaments from the edge of its body. During the period of larval development, the tomato plant continues to grow and thus the juvenile stages are found on the lower leaves. The 'puparium' (scale-like final juvenile stage) is flat and whitish to yellowish in color. The life cycle in warm weather takes 3-4 weeks to complete.

Damage symptoms

Leaves have numerous chlorotic spots or areas. These spots grow together forming different sized yellow areas. In severe cases, only the veins remain green. Some leaves
appear completely brown and dried. Wilting and leaf drop may occur. A sticky, black mold may be found on leaves and stems.

Management

- Whiteflies are attacked by a number of natural enemies such as parasitic wasps *(Eretmocerus* spp. and *Encarsia* spp.), phytoseiid mites *(Amblyseius* spp. and *Typhlodromus* spp.) by lacewings and ladybird beetles. Conservation of these and other natural enemies is important.
- Preventing physical contact of the whiteflies with the plant can prevent the transmission of virus diseases. Covering tomato seedling nurseries with nylon nets protects seedlings from whitefly infestations. These methods have been reported to reduce the transmission of the TYLCV and delay the spread of the virus in different countries.
- Time of sowing and transplanting can be an effective cultural approach for disease management. Avoid the season when whiteflies are more likely to occur.
- Weeds play an important role in harbouring whiteflies between crop plantings. They also often harbour whitefly-transmitted viruses. Therefore, attention should be paid to removing weeds in advance of planting tomatoes. Tomato fields should also be kept weed-free.
- Whiteflies rapidly develop resistance to many insecticides and resurgence of populations is common. When chemical treatment is needed, it is essential to choose insecticides that are not damaging to biocontrol agents. Rotation of pesticides is essential to minimise or delay development of resistance. The insecticide Closer 240 SC (common name sulfoxflor) is currently undergoing registration process for whitefly control on tomato

in Ethiopia. Several insecticides are registered for whitefly control on other plants in Ethiopia.

- Neem-based insecticides are reported to provide good reduction in egg laying of B. *tabaci*, inhibit growth and development of nymphs, and significantly reduce the risk of TYLCV.

Whiteflies on tomato

Onion

Thrips

The only economically important insect pest of onion in Ethiopia is Thrips (*Thrips tabaci*)

Description and life cycle

Thrips are very small and silver-shaped, just barely visible to the naked eye. They are about the size of a flea. Immatures are either yellow or white. Older individuals are yellowish-brown and move quickly. They feed by sucking plant sap. They often congregate along the leaf veins. Adults have narrow wings that are fringed with hairs, which are only visible under the microscope. Eggs are inserted within leaf tissues and after two larval instars, the insects drop to the soil to pupate. Several generations can develop each season; hot and dry weather favors population buildup.

Eggs are laid in notches in the epidermis of the leaves and stem of young

plants. They are white, and take 4-10 days to hatch. Both nymphs and adults rasp the epidermis of the leaves and suck the sap that exudes. Nymphs moult twice in about five days; they are white or yellow. Pupation occurs in the soil and takes 4-7 days. The adult is a small, yellow brown thrips with darker transverse bands across the thorax and abdomen, and about 1 mm long. One generation can take place in about three weeks. There are 5 to 10 generations per year.

Damage symptoms

Thrips damaged onion leaves are silvery or have tiny brownish marks or spots. They may be wilted or distorted. Outer leaves are brown at the tips. In cases of severe injury, leaves drop and bulbs are small and misshapen.

Immature thrips on leaf Onion thrips damage on onion
Onion thrips adult

Management

- Plowing and crop rotation are useful tools to combat thrips. Plow fields after harvesting to eliminate resting sites for the pest. Avoid planting onion crops in succession.
- Mulching with straw may provide shelter for thrip predators, thereby reducing thrip populations.
- Insecticides are commonly used to control thrips. In the past, pyrethroid insecticides were used to effectively control onion thrips. However, their efficacy declined recently probably because of development of pyrethroid resistant thrips population. About a dozen of insecticides are registered for the control of thrips on onion in Ethiopia. Of these the insecticides Fighter (common name Imidacloprid) and Radiant (common name Spinetoram) were found effective from experiments conducted recently.

