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Mango

Mango
Scientific name: *Mangifera indica*
Family: Sapindales: Anacardiaceae
Local names: Embe (Swahili)
Pests and Diseases: Anthracnose Aphids Black spot Bugs Fruit flies Helopeltis bugs Malformation Mango gall flies Mango leafcoating mites Mango seed weevil Mealybugs Powdery mildew Scales Spider mites Stem-end rot Termites Thrips Whiteflies

General Information and Agronomic Aspects

The Mango fruit is one of the most important tropical fruits. It is native to the Indian Monsoon region and has been cultivated for the last 4000 years. It was introduced to East Africa in the 14th century. Mango has now become an important domestic and export crop in Kenya.

Mango has many uses: Ripened fruits are eaten fresh and used to make juice or marmalade. They can also be dried and made into candy. All remains from the fruits can be used to feed animals. The young leaves for example are a very good cattle feed.

Geographical Distribution of Mango in Africa

Cultivars

A wide range of mango cultivars is grown in Kenya. Local varieties include Apple, Batawi, Boribo, Dodo, Kiarabu, Kiimji, Kitovu, Mayai, Ngowe, Peach, Sabre and Shikio Punda. Among these, Apple and Ngowe are in high demand for local and export markets, particularly in the Middle East. Apple, Haden, Keitt, Kent, Ngowe and Tommy Atkins are important cultivars for the export markets.

Climate conditions, soil and water management

Mango grows best in tropical summer rain regions, at temperatures between 24°C and 28°C. Once a mango tree is well established, it is very resistant to drought. Mango needs a dry period or cooler temperatures to start blossoming and produce fruits. Rainfall during flowering seriously affects fruit setting. In the tropical regions that do not vary in rainfall or temperature, the trees will not produce any fruits. Mangoes grow well below an altitude of 1000m. Above 1200m production is often poor, but some cultivars such as Sabre and Harris are reported to yield well at up to 1800m.
Mango will grow on a rainfall as little as 650 mm per year, but do better on higher rainfall of around 1500 mm. Mango grow in most soils if they are well drained. Ideal for good growth is a deep (at least three m), fertile soil. Avoid poor, shallow, rocky and alkaline soils. A pH of 5.5 to 7.5 is desirable. Young trees should be irrigated as soon as the dry season starts. Older trees need a dry period of at least three months to start flowering. When the fruit is developing, it is very important to water the plant regularly. In Kenya, the major production season is December to March.

Propagation and planting

Mango seeds quickly loose their viability. Use healthy, fresh seeds from well-grown, mature trees. Wash the seeds and dry them in the shade for a few days. Sow them at a spacing of 15 x 30 cm and five cm deep. Place them on their sides; the most prominently curved edge upwards, so that they produce a straight stem. To speed up germination, the hard husk can be removed before sowing. The best place to cultivate seedlings is in half-shadow. Transplant them 5 to 6 weeks later, when they are about 10 cm high, into a nursery bed or into poly-bags. Irrigate seedlings during dry periods.
Select the site for the orchard carefully. Deep soil cultivation by ploughing is recommended. Clear the field of

trees, bushes and weeds. Transplanting should be done at the beginning of the rains. The planting hole should be 60 x 60 cm big and 100 cm deep. Under dry conditions, the hole should be bigger (about 90 x 90 cm and 100 cm deep). The spacing is 9 x 9 to 14 x 14 m between trees depending on variety and growth habit of the mango variety chosen. Mix a minimum of two buckets of good compost and a handful of Mijingu rock phosphate with the dug out soil, before returning the soil to the hole along with the young mango plant. Firm the soil around the plant. Water well and mulch. Irrigation should only be necessary to see the young tree through the first year.

Husbandry

Keep the area directly under the tree canopy free from weeds. During the first five years, intercropping with annual crops is recommended to maximise income until an economical mango yield is achieved. In young plantations mulching around the tree helps to suppress weeds and to retain soil moisture. Mango trees normally need pruning in order to shape young trees. Smoking of mango trees, apart from controlling pests also induces good flowering.

Formative pruning is done in the first years of the young tree to guide the tree into the desired shape. In the first year, cap the seedling at 1 m height in order to produce a spreading framework of branches. In the second year, prune to leave 4 to 5 well spaced branches to be the future main branches. Benefits from pruning:

- **Fruit is produced on the outside of parts of the tree**
- **Fruit hold to maturity**
- **Open tree structure allows for easy harvesting**
- **Tree produces larger fruits**
- **Crops can be grown under the trees**
- **Tree benefits from natural conditions of sun and wind movement. This helps in reducing relative humidity within the canopy and also creating environment less conducive to disease development.**
- **It controls tree height and prevents excessive spreading of limbs.**

Structural pruning should be done after fruit harvest: The canopy should be at least one m above the ground. Remove all dead branches and all sucker branches from the main structural branches. Prune canopy to allow sunlight to penetrate and reach the ground under the tree.

Improve fruit production by:

- **Keeping the orchard area clean**
- **Removing all ripe fruit and weeds from around the tree**
- **Removing 1/3 of fruit after fruit set to get better size of remaining fruit.**

Mango trees are susceptible to wind damage. Therefore, they should be protected from strong winds by windbreaks on the upwind side of prevailing winds.

Weeding. Clear excessive vegetation regularly from beneath the trees and use as mulch.

Mango fruits and farmers inspecting mango tree

Harvesting

Flowering usually begins after a period of dormancy due to cool or dry weather. Smallholder mango farmers usually induce flowering with smoke.

A mango plantation will supply its first commercially marketable amount of fruit around 4 to 5 years after being planted, and are in good production after eight years reaching full maturity at some 20 years of age. One tree should produce 200 to 500 fruits per year and varieties like Dodo and Boribo can produce 1000 fruits per year. Most varieties show biennial tendencies in production and a poor harvest may follow a good one. Selection should be based on varieties showing annual bearing tendencies.

Harvest mango fruit at the mature-green stage, when they are hard and green. A mature fruit has well-developed "cheeks". Pick fruit by hand. Clip them off with a long stalk of about 2 to 3 cm and pack the fruit in a single layer with the stalks facing downwards in the box or crate. It is important that the latex dripping from the stalk drops onto an absorbent material (for example tissue paper placed at the bottom of the container). Although mature mangoes ripen fairly rapidly, they have a poor tolerance to temperatures below 10°C, especially when freshly picked. Ripe fruits can, however, be stored as low as 7 to 8° C without developing chilling injury.

Yield. Fifteen tons/ha per year can be achieved from the seventh year onwards if proper husbandry is followed.

Post-harvest treatment

Hot water treatment (HWT) is an effective post-harvest treatment method for mango. Dipping newly harvested

fruits into hot water minimises fruit fly damage and anthracnose. The fruit is perishable and should be marketed as quickly as possible. For more information on hot water treatment click here.

Mango hygiene by smoking

Mango smoking reduces insect population drastically and improves fruit setting.
Smoke pots with holes in the bottom for air intake, containing wood shavings or sawdust with a topping of aromatic herbs (lemongrass etc) are hung at strategic places within the mango tree and the sawdust lit to produce a good amount of smoke which chases insects away from the tree.

Another option is to place dry grass on the ground below the tree in a position where the wind can blow maximum smoke into the top of the tree, cover it with green aromatic leaves like lantana etc and lit the grass to produce smoke.

Smoking of mango trees is reported both by KIOF and Meru Herbs Farmers, Kenya to be very effective in insect control.

Smoking also induces flowering in mango trees.

Information on Pests

Biological methods of plant protection

The worst pests for mangoes are cotton scales, mealybugs, cicadas and black flies (create honey dew). These are all sucking insects that live on the leaves, young buds and shoots. They can cause a lot of damage. Yet they all have natural enemies, such as e.g. ladybird larvae, wasps, spiders and other types, such as parasitic fungi e.g. with cicadas and black flies.

An ecological plantation with a variety of crops, enough plots under different crops e.g. forest and a sufficient amount of vegetation to cover the soil and enrich the variety of species (e.g. mulching only right after the plants have flowered), will provide enough enemies to combat the pests that measures against them are usually unnecessary. Cicadas are averse to open, well ventilated soil, also drain the soil well to avoid wet patches.

In emergencies, the following methods should help:

Scale insects can be regulated with a 'winter-spraying', i.e. with paraffin oil (white oil) shortly before the larvae hatch from their eggs. The paraffin oil is sprayed on as a 3 % water emulsion.

Plant spraying mixtures made of stinging nettles or Neem can be against cicadas. The worst damage occurs during blossoming, so the plantation should be checked regularly around this time in order to make up the brew and spray it early enough.

Mealybugs lay their eggs on the ground next to the trunk. By wrapping smooth plastic bands around the trunk, the larvae can be prevented from infesting too large an area. Should they infest the tree, a solution of 1% soft soap (potassium soap) with 1 % pure alcohol is quite effective.

Black fly can be kept under control by useful insects. A variety of prospatella species can be of use here. This requires a good functioning control system, because the useful larvae need to be made available for release in

time. Where this is not possible, spraying white oil shortly before the pests hatch, as such as with scale insects can be sufficient.

Examples of Mango Pests and Organic Control Methods

Mango fruit flies (*Ceratitis* spp./ *Bactrocera invadens*)

Fruit flies lay eggs under the skin of mature green and ripening fruit. Some fruit flies such as *Bactrocera invadens*, a new species recently introduced into East Africa, also lay eggs on small fruit. The eggs hatch into whitish maggots within 1 to 2 days. The maggots feed on the fruit flesh and the fruit starts to rot. After 4 to 17 days, the maggots leave the fruit, making holes in the skin.
Adult fruit flies are small, they are about 4-7 mm long.

What to do:

- **Collect and destroy all fallen fruits at least twice a week during the fruit season.**
- **Do not put collected damaged fruits into compost heaps. Instead, burn them or bury them at least 50 cm deep, so that the fruit flies cannot reach the soil surface.**
- **Remove fruits with dimples and those that ooze clear sap. This method is more laborious than picking the rotten fruits from the ground, but it is also more effective.**
- **Whenever possible, wrap fruit in newspaper or paper bags to prevent fruit flies from laying eggs on the fruit. This has to be done well before the fruit matures.**
- **Pick overripe fruits, as they attract fruit flies.**
- **Physical methods include fruit fly traps and fruit bagging, see on fruit-fly datasheet**

Fruit fly
Maggots of fruit fly dropping out of mango fruit to pupate.
© A. M. Varela, icipe.

Fruit fly

Mango frui…

Fruit fly …

The mango gall flies (*Erosomyia mangifera*)

It is a small midge about 1 to 2 mm long with long legs and antenna. The flies lay eggs on young leaves. Eggs hatch into maggots that bore into the leaf tissue to feed. Their feeding induces formation of small galls, which look like pimples on the leaves. Mature maggots leaves the galls and to the soil to pupate, leaving small holes on the leaves. These holes may serve as entrance for fungal infections. Leaves may be covered with galls and the surrounding tissue may die. Heavy infestation may lead to premature leaf drop.

What to do:

- **Conserve natural enemies. Mango galls are usually kept under control by parasitic wasps and no control measures are needed.**
- **In other countries, when infestations are heavy, the soil around the tree is flooded before flowering to reduce emergence of adult gall flies from the soil.**

Mango gall fly
Close-up of galls caused by gall flies on mango leaf (*Erosomyia mangifera*).
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Whiteflies and black flies (*Aleurocanthus woglumi*)

Whiteflies and black flies suck sap from leaves and may weaken the plants when numbers are high. They produce as excrete large amount of honeydew where sooty mould develops. High numbers of these insects can almost blacken trees, reducing photosynthesis and may cause leaf drop debilitating the tree.
Adults are small (1-3 mm long), with two pairs of wings that are held roof-like over the body. They resemble very small moths.

What to do:

- **Conserve natural enemies. They usually provide good control of these pests. For more information on natural enemies click here.**
- **If necessary spray neem extracts. Neem products inhibit growth and development of immature stages, repel whitefly adults and reduce egg laying.**

Whiteflies
Whiteflies on a mango leaf
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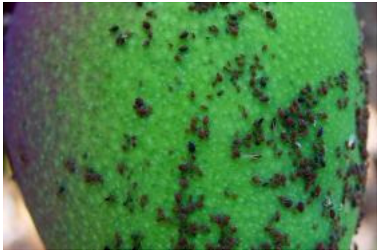
The mango aphid (*Toxoptera odinae*)

It is small (1.1 to 2.5 mm long), brown, black or reddish brown aphid covered with a light powdery dusting. Aphids live in clusters sucking sap on the underside of young leaves, on petioles, young branches and fruit. Their feeding causes slight rolling, or twisting of the leaf midrib. Sooty mould growing on honeydew produced by the aphids may cover leaves, twigs and fruit. Coating of the fruit with honeydew and sooty mould reduces its market value.

What to do:

- **Conserve natural enemies. Aphids are attacked by a wide range of natural enemies, which are very important in natural control of these pests.**



Mango aphid
Mango aphid (*Toxoptera odinae*) on mango fruit.
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Mango aphi… **Mango aphi…**

The mango seed weevil (*Sternochetus mangiferae*)

It feeds on mango leaves, tender shoots or flower buds. Female weevils lay one egg on the young fruit leaving a small, dark mark on the fruit skin. The larvae burrow through the flesh into the seed and destroy it. The larva develop and grows in the mango seed. When the larva has grown up to an adult beetle, it tunnels through the flesh and leaves a hole in the fruit skin. The tunnel gets hard and the fruit cannot be sold anymore.

What to do:

- **Keep the orchards clean of all fallen fruit and plant material by collecting, burying or burning it.**
- **Sticky bands applied at the upper end of the trunk before it branches has been recommended to prevent weevils form migrating to branches for egg laying. However, there are some reports that, although these weevils are not strong flyers, they can fly, and could infest the trees in spite of the banding. A method for**

banding is described in detail under citrus trees/ants.

- Scout fruit regularly and remove fruits with egg-laying marks and destroy weevils (larvae, pupa and adults) in seeds (stones).

Mango seed weevil
Damage by mango seed weevil (*Sternochetus mangiferae*). First instar larvae are elongate, cylindrical, legless and extremely slender; they are 1.3-1.4 mm long. The body is white and the head is black. Final instar larvae are white and legless, they have a curved form, and are 1.6-1.8 cm long.


Mango seed..


Mango seed..


Mango seed..


Egg of man…

Mealybugs (*Rastrococcus* spp.)

Mealybugs are small, flat, soft bodied insects covered with a distinctive segmentation. Their body is covered with a white woolly secretion. They suck sap from tender leaves, petioles and fruits. Seriously attacked leaves turn yellow and eventually dry. This can lead to shedding of leaves, inflorescences, and young fruit. Mealybugs excrete honeydew on which sooty mould developed. Heavy coating with honeydew blacken the

leaves, branches and fruit. This reduces photosynthesis, can cause leaf drop and affect the market value of the fruit.

A wide range of natural enemies attacks mealybugs. The most important are ladybird beetles, hover flies, lacewings, and parasitic wasps. These natural enemies usually control mealybugs. However, mealybugs can cause economic damage to mango when natural enemies are disturbed (for instance by ants feeding on honeydew produced by mealybugs or other insects) or killed by broad-spectrum pesticides, or when mealybugs are introduced to new areas, where there are no efficient natural enemies.

The latter is the case of two serious mealybug pests on mangoes in Africa: *Rastrococcus invadens* in West and Central Africa and *Rastrococcus iceryoides* in East Africa. These mealybugs, of Asian origin, were introduced into Africa, where they developed into serious pests since the natural enemies present were not able to control them. They cause shedding of leaves, inflorescences and young fruits. In addition, sooty moulds growing on honeydews excreted by the insects render the fruits unmarketable and the trees unsuitable for shading. They cause direct damage to fruits leading to 40 to 80% losses depending on locality, variety and season. *Rastrococcus invadens* was brought under control in West and Central Africa by two parasitic wasps (*Gyranusoidea tebygi* and *Anagyrus mangicola*) introduced from India (Neuenschwander, 2003).

***Rastrococcus iceryoides* is a major pest of mango in East Africa, mainly Tanzania and coastal Kenya. Although several natural enemies are known to attack this mealybug in its aboriginal home of southern Asia (Tandon and Lal, 1978; CABI, 2000), none have been introduced so far into Africa (ICIPE).**
Insecticides do not generally provide adequate control of mealybugs owing to their wax coating.

What to do:

- **Destroy affected parts at the beginning of the infestation. Heavily infested branches may be pruned to control the pest, especially on the tender branches before flowering begins.**
- **Conserve natural enemies.**

- **Avoid excessive spraying and the use of broad-spectrum pesticides, since they may kill natural enemies.**
- **Control ants tending mealybugs - see also section on mealybugs on citrus datasheet.**
- **When necessary spray only the affected branches/trees (spot spraying). Mineral oils, neem products and soapy solutions (1 to 2%) are reported to give satisfactory control of mealybugs.**

Mealybugs
Mealybugs (*Rastrococcus* spp.) on a mango fruit
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Scales

Scales are small (1 to 7 mm long), generally immobile insects, varying in colour and shape according to the species. Female scales have neither wings nor legs. They resemble small shells glued to the plant. Females lay eggs under their scale. Once hatched, the tiny scales (known as crawlers) emerged from under the protective scale. They move in search of a feeding site and do not move afterwards. They suck sap on all above the ground plant parts.

There are two main groups of scales on mangoes: soft and armoured scales. Soft scales excrete honeydew. The most common soft scales on mangoes are soft green scales (*Coccus viridis*), brown soft scales (*Coccus hesperidum*), and wax scales (*Ceroplastes* spp.). The most important armoured scale on mango is the mango white scale (*Aulacaspis tubercularis*). The body of this scale is reddish brown. Females are covered with a white round shell, while males have a small rectangular shell with two groves.

Feeding by scales may cause yellowing of leaves followed by leaf drop, poor growth, dieback of branches, fruit drop, and blemishes on fruits. Heavily infested young trees may die. In addition, soft scales excrete honeydew, causing growth of sooty mould. In heavy infestations fruits and leaves are heavily coated with sooty mould, turning black. This reduces photosynthetic capacity. Fruits contaminated with sooty mould loose market value. Ants are usually associated with soft scales. They feed on the honeydew excreted by soft scales, preventing a build-up in sooty moulds, but also protecting the scales from natural enemies. Armoured scales do not excrete honeydew.

What to do:

- **Conserve natural enemies. Scales are attacked by a large range of natural enemies, mainly parasitic wasps and predators (ladybird beetles, lacewings, etc). These natural enemies usually control scales. Outbreaks are generally caused by the use of broad-spectrum pesticides that kill natural enemies, and/or to the presence of large number of ants that feed on honeydew produced by soft scales or other insects (mealybugs, whiteflies, aphids, black flies).**
- **Spray if necessary with light mineral oils. However, care should be taken when using mineral oils, since at high concentrations, they may be harmful to the trees. Oil sprays should be carried out after picking and not during flowering or during periods of excessive heat or drought. Sprays should target young stages of the scales.**
- **To protect natural enemies spray alternate tree rows each season.**
- **At early stages of an outbreak cut and burn affected branches and leaves.**

Scales
Soft brown scale (*Coccus hesperidum*). Scales are small, they attain a lenght of 1-7mm.

Bugs

Several species of bugs feed on mangoes. Both adults and nymphs (young stages) feed inserting their needle-like mouthparts in young tissue, causing dieback and tip wilting. Other feed on the fruit, causing fruit fall and fruit deformation.

The coconut bug (*Pseudotheraptus wayi*)
It feed on fruits. Damaged young fruits show dark brown or grey indentations on the skin and normally drop. Bug feeding on mature fruit causes sunken lesions. The coconut bug is reddish brown, about 1.5 cm long. Eggs are laid scattered over the fruit, small twigs, flowers and blossom stems. The young bugs are light brown with long thick antenna.

Tip wilters (*Anoplocnemis curvipes*)
They are large (about 2.5 cm long) bugs, and dark brown in colour. The hind legs of the male are enlarged. Both young and adult bugs feed on young flush, on the mid-vein of young leaves, or on flower stalks, causing wilting and death of new growth. Heliopelthis bugs, also known as mosquito bugs are about 7-10 mm long and have slender bodies and long legs and antenna. Adults and young bugs (nymphs) feed on fruit and young shoots. Feeding on fruit causes dark lesions with a brown dark centre. Young shoots die back, resulting in vigorous secondary branching. Bugs are difficult to control since they usually feed on a wide range of crops and are very mobile.

What to do:

- **Hand pick and kill bugs regularly, especially on young trees during flushing periods and during fruit development.**

- **Conserve natural enemies. Assassin bugs, spiders, praying mantises and ants are important predators of bugs. They kill or deter bugs. Weaver ants, tree-nesting ants common at the coast give effective protection against bugs.**
- **Also tree smoking may help against bugs.**

Coconut bug
Adult coconut bug (*Pseudotheraptus wayi*. Real size 1 to 1.5cm long.
© A.M.Varela, icipe



Cocon bu… **Tip wilter** **Helope**

Helopeltis bugs (*Helopeltis schoutedeni* and *H. anacardii*)

Helopeltis bugs, also known as mosquito bugs or mirid bugs are slender, delicate insects, about 7- 10 mm long with long legs and antennae, the antenna being nearly twice as long as the body. The females are red and the males brown to yellowish red. They lay eggs inserted into the soft tissue near the tips of flowering or vegetative shoots. Nymphs (immature bugs) are yellowish in colour. Both adults and nymphs feed on young leaves, young vegetative and flowering shoots, and developing fruits.

Attacked leaves are deformed and show angular lesions, particularly along the veins, which may drop off, so

that the leaves appear as if attacked by biting insects. Feeding on the stalks of the tender shoots causes elongated green lesions, sometimes accompanied by exudation of gum. Severely damaged shoots die back due to the effect of bug saliva in combination with fungi, which enter the plant tissue through the feeding lesions; the subsequent development of numerous auxiliary buds causes a bunched terminal growth known as 'witches broom'. In case of serious infestations the trees may appear as if scorched by fire. Bug feeding on developing apples and nuts causes brown sunken spots. The growth of trees is seriously retarded and fruit formation of attacking flowering shoots is reduced.

What to do:

- **Monitor the crop regularly. Helopeltis attack occurs very suddenly and great vigilance is very important to control this pest, particularly during the rainy season or when water is available leading to flushing (production of young shoots) when Helopeltis populations normally build up.**
- **Conserve natural enemies. Weaver ants build nests on cashew trees providing good protection against this and other bug pests.**
- **Do not interplant mango with crops that are host for Helopeltis bugs, such as cotton, tea, sweet potato, guava and cashew.**

Helopeltis bug
Helopeltis bug. Real size: 6 to 10 mm long.
© F. Haas, icipe


Helope Helope

Mango leafcoating mite (*Cisaberoptus kenyae*)

The mango leafcoating mite is tiny (about 0.2 mm), light coloured and cigar shaped. It cannot be seen with the naked eye. The mites leave in groups under a white coating on the upper leaf surface. The white coating can be easily rubbed off by hand. Leaves covered with the white coating tend to turn yellow and drop prematurely. In general, the coating has minimal effect on fruit yield.

What to do:

- **Remove and destroy leaves with white coating.**
- **Usually no further control measures are needed.**

Leaf-coating mite
Mango leaves showing symptoms of (*Cisaberoptus kenyae*) attack.
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Thrips (*Selenothrips rubrocinctus*)

The adult of the red banded thrips is reported as a pest of mangoes in Kenya (AIC, 2003). Adult thrips are dark brown thrips, about one mm long. Immature thrips (nymphs) are yellow with a bright red band around the base of the abdomen. Nymphs and adults feed together, normally on the underside of the leaves. Attacked leaves become dark stained and rusty in appearance with small shiny black excreta present. Leaf edges are curled.

Several other species of thrips are found on mango flowers. However, not all of them are pests. Their role varies according to the species. Some species are present in large numbers in mango flowers, but there is no evidence of damage or crop loss. Some thrips species are considered important pollinators. Other species of thrips attack the mango fruit. Thrips feeding on the fruit surface cause a rough, greyish white discolouration.

What to do:

- **Conserve natural enemies. Predatory thrips and mites, anthocorid bugs among other natural enemies are important in natural control of thrips.**

Red-banded thrips
Immature stage of the red banded thrips (*Selenothrips rubrocinctus*). Note a bright red band across the abdomen of immature thrips. Real size: about 1mm long.
© A. M. Varela

Bark eating termites

They are generally associated with old mango trees. They may damage branches and other parts by tunnelling the wood, but usually are not of economic importance. Sickly, injured plants are more likely to be damaged than healthy, vigorous plants.

What to do:

- **Provide good growing conditions for the trees. Termites more often attack sickly or water stressed plants than healthy plants.**
- **Avoid unnecessary injury to the plants as this may facilitate entry of termites.**
- **Conserve natural enemies**
- **Inspect trees, especially pruned trees, for termites attack. Remove affected plant and kill the termites, they are normally found inside the hollowed parts**

Termites
Close-up termites on mango stem.

 

Termit Termit

Information on Diseases

Biological methods of plant protection

The most usual diseases with mango trees are fungus and bacterial diseases. The first important preventative measure is make sure that the propagation segments are healthy. The scions that were raised in tree nurseries and whose origins are maybe unclear, should be carefully examined. They shall not have been treated with any synthetic or chemical agents.

Anthracnose, caused by the fungus *Colletotrichum gloeosporioides*, is the most wide-spread disease among mangoes. The varieties vary in susceptibility. *Colletotrichum gloeosporioides* causes anthracnose on fruits, and drop of flowers on young branches. Anthracnose always appears as a result of scurvy (*Elsinoe mangiferae*). Fruits stricken with anthracnose can be plunged into a hot water bath (3- 5 min./55°C), in order to kill off the fungus. Preventative measures are nevertheless preferable, to preclude injuries and an infection with scurvy, because anthracnose can usually only take a hold on damaged fruits that are also affected by scurvy. A case of scurvy can usually be prevented by removing all dead plant material (branches, leaves and fruit). In exceptional cases, the fungus can be brought under control again with 1% Bordeaux Mixture.

While anthracnose generally attacks ripe fruits (only seldom the blossoms), a bacterial infection from *Erwinia* sp. can also affect young fruit. The symptoms are very similar to the flecks caused to the leaves and fruit by anthracnose. The bacteria usually survive in the ground - a heavy rainfall will then splash the spores against the lower leaves and fruits. Covering the ground can therefore help to protect against this. Active life in the soil will also help to prevent an explosive growth of bacteria. Sites where it can rain inside the blossoms can also be a problem.

Young fruit and also blossoms can be damaged by powdery mildew (*Oïdium mangiferae*). This fungus grows during warm and moist weather, during blossoming and when the fruit appears. A case of powdery mildew can dramatically affect the harvest. An open, well-ventilated population and regular cutting back of the coronets can best help to prevent mildew. In acute cases, mildew can also be brought under control with sulphur. When carrying this out, there should be no wind blowing, and the leaves should still be moist with dew.

The leaf spot disease (*Cercospora mangiferae*) on mangoes is visible as dented spots on leaves and fruit. The same applies for this fungus, an open and quick-drying population is the best protection against infection.

Fruit infected with Cercospora can no longer be sold, furthermore, both the leaf spot disease and scurvy prepare the way for a case of anthracnose. In exceptional cases, the leaf spot disease can be brought under control again with 1% Bordeaux Mixture (Copper). For more information on Bordeaux Mixture click here

Examples of Mango Diseases and Organic Control Methods

Anthracnose (*Colletotrichum gloeosporiodes*)

The most serious and widespread fungus is anthracnose. Anthracnose initially appears as small black spots. On leaves, the spots can grow to form an irregular patch. On young fruit, pin-sized, brown or black, sunken spots develop. Sometimes, a "tear stain" pattern develops on fruit. It is an important problem after harvesting the fruit, especially during transport and storage, where fruit can develop round, blackish sunken spots. The fungus is spread by rain splash and survives from season to season on dead leaves and twigs. Rainy weather during blooming and early fruit set will favour the development of anthracnose.

What to do:

- **Use tolerant varieties. Tommy Atkins is less susceptible to anthracnose than Haden, Sensation and Zill.**
- **Cut-out dead branches and twigs and dead leaves. Completely remove them from the mango orchard.**
- **Monitor for the disease weekly.**

Anthracnose

Anthracnose on mango *(Colletotrichum gloeosporioides)*. Anthracnose initially appears as small black spots. On leaves, the spots can grow to form an irregular patch. On young fruit, pin-sized, brown or black, sunken spots develop.
© A.A. Seif, A.M. Milena, icipe

Powdery mildew (*Oidium mangifera*)

Another fungal disease is the powdery mildew. It appears as a white, powdery growth on leaves, flowers and young fruit. Infected leaves curl and flowers fail to open and drop from the tree without forming a fruit. The disease is spread by wind and can spread very rapidly. It is more prevalent in dry weather when humidity is high and nights are cool. The fungus survives from season to season in dormant buds. The flowering stage is the most critical stage for infection.

What to do:

- **Consider appropriate cultivars that grow in cool, dry areas. Alphonse, Kent and Zill are highly susceptible to mildew. Haden and Keitt are moderately susceptible and Sensation and Tommy Atkins are tolerant.**
- **Monitor for the disease weekly.**
- **Spray a solution of: baking powder (six teaspoonfuls), white oil (three teaspoonfuls) and white bar soap foam in 15 litres of water. This solution has been shown to control powdery mildew.**
- **Sulphur based fungicides can effectively control powdery mildew if appropriately used.**

Powdery mildew
Powdery mildew (*Oidium mangifera*) on young mango leaves

Bacterial black spot (*Xanthomonas campestris* pv. *mangiferaeindicae*)

Bacterial black spot is rain related and is spread through rain splash within an orchard. Long-distance spread is by infected planting material. Important factors in infection are very small wounds that are easily caused by wind and wet weather. On leaves, spots are angular, dark, shiny in appearance and delimited by veins.
Fruit spots start off as water soaked and then become raised and black. Later they crack open in the centre in form of a star. In wet weather, these spots exude gum. Fruit becomes more susceptible with age.

What to do:

- **Consider which cultivars are appropriate to grow in wet, humid areas. Heidi, Kensington, Sensation and Tommy Atkins are tolerant to Bacterial black spot. Keitt and Kent are highly susceptible to the disease. No varieties are immune.**
- **Prune off diseased twigs and establish windbreaks around the orchard.**
- **Copper sprays are the only method of combating the disease and are not always successful when disease pressure is high. One or two post-harvest copper sprays to cover the post-harvest flush and tail end of the rain season are effective in reducing inoculum (disease) pressure for the following season.**
- **Monitor for the disease weekly.**

Bacterial black spot
Bacterial black spot (*Xanthomonas campestris* pv. *mangiferaeindica*) symptoms on mango fruit. Note star-like cracks on the fruit

 

Bacter ... **Bacter ...**

Malformation (*Fusarium subglutinans*)

The fungus produces compounds that have hormonal effect on the plant. The fungus is easily spread by grafting and infected nursery trees. In the orchard the disease spreads slowly despite of masses of spores produced on the panicles.
Symptoms consist of affected flowers taking on, to a greater or lesser extent, the appearance of a cauliflower head. The axes of the panicles are shorter and thicker than normal, branch more often, and a profusion of enlarged flowers is produced. The affected panicles retain their green colour, are sterile and produce no fruits. In the nursery, vegetative malformation can occur. Eriophid mites are believed to be vectors of the disease and their damage symptoms are similar to those caused by *F. subglutinans*. Symptoms consist of buds producing short shoots and small brittle leaves creating a compact "witches broom" appearance.

What to do:

- **Remove affected parts. These could either be burned or placed in plastic garbage bags and exposed to the sun for a day or two to be burned.**

Stem-end rot (*Dothiorella dominicana, Botryodiplodia theobromae*, and/or *Phomopsis mangiferae*)

Symptoms consist of a dark-brown, firm decay starting at the stem-end of the fruit and developing rapidly to involve the whole fruit. The fungi survive on dead twigs and branches where they produce large numbers of spores. During wet weather, these spores are spread to adjacent fruits where infection occurs. The rot generally does not develop until the fruits begin to ripen.
Chemical sprays are neither recommended nor necessary.

What to do:

- **Prune dead twigs and branches**
- **Avoid harvesting immature fruits**
- **Cool fruits immediately after harvesting**
- **Store fruits in well-ventilated containers**

Stem end rot
Mango stem end rot (*Dothiorella dominicana, Botryodiplodia theobromae*, and/or *Phomopsis mangiferae*)

Fresh Quality Specifications for the Market in Kenya

The following specifications constitute raw material purchasing requirements

PRODUCE:	MANGO
IMAGE:	
VARIETY:	Various
GENERAL APPEARANCE CRITERIA	
COLOUR:	Green yellow skin with red blush.
VISUAL APPEARANCE:	Pale yellow to orange flesh.
SENSORY:	Firm, yields slightly to finger pressure; smooth skin; sweet flavour, with some acid; pleasant aroma; no unpleasant odours/flavours (abnormal ripening).
SHAPE:	Round to oval heart shaped.
SIZE:	In pre-ordered size per requirements; uniform per tray, box or crate.
MATURITY:	Fully coloured ripened fruit.
INSECTS:	With no evidence of live insects.

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Information of www.infonet-biovision.org

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Onion

Onion
Scientific name: *Allium cepa*
Family: Aspargales: Alliaceae
Local names: Kitunguu, (Swahili, Kenya and Tanzania), Gitunguru (Kikuyu, Kenya)

Pests and Diseases: **Anthracnose** **Bacterial soft rot** **Botrytis leaf blight** **Downy mildew** **Fusarium basal rot** **Leafmining flies (leafminers)** **Onion fly** **Onion rust** **Purple blotch** **Slippery skin** **Sour skin** **Thrips** **White bulb rot**

General Information and Agronomic Aspects

Geographical Distribution of Onion in Africa

Onion is a biennial vegetable grown in temperate zones as an annual. In the tropics the varieties that do well are in effect annuals as they can produce seed within the first year of growing. Nutrient-wise 100g of onion provides about 30 g calcium, 0.5 mg of iron, vitamin B, 0.2 mg of riboflavin, 0.3 mg nicotinamide, and 10 mg ascorbic acid (vitamin C).

In general, onions are used for salads (bunching onion or sliced full-grown bulbs), pickling (for example, silverskin onions), cooking (such as in soups) and frying (for example, with meat). Onions are particularly suited to smallholder farming in most countries. It also plays an important role in traditional medicine (for example, as a diuretic). In the tropics onions can be grown year round where irrigation is possible.