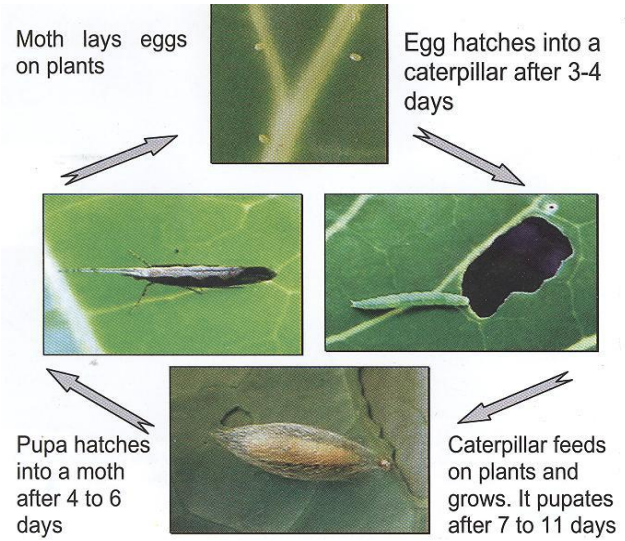
Cabbage

Diamondback moth *Plutella xylostella* (L.)

The diamondback moth is a serious pest of brassicas and attacks all *Brassica* spp. It is very common and widespread. It is completely cosmopolitan. In Ethiopia this pest inflicts heavy damage in the major brassica producing regions of Arsi highland and central rift valley region. Total crop failure is not uncommon in seasons of heavy infestation in the central rift valley cabbage fields

Description and Biology

The adult is a small greyish-brown moth, about 8 mm in length, with a wingspan of about 15 mm. It has a characteristic diamond pattern on its back, which can be seen when its wings are closed at rest, hence its common name**.** Eggs are tiny, white, flat and oval-shaped. They are laid on the leaves, either singly or in small groups. A single female can lay more than 400 eggs. The incubation period is 3 to 8 days depending on the environment (e.g. temperature). Larvae are pale green, and widest in the middle part of the body and measure 12 mm when fully grown. Larvae are active, and when disturbed wiggle violently and drop to the ground, remaining suspended only by a silken thread. The total larval period varies from 14-28 days. There are four larval instars. Pupation takes place inside a silken gauze-like cocoon that measures about 9 mm long, which is stuck to the underside of the leaf. The pupa is greenish at first and changes to a brown colour as the moth develops. It remains visible to the naked eye within the cocoon. The pupal period lasts 5-10 days. The adult lifespan is 16-17 days.



Life cycle of diamondback moth

Damage symptom

Feeding by larvae causes damage to leaves. Newly hatched larvae feed on the underside of the leaf, penetrating the epidermis and mining through it. Later instars also feed on the underside of the leaf, except that they either cut round holes through it (making the leaf appear 'windowed') or they scratch off the tissue, leaving the epidermis of one side untouched so that attacked leaves appear skeletonised (Plate 2.5.3). Life cycle of DBM is shown in plate 4. DBM infestations tend to be serious in the dry months. Rainfall has an adverse effect on DBM populations; thus, DBM is less likely to be a problem in wet years and during rainy seasons

Cabbage plant damaged by diamondback moth

Management

An IPM approach involving cultural biological and chemical control is useful in the management of Diamondback moth. These include the following:

- Intercropping brassicas with repellent plants such as tomato
- Use of sprinkler irrigation
- Remove and burn or compost crop residues immediately after harvest,
- Use of aqueous extracts of neem seed (30 kg per ha)
- the microbial insecticide (*Bacillus thuingiensis*);1 kg per ha
- Use of parasitoids such as *Diadegma semiclausum* in highland cabbage
- Rimon 10% EC (Novaluron) registered for the control of other pests on other plants (Apply at 0.5 L per ha).

Mealy cabbage aphids

Mealy cabbage aphids**,** *Brevicoryne brassicae* (L.), are considered a major pest of brassica next to diamondback moth in Ethiopia. The mealy cabbage aphid is virtually restricted to members of the Cruciferae. It is a serious pest of cabbage and other cruciferous crops.