Nutritive Value per 100 g of edible Portion

Raw Vegetable	Food Energy (Calories)	Protein (g)	Carbohydrates (g)	Ash (g)	Calcium (g)	Phosphorus (mg)	Iron (mg)	Potassium (mg)	Vitamin A (I.U)	Thiamine (mg)	Ribofl (mg)

Onion, Mature, Dry	**38**	**1.5**	**8.7**	**0.6**	**27**	**36**	**0.5**	**157**	**40**	**0.03**	**0.04**
Onion, Green Bunching	**36**	**1.5**	**8.2**	**0.7**	**51**	**39**	**1.0**	**231**	**2000**	**0.05**	**0.05**

Climate conditions, soil and water management

In temperate zones onion is cool-season biennial, and is tolerant to frost. They produce bulbs with growing day lengths. Optimum temperatures for plant development are between 13 and 24°C, although the range for seedling growth is narrow, between 20 and 25°C. High temperatures favour bulbing and curing. In the tropics only short day or day neutral onion varieties will form bulbs. These thrive in warm to hot climates of 15-30°C. If the temperature greatly exceeds that required for bulbing, maturity is hastened and bulbs do not grow to maximum size, consequently lowering the yields.

Onions can be grown on any fertile, well-drained, non-crusting soil. The optimum pH range is 6.0 to 6.8, although alkaline soils are also suitable. Onions do not grow well in soils below pH 6.0. On light sandy soils irrigation is necessary. Irrigation could be either overhead or on drip. Onions at the bulbing stage need a substantial amount of water, but excessive moisture must be avoided during the growing season. Avoid application of fresh manure to the crop, as this will cause the plants to develop thick necks and too much leaf at the expense of bulb formation.

Propagation and planting

Prior to planting, soils should be ploughed and disked sufficiently to eliminate debris and soil clods. In most commercial areas, beds 0.9 to 1.0 m wide are common, and two to six rows are seeded or planted on the bed.

If two rows, they may be two-line (twin) rows with plants staggered to achieve proper spacing and high population density.

Proper seed selection is recommended to minimise problems of splits and doubles. Over-fertilization, uneven watering, and temperature fluctuations also influence bulb formation. Onion is propagated by seed (most common in the tropics) or sets (immature bulbs ripened during the previous season - temperate zones).

Onion nursery

© A.A.Seif, icipe

In the tropics the seed is usually sown in a nursery under a mulch cover. In the nursery prepare raised beds maximum 1 m wide and incorporate plenty of well-decomposed compost as well as additional rock phosphate. Make rows about 15 cm apart, sow the seeds and cover lightly with soil and mulch. Irrigate liberally for the first 10 days. Seed rate is 2-3 kg per ha. After the seed emerges, the mulch is removed. About 6-8 weeks after sowing, when the seedling has a base as thick as a pencil and is approximately 15 cm tall, the seedlings are transplanted to the field.
The ultimate yield of onion is determined by the number of leaves that are formed prior to bulbing.

Common varieties grown in Africa (short day or day neutral varieties)

- **'Red Creole'. This is a popular standard variety in high demand because of its good keeping quality. It produces mainly single onions from transplants, red, flat-round and with a pungent taste.**
- **'Red Tropicana': Red bulbing type**
- **'Red Tropicana F1 Hybrid'. Produces large, red, thick flat onions with firm pungent flesh. It is highly productive and therefore demands high levels of management. It keeps well in dry aerated store.**
- **'Bombay Red'. It is a variety for dry and warmer conditions. It is small to medium sized, globe shaped, purplish red and pungent.**
- **'Yellow Granex FI Hybrid'. This is an early maturing high yielding attractive, thick flat onion with thin yellow**

scales. The flesh is medium firm, crisp and mild in flavor. The shape and size is uniform leading to higher market prices, and the storage quality is good.

- **'Texas early Grano'. This is a fresh market, early maturing variety with a rather short shelf life. It is yellowish, mild and not very pungent. The bulbs are high top shaped with dry yellow scales. It is a heavy yielder for altitude regions.**
- **'White Creole'. This is a white variety normally used for dehydration.**
- **'Green bunching': Non-bulbing spring onion**

When buying seed and not recognizing the variety name as one of the above, ask if it has been grown in Africa before. If not, better stick to a known variety in order not to lose the whole production.

Planting systems

- **Nursery seeding and transplanting is the most common and practical option in the tropics. Transplants normally have three to five well-formed leaves at transplant time. Roots are pruned during planting, in order not to be bent upwards when transferred to the field. This facilitates early establishment of the plant.**
- **Any germinated bulb of above mentioned varieties would produce 3-6 good size bulbs in about 3 months when planted with the rains. Choose only healthy bulbs for propagation.**
- **Sets are used in some areas in the temperate zones to ensure large bulb size and uniform maturity. Sets are small dry bulbs, approximately 12 mm in diameter, which have been produced the previous season by seeding thickly or growing under conditions that favor rapid bulbing.**
- **Direct seedling is possible and gives excellent results where herbicides can be used and the season is sufficiently long to provide early pre-bulbing growth. In the tropics this method is impractical due to enormous weeding costs in an organic system.**

Husbandry

Do not plant onions after the field has been planted with other Allium plants (for example, garlic). Mulching

onions with composted leaves and straw is highly recommended to maintain soil organic content, prevent soil borne diseases, and suppress weeds. Planting onions in raised beds improves drainage and prevents damping-off diseases.
Weeding and harvesting are mostly done by hand, although chemical weed control is possible but not organic.
Crop rotation is important to avoid the build-up of pests and diseases such as nematodes, *Sclerotium* and *Fusarium*.

Nutrient management
Onions respond very well to well decomposed organic manure. Organic manure at 25 to 40t/ha is recommended to obtain high bulb yield.

Harvesting

Harvesting takes place 90-150 days after sowing. Onions are ready for harvest when the leaves collapse. Alternatively the leaves can be bent over and left to dry for 10-12 days. The crop is pulled out by hand and kept for some days in the field with the bulbs covered by the leaves (= windrowing). The leaves are then cut off and the mature bulbs are bagged or packed in crates if they are to be stored.

Freshly harvested onions are dormant and will not sprout for a variable period of time (this depends on the variety). Storage will extend the dormant period. Sprouting will increase in storage temperatures above 4.4°C. It will decrease again as temperatures exceed 25°C.

Information on Diseases

Purple blotch (*Alternaria porri*)

Purple blotch attacks onion, garlic, leek and other *Allium* crops. Initially, small white sunken spots develop on the leaves. These enlarge and under moist conditions, turn purple with a yellowish border and are often covered with a sooty deposit of spores. After 3-4 weeks the leaves turn yellow and collapse. Bulbs may also

be attacked, mainly at the neck. This can be seen as a yellow to reddish watery rot.
A good timing of sowing or transplanting can minimize purple blotch attack by *A. porri*, depending on the local environmental conditions. The fungus requires rain or persistent dew for reproduction. It can grow through a wide temperature range of 6 to 33.8° C. Optimum temperature of fungal growth is 25° C.

What to do:

- **Varieties with waxy foliage are generally more resistant than those with glossy leaves.**
- **Increased ploughing between seasons may reduce the disease.**
- **Increased spacing between plants also may reduce disease development.**
- **]Other good practices include seed treatment, rotations, removal of crop debris and planting in well-drained soil.**
- **Under conventional production system fungicides are used when the disease is severe. In organic production systems no direct measures are allowed.**

Purple blotch
Purple blotch on onion. Leaf-tip dieback is a typical symptom of infection by *Alternaria porri* on onion and shallot.

Downy mildew (*Peronospora destructor*)

It attacks young plants, appearing as white specks, usually confined to the oldest leaves of young plants. A greyish white mould develops rapidly in cool damp weather and progresses down the sheath, and plants eventually fall over and dry up. Optimum temperatures for fungal growth are between 13 and 20° C. Because of the temperature requirements of the fungus, the disease is more serious in higher cooler areas.
The fungus survives in seeds, bulbs, sets, and on plant debris. Spores are carried long distances by air currents. The fungus can infect onion, Welsh onion, Egyptian onion, garlic, shallot, leek and possibly some other species of *Allium*.

What to do:

- **Use healthy seeds or sets**
- **Use resistant varieties, if available**
- **Rotate at least 3-years free of onions**
- **Wider spacing of plants help reducing humidity**
- **Preventative treatments with rock powder can reduce the attack of this disease.**

Downy mildew
Downy mildew (*Peronospora destructor*) on onion



Downy Downy Downy

mild… mild… mild…

Bacterial soft rots (*Erwinia carotovora* subsp. *carotovora*)

This is a big cause of loss in storage onions. Bacteria *Erwinia carotovora* subsp. *carotovora*) can enter the neck tissue as plants mature and then invade one or more scales. At this stage, the affected tissues are water-soaked and pale yellow to light brown. As the rot progresses, the invaded fleshy scales become soft.

Diseased bulbs can be diagnosed by pressing on the bulb: a watery, foul-smelling fluid often can be squeezed from the neck of diseased bulbs.

Bacterial soft rot bacteria enter only through wounds. Onion maggots (*Delia antiqua*) may carry the bacteria and introduce them while feeding. Onions with mechanical injuries, bruises or sunscald under warm, humid conditions are particularly susceptible to bacterial soft rot. Soft rot can affect many vegetables including carrots, celery, potato and parsnip.

What to do:

- **Onion tops should be allowed to mature well before harvesting**
- **Care should be taken to avoid bruising during harvesting and packing**
- **Storage places should be well ventilated to avoid accumulation of moisture on the surfaces of bulbs**
- **Onions should be stored at 0° C and a relative humidity (RH) of 65 - 70%.**

Soft rot on carrot
Bacterial soft rot caused by (Erwinia carotovora var. carotovora) - here on carrot

Soft rot o…

Onion fly

Slippery skin (*Pseudomonas allicolai* pv. *allicola*)

There are no symptoms on the outer surface of bulbs during early stages of disease development. When the bulb is cut open lengthwise, one or more of the inner scales can be found water-soaked or appears as if it has been cooked. The rot does not progress crosswise in the bulb. After the decay has progressed, the tissue begins to dry, the onion shrivels and secondary organisms can enter and cause a wet rot. The base of the bulb can be pressed hard enough to cause the centre core to slip out at the top, and for this reason the disease is known as slippery skin. The disease is favoured by high moisture.

What to do:

- **Proper maturing of the crop**
- **Quick drying after harvest**

- **Proper storage as in the case of bacterial soft rot**

Sour skin (*Pseudomonas cepacia*)

In contrast to soft rot and slippery skin, infected scales are not water-soaked but are slimy and yellow. Symptoms usually visible only after onions are dug. The upper portion of the bulb shrinks, and in advanced stages of the disease, the outer dry skin readily slips off during handling while the centre of the bulb still remains firm. Outer layer of scales often becomes darkened and almost orange. Decay of inner scales leads to a soft rot that has a sour, vinegar-like odour. The disease is favoured by wet warm conditions.

What to do:

- **Management measures for the disease are the same as for slippery skin.**

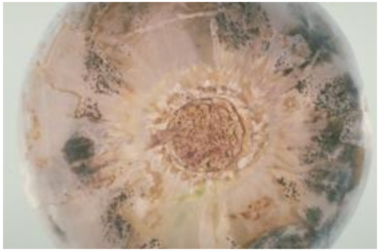
Sour skin
Sour skin (*Pseudomonas cepacia*) of onion.

Anthracnose (Onion smudge) (*Colletotrichum circinans*)

It usually appears in fields just before harvest and continues to develop during storage period. Under warm and wet soil conditions, it can cause seedling damping-off. The most common symptom is the small dark green or black stains (dots) on outer scales of bulbs. The dots develop concentric rings. In severe cases, the fungus attacks the living tissue causing a collapse of fleshy scales. On colored onions, the fungus is restricted to the neck of the bulbs making the flattened leaves colorless. The fungus survives on onions, sets and in the soil. Warm moist conditions favor development of the disease.
Optimum temperature for infection is from 23.9 to 29.4° C. White onions are very susceptible to the disease. Reduced market value results from marred bulb appearance and bulb shrinkage. It also attacks leeks and shallots.

What to do:

- **Disease management involves growing coloured varieties where smudge is a persistent problem.**
- **Harvesting the crop promptly**
- **Avoiding exposure to rain between harvest time and storage.**



Anthracnose
Anthracnose (*Colletotrichum circinans*) on onion
© Denis Persley, www.ecoport.org

White bulb rot (*Sclerotium cepivorum*)

The disease occurs mainly in the field and seldom causes injury in storage. The disease is called white rot because of characteristic basal bulb rot where the tissue is covered with white mat of fungal growth. Later numerous rounded black fungal bodies (sclerotia), each about the size of a pin's head, develop. The leaves of diseased plants decay at the base, turn yellow, wilt, fall over and die. The older leaves are the first to die. The roots of affected plants are usually rotted making the plants easy to pull.
Optimum temperature range for infection is from 15 to 18.3° C. The fungus survives in the soil as sclerotia and also in diseased onion sets and wild onion. It is most severe in light cool moist soils. Its host range includes Welsh onion, garlic, leek, shallot and some species of wild onion.

What to do:

- **Plant tolerant / resistant varieties, if available.**
- **Use healthy seeds**
- **Practice long rotation (8-10 years)**
- **Destroy wild onions and leeks**
- **Manure from animals fed on diseased plant material should not be used on onion fields.**

White rot
White (bulb) rot (*Sclerotium cepivorum*). Symptoms on onion bulbs. Infected onion bulbs displaying sclerotia (black) and hyphae (white) on the base.
© Dean A. Metcalf. Reproduced from the Crop Protection Compendium, 2006 Edition. © CAB International, Wallingford, UK, 2006.

Onion rust (*Puccinia porri*)

Affected leaves show small reddish to dusty orange spots (pustules). These later turn black and are covered until maturity by leaf epidermis. Leaves that are heavily infected turn yellow and die prematurely. A new crop of leaves may develop and the bulb size is usually reduced. The fungus attacks also leek, shallot and some wild species of *Allium*. The disease is favoured by high humidity coupled with moderate to low temperatures. Also excessive nitrogen in the soil favours disease development.

What to do:

- **Disease management involves rotation, and removal of weed hosts.**

Rust
Rust (*Puccinia porri*) on onion
© A.M. Varela, icipe

Fusarium basal rot (*Fusarium oxysporium* f.sp. *cepae*)

The above ground symptoms constitute yellowing of leaf blades at the tip. The yellowing at later stages cover the whole blade. The affected leaves shrivel and decay. Diseased plants can be easily pulled out because the root system is rotted. Affected roots are dark brown, flattened, hollow and transparent. When diseased bulbs are cut vertically, a brown discoloration is evident. The fungus survives in any soil moisture that permits crop

growth. Infection is facilitated by injuries to root system, Losses can occur in the field and in storage.

The disease is most prevalent where onions are grown under high temperature conditions. Although of no economic importance the disease could attack garlic, shallots, chives and leeks. It also can survive in weed, *Oxalis corniculata*.

What to do:

- **Rotate with non-related crops**
- **Avoid root injury**
- **Carefully harvest the bulbs**
- **Proper cure the bulbs before storage**
- **Store the bulbs at 0° C / 65-75% relative humidity is recommended**

Fusarium basal rot
Fusarium basal rot (*Fusarium oxysporium* f.sp. *cepae*) on onion
© David B. Langston, University of Georgia, Bugwood.org

Information on Pests

Onion thrips (*Thrips tabaci*)

The onion thrips are major pests of onions throughout Africa. The onion thrips attack an extensive range of

crops, including cereals and broadleaved crops. They are tiny (1 mm in length), slender and very mobile insects. Adult thrips are pale yellow to brown in colour. Immature thrips are whitish to pale yellow. Both immature and adult thrips pierce the upper surface of the leaves and feed on the plant sap, generally on the developing leaves, deep inside the plant. This results in white and silvery patches on the leaves.

The excreta of the thrips are clearly visible as small black dots on the silvery leaves. Severe infestations can cause browning of the leaf tips, slowing of plant growth, distortion of leaves and bulbs, and reduction in bulb size. Although thrips feeding during the early bulbing stage is the most damaging to yields, thrips must be controlled before onions reach this stage so that populations do not exceed levels that can be adequately controlled. Onions can tolerate higher thrips populations closer to harvest.

What to do:

- **Thrips infestations are more severe in dry seasons, and entire fields may be destroyed. To prevent infestation, keep plants well irrigated. Dry plants are more susceptible to thrips damage than well watered ones.**
- **Remove weeds, as the thrips population builds up on them.**
- **Remove heavily infested plant material.**
- **For control, neem extracts can be sprayed on attacked plants. However, care should be taken, since some neem preparations, in particular those with high oil content, can be phytotoxic to onions, specially at high concentrations (Schmutterer, 1995).**
  Therefore, when using a neem-based pesticide for the first time, it should be first tested for phytotoxicity on some plants. For more information on neem click here.
- **Also a garlic bulb extract can be sprayed thoroughly on the whole plant, preferably early in the morning. Spraying should be particularly directed to the neck area of the plant for good penetration into the plant. For information on garlic bulb extract clik here.**
- **Spray with insecticide 'Spinosad'. When using pesticides, read product label and ensure preharvest interval is observed**

Thrips
Thrips (*Thrips tabaci*) on onion. Leaf scaring injury.
© Whitney Cranshaw, Colorado State University, www.insectimages.org (Courtesy of EcoPort, www.ecoport.org)

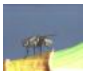
Onion fly (*Delia antiqua*)

The larvae of the onion fly, also called onion maggot is a major pest of onions. The maggot is small (about 8 mm in size when fully grown), white-cream coloured. It eats the lateral roots, then tunnels into the taproot and sometimes bores into the base of the stem. Attacked leaves wilt and the leaves turn bluish. The plants become shrivelled or eventually die. The maggots feed just above the base of seedlings killing them. A maggot can attack several seedlings in succession. This causes poor plant establishment resulting in many gaps in the field.
The maggots are also found inside developing onion bulbs. Their feeding exposes the plant to infection by diseases such as bacterial soft rot. Pupae are light to dark-brown in colour, and about 7 mm in length. Pupae are found in the soil near the base of the plant. The adult is a brownish grey fly, somewhat smaller than house flies. When at rest, they keep their wings folded one over the other. Adult flies do not cause damage. They lay eggs in the soil surface near the germinating plants.
Onion maggots are adapted to cool, wet weather, so usually they are less of a problem during hot dry periods. They prefer soils heavy in organic matter. The onion maggot attacks plants related to onion such as leeks, shallots and garlic.

What to do:

- **Avoid planting in soils that are high in undecomposed organic matter, such as fields just coming out of pasture or in very weedy conditions. Flies prefer to lay eggs in soil that is moist and with high organic matter. Do not plant onions unless the plant residues are dry and completely decomposed.**
- **In soils amended with animal manures, allow adequate time for the manure to break down before planting.**
- **Avoid planting successive onion crops. Practice rotation with crops not related to onions.**
- **Keep onion fields well separated. Onions grown in the season following an attack by onions flies should be sown as far away from infested land as possible.**
- **emove and destroy infested plants and burn them.**
- **To prevent an infestation with onion flies, carefully plough-under crop residues immediately after harvest.**
- **Turn soil to destroy pupae.**
- **Powdered hot pepper or powdered ginger placed around the stems helps when the onion fly population is moderate.**
- **Neem-based products have a deterrent effect on egg-laying. For more information on neem click here.**

Onion fly
Onion fly maggot (*Delia antiqua*) on onion
© Jarmo Holopainen

Onion Onion

fly **fly**

Leafminers (*Liriomyza* spp.)

Leafminers may cause damage to green onions. Damage is largely cosmetic, and mining on leaves may cause rejection of marketed onions, but generally does not affect plant growth. Damage in dry onions and garlic is of little concern unless populations become so high as to prematurely kill foliage.

What to do:

- **Leafminers are usually controlled by natural enemies, especially parasitic wasps. They can become a problem in areas with a high use of pesticides that kill natural enemies. Leafminers have the ability to develop resistance to pesticides in a short time. For more information on natural enemies click here**

Leafminer
Leafminer (*Liriomyza* spp.) symptoms on onion
© Ooi P. (Courtesy of EcoPort, www.ecoport.org)

Fresh Quality Specifications for the Market in Kenya

The following specifications constitute raw material purchasing requirements

PRODUCE:	ONION
IMAGE:	
VARIETY:	Various Red
OTHER NAMES:	Creole
GENERAL APPEARANCE CRITERIA	
COLOUR	With purple-red skin and purple-red edges on the white fleshy scales.
VISUAL APPEARANCE	Well-formed shape with smooth double layer of papery skin covering the overlapping concentric layers of flesh. Remnant cut stem not >50mm and roots not >10mm in length Free from foreign matter.
SENSORY	Firm, crisp texture; sharp flavour, not too pungent. Free from foreign and 'off' smells or tastes.
SHAPE	Squat to rounded squat.
SIZE	Loose 60 - 75 mm
MATURITY	Well cured, no greenery, with tight necks.
INSECTS	With no evidence of live insects.

© S. Kahumbu, Kenya

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Information of www.infonet-biovision.org

Sweet potato

Sweet potato
Scientific name: *Ipomoea batatas*
Family: Solanales: Convolvulaceae
Local names: Viazi vya tamu (Swahili); Makwasi (Kikamba, Kenya); Mapwoni (Luyia, Kenya)
Pests and Diseases: African armyworm Aphids Black rot Diplodia black storage rot Domestic and wild animals Eriophyd mites Fusarium wilt Mild mottle virus Millipedes Rats Root-knot nematodes Sweet potato butterfly Sweet potato hornworm or hawk moth Sweet potato moth Sweet potato virus complex Sweet potato weevil Termites Tortoiseshell beetles Whiteflies Termites

General Information and Agronomic Aspects

Geographical Distribution of Sweet Potato in Africa

Sweet potatoes are perennial vines, with one main season. It is widely grown throughout East Africa on a small scale mainly in subsistence farming and currently gaining popularity again along with other indigenous foods. The roots are eaten either boiled or roasted alone or with other foods such as milk, porridge, soups or meat. Young leaves are used as vegetable. The sweet potato vines are a useful and nutritious fodder crop, especially in the dry season. Some varieties are especially suited for this, producing abundant tops.

Among the great diversity of cultivars grown, two types are commonly recognised. The staple types, grown throughout the tropics, are usually white, red or purple, although yellow-fleshed types are becoming popular in Africa and Asia. The orange-fleshed types, typically have a higher sugar and vitamin A and lower dry matter content. Nutritionists in East Africa are promoting the use of yellow fleshed sweet potato varieties to combat wide spread vitamin A deficiency which decrease children's resistance to infectious diseases, contributing to infant mortality. The young leafy shoots, which are eaten as a green vegetable in some countries, are high in protein (approximately 20% of dry weight), and are also a good source of b-carotene, thiamine (vitamin B1), riboflavin (B2), folic acid and ascorbic acid (Villareal et al., 1985; Woolfe, 1992 quoted from International

Potato Center (CIP) information).

Climate conditions, soil and water management

Sweet potato is grown between latitudes 48°N and 40°S. At the equator it is grown at altitudes ranging from sea-level to 3000 m. Its growth is maximum at temperatures above 25°C; when temperatures fall below 12°C or exceed 35°C, growth is retarded.

Sweet potato is a sun-loving crop; however, it can tolerate a 30-50% reduction of full solar radiation. It grows best with a well-distributed annual rainfall of 600-1600 mm during the growing season. Dry weather favours the formation and development of storage roots. Sweet potato is relatively drought tolerant, however, it cannot withstand long periods of drought; the yield is considerably reduced if drought occurs about the time of planting or root initiation.

Maintaining soil organic matter is probably the most important management practice for managing water supply in rainfed crops. Organic matter incorporated through the soil will help it to hold more water and remain moist for longer. Plant mulches applied to the surface of the soil also help to reduce surface evaporation and keep the soil temperature even. They also prevent soil crusting and improve infiltration when it rains. Weeding is also important, as weeds compete with the crop for water and accelerate soil drying. Uprooted weeds can be left on the soil as mulch.

Where irrigation is available, a number of factors should be considered in irrigation management:

- **The aim is to keep the soil moisture conditions as constant as possible. In general, more frequent, light irrigations are preferred to larger water applications.**
- **Sufficient water should be applied to wet the root zone, without causing deep drainage or run-off. Apart from being wasteful of water, overwatering can cause considerable loss of soil nutrients (leaching) while contaminating the groundwater and streams with the nutrients, which may be directly toxic to people or promote algal growth and eutrofication.**

- **Light-textured (sandy) soils will require more frequent irrigation than soils with high clay or organic matter content. Light-textured soils will also require less water to wet them through, and are more prone to leaching and run-off losses.**
- **The crop's water needs will be much higher in clear, hot and/or windy weather than in still, overcast weather.**

The crop can be grown on a wide range of soil types, but a well-drained, sandy loam with a clayey subsoil is considered ideal. It cannot stand water logging and is usually grown on mounds or ridges. Flooding shortly before harvest may result in storage roots rotting in the soil or during subsequent storage. The optimum soil pH for sweet potato is 5.6-6.6, but it grows well even in soils with a relatively low pH, e.g. 4.2. It is sensitive to alkaline or saline soils.

Sweet potato grows best and produces smooth, well-shaped storage roots in a well-prepared soil. Good land or soil preparation involves removal or incorporation of crop debris and any vegetation that may compete with the sweet potato crop, and deep manual or mechanical cultivation.
Cultivation aims to turn over the topsoil and loosen the compacted soil below, to achieve a good tilth for forming the hills or ridges, and provide a soft, uniform medium where storage root growth is not impeded. This can be achieved by thorough plowing and harrowing, depending on soil condition. Plant mulches, manures or other additives such as lime, gypsum or rock phosphate, that have been applied to the surface, are mixed into the soil for greatest effect. Loosening up the soil increases the oxygen content, which favours the development of microorganisms.

After cultivation, the land is usually prepared into ridges. Mounds are preferred by farmers working entirely with hand tools. In some areas, broad raised beds are used. On deep, well-drained soil, planting may be done on flat fields.
Ridges should be oriented along contours on sloping land, to maximise rain infiltration and minimise erosion. Ridges are typically about 30-45 cm high, but may be higher in wet areas to maximise soil drainage. They are usually between 90 and 120 cm apart.

Propagation and planting

If there is no critical dry season, sweet potato can be planted at any time. In regions with a critical dry season, planting early in the rainy season is the best. It is usually planted towards the end of the rainy season if this is long and very wet.
Sweet potato planting material is either obtained from vine cuttings, the most common source, or from storage roots.

Use of stem cuttings: Farmers obtain cuttings from an established crop before or just after the harvest of storage roots. The cuttings are either used to establish a maintenance field, or directly for planting the next sweet potato crop. Below are some factors affecting yield, when using stem cuttings:

- **Care should be taken to select 'clean' planting material. This means choosing cuttings that are free of insects, soil, and any symptoms of viruses or fungal diseases.**
- **Generally the apical (tip) portion of the vine is better than the middle or basal portions. This portion is less likely to carry sweetpotato weevils and fungal pathogens, and has been found to establish faster than other portions. For cultivars with long vines, the second or third cut is acceptable. Sometimes, the second cutting is better than the tip portion, if vine growth has been so fast that the stem has not matured in the apical portion.**
- **Length of cutting is less important than the number of nodes. Typical size is 20-40 cm, with 5-8 nodes. The conditions of the field may influence the relationship between cutting length and crop development. Farmers should experiment to decide what length is best under their conditions.**
- **Usually one-third to two-thirds of the cutting is buried. A minimum of 2-3 nodes, but up to about 8 nodes, is placed under the soil.**
- **The delay between cutting and planting may affect yield depending on the storage conditions for the cuttings. Storing cuttings for one to two days in humid conditions may be beneficial, promoting rooting at the nodes. Longer storage may adversely affect establishment by exhaustion of the cuttings' energy reserves. To minimise losses, leaves should be stripped from the lower portion of the cutting, and bundles of cuttings wrapped in a wet cloth or sack and kept in a cool, shady place away from wind. If roots develop**

during storage, they should be planted carefully to minimise damage to the roots.

- **If planting material is to be maintained in a multiplication plot before planting of the next crop, plant cuttings at approximately 15 x 20 cm spacing. New growth may be ready for cutting after 45 days.**

Use of storage roots: Storage roots are used when there are insufficient stem cuttings available, or when the level of pest and disease infestation is high so that few healthy vines are left. They may also be used in highly mechanised production, as the sprouts can be harvested mechanically from the seedbed. Healthy storage roots should be selected from plants that produced high yield. The roots are planted densely in a seedbed located away from other sweetpotato crops. Roots are covered with about 3 cm of soil, and the bed covered with straw to help retain moisture. When the sprouts have grown long enough, they are cut near their base and planted directly in the field. To maximise the number of cuttings, remove the tips of the sprouts when they are about 20 cm long to promote branching.

Rapid seed multiplication: When large amounts of cuttings are needed, rapid multiplication may be done. Although the merit of this practice has not been fully acknowledged by sweet potato growers, it can be the easiest way to produce large amount of planting materials. This method involves the following steps:

- **Cuttings of about 30 cm are taken from either established plants or sprouted storage roots. These are then cut into single node cuttings, with the leaf attached. The tip of the vine is discarded.**
- **A seedbed is prepared with a mixture of loose, humus-rich soil and ash. The single-node cuttings are planted at a high density, with the stem section buried and the leaf upright.**
- **The seedbed is regularly watered and is prevented from drying especially during the first week of establishment.**
- **After about two weeks, when the seedlings have developed enough roots, they should be transplanted into the field. They should be removed from the seedbed with care to avoid damaging the roots. Transplanting should be done in the late afternoon to avoid excessive evaporation and wilting.**

Degeneration of planting material

When sweet potato is vegetatively propagated for a number of generations, yield decline is often observed. This is usually due to a build-up of viruses, many of which show no obvious symptoms. This often gives the impression that a new variety (carrying few viruses) yields much better than traditional varieties, when in fact it may be no better after a year or two when viruses have accumulated.

Viruses can be removed by heat treatment and meristem culture (from research institutions). This process usually results in a yield increase from 20 to 200%, of both vines and roots, depending on the severity of the original virus infestation. The higher yield may be maintained for several years in the field, before the virus load has built up again.

Planting method

After ridges or mounds are formed, the sweetpotato cuttings are planted by burying the lower part in the top of the ridge or mound. A hole may be made with a stick or by hand, and the soil gently pressed around the inserted cutting. The stem is usually placed at an angle. Some workers claim that cuttings oriented across the ridge yield better than those oriented along the ridge. In ridge planting systems, ridge spacing is typically 90-120 cm, and in row spacing is 20-30 cm (3-5 plants per meter). Generally, a higher plant density results in lower yield per plant but higher yield per hectare. Close spacing is used with short growing seasons, and wider spacing may be preferred where the market prefers larger storage roots.
For mounds, the size and spacing of the mounds depends on soil conditions. They may be 75-200 cm apart, and may be planted with several cuttings per mound.
Some farmers plant two cuttings at each mound, but there is little evidence that this is advantageous. It has been reported that single cuttings produce a higher proportion of large storage roots.

Varieties

Farmers plant a mixture of varieties, mostly based on yield, performance, maturity, culinary values and tolerance to pests. This strategy reduces the risk of failure since the varieties have different useful characteristics. Sweet potato varieties planted in north-eastern Uganda are presented in the table below.

Variety	Characteristic
"Osukut"	Early maturing, good yield, sweet, good marketability.
"Araka Red"	Early maturing, good yield, tolerant to *Cylas* spp
"Araka White"	Early maturing, good yield.
"Lira Lira"	Early maturing, good yield.
"Ateseke"	Good yield.
"Igang Amalayan"	Early maturing, good yield.
"Latest"	Early maturing, good yield, sweet.
"Osapat"	Good yield.
"Ekampala"	Good yield.
"Tedo Oloo Keren"	Good yield, tolerant to *Cylas* spp.
"Odupa"	Tolerant to *Cylas* spp.

Source: Ebregt et al, 2004.

The varieties grown in Kenya include:

"SPK 013"	Recommended for the western zone including the Lake basin
"SPK 004"	Suitable for most areas in the country
"Kemb 20"	
"Kemb 23"	Suitable for Central and coastal lowlands
"Kemb10"	Suitable for most areas in the country
"KSP20"	Good performance in dry areas
"KSP11"	Good performance in dry areas

"Simama"	
"Japaneese"	
"Mugande"	
"Muibai"	
"Ex-Diani"	Suitable for central and coastal lowlands
"Mafuta"	Best for foliage production. Good for all areas.
"CIP 420009"	Good performance in dry areas

Husbandry

Weed infestation during the first 2 months of growth poses a problem in stand development, and requires adequate control to ensure high yield. Thereafter, vigorous growth of the vines covers the ground effectively and smothers weeds. In the tropics, manual weeding is generally practised.

Sweet potato responds well to fertilisation, particularly if the land has been continuously cropped. However, fertiliser is seldom applied in the tropics. Manure or good compost should be incorporated to improve soil fertility. This is a common practice in smallholdings and traditional agriculture. Sweet potato is used in a wide variety of cropping systems around the world. Rotating sweet potato with other crops such as rice, legumes and maize is desirable to control diseases, pests and weeds. Intercropping sweet potato with other crops is very common in Africa.

Nutritional deficiencies can be determined using the guide provided in the website of the International Potato Center: http://www.lucidcentral.org/keys/sweetpotato

Harvesting

The harvesting period of sweet potato storage roots is not clearly defined; it varies with cultivar, cultural

practices and climate. 'Progressive harvesting' (piece-meal harvesting) is common practice in tropical countries where sweet potatoes are grown for home consumption. It is generally recommended to harvest within 4 months to prevent weevil damage. In the tropics, manual harvesting using implements such as a stick, spade or hoe is practised.

Information on Pests

Sweet potato weevil (*Alcidodes erronus*)

The sweet potato weevil is the most destructive insect pest of sweet potato in the tropics and subtropics. No resistant source is available.

Farmer experience: In Kilifi, Kenya, farmers create planting mounds or ridges incorporating a good amount of fresh leaves of Lantana camara before planting sweet potatoes. This improves soil organic matter and at the same time serves as a repellent of the sweet potato weevil, thus improving both yield and quality of harvested tubers. The superior quality of sweet potatoes grown using Lantana leaves have been confirmed by Ministry of Agriculture staff in the area.

What to do:

- **Rotation with cereals and forage crops**
- **Eradicate Ipomoea weeds**
- **Use clean planting material, deep planting and regular hilling to fill soil cracks around plants**
- **Flood to drown the weevils**
- **Hill up to prevent or fill soil cracks**
- **Irrigate to prevent soil cracks**
- **Mulch to keep the soil moist and prevent cracks, and provide a more favourable environment for natural enemies**

Sweet potato weevil
Sweet potato weevil (*Alcidodes erronus*). Adult female, body length 6-8 mm.

Sweet pota…

Sweet pota…

Root-knot nematodes (*Meloidogyne* spp.)

The nematodes belong to *Meloidogyne* spp.. Symptoms consist of poor growth, yellowing of foliage and or wilting of plants during dry hot weather. Root swellings or galls develop on feeder roots. Harvested roots often are misshapen, cracked, and rotted on the surface.