Description and biology

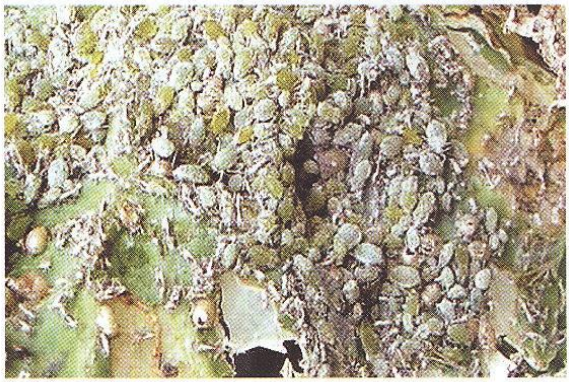
Aphids occur in colonies. Adult aphids are small- to medium-size. They can be winged or wingless. Wingless forms are the most prevalent. Normally, females give birth to living young. Cabbage aphids are usually found in colonies on the underside of leaves.

Adults of the mealy cabbage aphid measure 1.6-2.8 mm in length. They

are greyish-green or dull mid-green in colour and are covered with a fine waxy grey mealy powder). Cornicles are short and dark and there are irregular dark bands on the abdomen under the powdery wax covering. Winged forms have a dark head and thorax and black transverse bars on the back of the abdomen. Under laboratory conditions, fecundity averages 14.9 and 86.4 nymphs per female, at 30 oC and 15 oC, respectively. Adult lifespan varies from 8 days at 30 oC to 28 days at 10 oC.

Damage

Damage is by direct feeding and by virus transmission. Direct feeding by aphid colonies causes leaf curl, discoloration, stunted growth and even death of the infested plants. In heavy infestations, copious amounts of honeydew are produced on which sooty mould fungus grows. This reduces the quality of the crop.



The cabbage aphid Cabbage plant damaged by aphid

Management:

- Early detection and monitoring of initial aphid infestation build-up is important. Spraying should be considered if seedlings or transplants are at risk when heavy infestations occur.
- Aphids are naturally controlled by parasitic wasps of the families Aphidiidae and Aphelinidae, predators (ladybird beetles, hoverflies, lacewings etc.) and pathogens *(Entomophthora* spp.). The most important parasitoid of the cabbage aphid in Ethiopia and many countries of the world is the braconid *Diaeretiella rapae*.
- Destruction and removal of crop residues immediately after harvesting minimizes the spread of aphids to adjacent crops.
- Intercropping brassicas with other crops such as clover, spinach, beans, or grass reduces B. *brassicae* infestation.
- Neem seed extracts (15 to 30 kg /ha) have given effective control of the pest with minimal effect on its predator, hover fly from studies conducted in the central rift valley of Ethiopia.
- About half a dozen of insecticides are registered for the control of mealy cabbage aphids on cabbage in Ethiopia. The insecticides Closer 240 SC (common name Sulfoxflor), Phonix 5% EC (common name lambda cyhalothrin) and Sarikas (common name dimethoate) are some of them.

Pepper (Capsicum)

A large number of species including mites, aphids, thrips, fruit borers and termites are known as arthropod pests of capsicum world- wide. Of these, the pod borer (African bollworm) and, aphids are important Ethiopia. n in Ethiopia is mainly confined to western Ethiopia.

Pod borer (African bollworm)

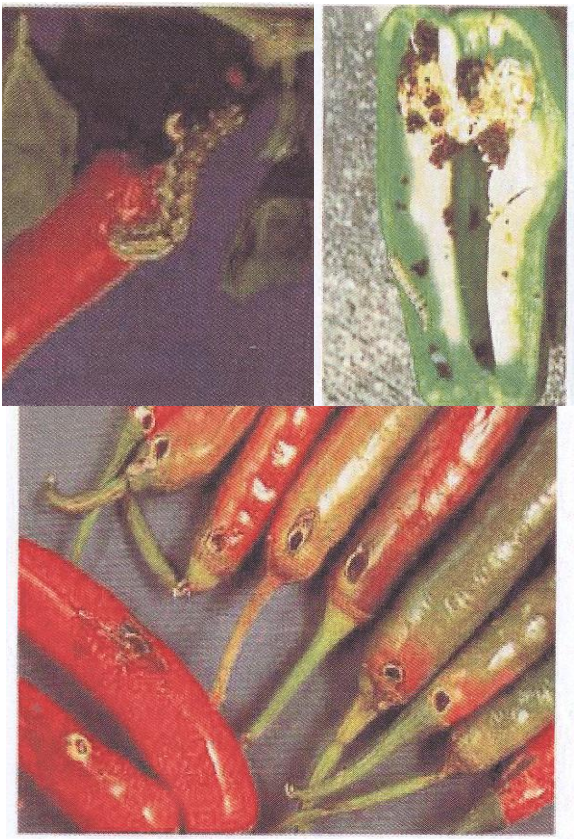
Description and Biology

Refer section under tomato (2.1.1) for description and biology of African bollworm.

Damage symptoms

A small darkened partially healed hole at the base of the fruit pedicle is evident. The inside of the fruit has a cavity that contains frass and decay. Damaged fruits ripen early, but these are not usually marketable. Look at the base of the fruit pedicle. If you find a darkened hole, remove the fruit and cut it open, inside you will see tunneling caused by the insect. This cavity may contain frass and decay.

Caterpillars often move from one fruit to the next destroying only small portion of each fruit. Pupation occurs in soil near the base of the plant.



ABW Caterpillar in pepper fruit and visible damage symptoms

Management

- The control options described above (2.1.1) apply here.
- Use of trap crops such as lupin has been reported to reduce population of African bollworm in pepper

Aphid

Description and Biology

Refer section 2.3.2 for general description and biology of aphids.

Damage symptoms

Leaves are distorted, stunted, and often curled under. The upper leaf surface is sticky and has a black mouldy growth (sooty mould). The plants have fewer fruit than usual. Some wilting may also be evident. The aphids attacking capsicum sp (cotton aphids) are small pear-shaped insects with prominent reddish eyes. They vary in color from green to black. Some have transparent wings. Looking at leaves that are beginning to curl under or have signs of black sooty mold on the upper surface reveal the insect. The cotton aphid has continual generations and many different hosts. When population on the host plant are high, winged forms are produced and they fly to adjacent plants to establish new colonies. Aphid colonies are commonly visited by ants which feed on the honeydew secreted by the aphids. This honeydew also serves as food on which the sooty mold grows. The cotton aphid is a virus vector and has a wide host range including many vegetable crops.



The cotton aphid (aphids on leaf – left, distortion and curling of leaves- middle; and sooty mold
on leaves – right)

Management
Refer section under mealy cabbage aphids.

Insect pests of tropical and subtropical fruit crops (Citrus, Mango, and Papaya)

In Ethiopia nearly 60 insect and mite species are recorded on fruits and citrus has the largest share. Only few are economically important. Major insect pests of citrus include Armored scale, Woolly whitefly, Fruit flies and False codling moth. Leaf miner, psyllid and orangedog are among minor pests of citrus. Although a large number of insect pests are known to associate with mango both in Ethiopia and elsewhere, only fruit flies (Diptera: Tephritidae) and white mango scale, *Aulacaspis tubercularis* (Hemiptera: Diaspididae)) are known to cause economic damage on mango in Ethiopia The status of other pest species is either minor or unknown currently. Scale insects and fruit flies on avocado and mites on papaya are regarded potential pests.

Citrus

Armoured scales (eg. Red Scales)

Description and Biology

The Citrus red red scale, *Aonidiella aurantii* (Maskell), belongs to the Diaspididae (Hemiptera: Coccoidea) family. The adult female is reddish and circular with a diameter of about 1.8 mm. The male is cylindrical, brownish with a diameter of 0.8 to 1.2 mm. The winged adult male is yellowish. The female lays 2 to 3 youngs for the period of four to six weeks. Within 1 to 2 days, the crawlers come out from the scale and settle on the leaves or branches where they start to feed. During this period, they may disperse from one leaf to another leaf or orchard by wind. They spend their entire life time attaching themselves and feeding except that winged adults emerge upon completion of its development. The adult flying male is yellowish white and has a pair of wings measuring 1.5 mm. The adult flying male is attracted by the female for mating by the pheromone the female releases and dies after hours. The time taken for one generation varies depending on the environment. Several research results show that a generation takes about 6 weeks at 27 oC. Research on the seasonal abundance of the pest conducted in Ethiopia showed that the peak breeding months of the pest are March/ April

and September/October following the short and long rainy seasons, respectively.