What to do:

- **Use resistant varieties, if available.**
- **Rotate with cereals and forage grasses.**

Root-knot nematodes
Roots infected with Root-knot nematodes. Field symptoms are typically of stunted, poorly growing plants with yellowing leaves. Infected root systems show characteristic knots or galls.
© H.J. Jensen (Reproduced from CABI 2006)

Millipedes

Apart from insects other pests reported to cause damage to sweet potatoes are millipedes. They are also known as "thousand-legged worms" or "Mombasa train". They have many legs (30-400) with a hard-shelled, round segmented body and are up to 30 cm long. They are brown to blackish brown in colour. They move slowly and curl-up when disturbed. Millipedes lay eggs single or in clusters of 20-100 in the soil. They live in moist soil and congregate around the plants in soil that is rich in organic content. They dry out easily and die. Thus, they seek wet places, such as compost piles, leaves and other plant debris, to hide under during the day.

Millipedes have recently become important pests of sweet potato in some areas of East Africa. Infestation tends to be severe at the beginning of the long rainy season often causing farmers to plant late. According to farmers in Uganda, millipedes generally do not affect the roots until 5 months after planting. They may be a problem when harvesting of sweet potato is delayed, especially if the roots are stored 'in-ground on the plants' during the dry season and harvesting is done at the first rains of the following growing season. Millipedes maybe a problem in nurseries located in shady sites (for example under a tree), especially if the

nurseries are used for long time.

What to do:

- **In areas where millipedes are a problem, do not rotate sweet potatoes with crops that are also attacked by millipedes, in particular groundnuts, and to a lesser extent cassava and beans.**
- **Some varieties are perceived by farmers in Uganda to have some tolerance to millipede damage: "Araka White","Tedo Oloo Keren", "Latest", "Lira Lira", "Odupa", "Ajara", "Bibi", "Chapananca", "Dyong Bar", "Josi-Josi" and "Acan-Kome-Tek".**

Millipedes
Millipedes are brown to blackish in colour and curl-up when disturbed.
© Agricultural Research Council of South Africa, EcoPort

Domestic and wild animals

Domestic animals (e.g. pigs, cows and goats) and wild animals (e.g. wild pigs, porcupines, baboons, monkeys, elephants, hippos, guinea fowl) can cause serious damage to sweet potatoes.

What to do:

- **The presence of hedges or thorn fences may act as deterrents against some of these pests.**
- **Domestic animals can be tethered. This is particularly important during the planting material production**

time when there is a high incidence of damage due to grazing by straying livestock.

Rats

Rats and mole rats occasionally feed on sweet potato storage roots either by digging through the ridges or accessing the exposed roots. They often spoil more roots than they actually eat. Rats and mice breed in burrows, destruction of these burrows can help reduce populations. Rodents like to hide in vegetation and rubbish, as they do not like crossing open spaces where they may be seen and exposed to predation, keeping the field and surrounding areas clean should reduce damage.

What to do:

- Some farmers dig a deep ditch around the perimeter of their field to deter rodents from digging tunnels straight into their fields.
- Traps can be set but care must be taken to ensure they are placed in locations where livestock and children will not interfere or get hurt by them.
- In areas of Tanzania farmers reported spreading the leaves of the local shrub 'intwinti' as a repellent.
- In Western Kenya a mixture of cow dung and pepper is made, placed in the burrows and then burnt to smoke the rodents out.
- Experiments showed that mole rat damage to cassava could be reduced by planting on mounds rather than ridges, and by planting the deep rooted, poisonous shrub Tephrosia vogelii in the field (CIP, the VITAA Partnership).
- Farmers in Wangige, Kenya chase away mole rats by pouring fermented cattle urine (one week old) into their burrowing holes. They report this method as being very effective.

The sweet potato butterfly (*Acraea acerata*)

It is found in all sweet potato production areas in Eastern Africa, but is only considered an important pest in relatively dry areas. The adults are butterflies with orange wings with black margins. These butterflies are capable of flying distances of several kilometres. They lay small, pale yellow eggs in clusters on leaves. Caterpillars are greenish-black and are covered with short-branched spines. Fully-grown caterpillars are about 25 mm long. Caterpillars feed on leaves of sweet potato. Young caterpillars feed in groups on the upper leaf surface protected by a layer of webbing for the first two weeks.

Older caterpillars become solitary and nocturnal hiding on the ground during the day. They eat the whole leaf leaving only the midribs. Heavy attack may result on complete defoliation. Mature caterpillars crawl up supports such as tall grasses, leaves or walls near the sweet potato field in order to find a site to pupate in vertical position. The pupae are yellowish and hang singly on their support. The total lifecycle takes 27-50 days. Caterpillars are attacked by predatory ants, ladybird beetles, lacewings and dragonflies. The fungus *Beauveria bassiana* has been observed on caterpillars in the field during the rainy season.

What to do:

- **Look for sweet potato butterflies and damage early in the season and destroy caterpillars in webs **Use clean uninfested planting material**Plant and harvest early. This enables the crop to escape heavy attacks**Intercropping sweet potato with onion/ or the silver leaf desmodium (Desmodium uncinatum) might reduce the number of eggs laid by the females (CIP, the VITAA Partnership)**

Sweet potato butterfly
Sweet potato butterfly (*Acraea acerata*) with orange and black wings with brown margins; 3-4 cm wingspan

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Beet armyworm (*Spodoptera exigua*)

Armyworms may damage sweet potatoes. Young caterpillars scrape sweet potato leaves, while the older caterpillars feed producing large irregular holes and may leave only the veins. Mature caterpillars measure up to 4 cm long and are generally black, heads faintly mottled with dark brown spots and with light yellow stripes at their backs (IRRI, 2001).

Predatory bugs, carabid beetles, spiders and wasps attack the caterpillars, and many parasitic wasps are also known to attack armyworms. Fungal diseases have been observed infecting caterpillars in the field.

What to do:

- **Eliminate weeds**
- **Collect and destroy leaves containing eggs and caterpillars**
- **Light traps can be hung over basins of water in the field to trap the adults at night**
- **When necessary the biopesticide Bt can be used for control of this pest. For more information on Bt click here.**

Beet armyworm
Fully grown larva of Beet armyworm *(Spodoptera exigua)*
© A.M. Varela, ICIPE

Sweet potato moth (*Omphisa anastomasalis*)

The sweet potato moth is a minor pest in West Africa. Damage to sweet potato plants results from the caterpillar boring into the main stem leading to the roots. Vines with severe tunnelling show weak growth and poor foliage development; this foliage later yellows and wilts. The distal part of the vine above the damage site often dies. Such plants show poor storage root formation. In some cases caterpillars may bore directly into storage roots.
This moth is a pest in Asia, but its status in East Africa is unknown.

What to do:

- **Handpick caterpillars or attacked vines and destroy them. This is feasible in small plots.**

Sweet potato moth
Sweet potato vine borer larva (*Omphisa anastomasalis*) on sweet potato (2.5-3 cm long)

Sweet potato hornworm or the hawk moth (*Agrius convolvuli*)

Adults are large grey hawk moths with black lines on the wings and broad incomplete pink bands on the abdomen. The female lays small spherical greenish eggs singly on either surface of the leaves. Caterpillars have a conspicuous posterior horn. They are variable in colour, usually greenish or brownish. Fully-grown caterpillars are large (up to 9.5cm long and 1.4cm broad). They pupate in the soil.

Caterpillars feed on leaves, causing irregular holes. They may eat the entire leaf, leaving only the petiole. Insect frass can often be found near the infested plant part. One large caterpillar can defoliate a plant on its own. When older caterpillars are present in large numbers they can defoliate a field overnight. Yield losses can occur if heavy defoliation takes place when the crop is young. But, if the young plants are healthy and growing well, they can recover. However, damage to the leaves may delay harvest, increasing the likelihood of attack by the sweet potato weevil.

What to do:

- **Handpick caterpillars from leaves. This is usually sufficient in small areas.**
- **Turning the soil over between crops exposes the pupae to predators and to the sun heat.**

- **Light traps can be used to monitor the population of moths.**
- **Manual removal of small caterpillars can prevent the build-up of a large population of older caterpillars.**

Mature larva of Sweet potato hornworm larvae (*Agrius convolvuli*) on *Merremia peltata*. Mature larvae reach 9 - 10 cm in length.

Tortoiseshell beetles (*Aspidomorpha* spp.)

Adults are broadly oval and shield-like, 6-8 mm long, and may be brightly coloured. They lay eggs singly or in batches on the underside of sweet potato leaves; sometimes the eggs are covered by a papery layer. The larvae are oval, flattened and spiny. Some species of tortoiseshell beetle larvae hold their tails up over their back, usually with excreta and previous cast skins. The pupa is less spiny than the larva, and is fixed to the leaf.

Both larvae and adults feed on leaves. The young larvae scrape on the upper surface of the leaves leaving the lower surface intact, while older larvae and adults eat large round holes in the leaves. Severe attacks can sometimes skeletonise the leaves and peel the stems. The damage on leaves is conspicuous, but generally is not of economic importance.

What to do:

- **Usually control is not necessary, removal of nearby alternative host plants may reduce the tortoiseshell beetle populations.**
- **Alternatively, planting far away from alternative host plants may help reducing damage to sweet potatoes. Alternative host plants include morning glory, coffee, potatoes, beets, and various flowers.**

Tortoiseshell beetle
Tortoiseshell beetle (*Aspidomorpha* sp.) is 6-8 mm long.
© Ooi P. / Shepard B.M. Courtesy of EcoPort (www.ecoport.org)

Whiteflies (*Bemisia tabaci*)

Whiteflies feed on the lower leaf surface. Direct damage by adults and nymphs sucking sap from the plant, is generally not economically important. However, high numbers of whiteflies may affect plant development, particularly during period of water stress and drought. They are more damaging as vector of virus diseases.

What to do:

- **Conserve natural enemies. Parasitic wasps and predators such as predatory mites, ladybird beetles, and lacewings are important in natural control of whiteflies.**
- **Spray neem extracts. Neem products inhibit growth and development of immature stages, repel whitefly adults and reduce egg laying.**

Whiteflies under leaf
Whiteflies under leaf. Adults are small (1-3 mm long).
© A.M. Varela, icipe

Aphids (*Aphis gossypii* and other species)

Aphids suck sap from leaves and stems. They may cause considerable damage during periods of water stress. Aphids are vectors of virus diseases.

What to do:

- **Conserve natural enemies. Aphids are attacked by a wide range of natural enemies, which are very important in natural control of these pests.**
- **Use reflective mulches. Reflective aluminium mulches deter aphids from landing on plants. The effect is lost once plants are large enough to cover the mulch.**
- **Neem extract and soap sprays have been reported effective against aphids. For more information on neem click here. For more information on soap sprays click here.**

Aphids
Cotton aphid (*Aphis gossypii*) is a small aphid. Adults range from just under 1-1.5 mm in body length.

Eriophyid mites (*Aceria* sp)

They causes hairiness on sweet potato, a common problem in many parts of East and Southern Africa also known as "erinose". Eriophyid mites are tiny, much smaller than the spider mites (about 0.2 mm long) and look like a speck of dust. They are not visible with the naked eye. The mites feed in the buds and on young foliage of sweet potato plants, injecting growth substances into it, which induce the plant to produce a dense mat of hairs. As a result the stems, leaf petioles, buds and undersides of leaves become covered with a dense layer of white hairs. The leaves and plants are also generally slightly stunted; the leaves and stems thickened, and the plants yield poorly.

Occasionally, whole crops are affected but often the symptoms affect just one or a patch of plants, and often only particular varieties. The mites invade crops by being blown like dust particles in the wind.

What to do:

- **Little is known about them despite their commonness and little is known about how to control them.**
- **Some varieties of sweet potato seem more prone to infestation than others but no research has been done so far. Where hairiness is a problem, farmers could plant varieties that are least affected.**

Information on Diseases

Black rot (*Ceratocystis fimbriata*)

The disease is caused by the fungus *Ceratocystis fimbriata*. Dark circular spots appear on infected roots. These spots can expand to cover much of the sweet potato. Small black fungal fruiting bodies (perithecia) develop and are visible at the centre of the spots. The diseased tissue is darkened and bitter in taste. On young sprouts black spots develop eventually encircling the plant causing dwarfing, yellowing of the foliage and finally death.

The fungus survives in the soil in diseased plant debris and also in diseased stored roots. The disease is favoured by temperatures near 25° C and moist soil conditions. In storage, decay progresses most rapidly in moist conditions at temperatures of 14 to 27° C.

What to do:

- **Plant disease-free sprouts.**
- **Practice a 3-year rotation and proper weeding.**
- **Do not wash roots in water after harvest as contaminated water may spread the disease from infected roots to healthy.**
- **Follow good sanitary practices in packing and storage buildings.**

Diplodia black storage rot (*Botryodiplodia theobromae* (*Diplodia tubericola*))

The disease is caused by the fungus *Botryodiplodia theobromae* (*Diplodia tubericola*). It affects sweet potatoes in storage. The inner part of the infected edible root becomes black and brittle. Many tiny black fungal bodies (pycnidia) form just below the sweet potato skin giving the root a pimply appearance. Infection occurs through broken ends and abrasions on storage roots. Wet conditions favour disease spread and development.

What to do:

- Use disease-free sprouts.
- Harvest roots carefully to minimise injuries.
- Do not store injured or wounded roots.
- Practise good storage hygiene and management.
- Ensure good ventilation in the store.

Fusarium wilt (*Fusarium oxysporum* f. sp. *batatas*)

It is caused by the fungus *Fusarium oxysporum* f. sp. *batatas*. Initial symptoms on sweet potato are yellowing of the leaves. Leaves later wilt and fall off, stunting results and eventually death of the plant. Death of the stem vascular bundles occurs with brown to purple discoloration; this may be accompanied by cracking of the stem. The vines may turn tan to light brown. Diseased plants may manage to produce storage roots, but these usually have some discoloured, infected vascular tissues. Rot may follow in storage or the disease may be transmitted to the next crop by infected cuttings. Dying vines often have pinkish fungal growth.

What to do:

- Use resistant varieties, if available.
- Use disease-free planting stocks.

- **Avoid fields with a history of wilt.**
- **To reduce infection near transplanting time is to hold transplants for 24 hours at 29°C to promote suberisation of the injured surface, also yield loss can be reduced by planting more than one transplant per hill. Even though the percent of plants affected is not reduced, yield per unit land is maintained because there is less chance that all plants in a hill will be killed and also because productivity is similar for single-plant and multiple-plant hill.**

Fusarium wilt
Fusarium wilt (*Fusarium oxysporum* f.sp. *lycopersici*) symptoms on tomato plant in field crop.

Mild mottle virus

It is caused by a potyvirus (sweet potato virus B/ sweet potato virus T/ sweet potato ipomovirus). The virus is transmitted by whiteflies (*Bemisia tabaci*). The virus has a wide host range including tomato, tobacco and ornamental species. Symptoms of the disease include leaf mottling and plant stunting. The wishbone flower (*Torenia fournieri*) is a potential wild reservoir host in East Africa.

What to do:

- **Use plant resistant varieties: (e.g. in Uganda the variety "Namujuna").**

- **Use disease-free planting material.**
- **Isolate new plantings from old plantings.**
- **Control the virus vector (whiteflies). For more information on how to control whiteflies click here**

Mild mottle virus
Mild mottle virus symptoms on sweet potato leaf

Sweet potato virus complex

This disease is caused by a combination of sweet potato feathery mottle virus (SPFMV) and sweet potato chlorotic stunt virus (SPCSV).
Symptoms include severe stunting of plants, the production of small distorted leaves, excessive branching, yellowing of vines and dark, brown to blackish corky spots in the roots. SPFMV is a potyvirus transmitted by aphids in a non-persistent manner whereas SPCSV is a crinivirus transmitted in a semi-persistent manner by the whitefly *Bemisia tabaci*.

What to do:

- **Use resistant or tolerant varieties, if available.**
- **Use disease-free planting material.**
- **Avoid diseased plants as sources of planting material.**

- **Practice proper field sanitation.**
- **Control the virus vectors. For information on how to control aphids click here. For information on how to control whiteflies click here.**

Information Source Links

- **AVRDC International Cooperator's Factsheet on Sweet Potato Vine Borer: http://www.avrdc.org/LC/sweetpotato/vineborer.html**
- **Agricultural Information Centre, Nairobi, Kenya (2002). Field Crops Technical Handbook**
- **Blay, E., Cudjoe, A. R. and Braun, M. (eds).(2000). Handbook of crop protection recommendations in Ghana: An IPM approach. Vol. 3: Root and Tuber Crops, Plantains.Published byPlant Protection and Regulatory Services Directorate (PPRSD). with support of the German Development Cooperation (GTZ). ISBN: 9988-8025-6-0.**
- **CAB International (2005). Crop Protection Compendium, 2005 edition. Wallingford, UK**
- **CIP website: www.lucidcentral.org/keys/sweetpotato**
- **CIP. Manual for Sweet potato Integrated Production and Pest Management Farmer Field Schools in Sub-Saharan Africa. The VITAA Partnership.Last Updated June 16, 2004. http://www.cipotato.org/vitaa/manual.htm**
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- **Ebregt, E., Struik, P.C., Abidin, P.E. and Odongo, B. (2004). Farmers' information on sweet potato production and millipede infestation in northeastern Uganda. I. Associations between spatial and temporal crop diversity and the level of pest infestation. http://library.wur.nl**
- **Ebregt, E., Struik, P.C., Abidin, P.E., Odongo, B. (2004). Farmers' information on sweet potato production and millipede infestation in North-eastern Uganda. II. Pest incidence and indigenous control strategies. NJAS - Wageningen Journal of Life Sciences 52: 69-84. http://library.wur.nl**
- **Hill, D. (1983). Agricultural insect pests of the tropics and their control. 2nd edition. Cambridge University Press. ISBN: 0-521-24638-5.**

- Smit, N.E.J.M. (1997). Integrated pest management for sweet potato in Eastern Africa. PhD thesis Wageningen University, Wageningen, 151 pp.
- Wangige Organic Farmers Self Help group, Wangige, Central province, Kenya.
- Youdeowei, A. (2002). Integrated Pest Management Practices for the Production of Root and Tubers and Plantains. Integrated Pest Management Extension Guide 3. Ministry of Food and Agriculture (MOFA) Plant Protection and Regulatory Services Directorate (PPRSD), Ghana, with German Development Cooperation (GTZ). ISBN: 9988-0-1087-7.

Information of www.infonet-biovision.org

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Sorghum

Sorghum
Scientific name: ***Sorghum bicolor***
Family: Cyperales: Poaceae
Local names: Mtama (Swahili)
Pests and Diseases: African armyworm African bollworm African maize stalkborer Anthracnose Aphids Birds Charcoal rot Covered kernel smut Crazy top downy mildew Cutworms Damping-off diseases Ergot Head bugs Head smut Leaf blight Loose kernel smut Maize dwarf mosaic virus Other bugs Purple witchweed Rust Shoot fly Sorghum midge Spotted stemborer Storage pests Termites Chafer grubs

General Information and Agronomic Aspects

In Africa, a major growing area runs across West Africa south of the Sahara almost to the coast and eastward into Sudan, Ethiopia, and Somalia. It is grown in upper Egypt but is minor along the north African coast. It is commonly grown in Uganda, Kenya, Tanzania, Rwanda, and Burundi and fairly important in Zambia, Malawi, and drier areas of Mozambique. It is important in Botswana and Lesotho and common in South Africa,

Geographical Distribution of Sorghum in Africa

and minor in Namibia.

Sorghum is perhaps the world's most versatile crop. Some types are boiled like rice, some cracked like oats for porridge, some "malted" like barley for beer, some baked like wheat into flatbreads, and some popped like popcorn for snacks. A few types have sugary grains and are boiled in the green stage like sweet corn. The whole plant is often used as forage, hay, or silage. The stems of some types are used for building, fencing, weaving, broom making, and firewood. The stems of other types yield sugar, syrup, and even liquid fuels for powering vehicles or cooking meals. The living plants are used for windbreaks, for cover crops, and for staking yams and other heavy climbers. The seeds are fed to poultry, cattle, and swine. (Lost Crops of Africa, Vol I, 1996) Sorghum plays an important role as a food security crop especially in semi arid lands of Kenya. It can survive drought conditions for some weeks by rolling up its leaves and thus decreasing transpiration. Please also check KARI update: "Sorghum helps provide better food security", July 1997, available in English on http://www.kari.org/ENGLISH/Sorghumfood.htm (click to follow link) or in Swahili http://www.kari.org/KISWAHILI/MtamaChakula.htm

Climate conditions, soil and water management

Sorghum is adapted to a wide range of environmental conditions and will produce significant yields under conditions that are unfavourable for most other cereals. Sorghum is particularly adapted to drought.
Sorghum also tolerates water logging and can be grown in areas of high rainfall. It is, however, primarily a plant of hot, semi-arid tropical environments with rainfall from 250 mm that are too dry for maize but performs best with more than 900 mm annually. It is also grown widely in temperate regions and at altitudes of up to 2500 m in the tropics. Sorghum tolerates a wide range of temperatures. Sterility can occur when night temperatures fall below 12-15°C during the flowering period. Sorghum is killed by frost.
Sorghum can be grown successfully on a wide range of soil types. It is well suited to heavy clay soils (vertisols) found commonly in the tropics, where its tolerance of water logging is often required, but is equally

suited to light sandy soils. It tolerates a range of soil pH from 5.0-8.5 and is more tolerant of salinity than maize. It is adapted to poor soils and can produce grain on soils where many other crops would fail.

Propagation and planting

Sorghum is normally grown from seed. A fine seed-bed is preferable but is often not achieved. The seed is usually sown directly into a furrow following a plough, but can also be broadcast and harrowed into the soil. Optimum plant spacing depends on soil type and availability of moisture. For favourable conditions, row spacing of 45-60 cm and plant-to-plant spacing of 12-20 cm, giving populations of about 120 000 plants per ha, are normal. For drier or less fertile conditions, wider spacing and lower plant populations are usually optimal. The seed rate varies from 3 kg/ha in very dry areas to 10-15 kg/ha under irrigation. Occasionally, seedlings are grown in a nursery and transplanted into the field early in the dry season, e.g. on the floodplains round Lake Chad in Africa.

Production zones in Kenya and recommended sorghum varieties and their major characteristics:

Eco-zone and area	Variety	Maturity months	Grain colour	Yield potential Bags/acre
Moist-mid-altitude Busia, Siaya, Kakamega, Kisumu, Homabay, Kuria, Migori, Coffee zones of Meru, Embu and Nyeri Districts	Serena Serodo KARI/MTAMA	3 3.5 3-3.5	Brown Brown Brown	12 12 15
Semi-arid low lands Machachos, Kitui, Makueni, Mwingi, Lower Embu and Tharaka Nithi, Kajiado, Parts of Rift Valley, Parts of North Eastern Provinces	1576 KARI/MTAMA	3 3-3.5	White Brown	10 15
Cold semi-arid Highlands Nakuru, Baringo, Laikipia, Naivasha, Narok,	E 1291 E 6518	7 8	Brown brown	12 15

Parts of Koibatek, Taita Taveta				
Humid Coast Lamu, Kilifi, Taita Taveta, Kwale, Mombasa	Serena Serodo	3 3.5	Brown Brown	12 12

Husbandry

Sorghum is usually grown as a rainfed crop, sown after the onset of the monsoon season. Seeding rates are often higher than optimum to compensate for poor seed-bed or to allow for unfavourable moisture conditions. All sorghum varieties require a fine seed bed for better seedling establishment. If tractor or oxen are used to open up a shamba, it is advisable to harrow after the first ploughing. When jembes (hoes) are used for land preparation, farmers are advised to ensure that large clods are reduced by breaking them to provide a smooth seed bed. The planting field should be prepared well in advance of sowing. Seed rate is 7-10 kg/ ha or 3-4 kg/acre. Dry planting is highly recommended. Thus plant before or at the onset of rains by either drilling in the furrows made by tractor or oxen plough, or hill plant in the holes made by jembe or panga. When dry planted, planting depth should be 5 cm but when planting in a moist soil use planting depth of 2.5-4 cm. Common row spacing is 75 cm and distance between plants about 20 cm. In semi arid areas where the ox plough yoke is fixed at 90 cm especially in Machachos, Makueni, Kitui and Mwingi districts, the recommended spacing between plants is 15 cm.

Subsistence farmers rarely apply fertilizer, as responses depend on moisture availability, which is usually very uncertain. Under more favourable conditions, farmyard manure is used with advantage, but even so the quantities used are usually below optimum. Optimally sorghum needs the availability of about 20 kg N/ha and 20 kg P/ha at planting time, which can be supplied by alternate cropping with legumes and application of compost or manure. Also intercropping with legumes is recommended with grain legumes such as beans, cowpeas, pigeon peas and green gram. Manure and compost improve organic matter content of the soil, soil moisture retention ability and soil structure. Manure can be broad cast in the field or applied in planting furrows and mixed with soil before seeds are planted. The standard farm wheelbarrow when full holds approximately 25 kg of dry manure/compost. At a low rate, two wheel barrows are enough for a 10m by 10m

area. This translates into 200 wheelbarrows or 5 tons/ha. When aiming for high rate apply 400 wheelbarrows or 10 tons per ha.

The crop is usually weeded by a combination of inter-row cultivation with animal-drawn implements and hand weeding within rows. Thinning is carried out at the same time as hand weeding, or at intervals during the crop cycle, particularly where thinnings are used to feed livestock. Gapping by transplanting thinnings is encouraged when thinning is done within 2 weeks after emergence and when the soil is moist.

Sorghum ratooning

Ratooning is a practice of getting more than one harvest from a single sowing. Two ratooning systems have been identified. One in the bimodal rainfall zones in semi arid lowlands giving 2 crops and the other in the moist mid altitude coffee zones where the local varieties are the two seasons ratooning type. A ratoon crop compared to a newly sown crop has an established root system which will utilize the available water in the root zone for crop growth early in the season, reduce ploughing and planting labour and avoid migratory quelea birds in August by maturing early.
In bimodal rainfall zones of semi-arid lowlands in Eastern province sorghum is planted in short rains (October-November). When the crop is mature, it is harvested in February and immediately ratooned to take advantage of the long rain season which starts in mid-March. To achieve good yields, the crop is thinned to 2-3 tillers per hill. Weeding and other management practices are done as for a newly sown crop.

Harvesting

Sorghum is usually harvested by hand when it has reached physiological maturity - which means the grain is hard and does not produce milk when crushed. Cut the heads with sickles or a sharp knife from plants in the field or cut the whole plant and remove the heads later. Sun dry the harvested panicles to a moisture level of 12-13 % and thresh and store the grain. For further information on storage, please also refer to datasheets on grains and legumes e.g. green gram (click to follow link).

Information on Diseases

Anthracnose (*Colletotrichum graminicola*)

The anthracnose fungus damages foliage and stems of grain sorghum. On susceptible hybrids, the stem holding the head (peduncle) becomes infected and a brown sunken area with distinct margins develops. When infected stems are cut lengthwise with a knife, one can see that the fungus has penetrated the soft pith tissue and caused brick-red discolorations. This peduncle infection inhibits the flow of water and nutrients to the grain causing poor grain development.

The fungus also invades individual grains and the small branches of the panicle. Rapid and severe yield loss can result from panicle and peduncle infections. Leaf lesions are small, elliptical to circular, usually less than 3/8-inch in diameter. These spots develop small, circular, straw-coloured centres with wide margins that may vary in colour from reddish to tan to blackish purple. The spots may coalesce to form larger areas of infected tissue.

What to do:

- **Use resistant hybrids**
- **Rotate with non-cereals preferably with pulses**
- **Good management of crop residues**

Anthracnose (*Colletotrichum graminicola*) on sorghum
© Frowd JA, Courtesy of EcoPort, www.ecoport.org

Damping-off diseases

They are caused by various fungi. Seed may be attacked by one or more seedborne or soil-borne pathogens prior to either germination or emergence. This usually occurs when conditions are not optimum for plant development, such as in poorly-drained, cold, wet soils, or in very dry, crusted soils. Sorghum seedlings are very delicate during the emergence period and are slow to establish a permanent root system. As a result, sorghum depends upon its primary, temporary root system for a period longer than many other crops. Under less than optimal growing conditions, this primary root system is extremely vulnerable to soil-borne pathogens. This is when damping-off in a field is most visible and damaging. Affected seedlings are unthrifty and may show yellowing, wilting and death of leaves. Roots of diseased plants may be discoloured (whitish grey to pinkish brown) and rotted.

What to do:

- **Use certified disease-free seeds**
- **Avoid planting in poorly drained soils**

Maize dwarf mosaic virus (MDMV)

Maize dwarf mosaic is a virus disease that occurs over all the sorghum producing areas. Its ability to cause damage is dependent on the presence of an over-seasoning virus host (mainly Johnson grass), aphid populations to facilitate virus transmission and the susceptibility of the varieties being grown. Affected plants have mottled (light green blotches) terminal leaves. These alternate light- and darker-green areas in the leaf

can be more easily seen when held between the viewer and a light source. Observers should always look at the newest leaves for the most severe symptoms. Highly susceptible hybrids are stunted with chlorotic symptoms in the upper leaves and suffer significant yield losses. Some hybrids produce a red leaf symptom when plants are infected and when night temperatures are below 13° C.

What to do:

- **Use resistant/tolerant hybrids**
- **Control Johnson grass in and around the field**

Covered kernel smut (*Sporisorium sorghi*)

The disease destroys all kernels in a head and replaces them with a cone-shaped gall or may affect only portions of a panicle. At harvest time, these galls are broken and spores contaminate the outer surface of other kernels.

What to do:

- **Use of certified disease-free seed**
- **Plant resistant hybrids**

Covered kernel smut
Covered kernel smut (*Sporisorium sorghi*) on sorghum

Loose kernel smut (*Sphacelotheca cruenta*)

It attacks all groups of sorghum including Sudan-grass and Johnson grass. Galls formed by loose kernel smut are long and pointed. The thin membrane covering the galls usually breaks soon after galls reach full size. The dark-brown spores contained in the galls are wind-blown away leaving a long, dark pointed, curved structure (called columella), in the central part of the gall. As in covered kernel smut, the spores of the fungus are carried on the seed and germinate soon after the seed is planted and invades the young sorghum plant. It continues to grow unobserved inside the plant until heading, when the long pointed smut galls appear in the heads in place of normal kernels. Unlike covered kernel smut, this disease stunts the infected plants and often induces abundant side branches.

What to do:

- **Certified disease-free seeds**
- **Plant resistant varieties**
- **Control weeds**
- **Rotation with non-cereals**
- **Practice good field sanitation**

Loose kernel smut
Loose kernel smut (*Sphacelotheca cruenta*) on sorghum

Head smut (*Sporisorium reilianum*)

This disease is characterized by the large, dark-brown smut galls that emerge in place of the panicle. The gall is first covered with a whitish membrane, which soon breaks and allows spores to be scattered by the wind. Plants become infected while in the seedling stage but evidence of infection is not apparent until heading time. The smut gall produces thousands of spores, which become soil-borne and initiate systemic infection of seedlings in subsequent years. Different races of the fungus exist which may result in a sorghum hybrid being resistant in one area but not another.

What to do:

- **Utilize resistant hybrids to avoid losses**
- **Use disease-free seed**
- **Rotation with non-cereals**
- **Plough deep**

Charcoal Rot (*Macrophomina phaseolina*)

Grain sorghum plants affected by the charcoal rot fungus fail to fill grain properly and may lodge in the latter part of the season. Infected stalks show an internal shredding at and above the ground line. This can be observed by splitting the stalk and noting the deteriorated soft pith tissue leaving the tougher vascular strands. Fungal structures (sclerotia) can be observed in the affected tissue, which appears as though it has been dusted with black pepper. Another type of stalk rot (Pythium sp. and Fusarium sp.) may show the shredded condition but the black specks (sclerotia) will be lacking.

Conditions under which charcoal rot is favoured include stressful hot soil temperatures and low soil moisture during the post-flowering period. Host plants are usually in the early-milk to late-dough stage when infection occurs. The fungus is common and widely distributed in nature.

What to do:

- **Avoid moisture stress**
- **Manage properly crop residue**
- **Rotate crop with non-cereals and pulses**
- **Avoid excessive plant populations**
- **Balance nitrogen and potassium fertility levels**
- **Grow drought-tolerant, lodging-resistant hybrids**

Rust (*Puccinia purpurea*)

Rust appears on leaves as small raised pustules or blisters that rupture and release many reddish-brown spores. These pustules occur on both the upper and lower leaf surfaces. This disease usually appears when plants near maturity and infection are confined primarily to mature leaves. Grain yield losses are usually not

serious and occurrence of the disease is sporadic. Forage sorghum yields may be affected most. The rust fungus also attacks Johnson grass and over-seasons on this host.

What to do:

- **Use resistant varieties**
- **Rotate with non-cereals**
- **Control weeds**

Rust
A sorghum rust infection (*Puccinia purpurea*) at this level can cause substantial reduction in yield.
© Nowell DC, EcoPort

Ergot (*Claviceps sorghi*)

Cream to pink sticky droplets "honeydew" ooze out of infected florets on panicles. The droplets dry and harden, and dark brown to black sclerotia (fungal fruiting bodies) develop in place of seeds on the panicle. Sclerotia are larger than seed and irregularly shaped, and generally get mixed with the grain during threshing. Conditions favouring the disease are relative humidity greater than 80%, and 20 to 30°C. The sclerotia falling on the soil or planted with the seed germinate when the plants are flowering. They produce spores that are wind-borne to the flowers, where they invade the young kernels and replace the kernels with fungal growth. The fungal growth bears millions of tiny spores in a sticky, sweet, honeydew mass. These spores are carried

by insects or splashed by rain to infect other kernels.

What to do:

- **Plant resistant varieties, where available**
- **Remove affected panicles**
- **Avoid planting seeds from infected panicles**
- **Plough deep**
- **Rotate with non-cereals preferably with pulses**
- **Practice good field sanitation**

Ergot
Ergot (*Claviceps africana*) on sorghum crop
© Odvody G. (Courtesy of EcoPort, www.ecoport.org)

Leaf blight (*Helminthosporium turcicum*)

Leaf blight (*Helminthosporium turcicum*) It attacks sorghum, Sudan-grass and maize. The causal fungus is carried on the seed and also lives in the soil on dead or decaying plant material. It may cause seed rot and seedling blight, especially in cool and excessively moist soil. Seedlings then can become infected readily and may either die or develop into stunted plants. Small reddish-purple or yellowish-brown spots usually develop on the leaves of infected seedlings.

The spots may join to kill large parts of the leaves, which then dry to the extent that severely affected plants look as if they have been burnt. A greenish, mould-like growth of spores develops in the centre of the leaf spots during warm, humid weather. The spores are spread by wind or rain and infect other leaves and plants. Under warm, humid conditions the disease may cause serious damage by killing all leaves before plants have matured.

What to do:

- **Plant resistant varieties**
- **Use certified disease-free seeds**

Leaf blight
Leaf blight (*Helminthosporium turcicum*)on sorghum

Crazy top downy mildew (*Sclerophthora macrospora*)

This fungal disease can be troublesome in low lying areas that become flooded. Infected plants have thick, stiff, twisted, pale green leaves with bumpy surfaces. The leaves often turn downward, and the plants produce many shoots or suckers giving a bunchy appearance. Infected plants do not produce heads or produce a proliferation of leafy tissue in place of the head. Wild and cultivated grasses can serve as sources of infection.

What to do:

- **Plant resistant varieties**
- **Remove diseased plants from the field**
- **Rotate with non-cereals**
- **Avoid excess soil moisture in the field**

Crazy top downy mildew
Crazy top downy mildew (*Sclerospora graminicola*)
© Kranz J., Courtesy of EcoPort, www.ecoport.org

Information on Pests and Weeds

Cutworms (*Agrotis* spp and *Spodoptera* spp.)

Several species damage sorghum. They may cut off young plants at or slightly below the soil surface. Some feed on above-ground plant parts, and others feed on the roots. Plants with severed stems die, leaf feeding by cutworms cause ragged leaves and feeding on roots may kill young plants or stunt older plants.

Chaffer grubs (*Schizonycha* spp) also feed on roots and may kill very young seedlings. Stand loss can occur within ten days after plants emerge in severely infested fields.

What to do:

- **Harrow and plough field and remove weeds well ahead of planting the crop in the field. Ploughing exposes caterpillars to predators and to desiccation by the sun. If the field is planted soon after land preparation some cutworms may be alive and attack the new crop**
- **Inspect soil carefully when preparing land for planting for the presence of cutworms or white grubs**
- **Monitor damage by counting damaged and freshly cut young plants**
- **Collect and destroy cutworms. Cutworms are found in the soil close to damaged plants at day time. Monitor cutworm at dawn**

Black cutworm
Black cutworm (*Agrotis ipsilon*). Early instars are about 7 to 12 mm long. Fully grown caterpillars are 3.5 to 5cm long.

Black cutw..

Whiteg

Storage pests

Sorghum is very susceptible to damage by storage pests, the main ones being greater grain weevils, in particular the rice weevil (*Sitophilus oryzae*), the flour beetle (*Tribolium castaneum*) and the grain moth

(*Sitotroga cerealella*). Heavily attacked grain losses much of its content and become unfit for sale and consumption.

What to do:

- **Damage can be minimized by drying grain adequately before storage. Cultivars with hard grain also suffer less damage.**

Rice weevil
Rice weevil (*Sitophilus oryzae*). The adults are small (2.5 to 4.0 mm long).
© Food Agency and Ministry of agriculture, forestry (Courtesy of EcoPort, www.ecoport.org)

Rice weevi.

Grain moth

Birds

Birds are one of the most important pests of sorghum. They are capable of causing heavy losses. In Africa the most notorious species is Quelea quelea and is found in the Sahel region, from Senegal in West Africa through to Sudan, Uganda, Kenya, Southern Tanzania, Malawi, Zambia and South Africa.

What to do:

- **Damaging birds are mainly controlled by scaring them away from the sorghum fields and attacking their nesting sites. But not all birds are harmful. Some are also important predators and prey on insect pests of crops.**

Purple witchweed (*Striga hermonthica*)

The parasitic weed Striga is a major pest of sorghum, particularly in Africa, where severe infestations can lead to land being abandoned. Striga attaches itself to sorghum roots depriving it of nutrients and preventing them from establishing and growing properly.

What to do:

- **Striga can be controlled manually by vigorous uprooting before it produces seeds and/or by intercropping sorghum with fast spreading legumes which deprives the weed of sunlight and exude chemical substances the reduce striga growth. Desmodium for instance has been shown to depress striga almost completely. Considerable efforts have been dedicated to develop resistant varieties. Some of the varieties/lines developed or identified with resistance in Africa are: Dobbs, SAR 1 to 34, L.187, ICSV 1002, SRN, Framida, IS938 (ICRISAT).**

Witchweed
Witchweed (*Striga hermonthica*) flowering on a sorghum crop. *S. hermonthica* is a herbaceous annual plant 30-100 cm high, the most robust forms occurring in Sudan and Ethiopia.

The sorghum shoot fly (*Atherigona soccata*)

It is the most important pest of sorghum at the seedling stage. The adult is similar to the housefly, smaller in size (3-5 mm long), and greyish in colour, and abdomen yellow with brown patches. The larvae or maggots are yellowish or whitish in colour, up to 8 mm long. The fly lays eggs either at the base of young shoots near soil surfaces, or in older plants, on the leaves. The maggots crawl inside the sheath and bore into the heart of the young shoot killing the growing point and the youngest leaf, which turns brown and withers. This damage is known as "dead heart". When good growing conditions prevail the young plants are usually able to compensate the damage by producing new tillers, which may partly escape attack, but later the ripening of the earheads will be unequal. In weak plant repeated infestation may cause serious losses. Sometimes the damage is so severe that many seedlings die and the field has to be replanted. Older plants (over 30 days after seedling emergence) are generally not damaged by the shoot fly. However, when shoot flies are abundant (during the rainy season under moderate temperatures and high humidity) older plants may be attacked, but they do not produce the dead-heart symptoms. Instead, the damaged leaf becomes thin and papery, and wraps around the other leaves. As a result, the plants may fail to grow normally. Late infestations may also damage the panicle in the formative stage, resulting in rotting or drying up of a portion of the panicle affected

by shoot fly damage.

What to do:

- **Conserve natural enemies. A range of natural enemies attacks the sorghum shoot fly: parasitic wasps attack eggs and maggots and predators cause high mortality of eggs. In particular, several species of spiders are important predators on eggs. For more information on natural enemies click here**
- **Field sanitation. Crop residues should be collected and destroyed after harvest to reduce carry-over from one season to another.**
- **Plant resistant/tolerant varieties where available: Trials in Southern Africa has shown significant differences in resistance to shoot fly damage among varieties tested. Although the level of resistance in many of the sorghum varieties was low, several varieties with moderate levels of resistance were identified. Varieties Pirira-1 and Pirira-2 were the most resistant across seasons (van den Berg et al, 2005). In eastern Africa, varieties Serena and Seredo showed high levels of recovery resistance following shoot-fly damage (CABI; ICRISAT).**
- **Early sowing make often possible to have the period of vulnerability (seedling stage) over by the time the flies emerge.**
- **Uniform sowing of the same variety over large areas with the onset of rains reduces the damage by sorghum shoot fly.**
- **High seeding rates helps to maintain optimum plant stands and reduce shoot fly damage. There are reports that shoot-fly damage is higher when plant densities are low (CABI, 2000).**
- **Balanced fertilizer application. Application of fertilizer has been related to lower damage by shoot-fly possibly by increasing plant vigour. However, Shoot-fly damage has been found to be greater in plots treated with cattle manure. This may have been due to the attraction of shoot flies to the odours emanating from the organic manure.**
- **Intercropping. It has been shown that shoot fly damage is reduced when sorghum is intercropped with leguminous crops.**
- *** Fallowing and a closed season reduce the carryover and build-up of the shoot fly from one season to the next. These practices have been successfully used to reduce shoot-fly damage at ICRISAT. However,**

they may not practical for small-scale growers due to the shortage of land.

Shoot fly

Shoot fly (*Atherigona soccata*) The adults are dark brown, and similar to a housefly, but nearly half the size. © Georg Goergen, Courtesy of EcoPort, www.ecoport.org

Shoot fly

Sorghu sh...

African bollworm (*Helicoverpa armigera*)

It causes damage to sorghum by eating the seeds. Damage is particular serious on compact headed sorghums. The caterpillars appear on the earheads when the grains are in the milkripe stage. These caterpillars also feed on whorl leaves. A heavy infestation can cause an almost complete loss of yield.

What to do:

- **Inspect field once or twice a week after sorghum begins to bloom. Check for presence of caterpillars by shaking heads over a bucket or sweep net**
- **If necessary spray with Bt or neem extracts. Good spray coverage is very important, particularly in partially opened heads or in varieties that have tight heads where young caterpillars are well protected.**

For more information on neem click here. For information on Bt click here

- **Handpick and destroy pod borers. This helps when their numbers are low and in small fields.**

African bollworm
Fully-grown caterpillar of the African bollworm (*Helicoverpa armigera*) is 3 - 4cm long.
© A.M. Varela, icipe

African armyworm (*Spodoptera exempta*)

It is an occasional but seriously destructive pest. It causes serious damage to young plants in years of armyworm outbreaks. The leaves are eaten away often leaving only the base of the stem.

What to do:

- **Monitor regularly field margins, low areas where plants have lodged, beneath plant debris around the base of plants, on the ground, and underneath the plant leaves. Check daily young crops if conditions are known to be favourable to the pest.**
- **Spray Bt or botanicals such as neem and pyrethrum extracts. Spray when caterpillars are small. Once caterpillars are mature (about 3 to 3.5 cm long) they may have cause serious damage and it may no longer be economical to treat the crop. For more information on (neem click here, for pyrethrum click here and for Bt click here)**
- **Conserve and encourage natural enemies. For more information on natural enemies click here**

- **Practise field sanitation. For more information on field sanitation click here**

African armyworm
African armyworm (*Spodotera exempta*). Mature caterpillars measure up to 4 cm.
© University of Arkansas

Stemborers: Spotted stemborer (*Chilo partellus*)

Sorghum is attacked by several species of stemborers. The most important species include the spotted stalkborer (*Chilo partellus*), the pink stalkborer (*Sesamia calamitis*) and the maize stalkborer (*Buseola fusca*).

The feeding activity of the caterpillars inside the stems causes stunted plant growth, sterile or poorly developed earheads. Plants may dry and die if the infestation is severe.

What to do:

- **Early planting to ensure maximum pest escape.**
- **Use resistant varieties.**
- **Habitat management. Intercropping sorghum with pulses (cowpeas, groundnuts) in alternate rows, may reduce stemborer incidence by 20-30%.**
- **Sanitation (destruction of crop residues, volunteer plants and alternative hosts). Crop residues (stalks and other residues) should be destroyed after harvest through burning the stalks, or fed to livestock.**

However, burning of crop residues may not be practical in communities where soil fertility is low and no fertilizers are used since crop residue is the only source of organic matter.

- **Biological control. Recent research work on stemborers has been focussing on the introduction exotic parasitoids in countries where Chilo partellus is wide spread.**

Spotted stemborer
Spotted stemborer (*Chilo partellus*) are up to 25 mm long when fully grown.
© Agricultural Research Council of South Africa. Courtesy of Ecoport (www.ecoport.org)

Head bugs (*Calocoris angustatus* and *Eurystylus oldi*)

Nymphs and adults of the head bug (Calocoris angustatus) and the African head bug(Eurystylus oldi) feed on developing kernels as panicles emerge from the boot. Head bugs are small (3 to 5 mm long, and about 1 mm wide) and variable in colour from yellowish green (C. angustatus), or pale brownish-yellow to dark brown with red markings (E. oldi). Females insert long, cigar-shaped eggs between the glumes or anthers of sorghum florets. Eggs usually hatch in less than a week. Nymphs and adults suck juice from developing kernels as panicles emerge from the boot. Kernels attacked early in development are shrivelled, small, and off-coloured, resulting in yield loss. Bug-damaged kernels become infected by secondary pathogens that further deteriorate grain quality. Feeding punctures are visible on older kernels. The life cycle is completed in about three weeks. At least two generations feed on the same crop when panicles in the field do not mature at the same time.

What to do:

- **Conserve natural enemies. Assassin bugs and lygaeid bugs prey on earhead bugs. For more information on natural enemies click here.**
- **Selection of varieties. Open panicles are less affected than compact panicles.**
- **Resistant varieties. Some sorghum varieties are resistant to bugs.**
- **Timing of planting. Damage is less severe when kernels develop during dry periods.**

Bugs

A number of bugs feed on the milkripe sorghum grains: shield bugs including stink bugs (*Nezara viridula*, *Acrosternum* spp), *Mirperus jaculus*, *Riptortus dentipes*, Lygus bugs, blue bug (*Calidea degrii*) among others. The bugs puncture the seeds and suck the contents. Feeding punctures remain as dark spots on the testa. The seed weight is reduced; the rate of germination may be depressed. Sorghum is most susceptible to bug damage during the milk and soft dough stage. Injury normally is not damaging from hard dough to maturity. The damage is only of economic importance when bugs are present in large numbers.

What to do:

- **Use neem-based pesticides. Reportedly they reduce feeding by green shield bugs. For more information on neem click here.**
- **Check for bugs by beating or shaking panicles over a sweep net or bucket**

Green stink bug
Green stink bug (*Nezara viridula*) (nymphs and adults). Adults are about 1.2cm long. (Host: Pearl Millet)

The sorghum aphid (*Melanaphis saccari*) and the maize aphid (*Rhopalosiphum maidis*)

These are common on sorghum. The sorghum aphid is light yellow in colour, and the maize aphid is dark green to bluish-green in colour. These aphids are often found sucking on earheads or on the underside of leaves. They produce large quantities of honeydew, which enable black sooty moulds to grow. Attacked plants sometimes are stunted, leaves dry up and yield is reduced. Young plants suffering from drought stress maybe killed. Aphids can be a problem during dry periods. Heavy aphid infestations on sorghum at the booting and heading stages seriously reduce both grain quality and yield. The maize aphid transmits the maize dwarf mosaic virus to sorghum.

Adults are small, 1-4 mm long, soft-bodied insects.

What to do:

- **Conserve natural enemies. Parasitic wasps and predatory insects, including lady bird beetles, damsel bugs, lacewings, and hover fly larvae are important in natural control of aphids**

Maize aphid
Colony on of maize aphids (*Rhopalosiphum maidis*)
© www.inra.fr

The sorghum midge (*Stenodiplosis sorghicola*)

It is reported as one of the most important pests of sorghum in some countries, whilst in others (e.g. Ghana) is considered a sporadic pest. Nearly 30% of sorghum grain was damaged by sorghum midge in 1990 in western Kenya. In southern Africa, there are reports of 25% of sorghum grain damaged by sorghum midge (CABI, 2000). The adults are small (3 mm long), deep-red midges, with transparent wings. Eggs are laid in the flowering heads. The small orange larvae feed in the developing seed. Attacked seeds become shrunken and flat resulting in empty or "chaffy heads" as shrivelled grains fail to develop. The larva pupates inside the spikelet, and before adult emergence, the pupa wriggles its way to the tip of the spikelet. After adult emergence, the pupal case remains attached to the chaffy spikelet. Thus, damaged panicles have small, transparent midge pupal cases attached to the tip of the damaged spikelets.

What to do:

- **Synchronised planting. Epidemics of sorghum midge damage are common within an area, when sorghum is not planted at the same time, or different cultivars are planted that do not mature at the same time. Although landrace varieties often flower uniformly, high-yielding, early-flowering cultivars often do not. Sorghum that is planted and flowers later than normal is exposed to sorghum midge for a longer period**

and can suffer severe damage.

- **Planting density and thinning. Midge damage is reported to be higher in crops with low plant density (CABI, 2000).**
- **Selective removal of alternative hosts. Wild species of sorghum (for example, S. halepense and S. sudanense) act as alternative hosts for sorghum midge. Midge populations build up early in the season on wild species of sorghum and infest the sorghum crop later in the season. Removing these alternative hosts from the vicinity of the sorghum crop can reduce the rate of multiplication of sorghum midge populations. However, wild hosts also sustain the natural enemies, and thus may help in increasing the role of natural enemies in population suppression.**
- **Field sanitation. Crop residues should be collected and destroyed to reduce the carryover of larvae in the chaffy spikelets from one season to another.**
- **Fallowing and close season. Fallowing reduces the carryover and build-up of midge populations from one season to the next. However, this is not a feasible practice for smallholders due to the shortage of land.**
- **Use tolerant/resistant varieties where available. High levels of host-plant resistance are available for sorghum midge. In India, varieties SPH 837 and Pratap Jowar 1430 are claimed to be tolerant to the midge (www.nrcjowar.res.in/aicsip2005/achievements_udaipur.pdf). Also in India, variety DSV-3 is claimed to resistant to midge damage and is recommended to be plant in midge endemic areas (www.uasd.edu/research.htm).**
- **Crop rotations. Sorghum is generally rotated with cotton, groundnuts, sunflowers or sugarcane. This may reduce the damage caused by the sorghum midge.**
- **Mixed cropping. Damage by the sorghum midge is reduced when sorghum is intercropped with leguminous crops (CABI, 2000)**

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Citrus plants

Citrus plants
Scientific name: *Citrus* spp.
Family: Rutales: Rutaceae
Local names: Swahili: Machungwa (oranges), ndimu (limes), limau (lemons), madanzi (grapefruits), chenza (tangerines)
Pests and Diseases: African citrus psyllid Anthracnose Ants Aphids Citrus blackfly Citrus bud mite Citrus rust mite Citrus tristeza virus Damping-off diseases False codling moth Fruit flies Greening disease Leafmining caterpillars Mealybugs Phaeoramularia fruit and leaf spot Phytophthora-induced diseases Red fire or weaver ants Root-knot nematodes Scales Swallowtail butterfly Termites Thrips Whiteflies Termites, Couch grass

General Information and Agronomic Aspects

Geographical Distribution of Citrus plants in Africa

The most important species of citrus fruits are:

- **Sweet oranges (*Citrus sinensis*)**
- **Limes (*C. aurantifolia*)**
- **Grapefruits (*C. paradisi*)**
- **Lemons (*C. limon*)**
- **Mandarins (*C. reticulata*). These are often called tangerines.**

Citrus varieties of commercial importance include the following:

- **Oranges: 'Washington Navel' (alt: 1000-1800 m above sea level), 'Valencia Late', 'Hamlin' and 'Pineapple' (all alt from 0 - 1500 m above sea level)**
- **Mandarins: 'Kara', 'Satsuma' (0-1500 m above sea level), 'Clementine', 'Dancy' (0-1800 m above sea level), 'Pixie', 'Encore' and 'Kinnow'**
- **Tango/ Tangelo (hybrids of mandarins): 'Temple' a Tango (mandarin x orange) and 'Minneola' a Tangelo (mandarin x grapefruit)**
- **Grapefruit: 'Marsh Seedless', 'Duncan' and 'Ruby Red', 'Red Blush' (0-1500 m above sea level) and 'Thomson' (1000-1500 m above sea level)**
- **Lemons: 'Meyer', 'Eureka', 'Lisbon' and 'Villa Franca' (1000-1500 m above sea level), Rough lemon (0-1500 m)**
- **Limes: 'Mexican', 'Tahiti' and 'Bears' (0-1500 m)**

***Note*: All varieties mentioned are available in Kenya, particularly in Kenya prison farms, albeit their commercial availability is a problem due to citrus greening disease, which is prevalent in Kenya in all areas above 900 m asl. Since there is no citrus certification scheme in Kenya, there is no assurance that planting material derived from any Kenyan nursery is greening disease-free.**

Climate conditions, soil and water management

Citrus species can thrive in a wide range of soil and climatic conditions. Citrus is grown from sea level up to an altitude of 2100 m but for optimal growth a temperature range from 2° to 30° C is ideal. Long periods below 0° C are injurious to the trees and at 13° C growth diminishes. However, individual species and varieties decrease in suspectibility to low temperatures in the following sequence: grapefruit, sweet orange, mandarin, lemon/lime and trifoliate orange as most hardy.
Temperature plays an important role in the production of high quality fruit. Typical colouring of fruit takes place if night temperatures are about 14° C coupled with low humidity during ripening time. Exposure to strong winds and temperatures above 38° C may cause fruit drop, scarring and scorching of fruits. In the tropics the high lands provide the best night weather for orange colour and flavour.

Depending on the scion/ rootstock combination, citrus trees grow on a wide range of soils varying from sandy soils to those high in clay. Soils that are good for growing are well-drained, medium-textured, deep and fertile. Waterlogged or saline soils are not suitable and a pH range of 5.5 to 6.0 is ideal. In acidic soil, citrus roots do not grow well, and may lead to copper toxicity. On the other hand at pH above 6, fixation of trace elements take place (especially zinc and iron) and trees develop deficiency symptoms. A low pH may be corrected by adding dolomitic lime (containing both calcium and magnesium)

Zinc deficiency on citrus

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A citrus orchard needs continuous soil moisture to develop and produce, and water requirement reaches a peak between flowering and ripening. However, many factors such as temperature, soil type, location, plant density and crop age influence the quantity of water required. Well-distributed annual rainfall of not less than 1000 mm is needed for fair crop. In most cases, due to dry spells, irrigation is necessary. Under rainfed conditions, flowering is seasonal.
There is a positive correlation between the onset of a rainy season and flower break. With irrigation flowering and picking season could be controlled by water application during dry seasons. Irrigation systems involving mini sprinklers irrigating only soil next to citrus trees have been developed as an efficient and water conserving irrigation method.

Propagation

The most common method of citrus propagation is by budding. When old trees are top-worked, bark grafting is used. Citrus varieties grown from seed have numerous problems like late bearing, uneven performance due to their genetic variability and susceptibility to drought, root invading fungi, nematodes and salinity. Rootstocks are therefore used to meet all citrus requirements (tolerance / resistance to pests and diseases, suitability to soil and water conditions, as well as compatibility with variety selected). Rootstocks also improve the vigour and fruiting ability of the tree, as well as the quality, size, colour, flavour and rind-thickness of the fruit.

Citrus rootstocks have the following characteristics:

- **Rough lemon (*C. jambhiri*)**

Seedlings produce a uniform and fast growing rootstock, which is easy to handle in the nursery. The plant develops a shallow but wide root system with a vigorous taproot. Trees budded on rough lemon produce an early, good yield but the fruit quality especially during the first years is not satisfactory. Trees are comparatively short-lived. Rough lemon prefers deep, light soil and do not tolerate poor drainage or

waterlogging. It is tolerant to citrus tristeza virus but susceptible to *Phytophthora* spp., citrus nematodes and soil salinity. It is drought tolerant. Rough lemon can be budded with oranges, mandarins, lemons, limes and grapefruits. It is the most commonly used rootstock in East Africa.

- **Cleopatra mandarin(*C. reticulate*)**

It is suited to soils of heavier texture. On this rootstock, trees are slow growing with low yields in early years. Trees are long-lived. Its influence on fruit quality is good. It is tolerant to soil salinity. It is susceptible to poor drainage, *Phytophthora* spp and citrus nematodes. It can be budded with oranges, mandarins and grapefruits.

- **Citrus trifoliate (*Poncirus trifoliate*)**

It is a dwarfing stock and is most suitable for heavy and less well-drained soils. Rootstock propagation is slow, but budded trees yield heavily and produce high quality fruits. The plants develop abundant roots and often several taproots, which penetrate the soil deeply. It should not be used in calcareous soils. It is tolerant to *Phytophthora* spp. and citrus nematodes. It can be budded with oranges, mandarins and grapefruits.

- **Carrizo / Troyer citrange (*P. trifoliate* x *C. sinensis*)**

Rootstocks are somehow difficult to establish. In order to promote fibre roots, young plants should be undercut as long as they are in the seedbed. Citranges are not suitable for very light and strongly alkaline soils. They are sensitive to overwatering but once established produce high quality fruits. They are somehow tolerant to *Phytophthora* spp. and citrus nematodes. They can be budded with oranges, mandarins and grapefruits.

- **Citrumelo (*P. trifoliate* x *C. paradise*)**

Plants produce an expansive root system and therefore have good drought tolerance. They can be used on a wide range of soils and produce an outstanding quality of fruit. They are tolerant to *Phytophthora* spp. but susceptible to citrus nematodes. They can be budded with lemons and limes.

- **Rangpur lime(*C. aurantifolia*)**

This stock is suitable for various soil types, including deep sand. It prefers warm locations. It produces vigorous, well-bearing trees with a high degree of drought resistance. It is susceptible to *Phytophthora* spp. and citrus nematodes. It can be budded with oranges and grapefruits.

- **Sweet orange(*C. sinensis*)**

This rootstock produces large and vigorous trees and is suitable for light to medium soils, which are well drained. It produces good quality fruits and the trees are long-lived. It has low drought tolerance and is very susceptible to *Phytophthora* spp. and citrus nematodes. It can be budded with oranges, mandarins and grapefruits.

- **Sour orange (*C. aurantium*)**

An excellent rootstock in locations where citrus tristeza is not a problem since it is very susceptible to the disease. It is tolerant to poor drainage. It has low tolerance to drought. It produces very good quality fruits. It is tolerant to *Phytophthora* spp. but susceptible to citrus nematodes. It can be buddedwith oranges and grapefruits.

Planting

- **Select seeds from healthy mother trees**
- **Hot water treat seeds at 50° C for 10 minutes**
- **Seeds perform better when planted soon after they are extracted**
- **Sow seeds in seedbeds or polybags (18x23 cm). Seeds germinate in 2 to 3 weeks**
- **Water the seeds regularly, preferably twice a day until they germinate**
- **Seedlings are normally ready for budding when reaching pencil thickness or 6 to 8 months after germination.**
- **T-budding is the most common method**
- **Do budding during warm months. Avoid budding during cold periods and during dry conditions**
- **Budded plants are ready for transplanting 4 to 6 months after budding**
- **Alternatively, obtain budded plants from a registered fruit nursery. These budded plants should be ready for transplanting in the field.**

Transplanting in the field

- **Transplant in the field at onset of rains.**
- **Clear the field and dig planting holes 60 x 60 x 60 cm well before the onset of rains.**
- **At transplanting use well-rotted manure with topsoil.**
- **Spacing varies widely, depending on elevation, rootstock and variety. Generally, trees need a wider spacing at sea level than those transplanted at higher altitudes. Usually the plant density varies from 150 to 500 trees per ha, which means distances of 4 x 5 m (limes and lemons), 5 x 6 m (oranges, grapefruits and mandarins) or 7 x 8 m (oranges, grapefruits and mandarins).**
- **It is very important to ensure that seedlings are not transplanted too deep.**
- **After transplanting, the seedlings ought to be at the same height or preferably, somewhat higher than in the nursery.**
- **Under no circumstances must the graft union ever be in contact with the soil or with mulching material if used.**

Tree management / maintenance

- **Keep the trees free of weeds**
- **Maintain a single stem up to a height of 80-100 cm**
- **Remove all side branches / rootstock suckers**
- **Pinch or break the top branch at a height of 100 cm to encourage side branching**
- **Allow 3-4 scaffold branches to form the framework of the tree**
- **Remove side branches including those growing inwards**
- **Ensure all diseased and dead branches are removed regularly**
- **Careful use of hand tools is necessary in order to avoid injuring tree trunks and roots. Such injuries may become entry points for soil-borne diseases**
- **As a general rule, if dry spells last longer than three months, irrigation is necessary to maintain high yields and fruit quality. Irrigation could be done with buckets or a hose pipe but installation of some kind of irrigation system would be ideal**

Manure and fertiliser

For normal growth development (high yield and quality fruits), citrus trees require a sufficient supply of fertiliser and manuring. No general recommendation regarding the amounts of nutrients can be given because this depends on the fertility of the specific soil. Professional, combined soil and leaf analyses would provide right information on nutrient requirements.

In most cases tropical soils are low in organic matter. To improve them at least 20 kg (1 bucket) of well-rotted cattle manure or compost should be applied per tree per year as well as a handful of rockphosphate. On acid soils 1-2 kg of agricultural lime can be applied per tree spread evenly over the soil covering the root system. Application of manure or compost makes (especially grape-) fruits sweeter (farmer experience).

Nitrogen can be supplied by intercropping citrus trees with legume crops such as mucuna, cowpeas, clover or dolichos beans, and incorporating the plant material into the soil once a year. Mature trees need much more compost/well rotted manure than young trees to cater for the larger production of fruit.
Conventional fertilisation depend on soil types, so it is recommended to consult the local agricultural office.

Husbandry

In windy areas, a windbreak should be provided as citrus is sensitive to strong winds. A windbreak provides protection at orchard tree level for about 4-6 times its height.

- **Plant the windbreak as close as possible and at right angles to prevailing winds.**

Symptoms of mineral deficiency

Nutrient	Leaves	Fruit	Tree growth

Element			
Nitrogen	**Pale yellow to old ivory**	**Reduced crop**	**Reduced. May produce abundant bloom. Flower buds may fall without opening**
Phosphorous	**Small, dull**	**Reduced crop. Large. Puffy, bumpy surface, enlarged core cavity and thick rind.**	**Reduced**
Magnesium	**Yellow mottling along margin Developing a green wedge to "Christmas tree" pattern. Eventual complete yellowing and defoliation.**	**Reduced crop**	**Reduced**
Iron	**Yellow veins, remain green until final stage of general chlorosis. Reduced size**	**Reduced crop**	**Eventually reduced**
Zinc	**Mottled yellow between main veins. Small narrow Early fall. Reduced size**	**Reduced crop, some pale yellow off types**	**Eventually reduced**
Manganese	**Normal green along main veins. Rest of leaf pale green to light yellow**	**Reduced crop**	**Eventually reduced**
Potassium	**Old leaves curl and loose their green colour**	**Small, smooth, thin rind, drop prematurely**	**Reduced**

Copper	**Deep green, oversized, then darkened**	**Splitting and gumming. Dark brown gum soaked eruptions. May turn black. Gum in centre core**	**Twigs enlarge at nodes, blister and die back. Gum pockets. "Cabbage head" growth**

Intercropping

Intercropping with shallow rooted crops such as vegetables, herbs, green manure legumes sweet potatoes etc, is recommended in order to keep the soil cultivated around citrus trees.

Harvesting

- **Harvest fruits when they are mature. Mature fruits change colour where night temperature is about 14°C coupled with low humidity**
- **In low altitude areas where fruits remain green, it is necessary to test a few fruits for maturity**
- **Harvest fruits using a sharp knife, taking care not to bruise the fruits**
- **Fruits can also be plucked. However, plucking causes the stem to break close to the fruit thus increasing the chance of it being infected**
- **Wash, sort and grade fruits under shade. Washing water must be clean or treated**
- **Discard deformed and infected fruits**
- **Pack fruits in aerated containers for transport to the market**

Information on Pests

General Information

Organic pest and disease management places priority on indirect control methods. Direct control methods are applied as a second priority.

Indirect Control Methods:

- **Promotion of beneficial insects and plants by habitat management: organic orchard design, ecological compensation areas with hedges, nesting sites etc.**
- **Soil management: Organic compost and plant slurry to improve soil structure and soil microbial activity**
- **Pruning: good aeration of the orchard**

Direct Control Methods:

- **Biological control: release of antagonists, natural predators and entomophagous fungi**
- **Mechanical control methods**
- **Organic pest and disease control products**

Examples of Pests and Organic Control Methods

Most mites, insects and nematodes that attack citrus cause economic damage only occasional. Many pest problems in conventional citrus production are related to the almost complete elimination of natural enemies through the excessive use of synthetic pesticides. Organic growers make use of natural control agents to the maximum. Many pest problems can be controlled effectively with biological control methods. Generally, bio-control methods and agents usually help to decrease the level of pests rather than to eradicate them. The following list of important pests is not complete and shows just one important species for some pest families.

In some cases, preventive and bio-control measures are not sufficient and the damage by a pest or a disease may reach a level of considerable economic loss. This is when direct control measures with natural pesticides, such as pyrethrum, derris, neem, soaps, mineral and plant oil as well as mass trapping and confusion

techniques may become appropriate.

Scales

Scales are small insects (1.0 to 7 mm long), which resemble shells glued to the plant. There are many species (types) of scales on citrus, which vary in shape (round to oval) and colour according to the species.

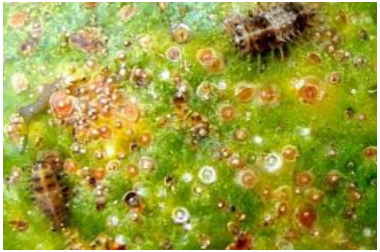
There are two main groups: hard (armoured) and soft (naked). The armoured scales are the most serious pests.
The most important armoured scales attacking citrus are the red scale (*Aonidiella aurantii*), the mussel purple scale (*Lepidosaphes beckii*), and the circular scale (*Chrysomphalus aonidum*).
The most important soft scales are the soft brown scale (*Coccus hesperidum*) and the soft green scale (*Coccus viridiis* or *C. alpinus*).

Female scales have neither wings nor legs. Females lay eggs under their scale. Some species give birth to young scales directly. Once hatched, the tiny scales, known as crawlers, emerge from under the protective scale. They move in search of a feeding site and do not move afterwards. They suck sap on all plant parts above the ground. Their feeding may cause yellowing of leaves followed by leaf drop, poor growth, dieback of branches, fruit drop, and blemishes on fruits. Leaves may dry when heavily infested, and young trees may die.

Soft scales excrete honeydew, causing growth of sooty mould. In heavy infestations fruits and leaves are heavily coated with sooty mould turning black. Heavy coating with sooty mould reduces photosynthesis. Fruits contaminated with sooty mould loose market value. Ants are usually associated with soft scales. They feed on the honeydew excreted by soft scales, preventing a build-up in sooty moulds, but also protecting the scales from natural enemies.
Armoured scales do not excrete honeydew.

What to do:

- **Scales are attacked by a large range of parasitic wasps and predators. These natural enemies usually control scales. Outbreaks are generally related to the use of broad-spectrum pesticides that kill natural enemies, and or to the presence of large number of ants.**
- **Chemical control is possible with light mineral oils, at low concentrations, mixed with other insecticides. At high concentrations, mineral oils may be harmful to the trees. Sprays should target young stages of the scales.**
- **Oil sprays should be carried out after picking and not during flowering or during periods of excessive heat or drought.**
- **To protect natural enemies alternate tree rows can be sprayed each season.**
- **At early stages of an outbreak cut and burn affected branches and leaves.**



Scales and ladybird larvae on orange
Larvae of ladybird beetles *(Cheilocorus sp)* feeding on red scales on an orange fruit
© A. M. Varela, icipe


Scales and…


Scale dama…


Armou s…

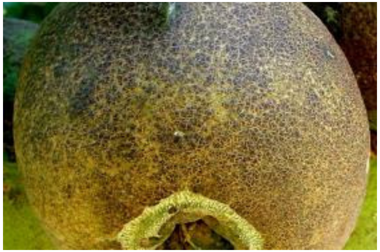
The citrus rust mite (*Phyllocoptruta oleivora*)

The yellow tiny citrus rust mite attacks mainly the fruit. Its feeding causes the rind of the fruit to turn silvery,

reddish brown, or blackish. One result of mite damage is small fruit, which deteriorates rapidly. This damage lowers the market value of the fruit. Heavy populations of the rust mite cause bronzing of leaves and green twigs, and general loss of vitality of the whole tree. Warm and humid conditions favour the development of this rust mite.

What to do:

- **Some predatory mites feed on the rust mites, but they cannot control heavy infestations.**



Citrus rust mite
Damage by the citrus rust mite (*Phyllocoptruta oleivora*) on an orange fruit
© A. A. Seif, icipe

The citrus bud mite (*Aceria sheldoni*)

It is a tiny, worm-shaped, creamy white mite. It has only two pair of legs, and is is hardly visibly without a magnifying glass. These mites occur in protected places such as under the bracts of buds. They attack the growing points of the twigs, causing malformation of the young leaves and flower buds. As a consequence, the growth of the trees is retarded.