Damage symptoms

The citrus red scale attacks all aerial parts of the citrus tree including twigs, leaves, branches, and fruit by sucking the sap on the plant tissue. This weakens the infested organ and the plant itself, causing thereafter deformations by the action of toxic saliva. The sucking of the fruit cells by the scale cause chlorosis and yellowing in fruit when still green in colour; extremely intense attacks may encrust the fruit and dry it up to mummification. Injurious effects include the yellowing of foliage (the leaves develop a characteristic yellow spot under and around each female scale) and defoliation; the dying back of small twigs, the large branches, and finally, if the insect remains unchecked, big parts of the tree can be killed.

Yellowing of fruit (left) and mummification (right) caused by severe attack of citrus red scale

Yellowing of leaf (left) and twig infestation (right) by the citrus red scale

Management

- **Use clean planting material (prevention)**: raise seedlings in places free from the pest and restrict movement of infested plant materials from place to place.
- **Control ants**: paint stem of the citrus plant at the crown region about 10 cm wide with gasoline, grease or insecticide. This promotes biological control.
- **Sanitation**: prune heavily infested branches and put near the orchard

- **Good maintenance**: provide plants with good growing conditions and proper cultural care, especially appropriate irrigation
- **Insecticidal control**: during peak breeding period of September/ October and March/April through monitoring, application of white oil (2%) or methidathion with 1.5% white oil can provide effective control of red scale.

Woolly whitefly

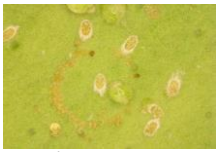
Description and Biology

As many as 200 eggs are laid by one female and the eggs hatch in a week time. The eggs are laid on the underside of leaves. Eggs are sausage shaped (laid in circle or semi-circular pattern). Immatures (nymphs) are flattened and oval. As nymphs age, they cover themselves with "woolly" white waxy filaments and hence the name woolly whitefly. The dense colony of immatures is the most conspicuous sign of WWF infestation. The immatures are distinguished from other whiteflies by the mass of waxy white filaments covering their surface. There are four nymphal stages lasting a total of 15 days or more depending on the weather. The first instar is mobile and the rest are sedentary. The adult emerges by splitting the last instar (pupa) vertically. Woolly whitefly requires about 3 weeks to complete its life cycle in warm weather.

Damage symptoms

Woolly whiteflies suck phloem sap, causing leaves to wilt and drop when populations are where copious amounts of honeydew are produced, can result in the blackening of entire trees. This reduces photosynthesis, resulting in decreased fruit size. Honeydew and sooty mold can also contaminate the fruit.

Adult WWF



Second instar WWF and eclosed eggs

Third and Fourth instar WWF covered by waxy filaments

Sooty mold growth from wwf honey dew

Dense colony of WWF

WWF severely infested trees showing wilting, leaf drop and branch

Woolly whitefly on citrus

Management

An IPM approach involving biological and cultural control are primarily used for managing woolly whiteflies on citrus

- Several effective parasites are known. The aphelinid parasitoid, *Cales noaki*, introduced from Israel for biological control of the citrus woolly whitefly has been established and a promotion work is currently underway in the central Rift Valley of Ethiopia. Ants which collect honeydew disrupt the natural control system. Ants must be controlled by preventing their access to the tree.
- Quarantine movement of nursery stock
- Hosing the lower leaf surface of trees infested with WWF with high pressure water (home)
- Chemical treatment of whiteflies is not effective. Pest resurgence is common after temporary suppression using chemical treatments. Experiments conducted in Ethiopia showed better performance of foliar application of the insecticides Lambda cyhalothrin and profenofos in controlling woolly whiteflies. Spraying with soap solution; e.g. by mixing 30 ml of liquid soap with 15 liters of water reduce the infestation level.

Fruit fly (several species)

Description and Biology

The term "fruit fly" refers to flies (Diptera) that infest or attack fruit. Fruit flies that are fungi feeders (feeding on decaying fruit) are Drosophilid flies (Family Drosophilidae). The fruit fly species which are mostly colorful and phytophagous are Tephritid flies (True fruit flies). Eggs of fruits flies are small, white, and slender. They are laid under the skin of fruits in groups of 3 to 8 eggs, depending on the species. The flies lay eggs on mature green and ripening fruit. Some species may lay eggs in unripe fruitlets. Eggs hatch within 1 to 2 days. The larvae are whitish maggots. They feed on the fruit flesh causing the fruit to rot. After 4 to 17 days the maggots leave the fruit, making holes in the skin, and drop to pupate in the soil. The pupae are white, brown or black and 4 to 12 mm long. They are found in the soil 2 to 5 cm beneath the host plant. The flies emerge from the pupae 10 to 20 days after pupation depending on climatic conditions. Adult fruit flies are 4 to 7 mm long, brightly colored, usually in brown-yellow patterns. The wings are spotted or banded with yellow and brown margins.