The fruit set can be seriously reduced and infested fruit may be malformed. Bud mites are more abundant during the hot season. Commonly found in developing and leaf buds. Damage under the bracts causes the

death of the buds. Flower bud development is reduced, growth is retarded, branches become stunted and deformed, and rosette-shaped leaves are formed. The fruits, particularly in lemons are deformed. Almost all deformed fruits fall off at an early stage of development. Even light infestations may cause damage and control measures should be applied on time and regularly. Spots decrease the market value of the fruit and provide entry for fungal infection.

Damage fruits loose moisture rapidly and do not keep well. Infestation on ripe fruits causes light yellow or silver discolouration. These mites attack all citrus species, but damage is usually worst in lemons. Damaged fruit could drop prematurely or assume abnormal shapes. The juice content of damaged fruit is significantly lower than that of normal fruit.

What to do:

- **The bud mites are not well controlled by natural enemies, and use of biopesticides is necessary for their management.**
- **Sulphur at a concentration of 2% controls both the rust and bud mites. However, sulphur kills also beneficial mites and may disrupt the natural control of other potential citrus pests. Sulphur must not be used at a temperature exceeding 30° C. A four-week interval must be maintaned between sulphur and oil sprays. No other pesticides or mixtures may be added to sulphur.**

Citrus bud mite
Citrus bud mite damage (*Aceria sheldoni*)

© A.A. Seif, icipe

Mealybugs

Several species of mealybugs attack citrus. They suck sap from tender leaves, petioles and fruit. Feeding on the fruit results in discolored, bumpy, and scarred fruit, with low market value, or unacceptable for the fresh fruit market. Mealybugs excrete honeydew, which leads to the growth of sooty mould on fruit and leaves. Fruit cover with sooty mould at harvest must be washed. The most important is the citrus mealybug (*Planoccous citri*).

What to do:

- **Mealybugs frequently are under effective control by a wide range of natural enemies (parasitic wasps, lacewings, ladybird beetles. etc) and do not cause economic damage. However, if the natural balance is disturbed by application of pesticides or by presence of ants, mealybug populations may increase to damaging levels.**

Mealybugs
Mealybugs on citrus (*Planoccous citri*)
© A.M. Varela, icipe

Ants

Certain ants are major indirect pests in citrus orchards. Although they do not damage the trees, they are associated to honeydew-producing insects such as soft scales, aphids, whiteflies, blackflies and mealybugs. Natural enemies often keep these insects under control; however, ants feeding on the honeydew give them indirect protection by disturbing natural enemies. As a result numbers of these honeydew producing insects, and indirectly other pests such as armoured scales, may rise to damaging levels.

Ant management does not imply eradication of all ants. There are many different types of ants in citrus orchards. Many of them are important predators of other insects, including pests of citrus. Some of the species that could be a problem due to their association with honeydew-producing insects (e.g. the big headed ant *Pheidole megacephala* and the pugnacious ant, *Anoplolepis custodiens* are also beneficial preying on a variety of insects, and are valuable predators on the ground. Therefore these ants should not be destroyed but kept off the trees.

What to do:

- **Undesirable ants can be kept out of the citrus trees by banding the stems with sticky stripes, or by spraying the tree trunks with insecticides.**
- **To keep these ants out of the trees low branches on the tree must be pruned and all weeds that touch the canopy must be removed, so that they do not provide access to the tree for the ants.**
- **When using sticky bands, they must go completely around the stem. In addition, they should be checked regularly for efficiency. Sticky bands (strips) soon become non-adhesive in dusty and windy conditions. Moreover, over time insects get stuck to the bands clogging them and forming bridges, which the ants can cross. Therefore regular applications of the sticky substances are needed.**
- **Sticky substances (grease and others) may burn the bark, particularly, in young trees under direct sunlight. Therefore, it should not be applied directly to the trunks, but using polyurethane stripes as a base.**

Pheidole megacephala
Brown house ants streaming up and down the white-washed trunk of an orange tree
© Bedford ECG, de Villiers EA. Courtesy of Ecoport www.ecoport.org.

Red fire ants or weaver ants (*Oecophylla longinoda*)

A particular case is that of the red fire ants or weaver ant swhich nest on citrus and other fruit trees (guava, soursop, cashewnuts, coconut palms among others). These ants are present in many countries in Africa. They are common in the coastal regions in East Africa.
They built nests on trees by joining leaves with silk produced by the larvae. These ants are very active moving on the trees and on the ground in search of food. They are highly voracious feeding on a large range of insects visiting the trees, and are important in controlling many insect pests in fruit trees and coconut palms. In spite of these benefits, weaver ants are considered by some as a pest due to their aggressiveness combined with painful bites, which makes fruit picking difficult, and to their association with honeydew-producing insects. They can foster the build-up of these insects, but it has been observed that they do kill some of them when the amount of honeydew produced by these insects is bigger than the amount required by the colony of weaver ants.

The benefits provided by predatory ants feeding or deterring insect pests must be outweighed against the damage they may cost indirectly. As a whole weaver ants are considered beneficial. They have been used actively in China for the control of citrus pests for centuries (Way and Khoo, 1992). Experienced farmers in

Asia and Africa have developed their own methods to deal with the inconvenience of weaver ants during harvesting.

What to do:

- **A common practice among farmers is to throw wood ash on the branches of the tree they want to climb. The ants fall down of the branches and have difficulties to return giving time to the farmer to harvest.**
- **Other farmers rub their hands and arms with wood ashes, to prevent the ants from attacking them.**
- **Other rub their arms and feet with certain repellent products before climbing the tree, use protective clothing or harvest at times of the day when weaver ants are least active (Van Mele and Cuc, 2007)**

Weaver ants
Weaver ant nest on a citrus tree
© A.A. Seif, icipe

Nematodes

More than 40 nematode species have been associated with citrus worldwide. The economically important species are the citrus nematode (Tylenchulus semipenetrans) and the burrowing nematode (Radopholus similis).

1) The citrus nematode *(T. semipenetrans)*

It causes a slow decline of citrus trees. Affected trees show reduced vigour, small yellow leaves, defoliation, die-back of twigs, and small fruits. The citrus nematodes are ectoparasitic and sedentary. Only females are parasitic on roots. They are found on the surface of fibrous roots under debris-covered egg masses embedded in a gelatinous matrix. The life cycle, from egg to egg, is completed within 6-8 weeks at temperatures of 24-26° C. Optimal reproduction occurs at 28-31° C. Soil salinity increases the population density of citrus nematode. In affected orchards, populations of the nematode are concentrated in upper soil layers. Movement of plant material and soil is responsible for the spread of the nematode. Also agricultural implements and water (irrigation or rain) spread the nematode in a citrus orchard or in growing region.

2) The burrowing nematode *(Radopholus similis)*
It is called "burrowing nematode" on account of the cavities and tunnels it produces in the root tissues. Symptoms are generally present on groups of trees that increase in number with time, hence, the name, spreading decline. Symptoms are much more severe than in the case of T. semipenetrans and the spread is much quicker. Affected trees show fewer and smaller leaves and an abundance of dead twigs and branches. Trees wilt during periods of lack of moisture but generally the trees are not killed. It is an endoparasitic and migratory. Two distinct races of the nematode are known: the banana and citrus race. The former is known to attack banana roots but not citrus. The citrus race attacks bananas and citrus. The life cycle requires 18-21 days at 24-26° C, the optimum temperature being 24° C. Burrowing nematodes migrate through roots and from root to root to feed. The nematodes are rarely found in the top 10 cm of the soil, highest populations being between 30 and 180 cm. Primary spread is thorough propagating infested seedlings.

What to do:

- **Use certified nematode-free planting stocks**
- **Use tolerant / resistant rootstocks**
- **Use cultural practices that enhance plant growth.**

Nematodes
Lemon tree infested with citrus nematodes (*Tylenchulus semipenetrans*)
© Bedford ECG, de Villiers EA (EcoPort)

The citrus woolly whitefly (*Aleurothrixus floccosus*)

The citrus woolly whitefly was reported for the first time in East and Central Africa in the early to mid 90s. Serious attacks on citrus were observed in Kenya, Malawi, Tanzania and Uganda. The adults of this whitefly resemble small white moths, covered with mealy white wax. Eggs are laid on the lower surface of young leaves. The young stages resemble soft scale insects and have a woolly appearance. They produce large quantity of honeydew that leads to the growth of sooty mould on the infested trees. This may cause defoliation, loss of fruits and dwarfing of trees. Small, mottled fruits are produced.

What to do:

- **The citrus woolly whitefly is kept under control by its natural enemies in its area of origin. In the mid to late 90s, one of the most efficient parasitic wasp (Cales noacki), which has controlled this pest in many countries, was introduced and released in Kenya, Malawi, Tanzania and Uganda. Data collected in Kenya and Uganda showed that this parasitic wasp is effectively controlling the citrus woolly whitefly.**
- **Use of pesticides should be avoided since it may kill this parasitic wasp. Moreover, chemical control is not economical feasible. Pesticides are often inefficient since the immature stages are covered by wax. When effective, pest resurgence commonly occurs within a few weeks of application.**

Citrus woolly whitefly
Immature stages of the citrus woolly whitefly (*Aleurothrixus floccosus*)
© B. Loehr, icipe

Citrus woo… **Damag by …** **Citrus woo…**

The citrus blackflies (*Aleurocanthus woglumi* and *A. spiniferus*)

Adults of the citrus blackflies resemble tiny (1.3 to1.7 mm in length) greyish moths. Eggs are usually laid in a spiral pattern on the lower surface of leaves. The immature stages are shiny black scale-like insects and are up to 1.2 mm in length. A white fringe of wax surrounds the body of older larvae and the pupae.
The insects are most noticeable as groups of very small, black spiny lumps on leaf undersides. They produce a large amount of honeydew, which accumulate on leaves and stems and usually develop black sooty mould fungus, which cover the leaves blackening the foliage and sometimes the whole plant. Ants may be attracted by the honeydew. Heavy infestation causes general weakening and eventual death of plants due to sap loss and the development of sooty mould on leaves. Infested leaves may be distorted.

What to do:

- **Citrus blackfly has been effectively controlled by natural enemies. This is the most cost-effective and** sustainable method of control, and the parasitoids available are capable of controlling it wherever it becomes established (e.g. Encarsia opulenta, Eretmocerus serius as natural enemies in Kenya).

- Spraying with neem seed extract (4%) at the emergence of new flush and repeated at 10 days intervals once or twice is recommended in India (Tandon, 1997).
- In case of localised infestations affected shoots should be removed and destroyed.

Citrus blackflies
Immature stages of blackflies on a citrus leaf (*Aleurocanthus woglumi*) and (*A. spiniferus*)


Citrus bla…


Citrus bla…

Citrus aphids (*Toxoptera citridus* and *T. aurantii*)

They are small (1 to 3mm in length), brown to black in colour, and may be winged (having two pair of wings) or wingless. They feed by sucking on new growth and blossoms. High numbers are found on the leaf surfaces during the period of flushing (production of new shoots) and stems of attacked young shoots die back. Attacked leaves are curled and distorted. Flower buds are damaged or drop. Aphids excrete large amounts of honeydew. Leaves and fruits may turn black due to the growth of sooty mould. Symptoms can be severe on flush growth during dry periods following rainy spells.

Citrus aphids transmit tristeza and other virus diseases in citrus. The black citrus aphid *T. citridus* is the most efficient vector of the Citrus Tristeza Virus.

What to do:

- **Citrus aphids are frequently kept in check by natural enemies, especially ladybird beetles, lacewings, hoverflies and parasitic wasps. Aphids are likely to become less of a problem if their natural enemies are not destroyed by pesticides.**
- **Management of ants may increase the efficiency of these natural enemies.**
- **Insecitides should be applied only when heavy aphid populations are developing on the new flush. Only infested shoots should be treated, especial attention should be given to the lower leafsurface.**
- **Neem products are reported to give good control of this aphid. The application of a 2% Neem Seed Kernel Extract (NSKE) at the beginning of the infestation on lime to kept this aphid below the economic threshold level in the field in India. For more information on neem click here (Jotti et al., 1990).**

Citrus aphids
Heavy attack of the citrus aphid (*Toxoptera citridus* and *T. aurantii*)

The citrus leafminer *(Phyllocnistis citrella)*

The caterpillar of the citrus leafminer usually attacks young leaves and shoots. It mines the undersurface of

young leaves, but it can attack both leaf surfaces, in heavy infestations, and occasionally the fruit. Its feeding causes serpentine mines that have a silvery appearance and reach a length of 5 to 10 cm. The middle of the mines is marked by a light or a dark coloured stripe, which consist of the excreta of the caterpillars. The caterpillars are greenish yellowish and are to 4 mm in length. Caterpillars pupate within the mine, near the leaf margin, under a slight curl of the leaf. The moths are tiny (2 to 3 mm long), greyish white in colour with fringed wings.

Eggs look like small dew drops and are usually laid on the underside of the leaves. Attacked young leaves are twisted, show brown patches of dead tissue and eventually fall off.

Heavy infestations can interfere with photosynthesis because of the reduction in leaf surface. This pest is especially troublesome in citrus nurseries. It can kill young nursery plants. This leafminer was a frequently observed pest during a survey of major citrus pests conducted in Kenya, Malawi, Uganda, Tanzania and Zambia in 1995 (B. Löhr, personal communication).

What to do:

- **In Asia, mineral oils and neem extracts (neem seed extract 2%) are recommended for control of the citrus leafminer (Tandon, 1997).**
- **Neem water extracts (1kg neem cake / 10l water) has given protection against this pest for up to two weeks (Zebitz, in Schmuttererr, 1995). In South China 1.4% emulsified neem oil gave protection against this pest in the nursery and also in young and old citrus trees (GTZ, 2001). For more information on neem click here.**

Citrus leafminer
The caterpillar of the citrus leafminer *(Phyllocnistis citrella)* usually attacks young leaves and shoots.
© A.A. Seif, icipe\n

Citrus lea… **Citrus lea…**

The African citrus psyllid (*Trioza erytreae*)

It prefers cool climates and it is found in Kenya only at elevations above 800 m. The adult is about 2 mm long, brownish yellow with long transparent wings with market veins. They resemble winged aphids. The adults jump and fly short distances when disturbed. When feeding, adults take up a distinctive position, with the abdomen raised. The orange-yellow eggs are laid on the edges of tender young leaves. They can be distinguished with the naked eye as a yellow fringe to the leaf. After hatching the nymph moves only a very short distance and settles down to feed on the underside of leaves. Once settled, it does not move again unless disturbed. They resemble small green or yellow scale insects, and are up about 1 mm long. Parasitised nymphs are dark brown to black in colour. Pit-like depressions are formed beneath the nymphs-bodies. These depressions look like raised bumps on the upper side of the leaves, and remain even after the nymphs have become adults.

As result of these pock marks young leaves may be severely deformed, and flush growth depressed. They also cause damage by sucking sap from the leaves. However, in general, these types of damage do not seriously affect infested trees. The main damage caused by the citrus psyllid is as the vector of the greening disease, a major disease of citrus. A few psyllids in an orchard can spread the greening disease, but when high numbers are present, the spread is particularly rapid. It is therefore necessary to manage the citrus psyllids to retard the spread of the greening disease.

What to do:

- **Several natural enemies attack the citrus psyllid. Predators such as lacewings, spiders, predatory mites, ladybird beetles and hover flies feed on the citrus psyllid, but often they cannot control this pests effectively. Parasitic wasps play an important role in the control of citrus psyllids. Psyllaephagus pulvinatus attacks nymphs in Kenya and South Africa, and Tamarixia (Tetrastichus) dryi attacks nymphs in South Africa. In Reunion, the African psyllids has been successfully controlled by the introduction of T. dryi, from South Africa.**
- **Prevention of the spread of the citrus psyllids is crucial for managing greening disease. Drenching should be preferred method of pesticide application to avoid killing of the natural enemies. This should be done at onset of rains.**

Adult of the African citrus psyllid *(Trioza erytreaea)*
© A. A. Seif, icipe



The citrus thrips (*Scirtothrips aurantii*)

Citrus thrips are tiny insects (0.7 to 1 mm in length), and orange yellow in colour. Young stages are wingless, but adults have two pairs of narrow wings. Damage is caused by larvae and adults feeding on young twigs, leaves and fruits. Thrips feeding produces brown blemishes on the rind. Typical damage is the presence of rings of brown russet marks around the stem of the fruit. The damage is cosmetic and does not affect eating quality. However, external fruit blemishes can be so severe that the fruits are unmarketable. New shoots can be severely damaged. If thrips are abundant on young twigs, their feeding causes deformation of the twigs, which become thickened and distorted. In severe infestations, the leaves are deformed; young leaves are underdeveloped and drop when touched.

What to do:

- **Neem is effective against this thrips species.**

Thrips
This is a close-up of a related thrips species (Frankinella occidentalis). Immature thrips (left) and adults. Very much enlarged. Real size 0.9 to 1.1 mm.
© A.M. Varela, icipe

The false codling moth (*Cryptophlebia leucotreta*)

It is small (wingspan of 16-20 mm), dark brown to grey in colour. The moths are active at night. Female moths lay single eggs on ripening citrus fruits. The young caterpillar mines just beneath the surface, or bores into the pith causing premature ripening of the fruit and fruit drop.
The initial symptom on the fruit is a yellowish round spot with a tiny dark centre where the insect entered the fruit. In a later stage brown patches appear on the skin, usually with a hole in the centre. The young caterpillar is creamy-white with a dark brownish head. With age the body turn pinkish red. The fully-grown caterpillar is 15 to 20 mm in length. When mature the caterpillar leaves the fruit and pupates in the soil or beneath surface debris. Navel oranges seem to be the most heavily attacked. Grapefruit is less susceptible. In lemons and limes larval development is rarely, if ever, completed.

What to do:

- **Proper orchard sanitation in combination with egg and larval parasitoids normally keep this pest under control.**
- **Infested fruits (both on the tree and fallen fruits) should be removed regularly (twice a week), and buried at least 50 cm deep, or dump in a drum with water mixed with a little used oil. The fruits should be left in the drum for one week.**
- **This moth also attacks cotton, maize, castor, tea, avocado, guava and carambola fruits. Other host plants include wild guava plants, oak trees and wild castor among others. These other host plants should be included in the sanitation programme.**
- **If possible wild host plants should be removed from around the orchard. This pests is recorded in many African countries.**

The false codling moth
Caterpillar of the false codling moth (*Cryptophlebia leucotreta*)
© A. M. Varela, icipe


The false …

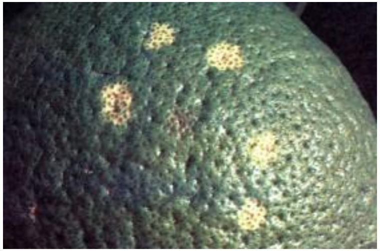

The false …

Fruit flies (*Bactrocera invadens, Ceratitis capitata* and *C. rosa*)

Several species of fruit flies are pests of citrus in Africa. In East Africa the most important are *B. invadens*, a new species of fruit fly recently introduced in the region, and *C. capitata* (Sunday Ekesi, personal communication). The female fly lays eggs within the sking of ripening fruits. Spots develop on the skin where eggs were laid and the hatching larva enters the fruit. The attacked area becomes soft, turns brown and decays as a result of secondary infection.

What to do:

- **These pests are controlled by orchard sanitation and application of baits.**
- **Monitoring fruit flies to determine when they arrive in the orchard is very important for the management of these pests.**



Fruit flies
Egg laying marks by fruit flies on an orange fruit
© A.A Seif, icipe

Fruit flie…

Fruit flie…

The swallowtail butterfly (*Papilio demodocus*)

The caterpillars of the swallowtail butterfly are also known as "orange dog". The butterfly is black with yellow markings on the wings, and has a wingspan of about 10 cm. They are common during the rainy season. Female butterflies lay whitish/grey eggs mainly on the tender terminal twigs and leaves. The caterpillars are white-brown, or green in colour. Most spines disappear as the caterpillar grows. Young caterpillars are brownish with white patches and are spiny. They resemble fresh bird droppings. Older caterpillars are green with some light markings and two eye-like spots at both sides of the front part of the body. When disturbed caterpillars shoot out a fleshy, forked retractable organ, through a slit behind the head, which gives off a repulsive smell.

Fully grown caterpillars are about 5 cm long. Caterpillars feed specially on the new growth of citrus trees. They can cause extensive damage to young trees, especially in citrus nurseries where their feeding can cause

complete defoliation of the plant.

What to do:

- **Control is usually necessary on the nursery and on young trees (up to 2 years old). Several natural enemies such as parastitic wasps, and birds attack the caterpillars.**
- **Hand picking and destruction of caterpillars and eggs usually provides satisfactory control on small trees provided the plants are regularly checked.**
- **Neem products have been shown to provide satisfactory control of this pest (Schmutterer, 1995). In particular weekly applications of neem water extracts effectively controlled this pest on sweet orange seedlings in Gambia (Rednap, 1981). For more information on neem click here**

Orange dog buterfly
The swallowtail butterfly (*Papilio demodocus*) also known as orange dog. Adult moth.
© A.M. Varela, icipe

Orang dog… Orang dog…

Information on Diseases

General Information

Organic pest and disease management places priority on indirect control methods. Direct control methods are applied as a second priority.

Indirect Control Methods:

- **Promotion of beneficial insects and plants by habitat management: organic orchard design, ecological compensation areas with hedges, nesting sites etc.**
- **Soil management: Organic compost and plant slurry to improve soil structure and soil microbial activity**
- **Pruning: good aeration of the orchard**

Direct Control Methods:

- **Biological control: release of antagonists, natural predators and entomophagous fungi**
- **Mechanical control methods**
- **Organic pest and disease control products**

Examples of Diseases and Organic Control Methods

There are a large number of citrus diseases caused by bacteria, mycoplasma, fungi and viruses. The following list contains some important examples. The organic citrus disease management consists in a three-step system:

- **Use of disease-free planting material to avoid future problems**
- **Choosing rootstocks and cultivars that are tolerant or resistant to local diseases**
- **Application of organic fungicides such as and copper, sulfur, clay powder and fennel oil. Cu can control several disease problems. However, it must not be forgotten that high Cu accumulations are toxic for soil microbial life and reduce the cation exchange capacity**

Damping-off (*Rhizoctoni solani*) and *Phytophthora* spp.

Damping-off of citrus is most often caused by *Rhizoctonia* spp. *Phytophthora* spp. are also a common cause of damping-off of citrus. The typical symptom of damping-off is dying of seedlings just after emergence from the soil. However, damping-off fungi can also cause seed rot, resulting in sparse stands of seedlings in nursery beds.

What to do:

- **Damping-off diseases are favoured by abundant moisture in the soil. Adequate control of damping-off diseases can be achieved by avoiding infested soils and overwatering.**
- **In case of Phytophthora spp., seeds must be hot water treated. For more information on hot water treatment click here.**
- **Contaminated soil, tools or irrigation water should not be used in or near seedbeds.**

Citrus tree
Phytophtora on citrus tree
© A.A. Seif, icipe

Greening disease

It is caused by the bacterium (*Candidatus Liberibacter africanus*). The disease is transmitted by citrus psyllids

(*Trioza erytreae*) and through use of budwood obtained from diseased trees. The disease is not soil-borne. It is not seed-borne and it is not mechanically transmitted.

Symptoms on the leaves show mottling, yellowing of veins or zinc defiency (i.e. small leaves, interveinal chlorosis and brush-like growth). Zinc deficiency induced by greening is confined to one or several branches within a tree (sectoral infection).
Trees infected by greening are distributed within the orchard randomly. Affected branches bear few fruits and in some cases do not fruit. The affected fruits are usually under-developed, reduced in size, lopsided, start to colour from the stem end instead of the stylar end as in the case with healthy fruits. Affected fruits drop prematurely. In seedy citrus varieties, seed abortion occurs. Severely diseased trees exhibit open growth, sparse chlorotic foliage, dieback of branches and severe fruit drop.

In Kenya, the disease is not found below 800 m above seas level because both the bacterium causing the disease and citrus psyllids are sensitive to high temperatures. Optimum temperature for symptom expression is 21 to 24°C; symptoms are masked above 26° C. The disease is especially destructive to sweet oranges and mandarins. It is less severe on lemon, grapefruit, citron and West Indian lime.
Rootstocks have no effect on greening disease.

What to do:

- **Use disease-free budwood**
- **Strict control of citrus psyllids.**
- **Very severely infected trees not producing economical yield should be up-rooted. If only a few branches are affected, they can be pruned out.**
- **Diseased young citrus trees should be replaced, as they will never bear fruit.**

Citrus greening disease
Greening disease
© A.A. Seif


Citrus gre… Citrus gre…

Phaeoramularia fruit and leaf spot

The disease is caused by fungus *Phaeoramularia angolensis*. The disease is favoured by wet, cool conditions. On leaves, the fungus produces circular, mostly solitary (single) spots that are up to 10 mm in diameter with light brown or greyish centres. Each spot is usually surrounded by a yellow halo. Occasionally, the thin necrotic tissue in the centres of old spots falls out, creating a shot-hole effect. During rains, leaf spots on young leaves often join together ending in generalized chlorosis. Premature defoliation takes place when leaf petioles are infected. On fruit, the spots are circular to irregular in shape or joining together and surrounded by yellow halos. Most spots measure up to 8 mm in diameter. On young fruits, symptoms often start with nipple-like swellings without yellow halos.

Spots on mature fruits are normally flat, and often a dark brown to black sunken margin similar to anthracnose around the spots is observed. Fruits of more than 40 mm in diameter are somehow resistant to

the disease. The disease has been observed on all citrus species including grapefruit, lemon, lime, mandarin, pummelo and orange. Grapefruit, mandarin, pummelo and orange are very susceptible. Lemon is less susceptible and lime is least susceptible.

What to do:

- **The disease can be effectively be controlled by a number of fungicides including copper based products.**
- **Successive use of coppers may cause stippling (dot-like marks) on the fruits. The disease can reduce yield by 50 to 100%.**

Phaeoramularia fruit spot on orange
Orange fruits infected by (*Phaeoramularia angolensis*)

Phaeo Phaeo Phaeo

Citrus tristeza virus (CTV)

It has been found in all citrus growing areas of the world. It is spread by infected propagative material and several species of aphids (*Toxoptera citricidus, T. aurantii, Aphis gossypii, A. craccivora, A. spiraecola* and *Myzus persicae*).

***T. citricidus* is the most efficient vector of CTV. The virus has also been transmitted from plant to plant by the use of dodder (*Cuscuta americana* and *C. subinclusa*). CTV is not transmitted through citrus seeds. Most species of Citrus are hosts for CTV. The virus has naturally occurring field strains, which vary considerably in their ability to cause symptoms on different host plants and in the intensity of the symptoms expressed.**

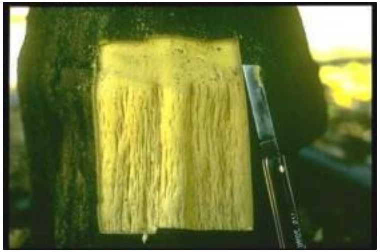
Symptoms caused by these strains include:
Seedling yellows (SY): This symptom consists of leaf yellowing and stunting in sour orange, grapefruit and lemon seedlings. This is a field problem when trees infected with SY strains of CTV are top-worked with grapefruit or lemon.
Decline on sour orange: Sweet orange, grapefruit or tangerine scions on sour orange rootstock become dwarfed, yellow (chlorotic), and often die. The decline may occur over a period of several years or very rapidly (quick decline). Trees that decline slowly generally have a bulge (swelling) above the bud union, and honeycombing (many fine holes or pitting) is present on the inner face of bark flaps removed from the sour orange rootstock. When trees decline rapidly, honeycombing does not occur, but a brown line may be observed at the bud union after the bark is removed. When budwood infected with decline-inducing strains is propagated on sour orange seedlings, the trees produced are stunted and unthrifty.
Stem-pitting on limes, grapefruit and sweet orange. Severely affected trees are stunted and may have bushy appearance. Leaves are yellow, and the twigs are brittle and break easily when bent. When the bark is removed from the affected twigs, elongated pits are seen in the wood. Trees affected by stem pitting have reduced yield and fruit quality is poor. Some strains cause longitudinal pits in the trunk, resulting in ropey appearance, and when bark is removed from the depressed parts deep pits can be seen in the wood.

What to do:

- **A practical safeguard against CTV is to use only disease-free budwood and to ensure that they budded onto tolerant rootstocks.**
- **In Brazil, where CTV has been the major problem of citrus, its control has been achieved by use of budlines pre-immunized with mild strains of the virus to protect against severe strains.**
- **It is, economically, impossible to prevent CTV spread by aphid control. However, selected control, at**

early stages of infection and during periods with high aphid populations, reduces the rate of spread.

- **Remove infected trees;**
- **Rootstock varieties generally considered tolerant to CTV are Sweet orange, Cleopatra mandarin, Rough lemon, Rangpur lime and Trifoliate orange.**



Citrus tristeza virus
Citrus tristeza virus

Phytophthora-induced diseases (*Phytophthora* spp.)

They cause the most serious soil-borne diseases of citrus. These fungi are worldwide in distribution and cause citrus production losses in irrigated, arid areas as well as in areas with high rainfall. Diseases caused by *Phytophthora* spp. include damping-off in seedbeds, gummosis and brown rot of fruits. The most widespread and important *Phytophthora* spp. are *P. nicotianae* and *P. citrophthora*. Others of lesser importance in the tropics are *P. citricola, P. hibernalis*and *P. palmivora*. The most serious disease caused by *Phytophthora* spp. is gummosis (also known as foot rot).

Gummosis: An early symptom of gummosis is gum oozing from small cracks in the infected bark around the bud-union giving the affected trees a bleeding appearance. Citrus gum, which is water soluble, disappears after heavy rains. Severely affected tress have yellow foliage that eventually drops and twigs die-back often with a crop of small-sized fruits still hanging from bare branches. The feeder roots are destroyed when the

root cortex is attacked; turn soft and easily separate giving the root system a stringy appearance. In an advanced stage, the trunk becomes girdled (encircled) and the affected trees decline and eventually die.

Gummosis is favoured by high moisture in the soil. Infection of fruit by *Phytophthora* spp. produces brown rot. The affected area is light brown, leathery and not sunken compared with the adjacent rind. Under humid conditions, white fungal growth (mycelium) forms on the rind surface. In the orchard, fruits on or near the ground become infected when they are splashed with water or come in contact with soil that is infested by *Phytophthora* spp.

Most of the infected fruits drop, but those that are harvested may not show symptoms until after they have been held in storage for a few days. Brown rot epidemics are usually restricted to areas where rainfall coincides with early stages of fruit maturity. It is important to note that most *Phytophthora* spp. are seed-borne.

What to do:

- **Treat citrus seeds with hot water at 50° C for 10 minutes (just too warm to keep a finger in for any amount of time)**
- **Soil drenches of copper based fungicide (allowed under organic farming in East Africa) are useful in preventing Phytophthora diseases in the nursery.**
- **Use tolerant or resistant rootstocks. Trifoliate orange is resistant. Swingle citrumelo, sour orange, rough lemon, and citranges (Carrizo and Troyer) are tolerant.**
- **Bud seedlings at a height of 25 cm and above, which will keep the bud union well above ground level.**
- **Avoid transplanting on heavy or poorly drained soils.**
- **Do not heap soil around the tree base.**
- **Avoid basin and flood irrigation. Do not over irrigate and ensure water does not contact the bud union.**
- **Avoid injuries to roots and trunks when cultivating.**
- **Gummosis can be halted by bark surgery before 50% of the trunck is affected. Scrape away dead bark tissue, remove about 10 mm margin of healthy tissue and paint the wound with a slurry of copper based**

fungicide (allowed under organic production) or under non-organic production with metalaxyl or fosetyl-Al.

- **Do not replant citrus into planting sites where other citrus has been grown and proven unhealthy.**

Gummosis disease
***Phytophthora*-gummosis on grapefruit tree**
© A.A. Seif, icipe

Anthracnose *(Colletotrichum* spp.)

There are three anthracnose diseases of citrus caused by *Colletotrichum* spp. Postbloom fruit drop, which affects flowers of all citrus species and induces drop of fruitlets and is caused by *C. acutatum*. Lime anthracnose, which attacks all juvenile tissues of only Mexican lime, is also caused by this *Colletotrichum* species. *C. gloeosporioides* causes a rind blemish on fruit, especially grapefruit, in the field.

Postbloom fruit drop
Description: *C. acutatum* infects petals and produces water-soaked lesions that eventually turn pink and then orange brown as the fungus sporulates. Infected fruitlets abscise at the base of the ovary, and the floral disk, calyx, and peduncle remain attached to the tree, forming structures commonly referred to as 'buttons'. Leaves surrounding an affected inflorescence are usually small, chlorotic, and twisted and have enlarged veins. Warm, wet weather favours disease development.

Lime anthracnose

Description: It affects only Mexican lime. It attacks flowers, young leaves, young shoots and fruits. Infected fruitlets abscise, and 'buttons' are produced as in postbloom fruit drop. In severe cases, young leaves become totally blighted and drop, and shoot tips die-back, producing wither tip symptoms. The fruit lesions are often large and deep, and cause fruit distortion. The disease is favoured by warm, wet weather.

Rind blemish on fruit

Description: The disease is caused by *C. gloeosporioides*. It is particularly severe on grapefruits. The blemish appears as a superficial, reddish brown discolouration, often in the form of tear stains, that usually appears following prolonged light rains in warm weather.

What to do:

- **Avoid overhead irrigation (opt for under-tree sprinklers where feasible)**
- **Wide tree spacing**
- **Pruning of dead tree tissues**
- **Copper preventive sprays**

Anthracnose
Anthracnose (*Colletotrichum* spp.) on Key lime leaves

Anthra Anthra Anthra

Fresh Quality Specifications for the Market in Kenya

The following specifications constitute raw material purchasing requirements.

PRODUCE:	**Lime**
IMAGE:	
VARIETY:	**Various**
General appearance criteria	
COLOUR:	Bright green skin, nil with very dark green skin; pale green flesh with white core and small seeds, or seedless.
VISUAL APPEARANCE:	Skin with small oil glands and shiny sheen, no foreign matter.
SENSORY:	Green, tangy, strongly flavoured juice; highly aromatic when cut; no foreign odours/tastes.
SHAPE:	Round as well as oval fruit.
SIZE:	As per pre-ordered size requirements, generally 5 –10cm length; max 10% variation within lot.
MATURITY:	Juicy and not dry
INSECTS & PHYSICAL DAMAGE:	With no insects (e.g. mealy bugs), especially in navel or button. With no cuts holes, splits, bruises and cracks (that break the skin).

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Bananas

Bananas
Scientific name: ***Musa*** **spp.**
Family: Zingiberales: Musaceae
Local names: Plantain, ndizi, matooke
Pests and Diseases: Anthracnose Aphids Bacterial wilt Banana bunchy top disease Banana weevil Black leaf streak Cigar end rot Fruit flies Fusarium wilt Root-knot nematodes Snails (Giant East African Snail) Thrips

General Information and Agronomic Aspects

Geographical Distribution of Banana in Africa

Bananas are perennial tropical plants whose fruits are used both for cooking and as table fruits. They may also be processed into starch, chips, purée, beer (in Africa), vinegar, or may be dehydrated and sold as dried fruit. Flour is produced from both plantains and table bananas, which can then be used in soups, baking or as a drink. The flowers can be used as a vegetable, but they have to be heated briefly in salty water to remove the bitterness. The fresh leaves have a high content of protein and cattle and chicken like them because of their taste. The leaves are also used as packing material and for roofing. Together with the stem (its actually a pseudo-stem) it also offers an excellent mulching material. Bananas can also be planted as a windbreak to a vegetable garden. Bananas are a staple food in many of the lower altitude, wetter areas of East

Africa. They are mostly grown as a subsistence crop, although there is much internal trading.

Climatic conditions, soil and water management

The ancestors of the commercial bananas originated from the Malaysian Peninsula, New Guinea and South-East Asia. They grow in alluvial and volcanic soils, as well as in river deltas and forest perimeters, where the soil is rich in organic matter. They are found at the top or the middle of secondary forests, according to variety. This means that they are more or less adaptable to shade, according to variety.

Banana grows well in fairly hot and humid areas that is within an altitude of 0-1800 m above sea level with the exception of "Dwarf Cavendish" which can grow well up to 2100 m.a.s.l. (meters above sea level). For survival a rainfall of at least 1000 mm per year is necessary, but in order to achieve good yields bananas should receive 200-220 mm water per month as a regular supply. For most commercial banana growers this means irrigating during the dry months. Commercially used varieties cannot endure stagnant water conditions, so flood irrigation should only be used if the soil has good drainage.

Temperature is a major factor; the optimum for growth is about 27°C and the maximum 38°C. Plant growth is retarded and chilling injury occurs below 13°C.

Banana is sensitive to strong wind, which shreds the leaves, causes crown distortions and blows plants over, and are susceptible to lodging in the absence of windbreaks. Planting in wind sheltered positions and in blocks rather than strips is recommended. If planted in blocks the plants protect each other against wind.

The best soil for banana is a deep, friable loam with good drainage and aeration. High fertility is a great advantage and organic matter content should be 3% or more. Bananas therefore respond well to application of well decomposed good quality composts. The plant tolerates pH of 4.5-7.5 and optimun pH is between 6 and 7.5. Plantains require more fertile soils than table bananas. Agricultural lime or preferably dolomitic lime (Ca +

Mg content) can be added to soils that are very acidic in order to make them less acidic and better suited for banana production.

Propagation and planting

Bananas are propagated by vegetative means. There are several types of vegetative planting material. Selection is done according to availability, required amounts and transport possibilities. Smallholders propagate banana mostly by corms / rhizomes (the bottom part of the plant that remains underground and bears several buds which develop into suckers) and suckers. Corms / rhizomes can be used as a whole or in pieces each bearing one or more buds. Using whole corms is laborious, requires a large amount of starting / planting material and generates high transport costs. Using corm pieces is less expensive.

Suckers are produced profusely at the base of each plant. Very young suckers just appearing above the ground, known as peepers, are easy to transport, but will produce first yield after two years. Sword suckers, about 75 cm high with corm diameter of about 15 cm, have a well-developed base with narrow sword-shaped leaves. They will produce the first yield about 18 months after planting. Maiden suckers are tall suckers normally 5-8 months, which have not yet set a bunch. They will produce a bunch in the first year. Water suckers, which have broad leaves should not be used for propagation since do not produce healthy banana clumps and the survival rate after planting is low.

Banana plants are also propagated through tissue culture (TC). Normally disease and pest free plantlets are multiplied under controlled conditions. Plantlets are supplied in pots and are planted in the field after hardening them off. These tissue culture bananas yield considerably better than traditionally propagated bananas when planted in clean soil that has not been previously used for banana production in the recent past. They are commercially available in Kenya from both Kenya Agricultural Research Centre, Thika, Jomo Kenyatta University of Agriculture and Technology, Juja and several private companies. The TC banana plants should be minimum 200-300 mm high at planting and have at least five healthy dark leaves and wider

internodes at time of transplanting.

Planting material should be selected from healthy plants, free of diseases and pests (e.g. bunchy top virus, nematodes and banana weevils), having all the desirable bunch qualities and high yielding ability. It is very important that the planting material is undamaged. Prior to planting, the roots and any damaged part of the rhizome should be removed with a sharp knife. Rhizomes or suckers showing symptoms of disease or pest attack (in particular nematodes or banana weevils) must be discarded.

Planting holes should be at least 2 feet (0.6 m) deep and 2 feet in diameter and should be filled with topsoil mixed with organic manure. In areas with marginal rainfall larger pits of about 5feet 1.5 m) in diameter and 3 feet deep (1 m) are recommended.

The spacing depends on variety, soil conditions and type of planting system. Short varieties, such as the *'Dwarf Cavendish'*, can be planted in a density of 2500 plants/ha, but more commonly in holes with spacing of 3m x 3m. The taller varieties *'Giant Cavendish'*, *'Robusta'* or other strongly developing varieties are set at 600-1200 plants/ha or in planting holes spaced at 3m x 4m. Experiences in the different regions have led to various recommendations regarding size and depth of hole required, which should be followed. It is recommended to cover the planted rhizome with mulch.

The most suitable planting period is towards the end of the dry season, or at the beginning of the rainy season.

Intercropping

Bananas can be combined with practically any type of cultivated or wild plant, which has similar requirements. Young banana plants are excellent nurses for other crops and forest plants (cocoa, coffee, black pepper etc.), which can be planted very close to the bananas. During the first year bananas should be intercropped with shallow rooted crops for ease of weeding. Following illustrations show 3 examples how to intercrop bananas:

Diversification strategies, Example 1

1. year	2. year	3. year	5. - 10. year	from 11. year
Maize				
Papaya	Papaya			
Banana	Banana	Banana	Banana	
Cocoa	Cocoa	Cocoa	Cocoa	Cocoa
Forest trees	Forest trees	Forest trees	Forest trees	Forest trees

These *diversifications strategies* are suitable for the common eating (table) banana. Because of their high demands on soil, an intensive accompanying vegetation is required. With sufficient foresight and planning, this can later be used to replace the bananas.

Diversification strategies, Example 2

1. year	2. year	3. year	5. - 10. year	from 11. year
Hibiscus				
Banana	Banana	Banana	Banana	
Coffee	Coffee	Coffee	Coffee	Coffee
Forest trees	Forest trees	Forest trees	Forest trees	Forest trees

If no other crops are to be integrated into the system, then it is sufficient to combine the bananas with forest trees and native fruit trees. If other crops are to be introduced onto an existing monoculture plantation, the fruit carrying pseudo-stems will need to be thinned out.

Diversification strategies, Example 3

1. year	2. year	3. year	5. year	6. - 10. year	from 11. year
Maize/Manioc					
Pineapple	Pineapple	Pineapple	Pineapple		
Banana	Banana	Banana	Bananas	Bananas	
Forest trees	Forest trees	Forest trees	Forest trees	Forest trees	Forest trees

A wide variety of species and high density of plants should be striven for. The high plant density can be useful for example in suppressing the growth of other vegetation (like grasses, etc.) It also provides sufficient mulching material, which needs to be continually cut and added to the soil. Satisfactory banana production can only be achieved with a large amount of organic material produced on the plantation itself.

Husbandry

Around 4-6 weeks after the bananas and additional crops have been planted, a primary selective weeding should be done. Frequent shallow weeding is required until the plants shade out weeds. Weeds are controlled by mechanical means (slashing, hoeing, etc.) or by hand. Grasses should be pulled up, and replaced by other non-creeping plants, for instance jack beans (*Canavalis ensiformis*) and *Crotalaria* spp.

Surplus shoots need to be regularly cut away from the planted bananas. The number of plants to leave per stool depends on the farmer's preferences. Many plants on a stool will result in a large number of small bunches per stool. Fewer suckers per stool will result in less but bigger bunches than are readily marketable. A common practice is to allow one flowering or fruiting stem and two to three suckers of different size for continuous banana production.

Tissue culture bananas produce large numbers of suckers 1-2 months after planting. These suckers should be cut off at the ground level to allow the development of the mother plant or until the mother plant reaches 1 m in height, at which time one following sucker is selected to continue. For good yields it is extremely important to follow the correct sucker selection:
a) Selection should be done when the mother plant is 1 m tall.
b) When the mother plant is 1 m tall 3 vigorous sword suckers facing eastward up to the slope (on slopy land) should be selected. All other suckers should be cut at base, gorged out in the middle and growing point destroyed. After 1-2 months, the most vigorous sucker should be selected and the rest removed. This will be the first ratoon crop and the first sucker. The first sucker that is produced by the first ratoon sucker should be selected as the second ratoon crop. If the sucker selection is properly done, a large daughter sucker and a small grand daughter, a peeper all aligned in one direction will be seen.

Mulching
Mulch vegetation (bushes and trees) shoul be cut back, and the resulting material chopped up and spread around the surface as a mulch. This should be carried out once or twice a year, according to growth.

Regular mulching with organic matter derived from pruning and weeding help to maintain a layer of humus and also enhances microbiological activity in the soil. Pruning and weeding also helps in improving the general hygiene of the plantation, increase light penetration and air circulation, thus stimulating new growth. It also results in a continuous supply of organic matter for mulching.

It is important that the material is spread evenly throughout the entire plantation. However, mulching material should be placed away from the stool (about 60 cm) to ensure that the roots bury themselves deep in the ground at the base of the corm in search of moisture giving good anchorage to the plants. In addition, thrash/mulch may give shelter to banana weevils and should not be left near to the stool.
Addition of Mijingu rock phosphate will promote strong root formation and intercropping with legumes such as mucuna, dolichos or cowpeas for green manure will help supply nitrogen from the atmosphere. These

measures will suffice to maintain the fertility of the soil even in situations of continuous banana growing.

The majority of banana varieties cultivated for export purposes require a high soil quality. In natural forest ecosystems, banana plants must be replaced by other species about every 10-15 years. If this is not done the soil will be depleted of nutrients and incidence of pests and diseases may build-up thereby necessitating application of fertilisers and pesticides.

Banana stems are liable to break under the weight of a heavy bunch. As the fruits develop and the weight of the bunch increases, the fruiting stem should be supported with a wooden pole to prevent the whole stem from breaking. Forked poles are used to keep the stems upright and support the weight of the bunch.

Irrigation is necessary in areas with a long dry season but also if rainfall is less than 220mm per month.

Harvesting

Harvesting banana bunches is usually spread evenly throughout the whole year. Whilst still green, the fruits have a distinctly edged appearance, which gradually becomes almost round as they ripen. The stage of maturity is judged by the angularity of the fingers: The more rounded a finger is in a cross-section, the more mature it is. The fingers are considered mature for harvesting when they are ¾ round (75% maturity) and still green.

The fruits in a bunch do not ripen at the same pace. If some fruits have begun to turn yellow on the plant, then it is already too late to transport them any great distance, as they quickly become too soft and rot.
Bunches are harvested by cutting them away from the plant just above where the fruit begins. The stem is cut-off with a clean cut at ground level after harvesting the bunch. It is very important that bunches do not fall or bump during transport, as this causes them to blacken and rot. To avoid damaging the bunches during harvesting at least two people should be involved in harvesting, in particular heavy bunches or tall varieties, one to do the cutting and the other one to support the bunch so that it does not fall to the ground. An

experienced worker, however, can harvest alone.

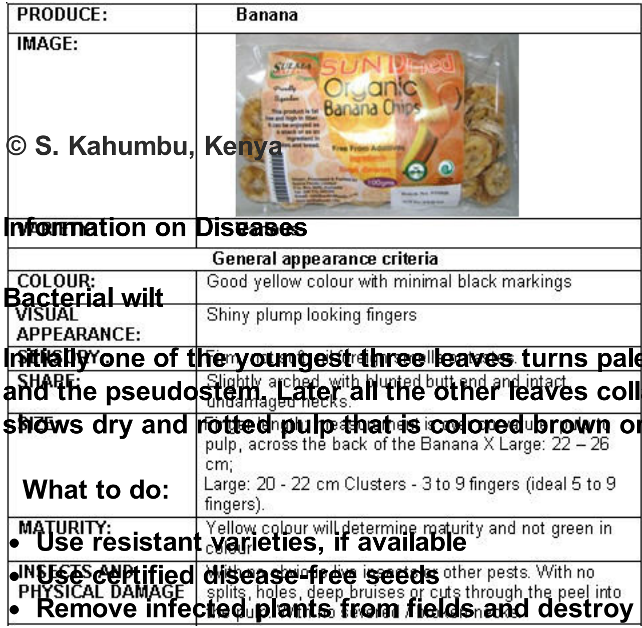
Harvested bunches should be kept in the shade. It is advisable to handle and transport banana hands rather than the whole bunches because this reduces physical damage. Bunches are dehanded and the hands are deflowered, washed, sorted and packed in carton boxes.

Storage life of green bananas ranges from 21 to 30 days at 13-15°C.

Ripening is increased when bunches are packed in closed chambers with restricted air circulation.

Fresh Quality Specifications for the Market in Kenya

The following specifications constitute raw material purchasing requirements



PRODUCE:	Banana
IMAGE:	
[illegible]	[illegible]
General appearance criteria	
COLOUR:	Good yellow colour with minimal black markings
VISUAL APPEARANCE:	Shiny plump looking fingers
[illegible]	[illegible]
SHAPE:	Slightly arched, with blunted butt end and intact undamaged necks.
SIZE:	[illegible] pulp, across the back of the Banana X Large: 22 – 26 cm; Large: 20 - 22 cm Clusters - 3 to 9 fingers (ideal 5 to 9 fingers).
MATURITY:	Yellow colour will determine maturity and not green in colour
INSECTS AND PHYSICAL DAMAGE	[illegible] other pests. With no splits, holes, deep bruises or cuts through the peel into the pulp. [illegible]

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Information on Diseases

Bacterial wilt

Initially one of the youngest three leaves turns pale-green or yellow in color and breaks down at the petiole and the pseudostem. Later all the other leaves collapse around the pseudostem. An infected finger or fruit shows dry and rotted pulp that is colored brown or black, and the presence of bacterial discharges.

What to do:

- **Use resistant varieties, if available**
- **Use certified disease-free seeds**
- **Remove infected plants from fields and destroy affected plants.**

Bacterial wilt
Banana Xanthomonas Wilt Disease

© Dr. Simon Eden-Green (Courtesy of EcoPort, www.ecoport.org)

Bacter …

Bacter …

The bunchy top disease

It is a virus disease transmitted by aphids (for more information on aphids click here .) The typical symptoms of bunchy top of banana are very distinctive and readily distinguished from those caused by other viruses of banana. Plants can become infected at any stage of growth and there are some initial differences between the symptoms produced in aphid-infected plants and those grown from infected planting material.

In aphid-infected plants, a few dark-green streaks or dots usually appear on the minor veins and the midrib of the second leaf to emerge after inoculation. They are best seen from the underside of the leaf in transmitted light. The 'dot-dash' symptoms can sometimes also be seen on the petiole. The following leaf may display whitish streaks along the secondary veins when it is still rolled. These streaks become dark green as the leaf unfurls. Successive leaves become smaller, both in length and in width of the lamina, and often have chlorotic, upturned margins. The leaves become dry and brittle and stand more erect than normal giving the plant a rosetted 'bunchy top' appearance.
Suckers from an infected stool can show severe symptoms in the first leaf to emerge. The leaves are rosetted and small with very chlorotic margins that tend to turn necrotic. Dark-green streaks are usually evident in the leaves.
Infected plants rarely produce a fruit bunch after infection and do not fruit in subsequent years. Plants infected late in the growing cycle may fruit once, but the bunch stalk and the fruit will be small and distorted. On plants infected very late, the only symptoms present may be a few dark green streaks on the tips of the flower bracts.


Banana bunchy top virus

© Denis Persley and Tony Cooke, Department of Primary Industries and Fisheries, Queensland, Australia (Courtesy of EcoPort, www.ecoport.org)

What to do:

- **Eradicate diseased plants. The whole stool, including rhizome/corm and all associated suckers, must be destroyed by uprooting and chopping into small pieces, as the virus can ultimately spread to all parts of the mat. Control must be practiced across the whole production area to avoid the rapid re-infection.**
- **Use of virus-free planting material**
- **Genetic resistance to black leaf streak is a long-term goal for disease management, especially for smallholders who cannot afford to purchase chemicals.**
  Cultivars with high levels of resistance include 'Yangambi Km 5' (AAA), 'Mysore' (AAB), 'Pelipita' (ABB), 'Saba' (ABB) and 'Pisang Awak' (ABB).
  However, these do not suit all local tastes and some are susceptible to Fusarium wilt (Fusarium oxysporum f.sp. cubense).

Banana bunchy top
Banana bunchy top virus
© Pearson, M.N. Courtesy of EcoPort, www.ecoport.org

 

Banan bun… **Banan bun…**

Black leaf streak (*Mycosphaerella fijiensis*) (also called black Sigatoka)

It is a very serious disease that affects the leaves of banana. The spores of this fungus are carried in the wind. The spores germinate in moisture and infect the leaves. The lesions gradually grow larger and kill large areas of the leaf. This results in lower yields and causes the premature ripening of the fruit.

What to do:

- **Remove and destroy diseased leaves, as this will reduce source of infection. If diseased leaves cannot be removed from the plot and burnt, they should be deeply buried.**
- **Overhead irrigation encourages the disease. Under-canopy micro-irrigation or drip-irrigation is preferable. Plants are also more vulnerable to black leaf streak in sheltered areas where the humidity is high. Good drainage systems that take surface water rapidly out of plantations can reduce humidity.**
- **Avoid overcrowding of plants.**

Black leaf streak
Black leaf streak on banana leaf (also called black Sigatoka)
© INIBAP (www.inibap.org)

Fusarium wilt (*Fusarium oxysporum* f.sp. *cubense*) (also called Panama disease)

This is a soilborne fungus that attacks the roots and blocks the vascular system in the banana, so that the plant wilts. Diseased leaves turn yellow from the margins, dry up and collapse leaving a skirt of dead leaves draped around the plant.
There is no effective control for *Fusarium* wilt, which is spread on infected suckers and in ground water.

What to do:

- **Sanitation and cultural methods can minimize spread of the disease.**
- **In areas where Fusarium wilt is endemic resistant varieties such as 'Cavendish', 'Kisigame', 'Mararu' and 'Uganda green' (plantain) should be grown.**

Fusarium wilt
Fusarium wilton banana. Banana with yellowing symptoms on lower leaves, caused by Fusarium wilt



Fusari w... Fusari w... Fusari w...

The cigar end rot disease (*Trachysphaera fructigena*)

It is a fungal disease that can attack the ripening fruit of banana, causing a dry rot of the flower end that produces an ash grey wrinkled lesion similar to the burnt end of a cigar. In storage or during transport the disease may progress to involve the whole fruit. Symptoms are: lesions, abnormal shape, visible mould. The disease is usually of minor significance and seldom requires targeted control.

What to do:

- **Practise sanitation**
- **Avoid damage to the fruit and deflowering 8-11 days after fruit bunch emergence**
- **Bagging of maturing banana stems**

Cigar end rot
Cigar end rot disease on banana

Anthracnose

It is an important post-harvest problem of bananas especially during transport and storage. On green fruit, pin-size brown or black sunken spots develop. Infection in young fruit is not always manifested until the fruit ripens, when black, round, slightly sunken spots appear. The centres of the spots become dark because of the formation of small black fruiting bodies of the fungus. Under moist conditions, masses of spores are produced having a characteristic salmon (pinkish) colour. Pulp of diseased fruit is usually not affected unless the fruit is over-ripe.

What to do:

- **Practise good field sanitation**
- **Minimize bruising during fruit handling**
- **Hot water treat the fruit for 5 min at 50°C. For more information on hot water treatment click here**
- **Proper sanitation of handling facilities**
- **Reports from Philippine claim that sprays of jathropa oil extract at 5000 ppm (5 ml of oil extract in 5 litres of water) significantly controlled anthracnose on bananas and ripening was delayed by 12 days (Philippine Organic Agriculture Information Network, 2004).**

Anthracnose
Anthracnose fruit rot on banana
© A.A. Seif, icipe

Information on Pests

The burrowing nematode (*Radopholus similis*)

The burrowing nematode is the most destructive nematode species attacking bananas. Dark patches or spots on the roots indicate nematode infestation. Severely infected plants may show only stubs of rotted roots and may fall down when the bunch has formed. Bananas are also attacked by other nematode species such as *Pratylenchus* spp., *Helicotylencus* spp. and *Meloidogyne* spp.

What to do:

- **Remove infested plants**
- **Use nematode-free planting material**
- **Plant resistant cultivars**
- **Biological control is possible by Paecilomyces lilacinus, a fungus, which parasitizes the egg, larva and adult of the nematode.**
- **All nematode species can also be controlled incorporating neem cake powder into the soil near the banana plants. In Uganda neem extracts spread around the banana plant are recommended for control of**

nematodes (Karubaga and Kimaru, 1999). For more information on [neem click here.]

Burrowing nematodes
Toppled bananas due to root damage caused by *Radopholus similis*, the burrowing nematode.

Burrov …

Burrov …

Banana weevil borer (*Cosmopolites sordidus*)

The banana weevil It is the most important insect pest of banana. It is about 1-1.5 cm long. The larva (grub) is most destructive: It bores irregular tunnels in the rhizome/corm and pseudostems at ground level. A large proportion of the tissue is destroyed, this reduces the amount of water and nutrients the plants can take up as well as lessening their anchorage. Heavy infestation may kill young plants. Older plants are easily blown over by the wind.

What to do:

- **Chop up the rhizome/corm and pseudo-stem to hasten decomposition, trapping and collection of the adults**

- **To prevent an infestation, use non-infested planting material, destroy the shelter and feeding places of the adult weevil and maintain a clean area around the mat**
- **Some ants are important natural enemies of the banana weevil and are being used for its control**
- **Applications of neem powder effectively controlled weevils and nematodes in on-farm trials and in farmers' fields in Kenya. Application of 60 to 100 g of neem seed powder or neem cake at planting and then at four months intervals significantly diminished pest damage and increased yields. Application of over 100 g or neem oil was phytotoxic and uneconomical. Neem applications were economical in fertile soils with moderate pest infestation. Neem applications to banana plants grown in poor soil and under very high pest attack were uneconomical.**
  A combination of good crop management such as application of cow dung and neem treatments resulted in yield increases of 50 to 75% (Musabyimana, 1999).
  Dipping suckers in a 20% neem seed solution at planting protects the young suckers from weevil attack by reducing egg laying through its repellent effect on adult weevils. Egg hatching rates may also be lowered in neem-treated plants (Gold and Messiaen, 2000). For more information on neem click here
- **Hot-water treatment of banana suckers helps against banana weevils. For information on hot-water treatment click here**

Banana weevil
Banana weevil (*Cosmopolites sordidus*) in banana corm. Adults attain a body lenght of 1-1.6 cm.
© A.M. Varela, icipe

Banana silvering thrips (*Hercinothrips bicinctus*)

Banana-silvering thrips are small (1.5 mm long), slender, brown insects with pale yellow hind wings that appear as a yellow line down the back of the body when the insect is at rest. Adult thrips have characteristic wings; the transparent wings have a fringe of hairs around the outside edge standing out in the same plane as the wing. The tiny eggs are laid just into the plant tissue on the pseudostem or where two fruit touch. The nymphs hatch after 7 or 8 days, are pale yellow or white in colour and often have a black globule of excrement at the end of the abdomen. The larval stage lasts about 10 days after which the nymphs move down into the soil to pupate. Adults emerge after a further 7 to 10 days.

The banana silvering thrips is found in tropical and subtropical regions, it is polyphagous, in particular found on bananas. They feed on the skin of the fruit causing silvering patches (hence the common name of the insect), which turn brown and may cover the whole fruit and deep longitudinal cracks may appear as a result.

What to do:

- **To prevent this insect spreading, do not use planting bits and suckers from areas infested with silvering thrips.**
- **Bagging of bunches has been found to prevent thrips infestation. Click here for more information on bagging**
- **Conserve natural enemies. Thrips are attacked by predatory thrips, lacewings and predatory bugs. Avoid use of pesticides that kill natural enemies**
- **Whenever necessary spot spray the crop with botanicals or other biopesticides. Some plant extracts (e.g. garlic, rotenone, neem, pyrethrum, and a mixture of garlic and pepper) are reported to control thrips. Spinosad, a bacterial derivative, is effective in controlling thrips**

Banana silvering thrips
Banana silvering thrips (*Hercinothrips bicinctus*) damage on banana fruits
© A. M. Varela, icipe

 

Banan sil... **Thrips**

Fruit flies (*Bactrocera invadens* and *Ceratitis rosa*)

Two species of fruit flies (*Bactrocera invadens* and *Ceratitis rosa*) attack banana in Kenya. *Bactrocera invadens* is a new species recently discovered in Africa, its 2-3mm in size. This fruit fly is reported attacking banana in Sudan and Kenya and it is a major threat since it leads to rejection of banana in the export market.

One of the most effective control techniques against fruit flies in general is to wrap fruit, either in newspaper, a paper bag, or in the case of long/thin fruits, a polythene sleeve. This is a simple physical barrier to oviposition but it has to be applied well before the fruit is attacked. Little information is available on the attack time for most fruits, but few *Bactrocera* spp. attack prior to ripening.

Infected fruit on the ground will act as reservoir for re-infection. If infected fruit reaches the market then maggot infested fruit will be discarded, so allowing emerging adults access to new crop areas.

What to do:

- **Bagging of young banana fruits is an effective method, used in the Pacific and South East Asia for protection against fruit flies. (Personal communication S. Ekesi, AFFI, icipe; Ekesi and Billah, 2006). [Click here for more information on bagging]**

Fruit fly damage
Fruit fly (*Bactrocera invadens*) attack on green banana


Fruit fly …


Fruit fly …


Fruit fly

The banana aphid (*Pentalonia nigronervosa*)

It is a small aphid about 1-2mm long and blackish-brown in colour. Colonies are usually present on the base of young leaves. The direct damage caused by aphids sucking the plant sap is negligible. However, they are important pests as vectors of the virus causing the bunchy-top disease.

Large colonies of aphids can occur around the base of pseudostems of Musa, down to 7-8 cm below the soil surface. Dense colonies can also occur between the sheath of outer leaf and pseudostem. During drought,

aphids seek sheltered locations on the plant. In dull and humid weather, however, aphids may spread to foliage generally, and to the bases of maturing hands of fruit and all over the hands of young fruit.

Colonies of *P. nigronervosa* are attended by ants, which feed on the large quantity of honeydew produced. Many species of ant are involved worldwide. Stechmann et al. (1996) described how ant-attendance reduced the density of indigenous predators of P. nigronervosa considerably, which has implications for biological control (e.g. Wellings et al., 1994). Ants also transport aphids from plant to plant, establishing new infestations.

***P. nigronervosa* is not normally found on plantains, suggesting that they may have resistance to the aphid.**

Banana cultivars are all thought to be susceptible to Banana bunchy top virus (BBTV); although wide variations in the onset and severity of symptoms have been observed,

What to do:

- **Conserve natural enemies. They are important in natural control of aphids. For more information on natural enemies click here**
- **Monitor regularly the crop.**
- **Banana bunchy top virus (BBTV) is best controlled by quick and efficient early detection in banana, with frequent surveys by trained inspectors. Diseased plants should be removed and destroyed. Replanting is increasingly done with virus-free tested material.**

Banana aphids
Banana aphids (*Pentalonia nigronervosa*) often gather on the youngest leaves of young plants. They may form large colonies where they are uncontrolled and protected by ants. They feed by piercing the plant cells with a syringe-like mouthpart.

Banan aph…

Banan aph…

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Contact Information

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- **Zuchinni Green Grocers 0204448240**

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Pigeon pea

Pigeon pea
Scientific name: *Cajanus cajan*
Family: Fabales: Fabaceae
Local names: Swahili: Mbaazi
Pests and Diseases: Aphids Blister beetles Bugs Cercospora leaf spot Cowpea seed beetle Cutworms Fusarium wilt Jassids Macrophomina stem canker Phytophthora blight Pod borers Pod fly Pod weevil Powdery mildew Purple witchweed Root-knot nematodes Rust Spider mites Termites Thrips Whiteflies Cutworms, Termites, Purple witchweed

General Information and Agronomic Aspects

Geographical Distribution of Pigeon pea in Africa

Pigeon pea is an important grain legume crop of rain-fed agriculture in the semi-arid tropics. Main pigeon pea producing regions are the Indian sub-continent, Central America and Southern and Eastern Africa. Pigeon pea is produced as a vegetable or export grain crop in southern and eastern Africa. In Kenya, pigeon pea is the third most widely grown pulse crop, and it is one of the fastest growing cash crops with an annual growth rate of 3% in the last decade. Green pigeon pea is being exported from Kenya to Europe (Snapp et al, 2003). The dry grain is also an important local pulse and export commodity in several African countries (Kenya, Malawi, Mozambique, Tanzania and Uganda) (Minja, et al, 1999).

Pigeon pea is a perennial shrub that is commonly grown as an annual crop. It has very

slow initial development (up to 2 months after planting). With a deep taproot, pigeon peas are able to take up nutrients and water from lower subsoil layers. Therefore, in crop mixes they hardly compete with the companion crops. This crop grows and yields well under conditions of low rainfall and poor soil.

Pigeon pea is well balanced nutritionally and an excellent source of protein. It is eaten as a vegetable (immature pods or green pea) or as dried grain (cooked and eaten as dhal, dry split cotyledons). The crop has many other uses: the wood is used as fuel, and the leaves and husks provide livestock feed.

Pigeon pea is useful as tall hedges on dry soil and on the bunds of paddy fields. The branches and stems can be used for baskets and firewood. It is often grown as a shade crop, cover crop or windbreak. After establishment, pigeon pea improves the soil by its extensive root system. The bacterium *Rhizobium* that lives on the roots of the pigeon pea is able to fix nitrogen and thus to improve soil fertility. Fallen leaves are used as mulch. Traditional uses as medicine are many, e.g. young leaves are applied to sores, herpes and itches.

Climatic conditions, soil and water management

Optimum temperatures range from 18 to 38°C. Pigeon pea does not tolerate frost. Above 29°C, soil moisture and fertility need to be adequate. Rainfall optimum is 600-1000 mm/year. Pigeon pea is a short day plant. Flowering is triggered by short days, whilst with long days plants grow vegetative. It is sensitive to high salinity and to water logging. It flowers well where rainfall is 1500 to 2000 mm. On deep, well-structured soil it will grow where rainfall is 250 to 370 mm. Pigeon pea is rarely found above altitudes of 2000 m. Drained soils of reasonable water-holding capacity and with pH 5-7 are favourable for its growth. Pigeon pea does not tolerate shallow soils or water logging.

Propagation and planting

Propagation is by seed, stem cuttings rarely succeed. Pigeon pea varieties differ not only in form of seeds, colour and taste, but also in growth habit, time of flowering and susceptibility towards pests and diseases. Pigeon pea varieties (available in Kenya) and their characteristics:

Variety	Maturity period (days)	Potential yield (bags/acre)	Characteristics	Sole cropping plant density
Kat 60/8	135-150	5-7 for one season (13 for 2 seasons)	Grains are white with brown spots and smaller seed size than local races. Grows between 0-1800 m above sea level and performs well where temperatures are high.	75 cm between rows and 50 cm between seeds
Kat 81/3/32	170-185	6-11	Tolerant to wilt, pod sucking bugs and pod borers. Cream white grain with large brown patches. Adapted to medium and higher altitudes (over 900 m above sea level)	90 cm between rows and 50 cm between seeds
Kat 777	160-180	6-10	Oval white seeds. Adapted to medium and higher altitudes (above 900 m above sea level)	90 cm between rows and 50 cm between seeds
ICPL 89091	120	4 for one season, 8 for 2 seasons	Is grown in the same range of altitude as KAT 60/8 but is more adapted to the more humid coastal zones. Performs best in pure stands at quite high density.	50 cm between rows and 10 cm between seeds
Local varieties				1,2 m between rows and 650 cm between plants

Seed rate: 20-25 kg per ha (8-10 kg per acre)

Land preparation
Pigeon pea thrives best in seedbeds prepared by deep ploughing and cultivations to reduce weeds. Seeds should be sown in rows with spacing of 30-50 cm x 75-150 cm and 10cm deep. There is no standard spacing - spacing depends on variety, soil type and production system. See table above for spacing recommended for different varieties. In dry areas, and especially in coarse-textured, infertile soils, farmers use wide spacing

between plants to limit competition.
Plants are fairly slow to start and weed control for the first two months is important in crop establishment.
Once plants are established they grow vigorously.

Husbandry

Weeds must be controlled to facilitate slow initial growth. Wind may bend the plants but staking is not practised. Response to fertilisers is seldom economic. In Eastern Africa, the crop is cultivated on marginal lands by resource-poor farmers, who traditionally grow landraces. Inputs such as fertilisers, irrigation and pesticides are hardly used.

Intercropping

In intercropping, the crop performs well with two rows of cereals (e.g. sorghum, millets), cotton or groundnut. After harvest of the intercrop, long-duration pigeon pea continues to grow and protects the soil. Pigeon pea is regarded as a good plant for restoration of fertility and is used in a rotation with crops such as maize-groundnut-tobacco-pigeon pea for three to four years in Uganda. One of the advantages of pigeon pea is the increased growth of the grass interplanted with it. In Uganda, it is usually sown in alternate rows with sesame or African finger millet (*Eleusine coracana*), and in Malawi with maize. In Tanzania, the main intercrop is cassava. In Kenya, sorghum and maize are the most common intercrops with pigeon pea. However, due to its high demand, there is a tendency to move away from traditional intercropping to monocropping. In Ukambani and Coastal strip, Kenya, the crop is grown commercially in large plots.

Harvesting

The crop is usually cut near the ground when most pods are mature, or mature pods are picked individually. Green pods are picked over a long period in home gardens or hedge crops. Ratoon cropping is mostly practised in pigeon pea producing areas in Kenya. After harvest the stems are cut back to facilitate re-growth and a second crop is harvested in the subsequent season. Entire air-dried plants or pods are threshed, usually by hand or with cattle, and seed is cleaned. Clean bins prevent insect attack, which can be considerable. Storage as split peas reduces bruchid attacks. Processing includes dhal making, either wet

(after sprinkling heaps of seed) or dry, by milling.

Information on Pests

General information

The most important pests of pigeon peas are insects feeding on pigeon pea pods and seeds. Surveys in Kenya, Malawi, Tanzania and Uganda have shown that the most important pests of pigeon pea pods and seeds in the region are:

- **pod sucking bugs,**
- **pod and seed boring caterpillars,**
- **pod flies**

(Minja et al., 1999).

Varieties that mature during the dry season have low damage levels (Snapp et al., 2003). A number of caterpillars (e.g. hairy caterpillars and semiloopers), and beetles (e.g. weevils, and foliage beetles) that feed on foliage of other legumes and grain legumes also attack pigeon peas, but they are usually not important.