Damage symptoms

Fruit flies cause direct damage by puncturing the fruit skin to lay eggs. During egg laying bacteria from the intestinal flora of the fly are introduced into the fruit and cause rotting of the tissues surrounding the egg. When the eggs hatch, the maggots feed on the fruit flesh making galleries. These provide entry for pathogens and increase the fruit decay, making fruits unsuitable for human consumption. Generally, the fruit falls to the ground as, or just before the maggots pupate.

Fruit fly on orange (left) and piled damaged and dropped fruits from fruit fly infestation (right)

Bacterocera invadens

Ceratitis capitata

Ceratitis Cosyra

Daucus spp.

Ceratitis fasciventris

Ceratitis fasciventris

Some of the fruit fly species occurring in Ethiopia

Management

- **Cultural control:** Remove fruits with dimples and oozing clear sap. To be effective this has to be done regularly (twice a week for the entire season). Kill the maggots by burning, burying or feed to poultry. When burying fruits, ensure that the fruits are buried at least 50 cm (about two feet) deep to prevent emerging adult flies from reaching the soil surface. **Early harvesting and fruit bagging can help lower fruit fly infestation**
- **Chemical control (Bait spray and mass trapping)**: Apply the insecticide Success bait (Spinosad GF-120) at the rate of 1-1.5 lt/ha as spot-spray on $1m^2$ of canaopy to attract and kill female and male fruit flies.
- **Male warfare**: Mix Methyl eugenol and insecticide and soak a cotton wick in the mixture, then place the wick in a trap.
- **Biological control**: Using biopesticides suchas *Metarhizium anisoplie* and *Beauveria bassiana*. Apply biopesticide directly to the soil to kill the maggots and pupae. Release parasitoids such as *Fopius arisanus*

False Codling Moth (FCM), *Cryptophlebia leucotreta*

Description and Biology

The adult moth is inconspicuous with mottled gray forewings and paler, fringed hind wings. Female moth lay up to 300 eggs each (mostly singly on the rind of the fruit). Eggs are cream colored, flat, oval shaped (0.7mmx0.6mm), incubates in 6-12 days. Neonate larvae are white with a black head; bore into the fruit shortly (24 hours). Larvae feed inside the fruit. There are five larval instars which take 35 to 67 days. With age the larva becomes redish and pinkish. The last instar (fifth) leaves the fruit before or after it has dropped. Pupation occurs in the ground and takes 21 to 80 days. A generation requires 1.5 to 3 months.

Damage symptom

Infestation in the fruit causes the fruit to drop and can therefore result in a reduction in yield

Management

Cultural control

Orchard sanitation. Orchard sanitation is important to reduce moth population in the orchard. All infested fruit, both on the trees and on the ground, should be collected regularly and destroyed. Weekly cleaning of orchards and deep burial of infested fruits (not less than 50 cm) is required to prevent the emergence of the adult moth. A programme of regular sanitation could save between 24 and 60 fruit per tree from *C.leucotreta* infestation (Stofberg (1954).

Weekly. Equally important in reducing moth population using sanitation is collection of out of season fruits.

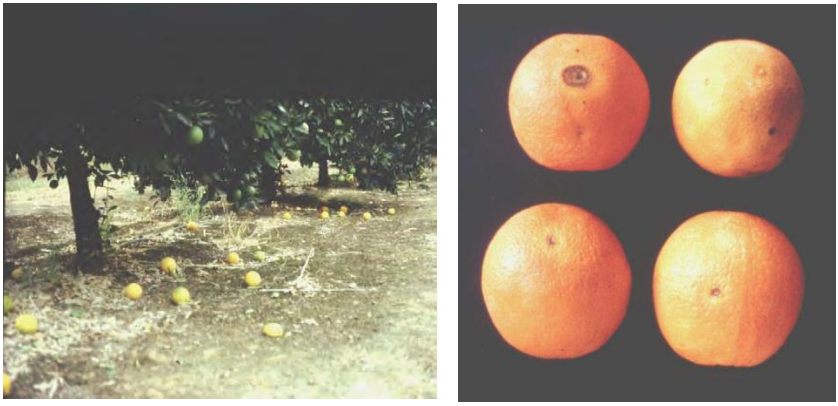
Chemical control

Several growth regulating insecticides including Alsytin (triflumuron), Nomolt (triflubenzuron), Penncap-M (micro-encapsulated methyl parathion) and Meothrin (fenpropathrin) are registered for the control of *C. leucotreta* on citrus elsewhere (Moore 2002). In Ethiopia, the only registered insecticide for the control of this pest is Runner 240 SC (Methoxyfenozide) (MOA 2016). Attract and kill technique using a mixture of a synthetic sex pheromone and

pyrethroid) applied in droplet forms to trees (e.g. Last call FCM) is used in South Africa for controlling the pest.

Biocontrol

Using the egg parasitoids, *Trichogrammatoidea cryptophelebiae* (Hym: trichogramatidae; four release of 25 000 per ha). Use of entomopathogens eg. FCM granuolovirus is used in South Africa for controlling the pest.



C. leucotrela larval entrance marks on orange (left) and fruit drop (right) due to its infestation

Adult false codling moth (left); FCM damaged fruit (cener) and mature instar (right)

Mango

Fruit flies (Several species), mealy bugs, mango gall flies, whiteflies, scales, and thrips are known to inflict damage on mango in different countries of the world. Of these fruit flies are economically important on mango in Ethiopia. The status of other species is either little or unknown.

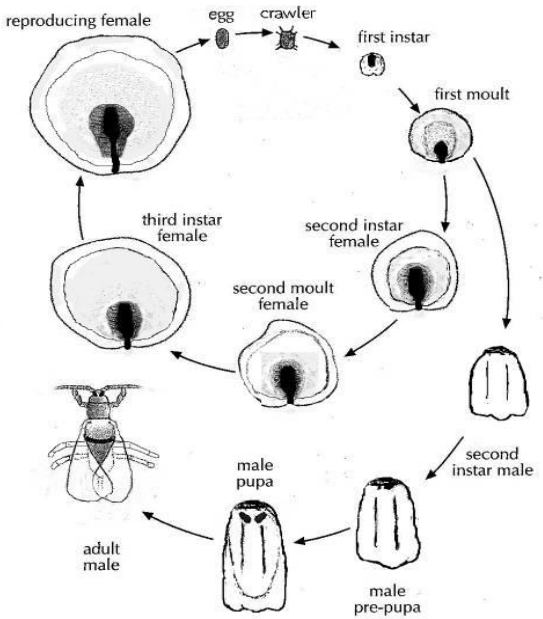
White mango scale

White mango scale, *Aulacaspis tubercularis* Newstead (Hemiptera: Diaspididae), is the most common armoured scale on mango. Occurrence of white mango scale in Ethiopia was first reported in August 2010 (Mohammed et al.2012). It is now found in the central rift valley regions between Zeway in the south to Shewa robit in the North. Its geographic coverage is expanding from year to year. The pest is found associated with the crop throughout the year although it is found in large number during the flowering and fruiting periods of the crop.

Description and Biology

Females have a round white covering, while males have a small rectangular covering with two distinctive groves. Females lay 80-200 eggs depending on temperature. After hatching crawlers move to feeding sites settling within 24 hours. Female crawlers settle randomly, male crawlers settle in groups close to females. Up to 80% of crawlers become males. Life cycle takes 35 to 85 days depending on temperature.

Leaf with female (round white covering) and male male (rectangular covering) (Left); Females whose round white covering removed with eggs and crawlers (Center) and males with two distinct groves (right)



Life Cycle of Mango white scale

Damage symptoms

Scales infest young twigs, leaves and fruit. Severe early-stage infestation retards growth. Leaves may dry when heavily infested. Heavy infestation may result in yellowing and premature drying and shedding of leaves, wilting and die-back of stems. Young trees are vulnerable to leaf loss and death of twigs due to scale attack during hot dry weather. Infested fruits show pinkisk blemishes affecting the fruits commercial values

Yellowing in white mango scale damaged leaf (left) and pinkish blemish on fruit (right)