Examples of Pigeon Pea Pests and Organic Control Methods

Leafhoppers or Jassids (*Jacobiasca lybica*)

Jassids (Leafhoppers) have been reported to cause damage to pigeon peas in Kenya. These small (2.5 mm) green and very mobile insects occur on the upper and lower leaf surface. The adults fly or hop away when disturbed. Nymphs resemble adults, but have no wings, and run sideways when disturbed. The eggs are inserted in the veins on the underside of leaflets. Adults and nymphs feed by sucking on the leaflets. Attacked

leaves become cup shaped and yellow at the edges. Heavy attacks result in the leaflets turning red-brown, with subsequent defoliation and stunting.

What to do:

- **Use neem kernel extract and other neem products**
  Neem treatments against aphids should be enough to control jassids at the same time. For more information on neem click here

Leafhopper (Jassid)
Leafhopper. Adults are small, about 2.5 mm long. Picture shows *Empoasca fabae*
© Steve L. Brown, University of Georgia, Bugwood.org

Storage pests: Bruchids (*Callosobrochus* spp.)

They are the most common and widespread insect pests in storage. Adults are 2-3.5 mm long. They attack both pods in the field and seeds in storage. They attack nearly mature and dried pods. Infested stored seeds can be recognised by the round exit holes and the white eggs on the seed surface. Post-harvest losses are highly variable, but losses can be over 90%.

What to do:

- **Pods should be harvested as soon as they mature and the seeds sun dried before stored in clean beetle-**

proof containers.

- **A coating of edible oils or of inert clay can prevent further development of bruchids in the stored seeds.**
- **Some farmers in East Africa use wood ash in grain stored for food or seed for planting, or chillies or smoke from cooking fire to preserve seeds for planting.**
- **Other farmers store unthreshed pods as a strategy to minimise grain damage by bruchids (Minja et al. 1999).**

Cowpea seed beetle
Cowpea seed beetle (*Callosobruchus maculatus*) adults are 2.-3.5 mm long. The adults emerge through windows in the grain, leaving round holes that are the main evidence of damage.
© Clemson University - USDA Cooperative Extension Slide Series, www.insectimages.org

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Root-knot nematodes (*Meloidogyne incognita / M. javanica*)

Affected plants are normally stunted and eventually wilt and die. The most characteristic symptom is formation of root galls (knots) and these can be seen with the naked eye. Affected roots rot.

What to do:

- **Plant resistant varieties / lines, if available**
- **Plant in fields with no previous record of nematode infestation**
- **Rotate with cereals**

- **Amend soil with neem extracts**
- **A number of bio-products for control of nematodes are going through registration process in Kenya. For more information on [nematodes click here]**

Root-knot nematodes
Root-knot nematode galls (here on tomato roots). Affected plants are normally stunted and eventually wilt and die. The most characteristic symptom is formation of root galls (knots) and these can be seen with the naked eye. Affected roots rot.

Red spider mites (*Tetranychus* spp.)

Red spider mites are about 0.6 mm long. They feed on the lower leaf surface causing white or yellowish spots on the upper leaf surface. Heavy infestation results in partial defoliation.

What to do:

- **Red spider mite attack is seldom severe enough to merit control.**
- **Use resistant cultivars. Most widely used cultivars appear to be relatively resistant to these mites.**

Spider mites
Two-spotted spider mite (*Tetranynchus urticae*). The adult female is 0.6 mm long. The male is smaller.
© Warwick HRI, University of Warwick.

Thrips (*Megalurothrips* spp. and *Frankliniella schultzei*)

Thrips are small (1.5 mm long), slender, brown insects with pale yellow hind wings that appear as a yellow line down the back of the body when the insect is at rest. Adult thrips have characteristic wings; the transparent wings have a fringe of hairs around the outside edge standing out in the same plane as the wing.

Several species of thrips are common on pigeon peas in Eastern Africa and are considered important pests. These thrips feed on leaves and flowers. Main damage is due to thrips feeding on flower buds and flowers. Heavy infestation can lead to shedding of buds and flowers. However, according to reports from India, pigeonpea plants produce more flowers than the plant can sustain, so many are lost naturally and it is difficult to assess thrips damage (Ikisan, 2000).

What to do:

- **Conserve natural enemies. Predatory mites and pirate bugs are important for the natural control of thrips. For more information on natural enemies click here**
- **Monitor the crop regularly. Early detection is particularly important at the onset of flowering**
- **Whenever necessary spot spray the crop with botanicals. Some plant extracts (e.g. garlic, rotenone,**

neem, pyrethrum, and a mixture of garlic and pepper etc.) are reported to control thrips. Spinosad, a bacterial derivative, is effective in controlling thrips.

Thrips
The Western flower thrips (*Frankliniella occidentalis*). Close-up, immature thrips (left) and adults. Very much enlarged. Real size (0.9 to 1.1 mm)
© M. Billah, icipe

Aphids

Several species of aphids have been reported feeding on pigeon pea. The black legume aphid (*Aphis craccivora*) is the most common.

What to do:

- **Aphids seldom are a problem on pigeon pea, probably due to the effect of natural enemies.**

Aphids
Black legume aphids *Aphis craccivora*) on cowpea

Bugs

Pod sucking bugs are primary pests of pigeon peas.

The most common pod-sucking bugs are: giant coreid bugs (*Anoplocnemis* spp), spiny brown bugs (*Clavigralla* spp), Riptortus bugs (*Riptortus* spp) and green stink bugs (*Nezara viridula*).

These bugs suck developing seeds through the pod wall. The seeds become shrivelled with dark patches. Attacked seeds do not germinate and are not acceptable as food. Fungal spores are sometimes transmitted with the mouthparts during feeding, resulting in rotting of the seeds. The spiny brown bug *Clavigralla tomentosicollis* is one of the most important pests of pigeon peas in Eastern Africa.

Sucking bug adults are difficult to control since they are very mobile and can invade crops from neighbouring sites.

What to do:

- **Immature bugs can be handpicked and destroyed.**

- **Adults can be collected with insect nets and destroyed.**
- **The main natural enemies of bugs are egg parasitoids, assassin bugs, ants and birds**
- **Spraying with aromatic plants (e.g. gums, lantana, khaki weed etc.) has been suggested to repel bugs (Elwell and Mass, 1995).**
- **Neem-based pesticides reportedly reduce feeding by green shield bugs. For more information on neem click here.**

Tip wilter
Tip wilter / giant coreid bug (*Anoplocnemis curvipes*) is about 2.5cm long.


Tip wilter…


Spiny brow…


Riptort…


Green stin…

Pod borers

The African bollworm (*Helicoverpa armigera*), the legume pod borer (*Maruca vitrata = testulalis*) the lima bean pod borer (*Etiella zinckenella*) are major pests of pigeon peas in East Africa. They feed on leaves, flowers and pods, destroying them.

The African bollworm (*Helicoverpa armigera*)

Caterpillars are 1.5 to 4cm long. They bore holes on pods and feed on the seeds. Usually developing and partly mature seeds are eaten completely.
For more information on the African bollworm click here.

The legume pod borer (*Maruca vitrata*)
The adult of the legume pod borer is a moth with a wingspan of 15-30 mm. It has light-brown forewings with white markings and pearly white hindwings. Though mainly nocturnal, the moth may also be seen during the day. They lay eggs in the flowers or buds, or on the pods. Caterpillars are whitish with black head and rows of conspicuous brown to black spots on the dorsal, lateral, and ventral surfaces of each body segment. Fully-grown caterpillars measure about 15mm in length. They pupate in the soil. Caterpillars web together leaves, flower buds and pods and feed inside the web. Flowers usually show little sign of damage until they wilt and drop. They typically attack pods at the point of contact between two pods, or between a pod and a leaf or stem.

The lima bean pod borer
Adults of the lima bean pod borer are brown moths with a wing span of about 20-25 mm. They lay eggs singly or in small groups on immature pods. Young caterpillars bore into the pod. They feed inside the pod reaching a length of 12 to 17 mm and are generally found in maturing and dried pods. Young caterpillars are green, turning red later. They feed inside the pod reaching a length of 1.4 cm and are generally found in maturing and dried pods. Faeces in the form of granules are found inside the damaging pods.

What to do:

- **Apply biopesticides such as Bt or neem products. They usually give good control of pod borers, provided they are applied to pods before the young caterpillars enter into the pods. Once the caterpillars have entered the pods they are difficult to control and by then they have caused damage. Other plant derivatives reported to control pod borers are tephrosia and chilli/garlic. For more information on Bt click here. For more information on neem click here**
- **Monitor regularly the crop to detect eggs and young caterpillars before they enter the pods**

- **Conserve natural enemies. Ants, parasitic wasps and pirate bugs are important in natural control. Bird perches placed just above the crop canopy are also reported to reduce the numbers of pod borers**

African bollworm
African bollworm (*Helicoverpa armigera*) damage on beans
© A.M. Varela, icipe



Africa bo… **Legum pod…** **Lima bean …**

The pod fly (*Melanagromyza chalcosoma*)

It is a small black fly that lays eggs through the walls of developing pods. The maggots (white in colour and about 3 mm long) feed inside the green seed. The brown barrel shaped pupa is formed inside the pod but outside the seed.

There are no obvious external symptoms of attack till the fully-grown maggot chew holes in the pod walls leaving a window through which the flies emerge after pupation in the pod. Damaged seeds are of no value. The pod fly causes most damage on pigeon pea maturing during cool weather and pigeon pea planted at altitudes higher than 500 m above sea level.

What to do:

- **In areas where the pod fly is a problem, it is best to avoid growing a mixture of cultivars of differing duration in one area because this will provide pods over a long period and allow several generations of the pod fly to develop.**
- **Neem has given control of a related pod fly (M. obtusa) on pigeon pea in India. Four weekly applications of aqueous neem seed extract (ANSE) 50g/l and fortnightly sprays of aqueous neem kernel extract (ANKE) 80g/l have given effective control (Ostermann and Dreyer, 1995). For more information on neem click here.**

Pod fly
Pod fly *Melanagromyza chalcosoma*) damage on pigeon pea
© Jeffrey Lotz, Florida Department of Agriculture and Consumer Services.\n

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The pod weevil (*Apion clavipes*)

It has been regarded as a major pest of pigeon pea in East Africa. Adults are small black weevils. The larvae are creamy white. Larvae damage the green seeds in pods but the damage is usually noticed only after adults emerge cutting the way out of the pod. The beetles also chew small holes in leaflets and flowers.

What to do:

- **Use neem extracts. Research in India has shown some efficacy of neem extracts against this pod weevil.**

For more information on neem click here.

Pod weevil
Pod weevil *Apion* species on bean pod.
© Frank Peairs, Colorado State University

Blister beetles (*Coryna* spp. and *Mylabris* spp.)

Adults feed on the flowers and reduce the number of pods that are set. In location where pigeon pea is grown over large areas blister beetles cause little damage. However, in small pigeon pea plots that are in the flowering stage during the period of peak adult activity, most of the flowers may be eaten by the beetles and crop losses maybe substantial. The adults are medium to large sized beetles (2 to 5 cm in length), usually black and yellow or black and red in colour. The immature stages (larvae) do not feed on plants. They live in the soil and eat grasshopper eggs, and are therefore beneficial.

What to do:

- **The adult beetles can be handpicked and destroyed. However, care should be taken, since when disturbed, they can release a liquid that burns the skin.**
- **Whenever possible wear gloves to protect the hands. Many types of essential oils extracted from eucalyptus and aromatic herbs can have repellent effects (caution: phytotoxic side effects are possible).**
- **In addition, rock powder or clay powder (kaolin) could have a repellent effect on these beetles. Since the larvae are beneficial, the aim should not be to destroy all adults, but to keep the numbers in check.**

Blister beetle
Blister beetles (*Mylabris oculata*) Adults are 2 to 5 cm in length.
© Botha AD (Courtesy of EcoPort, www.ecoport.org)

Information on Diseases

Examples of Pigeon Pea Diseases and Organic Control Methods

Fusarium wilt (*Fusarium udum*)

It is a fungal disease. Symptoms include partial or total wilting of plants at flowering and podding, a purple band of stems extending from the base upwards, browning of the stem tissue in the purple band area, and browning or blackening of internal tissue when the main stem or primary branches are split. Infected young plants may not show the purple band symptom but have conspicuous internal browning and blackening. Affected fields show patches of dead plants. *F. udum* is seed and soilborne. The fungus survives on infected crop debris in the soil for about three years.

Crop rotation is advisable against diseases such as Fusarium wilt. Pigeon pea is generally grown in inter- and mixed-cropping systems in rotation with other crops, particularly cereals. However, since the fungus-causing agent of wilt of pigeon pea survives on deep-seated roots of the host, the success of rotation will depend upon the field sanitation (removal of affected plants with their roots). A 4-5-year rotation has been found to free the field completely of the wilt pathogen (causing fungal agent). However, in smallholder scenarios this is

not practical due to land restriction. One-year breaks with either sorghum or fallow reduced wilt in the following pigeon pea crop from more than 50 to below 20%.
Pigeon pea rotation with tobacco has been recommended as a possible means of control because of the adverse effect of tobacco root exudates on the pathogen. For more information on fusarium wilt click here.

What to do:

- **Plant of resistant varieties / lines. For instance, the long duration varieties (cultivar) ICP9145 and ICEAP00040 are resistant to Fusarium wilt and have superior productivity on-farm (Snapp et al, 2003).**
- **Use disease-free seeds**
- **Plant in fields with no previous record of wilt for at least three years**
- **Uproot wilted plants (and use them for fuel wood)**
- **Collect and burn plant residues after harvesting**
- **Crop rotation with cereals**
- **Soil amendment with Trichoderma products. These are commercially available in Kenya**

Fusarium wilt
Fusarium wilt on beans
© A.M. Varela

***Cercospora* leaf spot (*Mycovellosiella cajani*)**

Small circular necrotic spots (lesions) usually appear on older leaves. These spots join up causing leaf blight and leaf drop. The African isolates of the fungus produce concentric areas on the leaf spots. The disease causes severe losses when defoliation occurs before flowering and podding. The disease usually appears when plants are flowering and podding. The fungus is seed-borne. It is favoured by cool temperatures (25º C) and humid rainy weather. The disease is more common in the long-duration and perennial varieties in eastern Africa.

What to do:

- **Plant resistant varieties / lines, if available**
- **Use disease-free seeds**
- **Plant in fields away from perennial varieties, which could be a source of inoculums (infection).**

Cercospora leaf spot
Cercospora leaf spot on soybean
© Clemson University, USDA (EcoPort, www.ecoport.org)

***Macrophomina* stem canker (*Macrophomina phaseolina*)**

Initial symptom on stems and branches are spindle-shaped spots with light grey centres surrounded by brown

margins. The centres of the spots have scattered dots (pycnidial bodies - fungal spores). The spots may join up and cause the branches or whole plants to dry up and die. Diseased plants suddenly wilt. When diseased plants are uprooted their roots are rotten and shredded. The fungus mainly attacks secondary finer roots. These roots have dark, blackened streaks underneath their barks with dots (pycnidial bodies - fungal spores). The disease could be a serious problem in late-sown and in perennial or rationed pigeon peas. Disease development is favoured by hot dry weather (30º C). Crops are more susceptible to the disease in the reproductive than in the vegetative stage.

What to do:

- **Plant resistant varieties / lines, if available**
- **Plant in fields with no previous history of the disease**
- **Avoid late planting**
- **Rotate with cereals and fodder grasses**

Stem canKer
Stem canker (*Macrophomina phaseolina*)

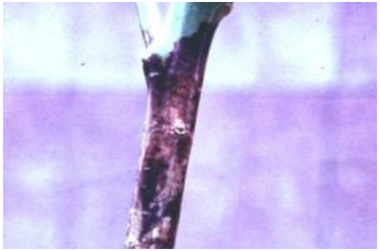
***Phytophthora* blight (*Phytophthora dreschsleri* f.sp. *cajani*)**

The disease causes sudden death of seedlings. Infected leaves have water-soaked spots that turn brown to

black. Infected leaves lose turgidity and finally become desiccated. On stems and leaf petioles the spots are slightly sunken. Affected stems or branches are girdled and foliage above dries up. Plants that are attacked but not killed often form large galls on their stems especially at the edges of spots. The fungus does not infect the root system. The fungus is soil-borne and it also survives on infected crop debris. The disease is favoured by cool temperatures around 25º C, cloudy humid weather and rain. Plants develop tolerance to the disease with age.

What to do:

- **Plant resistant varieties / lines, if available**
- **Plant in fields with no previous record of blight**
- **Avoid fields prone to waterlogging**
- **Use wide inter-row spacing.**



Phytophtora blight
Phytophtora blight (*Phytophthora dreschsleri* f.sp. *cajani*) on pigeon pea
© Y.L. Nene (EcoPort, www.ecoport.org)

Powdery mildew

The disease can infect all aerial parts: leaves, flowers and pods. Characteristic of the disease is white greyish powdery fungal growth on affected plant parts. Small chlorotic spots develop on the upper surface of leaves

and the corresponding lower surface develops white greyish powdery fungal growth. With time the powdery growth covers the entire lower leaf area. Severe infection causes heavy leaf drop. The fungus develops at temperatures ranging from 20 to 35º C, but 25º C is the optimum. The fungus survives on perennial pigeon peas and volunteer plants, and on the ratoon growth of the harvested plants. Plants with thicker leaves, as most varieties in Kenya are more tolerant to the disease than those with thin succulent leaves (Indian varieties).

What to do:

- **Plant resistant varieties / lines, if available**
- **Plant in fields away from perennial pigeon peas.**

Powdery mildew
Powdery mildew (*Leveillula taurica*) of pea
© AgrEvo (Reproduced from CABI 2006)

Rust (*Uredo cajani*)

Symptom appears as dark brown raised spots full of brown spores (uredia) on the lower leaf surfaces. Infected leaves dry and drop off. When disease is severe, it causes extensive defoliation. The disease is favoured by rain and wind that facilitate spore release, dispersal and development.

What to do:

- **Plant resistant varieties / lines, if available**
- **Avoid planting of pigeon peas close to bean fields**
- **Avoid dense planting.**

Rust
Rust on beans
© Dongxin Feng, Courtesy of EcoPort, www.ecoport.org

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Information of www.infonet-biovision.org

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Pumpkin

Pumpkin
Scientific name: *Cucurbita* spp. (*Cucurbita maxima, Cucurbita moschata* etc.)
Family: Cucurbitales: Cucurbitaceae
Local names: Budho (Luo), malenge (Kiwahili), lisiebebe (Luhya), marenge (Kikuyu), risoa (Kisii), ulenge (Kamba)
Common names: Squash / giant squash / summer squash / giant pumpkin / butternut

Pests and Diseases: Anthracnose Aphids Choanephora fruit rot Downy mildew Epilachna beetles Fruit flies Powdery mildew Scab Virus diseases Whiteflies

General Information and Agronomic Aspects

Geographical Distribution of Pumpkin in Africa

Pumpkin refers to certain varieties of Cucurbita moschata, C. maxima, and C. mixta. They are native to North America. These and other related cucurbits provide pumpkins and butternuts (*Cucurbita moschata*), squashes (*C. maxima*), gourds (*C. argyrosperma*), and zucchini or courgettes and ornamental gourds (*C. pepo*). Distinguishing them is often difficult. Pumpkins have long-running, bristled stems, large deeply-lobed leaves often containing white blotches and yellow or orange flowers separated into male and female types on the same plant. The fruit is variable in shape and colour but is often white, cream or green, containing about 70% flesh and several large white seeds.

Fruits, leaves and flowers of these cucurbits are used as vegetables, and their seeds are consumed roasted as a snack food. Pumpkin fruit contains 1% protein and 8% carbohydrates, and the dried seeds contain 23% protein, 21% carbohydrates and up to 50% oil, but little information is available about the nutritional characteristics of cooked leaves (Woomer and Imbumi, 2005).

There are numerous types and cultivars, which differ greatly in composition and therefore in their suitability for certain culinary uses. The younger leaves are collected and the outer tough skin of petioles (stalk of leaf) removed (together with the large leaf veins) then washed, chopped and boiled.

Immature and mature fruits of *C. moschata* are used as a blanched, steamed or fried vegetable and as an ingredient of soups. Various desserts are made from the fruits: steamed flesh with grated coconut and sugar, crisps made from steamed mashed flesh mixed with cassava flour, pumpkin custard, pumpkin pudding, pumpkin in coconut milk and sweet pumpkin paste. Ornamental gourds are cultivars of *C. pepo* with small, bitter and inedible fruits in many shapes, sizes and colours.

The potential of the seeds as a source of vegetable fat and protein has not been fully exploited. Fresh seeds have been reported to be used as a vermifuge, and seed decoctions as diuretic and to reduce fevers.

The pumpkin has been much used as a medicine in Central and North America. It is a gentle and safe remedy for a number of complaints. The seeds are widely used as an anthelmintic. The complete seed, together with the husk, is used to remove tapeworms. They are especially useful effective as tapeworm treatment for children and pregnant women for whom stronger and toxic remedies are unsuitable. The seeds are ground into fine flour, then made into an emulsion with water and eaten. It is then necessary to take a purgative afterwards in order to expel the tapeworms or other parasites from the body. The fruit and seed decoctions have been reported to be used as diuretic and to reduce fevers, and are used for curing indigestion. The pulp is applied to burns and scalds, inflammation, abscesses and boils. It is also used in the treatment of migraine and neuralgia (Plants for a Future 2003; CAB 2006).

Recently a new pumpkin relative, butternut has captured the market in Kenya. It was originally imported from South Africa and sold at very high prices in the upper level market, but is now widely grown by small farmers. Butternut has smooth yellow-orange flesh, is very nutritious and is widely used cooked and mashed as baby food. As the price came down this vegetable has gained wide popularity all over the country.

Nutritive Value per 100 g of edible Portion

Raw Vegetable	Food Energy (Calories)	Protein (g)	Carbohydrates (g)	Ash (g)	Calcium (g)	Phosphorus (mg)	Iron (mg)	Potassium (mg)	Vitamin A (I.U)	Thiamine (mg)	Ribofl (mg)
Pumpkin	26	1.0	6.5	0.8	21	44	0.8	340	1600	0.05	0.11
Squash	19	1.1	4.2	0.6	28	29	0.4	202	410	0.05	0.09

Climate conditions, soil and water management

Pumpkins and squashes (various *Cucurbita* spp.) are grown in the tropics from the lowlands up to 2500 m altitude. They are warm-season crops adapted to monthly mean temperatures of 18-27°C. *C. maxima* is the most tolerant of low temperatures, *C. moschata* and *C. argyrosperma* the least, with *C. pepo* intermediate. *C. maxima* and *C. pepo* have long been cultivated in temperate regions. Butternut appreciates part shade in very hot conditions, such as can be obtained when intercropped with other crops or grown under fruit trees.

Pumpkins and squashes respond very well to medium to heavy applications of compost or well- decomposed manure. They can be cultivated on almost any fertile, well-drained soil with a neutral or slightly acid reaction (pH 5.5 to 7). They are drought-tolerant, requiring relatively little water, and are sensitive to waterlogging. Excessive humidity is harmful because of the development of leaf diseases, so none of the species do well in the humid tropics.

Propagation and planting

Pumpkins and squashes are grown from seed. Seeds may be sown in containers and transplanted to the field when they are 10 cm high. Direct seeding of two to three seeds per hill is commonly practised. Trailing types are planted at distances of 2-3 m either way; the seed requirement is 2 to 3 kg/ha. The bushy types (mainly *C. pepo*) are planted closer, for example, plants spaced 60 to 120 cm in rows 1 to 1.5 m apart; the seed requirement is 3 kg/ha for pumpkin and 7 kg/ha for summer squash (*C. pepo*). Do not use seeds from plants where edible pumpkins and ornamental gourds are grown close together. Offspring will be bitter or even inedible.

Husbandry

Sole cropping is sometimes used for commercial production. Pumpkins and squashes are also planted in home gardens or mixed with field crops such as maize. Cultural practices to improve growth and development include the removal of growing tips (in trailing varieties) to check growth, and the bagging of fruits in paper to protect against fruit fly and other pests. Fruit setting may be stimulated by manual pollination. The fruit may rot when in contact with moist soil, so often cut grass or leaves are placed beneath the fruit.

Harvesting

Winter squashes and pumpkins are picked when mature in an once-over harvest or in several rounds, about 90 to 120 days after planting depending on variety.

Pumpkins are considered to be among the most efficient of vegetable crops when evaluated on nutritional yield in relation to land area and labour needed. Indicative figures for seed yield of *C. pepo* are 400 to 1500 kg/ha. A valuable source of oil and protein is thus neglected if the seeds are left unutilised. In seed production, isolation between fields of different *Cucurbita* species is recommended, not only for reason of purity but also for obtaining maximum yields (pollen of other species may cause reduced fruit set).

Information on Pests

Pumpkin and butternut are affected by similar pests and diseases as other cucurbits; this is plants belonging to the family Cucurbitacea, including melons, squash, zucchini (courgettes) and cucumber.

For more information on pests attacking cucurbits refer also to page on cucumber click here

Examples of Pumpkin Pests and Organic Control Methods

Aphids (*Aphis gossypii*)

Colonies of green to blackish aphids are found on tender shoots, mainly on the lower leaf surface, where they suck sap. Under heavy attack the growth of attacked shoots is stunted and leaves are curled and twisted. Aphids excrete honeydew, which leads to growth of sooty mould, and may also attract fruit flies. Aphids transmit virus diseases such as the watermelon mosaic virus to pumpkins.

What to do:

- **Use reflective mulch (e.g a polyethylene sheet covered with a thin layer of aluminium that is spread out on the growing bed at planting time). Covering the ground with a material like aluminium foil repel winged aphids, delay aphid colonisation and may delay virus infection**
- **Place sticky traps to detect arrival of winged aphids into the crop.**
- **Conserve natural enemies. Aphids have a wide range of natural enemies which usually keep them under control.**
- **If necessary spray with botanicals (e.g. neem extracts). Spray only attacked plants (spot spraying).**

Cotton aphid
Cotton aphid (*Aphis gossypii*) is a small aphid. Adults range from just under 1-1.5 mm in body length.

Whiteflies (*Bemisia tabaci*)

Whiteflies suck plant sap and excrete honeydew where moulds growth and may affect plant growth. However, the major damage is caused as vectors of various virus diseases, which cause considerable damage to cucurbits.

What to do:

- **Conserve natural enemies. Parasitic wasps are important in natural control of whiteflies.**
- **Use reflective mulches (see aphids). Reflective mulch repels whitefly adults in pumpkin, cucumber and**

zucchini squash, resulting in delayed and reduced attack by this pest with consequent reduction in damage as shown in experiments USA. Whitefly density on pumpkins and cucumbers plants growing over reflective mulch was reduced 10- to 14-fold as compared to plants growing on bare soil. This was reflected in significantly higher yields in plants grown over reflective mulch than in those grown over unmulched soil (UCANR, 2003; Summers & Stapleton 2002)
- **If necessary spray crop with neem products. Neem-based pesticides are reported to inhibit growth and development of immature stages, and to reduce egg laying by adult whiteflies.**

Whiteflies
Whiteflies (*Bemisia tabaci*) under leaf. Adult whiteflies are about 1mm long.
© Clemson University, Department of Entomology

The Epilachna beetle (*Epilachna chrysomelina*)

Adults of the Epilachna beetle, also known as the African melon ladybird are 6 to 8 mm long, reddish in colour with a number of black spots on the wing cases. The larvae are 7 to 9 mm in length, soft and covered with dark coloured spines. They pupate on leaves. Both adults and larvae feed on the leaves leaving a fine net of veins. Damaged leaves shrivel and dry up. They may also gnaw stems and eat holes in fruits.

These beetles are most likely to be a problem during establishment when plants are small; young plants can be entirely destroyed. Older plants can tolerate considerable leaf damage, but during flowering fruit set maybe affected. This beetle is a vector of squash mosaic virus. The Epilachna beetle attacks all cucurbits. They often

fly into a crop from nearby crops.

What to do:

- **Do not grow pumpkins near crops attractive to the Epilachna beetle (e.g. other cucurbits, potatoes, maize)**
- **If necessary apply neem products. Simple neem-based pesticides are effective controlling this pest. For instance, weekly foliar sprays of aqueous neem kernel extracts at concentrations of 25, 50 and 100 g/l and neem oil applied with an ultra-low-volume (ULV) sprayer at 10 and 20 l/ha significantly reduced feeding by Epilachna beetles in squash and cucumber in Togo (Ostermann and Dreyer, 1995)**

Epilachna beetle
Epilachna beetle (*Epilachna chrysomelina*) and damage caused on water melon
© A. M. Varela, icipe

Fruit flies (*Bactrocera cucurbitae*, *Dacus* spp and *Ceratitis capitata*)

Fruit flies are important pests of cucurbits including pumpkins. Fruit flies pierce the fruits and lay eggs in them. The fruit fly maggots feed inside the fruit causing sunken, discoloured patches, distortions and open cracks. These cracks serve as entry points for fungi and bacteria, which cause fruit rot.

What to do:

- **Avoid continuous cultivation of cucurbits at the same place.**
- **Destroy all infested fruit**
- **Wrap or bag individual fruits with newspaper or paper bags to prevent fruit flies form laying eggs on the fruit. Wrapping or bagging should be started shortly after fruit set.**
- **Spray with a pyrethrum solution in the evenings after the bees are mostly back in their hives (after 6 pm). There is a product commercially available called Flower-DS, made of natural pyrethrum and acceptable in Organic certified systems (see Hygrotech Company, contact-addresses below).**
  - Precautions: Be careful to spray late in the evening, follow the spraying instructions. Wear masks and skin protection.
  All insect poisons are also poisonous to humans even if coming from natural sources.
  - Frequency of spraying: start shortly after beginning of flowering, and repeat approx every 5 days or according to counts.
- **Frequent applications of neem can keep fruit fly attack to a minimum.**
  For more information on neem click here.

Fruit fly
Mediterranean fruit fly (*Ceratitis capitata*). 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.

Information on Diseases

Pumpkin and butternut are affected by similar pests and diseases as other cucurbits; this is plants belonging

to the family Cucurbitacea, including melons, squash, zucchini (courgettes) and cucumber.

For more information on diseases attacking cucurbits refer also to page on **cucumber click here**

Examples of Pumpkin Diseases and Organic Control Methods

Anthracnose (*Colletotrichum lagenarium (= C. orbiculare)*)

It is a very destructive disease. It causes defoliation and lesions on the fruits.

The fungus can attack all the above-ground plant parts. Cotyledons (seed leaves) of affected seedlings droop and wilt. Lesions (elongated spots) may form on stems of affected seedlings near the ground. Spots on leaves start as small yellowish areas that enlarge and turn brown. The affected tissue dries, breaks and the whole leaf dies. On vines, the spots are elongated and may kill the vines. Symptoms are most noticeable on fruits. Spots on fruits are circular, black, and sunken. When wet, the centres of the spots become salmon coloured due to a mass of fungal spores. Affected fruits can be destroyed by secondary soft-rot organisms, which enter through broken rind. The fungus is seed-borne. It can survive in crop debris and in weeds belonging to the cucurbit family. Fungal development is promoted by wet conditions, high relative humidity and moderate temperatures (20 to 23.9º C). Its host range includes cucumber, gherkin, gourd, muskmelon, and watermelon. Cucurbit weeds can also be attacked.

What to do:

- **Use certified disease-free seeds**
- **Treat own seeds in hot water for 20 minutes at 135° F (43° C)**
- **Plant resistant varieties, if available**
- **Practice crop rotation with non-cucurbits**
- **Destroy volunteer cucurbits in the field**

Anthracnose
Anthracnose (*Colletotrichum orbiculare*) damage to pumpkin leaf (*Cucumis sativus*).

Choanephora fruit rot (*Choanephora cucurbitarum*)

- **Powdery mildew (*Erysiphe cichoracearum*)**
- **Downy mildew (*Peronospora cubensis*)**
- **Scab (*Cladosporium cucumerinum*).**

What to do:

- **Destroy crop residues after harvest.**
- **Control cucumber beetles, which are responsible for fungal spread.**
- **Spray copper when the disease is observed**
- **Avoid humid conditions during storage.**

Choanephora fruit rot
Choanephora fruit rot (*Choanephora cucurbitarum*) on *Cucurbita maxima*.

Powdery mildew (*Erysiphe cichoracearum*)

Symptoms first develop as a whitish talcum-like powdery growth on lower leaf surface. The powdery growth is composed of fungal spore mass. These areas covered by white powdery growth may enlarge and join up to cover both lower and upper leaf surfaces. Severely affected leaves dry, turn brown and become brittle. Vines can be also attacked. Secondary effects of the disease include sun-burning and premature ripening of fruits.

Powdery mildew affects cucumber, gourd, muskmelon, pumpkin, squash and watermelon. Other hosts include African violets and pawpaws. The powdery mildew fungi are influenced by plant age, humidity and temperature. Foliage is most susceptible 16 to 23 days after unfolding. The fungi reproduce under dry conditions. Infection increases as humidity increases, but does not occur when leaf surface is wet. Optimum temperature for infection is about 27.4º C. However, infection can take place at a temperature as high as 32º C and relative humidity as low as 46%.

What to do:

- **Use resistant varieties, if available**
- **Spray with sulphur based organic fungicides, which provide good control**

- **Destroy weeds belonging to the cucurbit family**

Powdery mildew
Severe powdery mildew attack (*Sphaerotheca fuligenea*) on cucumber
© Jürgen Kranz Courtesy of EcoPort

Downy mildew (*Peronospora cubensis*)

Symptoms on leaves appear as small, pale-yellow areas on upper leaf surface. Under humid conditions, a purplish, grey whitish growth may be seen on the underside of the yellowish spots. Affected leaves curl, shrivel and die. Most downy mildew fungi require cool weather for reproduction and development. This is not true of the cucurbit downy mildew fungus. Optimum temperature for infection is at 16 to 22º C. It can survive when temperatures are over 37.8º C. The most critical factor for infection is a film of moisture and / or long dew periods on leaves.

Disease spread is primarily thorough by wind and rain splash. The fungus attacks only members of the cucumber family, mostly those that are cultivated, although it can infect wild cucumber and a few other weed hosts.

Downy mildew on cucumber
Downy mildew (*Peronospora cubensis*) attacking the upper leaf face

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Scab (*Cladosporium cucumerinum*)

It attacks all aboveground plant parts. Initial symptoms on leaves appear as light water-soaked or pale green spots. The spots are numerous and can appear on and between veins. Elongate spots may develop on petioles and stems. The spots later turn grey to white and become angular. The fine veinlets in the spots may be brown and are distinct against a white background. Dead leaf tissue cracks and breaks away until the whole leaf is ragged. Fruits can be attacked at all stages of growth. However, young fruits are most susceptible. Plant tissue near the spots may produce sap, initially watery but later becomes gummy to hard.