Management

No effective management method against white mango scale is currently available in Ethiopia. Research on its management has so far been limited to screening of insecticides. Management methods used in countries where this pest is problematic are outlined below

Cultural control

This includes removal and burning of heavily infested leaves, branches and fruits; and post-harvest pruning. Pruning to remove residual population after harvest and removal and destruction of infested leaves and branches

Chemical control

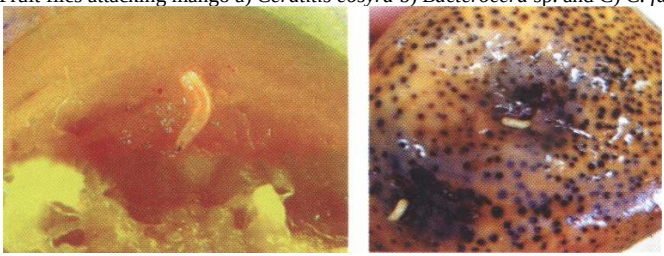
Use of systemic or growth regulating insecticides to prevent population build up is advisable. The insecticide Movento 240 SC (Spirotetramat) applied at 1 liter per ha was found promising in insecticide screening experiment conducted at Melkassa. A high water volume (up to 1200 L per ha) is good for full coverage of the tree. Insecticides registered for the control of armoured scales in Ehiopia including Medopaz 80% (white oil) (by mixing 2.5 liter of the product with 100 Liter of water) and Suprathion 40 EC (Methidathion) (by mixing 0.15 liter of the product with 100 liter of water) can be used. A water dispersable systemic granular insecticide Thiamethoxam 25% WG (Spark 250 WG) has been found to suppress the white mango scale population.

Fruit flies

Description and Biology

Refer to fruit flies of citrus for description. Fruit flies are 4-7 mm long, brightly coloured, usually in brownyellow-black 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 hatch within 1-2 days into whitish maggots, which feed on the fruit flesh, causing fruit rot. After 4-17 days the maggots leave the fruit, making holes in the skin, then drop to pupate in the soil. The affected part of the fruit becomes soft and colours prematurely.

Fruit flies attacking mango a) *Ceratitis cosyra* b) *Bacterocera* sp. and C) *C. fasciventris*



Maggots of fruit flies feeding on fruit flesh and dropping out of fruit to pupate (right)

Management

Refer to section under citrus

Papaya

Soft and armored scales, fruit flies, mites and thrips are recorded from papaya in Ethiopia. Of these mites are very common and regularly occurring particularly in the hot dryer season of the year. Leaf eating weevils (Systates

spp.) and aphids are known pests of Papaya in East Africa and other papaya growing areas although their status in Ethiopia is not known.

Spider mites

Several species of mites damage papaya. The spider mites suck the plant sap, leading to poor plant growth and blemish on the fruit. Infested leaves show yellow patches on the upper surface, particularly between main veins and midrib. Feeding by mites causes scarring and discolouration of fruit, and reduced fruit size affecting its market value. Infestations usually begin on the older leaves and the spreads to the younger growth. Serious infestations occur during long dry periods. Broad mites attack mainly the terminal buds; they feed on the young leaves as they emerge from the growing point. Affected leaves are thick and brittle, with down curled edges. Severe infestations inhibit new stem growth, with consequent reduction in fruit production.

Two-spotted spider mite. The adult female is 0.6 mm long. The male is smaller.

Table 1. Registered insecticides for use against Major insect pests of tropical and subtropical fruits (Registrant lists are available from Crop protection directorate of MOAL

no	Trade name	Common name	Target pest	Rate of application
1	Medopaz 80%	White oil	Red scales on citrus	2% a.i. (mix 2.5 L of the product with 100 L of water)
2	Suprathion 40 EC	methidathion	Red scales on citrus	0.06% a.i. (mix 0.15 L of the product with 100 L of water)
3	Success bait	Spinosad	Fruit fly on mango and other fruit trees	Mix 1 l of the product with 10 L of water and apply 30 ml of the mixture per tree as spot application (1 square meter) on tree canopy
4	Rimon 10% EC	Novaluron	False codling moth	5 g a.i. /100 L water (Mix 50 ml of the product with 100 liter of water)
5	Runner 240 SC	Methoxyfenozide	False codling moth	25 g ai/100 L water (Mix 60 ml of the product with 100 liter of water)

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