The fruit spots are cankerous and with time become darker, sunken until a pronounced cavity is formed. Under moist weather, a dark-green velvety layer of fungal growth appears on the cavities. The fungus survives in crop debris, soil and on seed. It is spread by insects, farm tools and wind. The disease is most severe at 100% relative humidity and at relatively cool temperatures (21-25ºC). Its host range includes cantaloupe, gherkin, muskmelon, pumpkin, squash and watermelon.

What to do:

- **Use resistant varieties, if available**

- **Use disease-free seeds**
- **Practice crop rotation with non-related crops**

Scab
Scab (here on a citrus leaf) symptoms on leaf

Virus diseases

Many important virus diseases affect cucurbits. These include:

- **Cucumber mosaic cucumovirus (CMV)**
- **Watermelon mosaic 2 potyvirus (WMV-2)**
- **Watermelon mosaic 1 potyvirus**
- **Zucchini yellow mosaic potyvirus (ZYMV)**
- **Squash leaf curl bigeminivirus (SLCV)**

Cucumber mosaic virus
It is not seed transmitted except through seed of perennial wild cucumber (*Echinocytis lobata*) and chickweed (*Stellaria media*). It is mechanically transmitted and in nature it is spread by various species of aphids. It has a very extensive host range including such varied species as bananas, carrots, cowpeas, lupine, lilies, onions, passion fruit, potatoes and tomatoes.

Watermelon mosaic virus
This virus is mechanically transmitted and also spread by several species of aphids. It is not seed transmitted. Its host range is primarily restricted to cucurbits although one of its strains infects peas.

Squash mosaic virus
It is mechanically transmitted. It is transmitted through seeds of melons and squash. It is also transmitted by spotted, striped and banded cucumber beetles, which attack cucumbers in the Americas. The Epilachna beetle (*Epilachna chrysomelina*) a pest of cucumber in Africa, is also vector of squash mosaic virus. Its host range includes cucurbits, peas, coriander, and salad chervil.

What to do:

- **Use tolerant / resistant varieties if available**
- **Remove infected plants (disinfect hands and tools with 70% alcohol after contact with infected plants)**
- **Do proper weeding**
- **Control insect vectors. A sustainable approach of controlling aphids is important to prevent aphids reaching the crops and transmitting virus.**
- **In case of squash mosaic virus use disease-free seeds**

Virus diseases
Virus on cucumber

Virus dise…

Mosaic vir…

Fresh Quality Specifications for the Market in Kenya

The following specifications constitute raw material purchasing requirements

PRODUCE:	Pumpkin
IMAGE:	
VARIETY:	Various
GENERAL APPEARANCE CRITERIA	
COLOUR:	Blue-green and orange to yellow mottled skin with yellow-orange flesh.
VISUAL APPEARANCE:	Slightly ribbed and smooth. Stem with clean cut. With no evidence of discolouration or disfigurement. Free from foreign matter.
SENSORY:	Smooth skin; smooth, dry and slightly sweet flavoured flesh. Free from foreign and 'off' smells or tastes.
SHAPE:	Squat to well rounded
SIZE:	2.5 kg to 5 kg weight; as per pre-ordered size requirements.
MATURITY:	Not undersized; with firm, hard skin.
INSECTS AND PHYSICAL DAMAGE:	With no evidence of live insects (eg whitefly, insect larvae). With no unhealed cuts, holes or splits that break the skin. With no loss of stem.

PRODUCE:	Butternut
IMAGE:	
VARIETY:	Various
GENERAL APPEARANCE CRITERIA	
COLOUR:	Cream to very light brown colour
VISUAL APPEARANCE:	Small gourd shaped bulbing at end away from stem
SENSORY:	Smooth skin; slightly sweet flavoured flesh. Free from foreign and 'off' smells or tastes.
SHAPE:	Small gourd shape
SIZE:	0.7 kg to 1.5 kg weight; as per pre-ordered size requirements.
MATURITY:	Not undersized; with firm, hard skin.
INSECTS AND PHYSICAL DAMAGE:	With no evidence of live insects (eg whitefly, insect larvae). With no unhealed cuts, holes or splits that break the skin. With no loss of stem.

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Millet

Millet
Scientific name: *Panicum miliaceum*
Family: Cyperales: Poaceae
Local names: Mawele (Swahili)
Pests and Diseases: African armyworm African maize stalkborer Blast Crazy top downy mildew Downy mildew Ergot Fusarium wilt Grasshoppers Long smut Mealybugs Millet head miner Purple witchweed Shoot fly Spotted stemborer Stemborers Storage pests

General Information and Agronomic Aspects

Geographical Distribution of Millet in Africa

Millets refers to a group of annual grasses mainly found in the arid and semiarid regions of the world. These grasses produce small seeded grains and are often cultivated as cereals. The most widely cultivated species are:

- Pearl millet (*Pennisetum glaucum*)
- Foxtail millet (*Setaria italica*)
- Common millet or proso millet (*Panicum miliaceum*)
- Finger millet (*Eleusine coracana*)

The husked grain of millet has a slightly nutty flavour and can be eaten whole after roasting or after cooking or boiling like rice. Millet flour is used for making mush, porridge, flat bread or chapatti. The flour is also used for making wine or beer. The grain is a feed for animals. The green plant is used as forage, but the quality of the straw is poor. Brooms are made from the straw. Starch from the grains is used for sizing textiles. Millet plays a vital role as a food security crop especially in semi arid lands of Kenya. Some millet varieties will survive drought conditions where maize crops often fail to reach maturity. The popularity of millet fell for some years due to introduction of maize, wheat and rice, but is again on the rise with millers being able to sell far more than is delivered. Millet is fast becoming a popular baby food as the grains are rich in calcium and have a pleasant flavour. Due to unpredictable rainfall patterns, Kenya has been experiencing frequent maize crop failure (the main staple) leading the Government of Kenya to encourage the production of indigenous, drought tolerant crops like millet.

Climate conditions, soil and water management

Millet is mostly grown in temperate and subtropical regions. It is adapted to conditions that are too hot and too dry, and to soils too shallow and poor for successful cultivation of other cereals. It is tolerant of a very wide temperature range but susceptible to frost. Cultivation occurs up to 3000 m altitude in the Himalayas. In Kenya millet is grown from 0 - 2400 m above sea level. Proso millet has one of the lowest water requirements of all cereals. An average annual rainfall of 200 - 450 mm is sufficient, of which 35 - 40% should fall during the growing period. Most soils are suitable for its cultivation, except coarse sand.

Varieties in Kenya

A lot of work has been done to identify improved varieties of millet to be grown under different ecological zones of Kenya.

Some recommended varieties and their characteristics:

Crop	Variety	Maturity (months)	Grain colour	Grain Yield Potential (bags/acre)
Finger millet	"P224" "Gulu E" "KAT/FM/FM-1" "LANET/FM-1"	4 4 3 4	Brown Brown Brown Brown	10 8 7.5 7
Pearl millet	"KAT/PM-1" "KAT/PRO-1"	2.5-3 2.5-3	Grey Grey	12 10
Proso millet	"KAT/PRO-1"	2.5	Cream	8

Fox tail millet	"KAT/FOX-1"	3-4	Yellow-cream	8

Proso and fox tail millet can be grown in all areas whereas Gulu E does best on coast and moist mid altitude. KAT/FM1 is recommended for semi-arid lowlands and Lanet/FM1 for cold semi arid highlands.

Propagation and planting

Selection of healthy seeds, free from bird and insect damage and diseases, is important to produce vigorous seedlings that could fare well in case of attack by pests or diseases. Prepare seed for sowing by threshing it (if at all stored on the head) and removing all admixtures such as glumes, bits of the rachis and peduncle, etc. This can be done by winnowing and occasionally by sieving. These processes also remove light and small seeds. A fast, easy and efficient method of quality seed selection uses a 10% salt solution to separate good seeds from bad seeds. The salt solution enhances the flotation of light and damaged seeds, fungal spores and light foreign matter. The good and heavy seeds and pebbles drop to the bottom. The floating portion is decanted and discarded and the sunken portion subjected to flotation one or two more times, after which the good seeds at the bottom are rinsed with clean water to remove excess salt. This portion is then sun-dried. After drying, the pebbles are removed by hand picking (DFPV, Niger).

Early land preparation is recommended. Millet requires a fine seedbed suitable for small grains, to ensure good germination, plant population density and effective weed control. If tractors or oxen are used to open up land for planting, it is advisable to harrow it after the first ploughing. When jembes (hand hoes) are used for land preparation, farmers are advised tobreak large clods to provide a smooth seedbed. Plant before or at the onset of rains by either drilling in the furrows made by oxen plough or tractor or by using a panga (cutlass) for hand planting in hills.

Spacing and seed rate. If the population is too high at emergence, thin when plants are about 15 cm tall, 2 weeks after emergence. Seed rate (when planted in furrows):

- **Finger millet - 3 kg/ha**
- **Pearl millet - 5 kg/ha**

- **Fox tail millet - 4 kg/ha**
- **Proso millet - 4 kg/ha**

For sole cropping the following distances should be followed:

- **Pearl millet varieties: 15 cm between seeds and 60 cm between rows**
- **Finger millet, foxtail and Proso millet: 10 cm between seeds and 30 cm between rows.**

Husbandry

Millet benefits from intercropping with such legumes such as green gram and cowpeas. It can also be rotated with legume crops to benefit from the soil improvement facilitated by these crops or intercropped with other non-cereal crops. Application of farmyard manure at 8-10 tons/ha is recommended in order to improve the soil organic matter content, moisture retention ability and soil structure. Phosphorous should be applied in the form of rock phosphate. For conventional farmers please use the fertilizer recommendations of the local extension office. Weeding should be done twice, first time 2-3 weeks after emergence and second weeding about two weeks later.

Harvesting

Harvest takes place 2-4 months after sowing, when the grain has a moisture content of 14-15%. Avoid delayed harvesting, as the seed shatters easily. If Millet is harvested during the rainy season with high relative humidity, the grain must be dried to 14% moisture content. In households, millet is usually dried above the domestic fire. Millet is threshed immediately after harvest. The grain stores well for up to five years. Sometimes the grain is mixed with ash or slightly baked before storage. Because of its small size, the grain is barely susceptible to insect attack.

Information on Pests

The African armyworm (*Spodoptera exempta*)

It is usually an occasional pest, but when outbreaks occur damage to millet can be devastating. The caterpillars eat the above-ground parts of the plants leaving only the base of the stem.

What to do:

- **Monitor regularly field margins, low areas where plants have lodged, beneath plant debris around the base of plants, on the ground, and underneath the plant leaves. Check daily young crops if conditions are known to be favourable to the pest.**
- **Spray Bt or botanicals such as neem and pyrethrum extracts. Spray when caterpillars are small. Once caterpillars are mature (about 3 to 3.5 cm long) they may have cause serious damage and it may no longer be economical to treat the crop. For more information on (neem click here, for pyrethrum click here and for Bt click here)**
- **Conserve and encourage natural enemies. For more information on natural enemies click here**
- **Practise field sanitation. For more information on field sanitation click here**

African armyworm
African armyworm (*Spodotera exempta*). Mature caterpillars measure up to 4 cm.

Stemborers

Several species of stemborers attack millet including the millet stemborer (*Coniesta ignefusalis*), the maize stalkborer (*Busseola fusca*), the spotted stalkborer (*Chilo partellus*), and the pink stalkborer (*Sesamia calamitis*).
Stemborer caterpillars bore into stems of millets disrupting the flow of nutrient from the roots to the upper parts of plants. Attack on young millet plants causes damage known as "dead hearts". In older plants the top part of the stem dies as a result of tunnelling by the borers.

The millet stemborer (*Coniesta ignefusalis*)
It is the dominant stemborer of millet in the Sahelian zone of Africa, and also attacks sorghum, maize, and wild grasses. Major damage has been reported in West Africa. It has also been found causing considerable damage to millet in Western Eritrea, being considered as the major pest of millets in Eritrea (B. Le Ru, icipe, personal communication). The moths have golden brown forewings. They are active throughout the night and during the day rest on the lower surface of leaves or along stems. Caterpillars are cream-coloured with black spots along the body. However in the dry season, when caterpillars enter in diapause (a resting period) they change colour to pale yellow or uniform cream white. They stay in this resting period from six to seven months, but occasionally for more than a year.

Moths lay eggs between the leafsheat and the stem in batches of 20 to 50 eggs. Caterpillars tunnel in the leafsheats and in the underlying stem. They normally pupate within the stem. Small plants on which eggs are laid may be thoroughly riddle with caterpillars and soon collapse, but in larger plants external symptoms show two to three weeks after stems have been infested.
Economic damage results from early plant death (deadheart) stem tunnelling, disruption of nutrient flow, steam breakage, poor or no grain formation and empty heads. Crop losses have been estimated at $91 million a year.
For more information on the African maize stalk borer click here. For more information on the spotted stalkborer click here.

What to do:

- **Sow early, soon after first rains. Delayed planting tends to increase the incidence of diapause, resulting in significantly higher numbers of diapausing larvae in millet stalks at the end of the growing season. Burn all crop residue left in the field after harvest. When using millet stalks for constructions, burn partially them immediately after harvest.**
- **Use resistant varieties if available**
- **Monitor the millet stemborer. In West Africa, pheromone technology has proved to be highly effective in monitoring this stem borer. These pheromones can also be used to reduce stemborer populations. Mass trapping using pheromones has been tried in farmers' fields in Niger. These traps were particularly effective along fences and granaries, areas that harbour borers. Results indicate that inexpensive, locally made pheromone-baited traps are efficient and well adapted to local conditions (ICRISAT).**

Spotted stemborer
Spotted stemborer (*Chilo partellus*)


Spotte st… **Millet ste…**

The millet head miner (*Heliocheilus albipunctella*)

It is the most important insect pest of pearl millet in the Sahel. Moths deposit their eggs on the heads of millet,

preferring half-emerged and fully-emerged flowering heads. The caterpillars mine into the seeds of the millet head, damaging the millet panicle (i.e. the flower head, where the grain is formed). It has been reported to cause complete crop loss. Pupation takes place in the soil.

What to do:

- **Plough deeply to expose residual larval populations and pupae to natural enemies and desiccation.**
- **Conserve natural enemies. Efforts in artificial augmentation (rearing and releases) of an effective parasitic wasp (Habrobracon hebetor), and identification of other useful, complementary natural enemies, are going on in West Africa. (IITA, The McKnight Foundation). A two-week delay in planting of short cycle millet varieties (75 days to maturity) to desynchronise the peak flight period of the susceptible phenological stage of the crop has been reported to be effective against this pest (DFPV, Niger).**

The shoot fly (*Atherigona soccata*)

Sorghum shoot fly, (*Atherigona soccata*), is a particularly nasty pest of sorghum in Asia, Africa, and the Mediterranean area. Females lay single cigar-shaped eggs on the undersides of leaves at the 1- to 7-leaf stage. The eggs hatch after only a day or two of incubation, and the larvae cut the growing point of the leaf, resulting in wilting and drying. These leaves, known as 'deadhearts', are easily plucked. When a deadheart is plucked, it releases an obnoxious odor.

Adult resemble small houseflies. They are about 0.5 cm long. The shoot fly has been reported as attacking pearl millet.

Damage occurs 1-4 weeks after seedling emergence. The damaged plants produce side tillers, which may also be attacked. The shoot fly's entire life cycle is completed in 17-21 days. Infestations are especially high when sorghum planting is staggered due to erratic rainfall. Temperatures above 35°C and below 18°C reduce shoot

fly survival, as does continuous rainfall.

What to do:

- **Conserve natural enemies. Parasitic wasps and several species of spiders are important predators on eggs.**
- **Collect and destroy crop residues after harvest to reduce carry-over from one season to the other.**
- **Use shoot-fly resistant varieties, if available**

Shoot fly
Shoot fly (*Atherigona soccata*) The adults are dark brown, and similar to a housefly, but nearly half the size (about 0.5 cm long).
© Georg Goergen, Courtesy of EcoPort, www.ecoport.org

Shoot fly

Sorghu sh...

Grasshoppers

Several species of grasshoppers attack millets. Short-horned grasshoppers include *Zonocerus* spp, *Oedaleus senegalensis, Kraussaria angulifera, Hieroglyphus daganensis, Diabolocantatops axillaris* among others. The

long horned edible grasshopper (*Homorocoryphus niditulus*) is a pest in East Africa.
Grasshoppers defoliate and eat the panicles. They are not of economic importance when present in low numbers. However, invasion by a swarm of grasshoppers may result in serious grain losses.

What to do:

- **Conserve natural enemies. Important natural enemies include ants, larvae of blister beetles, parasitic flies, assassin bugs, predatory wasps, birds, lizards, snakes, frogs, and fungi. Robber flies are also major predator of grasshoppers.**
- **Domesticated poultry (e.g. chickens, turkeys, guinea fowl, geese, and ducks) and wild birds are good for keeping grasshopper populations in check. However, enclose the birds in wire fencing along the perimeter to avoid damage to the crop.**
- **Ensure the ground is covered with crops, grass or mulch. This is reported to reduce grasshopper numbers since they prefer laying eggs on bare soil.**
- **Dig or cultivate the land before planting to expose the eggs to predators and to to the weather.**
- **Whenever necessary spray biopesticides. Neem extracts act as antifeedant (grasshoppers stop feeding when exposed to neem products) and affect development of grasshoppers. For more information on [neem click here]**
- **IITA (the International Institute of Tropical Agriculture) researchers and partners have developed an environmental friendly biopesticide "Green Muscle" for control of grasshoppers and locusts (www.iita.org).**

Grasshopper
Variegated grasshopper (*Zonocerus variegatus*). The size of adult grasshoppers may vary between 3 - 5 cm.

Storage pests: The lesser grain borer (*Rhyzopertha dominica*) and the khapra beetle (*Trogoderma granarium*)

Grains of pearl millet are attacked by major pests such as the lesser grain borer and the khapra beetle. For this reason, the popular concept that millets are hardly susceptible to damage by storage insect pests is erroneous, except for the very small-grained millets such as tef and fonio. The lesser grain borer and the kapra beetle are relatively well adapted to extremely dry conditions and will cause serious damage to millet. Other secondary storage pests do not thrive in semi-arid climates where millets are grown, where stored grain is typically very dry.

Other non-insect pests such as rats and birds may destroy a considerable part of the harvest.

What to do:

- **Keep millet in sealed storage e.g. in drums or underground storage. Lower the temperature during drying of millet. The optimum reproduction temperature for these pests is 30-35°C , thus lowering the temperature around 21°C could check reproduction (Kajuna).**
- **Following some farmer?s practices to manage millet storage pests in the Sahel (see reference: Sankung Sagnia):**
- **1. Hang millet heads over kitchen fires to repel storage pests with the smoke.**
- **2. Store millet on the head. This reduces damage by pests as opposed to storing it in the form of threshed grains because the glumes on the in-threshed head act as protective devices**
- **3. Mix seeds with inert substances such as sand and wood ash. These substances fill the endorsed spaces and thus prevent movement and dispersal of insects inside the stored seeds. They also act**

abrasive to enhance water loss through the insect cuticle, thus killing the insect.
- **4. Mix seeds with plant materials such as leaves of Boscia senegalensis, and mint, Hyptis spp, and pulverised pepper. These materials show a repellent action against storage pests.**

Lesser grain borer
Lesser grain borer (*Rhyzopertha dominica*). Adults are 2-3 mm in length and reddish-brown in colour (shown on wheat grains).

Information on Diseases

Ergot (*Claviceps* spp.)

Cream to pink sticky "honeydew" droplets ooze out of infected florets on panicles. Within 10 to 15 days, the droplets dry and harden, and dark brown to black sclerotia (fungal fruiting bodies) develop in place of seeds on the panicle. Sclerotia are larger than seed and irregularly shaped, and generally get mixed with the grain during threshing. Conditions favouring the disease are relative humidity greater than 80%, and temperatures between 20 to 30°C. The sclerotia falling on the soil or planted with the seed germinate when the plants are flowering. They produce spores that are wind-borne to the flowers, where they invade the young kernels and replace the kernels with fungal growth. The fungal growth bears millions of tiny spores in a sticky, sweet, honeydew mass. These spores are carried by insects or splashed by rain to infect other kernels.

What to do:

- **Plant resistant varieties, where available**
- **Remove affected panicles**
- **Avoid planting seeds from infected panicles.**
- **Plough deep.**
- **Rotate with non-cereals preferably with pulses.**
- **Practice good field sanitation.**

Ergot
Ergot (*Claviceps* spp.) on millet
© Reproduced from PEARL MILLET DISEASES - A Compilation of Information of the Known Pathogens of Pearl Millet (http://www.tifton.uga.edu/fat/pearlmilletdiseases.htm)

Blast (*Pyricularia grisea*)

Lesions on foliage are elliptical or diamond-shaped, approximately 3 x 2 mm. Lesion centres are grey and water-soaked when fresh but turn brown upon drying. Lesions are often surrounded by a chlorotic halo, which will turn necrotic giving the appearance of concentric rings. The disease is favoured by hot, humid conditions.

What to do:

- **Plant resistant varieties, if available.**

- **Practise good field sanitation.**

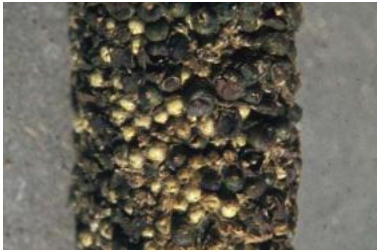
Blast
Blast (*Pyricularia grisea*) on millet
© Reproduced from PEARL MILLET DISEASES - A Compilation of Information of the Known Pathogens of Pearl Millet (http://www.tifton.uga.edu/fat/pearlmilletdiseases.htm)

Long smut (*Tolyposporium penicillariae*)

Immature, green fungal bodies (sori) larger than the seed develop on panicles during grain fill. A single fungal body (sorus) develops per floret. As grain matures, sori change in colour from green to dark brown. Sori are filled with dark spores. Infection takes place at temperature range of between 21 and 31°C, and at relative humidity greater than 80%. The disease is spread by wind-borne spores and rain.

What to do:

- **Plant resistant varieties, if available.**
- **Rotate with non-cereals.**
- **Plough deep.**
- **Practise good field sanitation.**



Long smut
Long smut (*Tolyposporium penicillariae*)
© Kranz J., Schmutterer H., Koch W. Courtesy of EcoPort, www.ecoport.org

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Crazy top downy mildew (*Sclerospora graminicola*)

Symptoms often vary as a result of systemic infection. Leaf symptoms begin as chlorosis at the base and successively higher leaves show progressively greater chlorosis. On the lower leaf surface of infected leaves greyish white fungal growth may be observed. Severely infected plants are generally stunted and do not produce panicles. Green ear symptoms result from transformation of floral parts into leafy structures. The disease is prevalent during rainy seasons.

What to do:

- **Plant resistant varieties, if available**
- **Remove diseased plants from the field**
- **Rotate with pulses**

Crazy top downy mildew
Crazy top downy mildew (*Sclerospora graminicola*) on millet

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Papaya

Papaya
Scientific name: ***Carica papaya***
Family: Violales: Caricaceae
Local names: Pawpaw, papayu (Swahili)
Pests and Diseases: Aphids Broad mite Damping-off and root rot False spider mite Fruit flies Mealybugs Papaya ringspot potyvirus Powdery mildew Ripe fruit rots Root-knot nematodes Snails (Giant East African Snail) Spider mites Systates weevil Whiteflies Anthracnose, Black spot, Black rust, Leaf spot, Stem rot, Mealybugs

General Information and Agronomic Aspects

Geographical Distribution of Papaya in Africa

Papaya is a widely cultivated fruit tree in the tropics and subtropics. It is a popular fruit in Kenya. Ripe papaya is a favourite breakfast and dessert fruit that is available year-round. It can be used to make fruit salads, refreshing drinks, jam, jelly, marmalade, candies and crystallized fruits. Green fruits are pickled or cooked as a vegetable. Young leaves are sometimes eaten. In some countries, seeds are used as vermifuge and to induce abortion (abortifacient).

Carpaine, an alkaloid present in papaya, can be used as a heart depressant, amoebicide and diuretic. In some countries papaya is grown in sizeable plantations for the extraction of papain, an enzyme present in the latex, collected mainly from the green fruit. Papain has varied uses in the beverage, food and pharmaceutical industries: in chill-proofing beer, tenderizing meat, drug preparations for digestive ailments and treatment of gangrenous wounds. It is also used in treating hides, degumming silk and softening wool.

There are 3 groups of papayas distinguished on the basis of their flowers: Female (pistillate), male (staminate) and hermaphrodite (bear both male and female flowers). These groups are only distinguishable at flowering stage. Fruits from female flowered trees are usually sweeter and of more round shape than fruits from hermaphrodite trees.

Climate conditions, soil and water management

Papaya thrives in warm areas with adequate rainfall and a temperature range of 21-33°C. Its altitude range is similar to that of the banana, from sea level to elevations at which frosts occur (often around 1600 m). However they grow best in areas below 1000 m. The quality and yield are low at higher altitudes. Frost can kill the plant, and cool and overcast weather delays fruit ripening and depresses fruit quality. Fruit tastes much better when grown during a warm sunny season. Evenly distributed annual rainfall of 1200 mm is sufficient if water conservation practices are employed. Plantations should be in sheltered locations or surrounded by windbreaks; strong winds are detrimental, particularly on sandy soils, as they cannot make up for large

transpiration losses.
Papaya grows best in light, well-drained soils rich in organic matter with soil pH of 6.0-6.5. It can tolerate any kind of soil provided it is well-drained and not too dry. The roots are very sensitive to waterlogging and even short periods of flooding can kill the plants.

Propagation and planting

Papaya is propagated by seed. To reproduce the desired characteristics it is best to get seeds through controlled pollination. The fleshy outer layer of the seed coat (sarcotesta) enveloping the seed is removed because it inhibits germination. This is achieved by rubbing the seed together against a fine-meshed screen under running water. Thoroughly dried seeds stored in air-tight containers remain viable for several years. Seeds are sown in small containers (tin cans, plastic bags or paper cups) at the rate of 3-4 seeds per container. Use of sterilized soil minimizes losses resulting from nematodes and damping-off fungi. Germination takes 2-3 weeks. Another practice is to sow the seeds in sterilized nursery beds and to prick out at the 2-3-leaf stage, transferring 3-4 seedlings to each container. Seedlings are transplanted about 2 months after sowing when they reach the 3-4-leaf stage or 20 cm height, preferably at the onset of the rainy season. During transplanting, take care not to disturb the roots. Older seedlings recover poorly after planting out.

Papaya needs adequate drainage and is often planted on mounds or ridges. Transplants must be watered regularly until they are established. Field spacings are in the order of 3 x 2 m to 2.50 x 1.60 m, giving densities of 1667 and 2500 plants/ha respectively. The same densities are obtained by planting in double rows spaced (3.25+1.75) x 2.40 m or (2.50+1.50) x 2 m. Thinning to one female or one hermaphrodite plant per hill is done when the plants reach the flowering stage. In the absence of hermaphrodite plants, 1 male plant per 25-100 female plants is retained as pollinator.

Papaya plants grown from seed produce fruits of different shapes, sizes, colour and even taste. Vegetative propagation of papaya provides a solution to most of these problems. The clone is selected for higher productivity and good quality fruits besides agronomic qualities such as dwarfness for easy harvesting and

good resistance to diseases. Propagation of papaya using tissue culture is fast gaining popularity, mainly because tissue culture has numerous advantages over other conventional methods of propagation. Tissue culture facilitates rapid production of disease free plants. In Kenya such plants are available from Kenya Agriculture Research Institute, Thika as well as several private companies.

Planting holes of 60 x 60 cm and at least 50 cm deep are prepared with 1 bucket of compost and a handful of rock phosphate is mixed in with the dug out soil and returned around the plant. Firm the soil and water liberally, then add mulch around the young plant.

Major varieties include:

- **'Honey Dew'. This is an Indian variety of medium height that produces oval juicy medium size fruit.**
- **'Kiru'. Is a Tanzanian variety that produces large fruits. It is a high yielder of papain.**
- **'Mountain'. originally the name for a variety grown at high altitudes with very small fruits only suitable for jam and preserves. Now the name is also used for a medium size variety with good fresh consumption qualities such as firm sweet tasting yellow flesh.**
- **'Solo'. Is a Hawaiian variety that produces small round very sweet fruits with uniform size and shape. It is hermaphroditic.**
- **'Sunrise Solo'. Hawaiin variety that produces smooth pear shaped fruit of high quality, weighing 400 to 650 g. The flesh is reddish orange. This variety is high yielding.**
- **'Sunset': Hawaiian variety with red flesh and having same characteristics as 'Solo'**
- **'Waimanalo'. another Hawaiian variety that produces smooth, shiny round fruits with short neck and is of high quality. The flesh is orange yellow, thick, sweet and firm.**

Most of commercial varieties grown in Kenya are derived from Hawaii. A few are from India and some known as 'Mountain varieties' whose origin / source is a rather not explained. None of these have been reported to have resistance to *P. palmivora*. However, information available claims that Hawaiian lines such as 'Waimanalo 23', 'Waimanalo 24' and 'Line 40' exhibit resistance to *P. palmivora*.

Another serious disease problem with papaya is papaya ring spot virus. However, according to a recent report by PIP COLEACP (www.coleacp.org/en), there are no commercial papaya varieties, except for transgenic, which are tolerant or resistant to papaya ring spot virus or bunchy top.

Intercropping

Papaya grows best when planted in full sunlight. However, it can be planted as an intercrop under coconut, or as a cash crop between young fruit trees such as mango or citrus. Low growing annual crops such as capsicums, beans, onions and cabbages are suitable good intercrops.

Husbandry

Clean cultivation is standard practice and weed control, particularly around the small plants, is very important. If weeds are only slashed - resulting in a grassy weed cover - papaya plants suffer severe competition. Experimental work shows a very good response to mulching. Irrigation is needed to minimize the abortion of flowers and maintain growth during the dry season. Watering once a week is recommended. Papaya is a fast-growing crop that requires a lot of nutrients. The use of manure and mulch steadies the release of nutrients. Calcium deficiency depresses growth and fruit set and enhances fruit drop; liming (to a pH of about 6) is the remedy.

Harvesting

The stage of physiological development at the time of harvest determines the flavour and taste of the ripened fruit.

The appearance of traces of yellow colour on the fruit indicates that it is ready for harvesting. Fruits harvested too early have longer post harvest life, but give abnormal taste and flavour. The fruits also tend to shrivel and suffer chilling injuries when refrigerated. The fruit is twisted until the stalk snaps off or cut with a sharp knife. Yields per tree vary from 30 to 150 fruits annually, giving 35 to 50 tons of fruit per ha per year. A papaya plantation can be productive for over 10 years but the economical period is only the first 3 to 4 years.

It is therefore advisable to renew the plantation every 4 years.

For papain production, latex is collected by tapping the green unripe fruit. Four longitudinal incisions, skin-deep and 2 to 3 cm apart are made with a sharp, non-corrosive rod (glass, plastic or horn). Latex is collected in a clean glass or porcelain container and dried, or a canvas covered tray fixed onto the trunk of the tree. The latex is later scraped off the canvas with a wooden scraper and dried. Fruits may be tapped once a week, until they show signs of ripening. The operation is best done early in the morning (before 10:00) because the latex flows slowly in hot weather. Tapping results in ugly scars on the fruit, although quality is unaffected. Tapped fruit can be processed or used as animal feed. The papain producing trees are productive for 2 to 3 years, with the first 2 years being the most productive. If kept longer production is uneconomical.

Information on Pests

Fruit flies

Two species of fruit flies have been recorded from papaya in East Africa, namely *Bactrocera invadens* and *Ceratitis rosa* (personal communication S. Ekesi, AFFI, *icipe*). The flies usually deposit their eggs in ripe fruit. Some fruit flies lay eggs on green pawpaw, but most of the eggs die due to the latex secreted when fruits are punctured by females while laying eggs. Developing larvae cause rotting of ripening fruits. Fruit flies are a major concern of papaya-importing countries.

What to do:

- **Fruit should be harvested at the mature green stage.**
- **Over-ripe and infested fruit should be buried.**

Fruit fly
Natal fruit fly (*Ceratitis rosa*), wing length 4-6 mm.
© Georg Goergen, Courtesy of EcoPort, www.ecoport.org

Spider mites

Several species of mites damage papaya:
*** Spider mites (Tetranychus spp., Eutetranychus spp. and Oligonychus gossypii)**
*** The false spider mite (Brevipalpus phoenicis)**
*** The broad mite (Polyphagotarsonemus latus)**

(personal communication, M. Knapp, ICIPE).

The 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 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.

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

The false spider mite (*Brevipalpus phoenicis*)

It 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 (Martin Kessing and Mau, 1992; CABI Compendium, 2000).

Size is tiny, about 0.1mm.

What to do:

- **Natural enemies, like predatory mites, often provide adequate control of the false spider mite.**
- **Wettable sulphur sprays can be used in case of heavy infestations (Sulphur has phytotoxic effects when**

used during hot weather).

The broad mite (*Polyphagotarsonemus latus*)

Broad mites are tiny (0.1-0.2 mm long) and cannot be seen with the naked eye, and are even difficult to detect with a hand lens. In addition, they have often disappeared before the damage is noticed. Therefore an attack by broad mites is usually detected by the symptoms of damage. Broad mite attacks mainly the growing point and the underside of young leaves causing hardening and distortion. Severe infestations inhibit new stem growth, with consequent reduction in fruit production. Broad mite damage may be confused with injury caused by some herbicides because in both cases the leaves become claw-like with prominent veins. Grey or bronze scar tissue between the veins on the underside of the leaves distinguishes mite from herbicide damage. For early detection of damage inspect the growing point of the tree regularly. This is important to allow control the pest before serious distortion of terminal growth occurs.

What to do:

- **Natural enemies, in particular predatory mites often provide adequate control of mites. Therefore, the use of acaricides or insecticides that also kill mites should be restricted.**
- **Sulphur, insecticidal oils or soaps are effective against mites. However, sulphur is reported to be toxic to predatory mites.**

Broad mite
Broad mite damage (here on chili)
© A.M. Varela

The cotton aphid (*Aphis gossypii*) and the green peach aphid (*Myzus persicae*)

These are the most important aphids in papaya growing. These insects suck sap from young leaves and flowers and may weaken the plants. However, this type of damage is usually of little importance. Their importance as pests is mainly due to their ability to transmit virus diseases, for instance the papaya ring spot virus and the papaya mosaic virus. Few aphids are enough to transmit mosaic virus. These aphids are also found on other crops such as cucurbits, potatoes and tobacco.

What to do:

- **Avoid planting these crops near papaya fields.**
- **Removing alternative hosts and the presence of natural predators can effectively reduce aphid populations**
- **Monitoring and control of aphids in the nursery is important.**

Cotton aphid
Cotton aphid (*Aphis gossypii*) is a small aphid. Adults range from just under 1-1.5 mm in body length.


Cottor aph…


Green peac..

The systates weevil (*Systates* spp.)

This is a very common weevil in East Africa. It attacks many crops and ornamental plants. The adult is a black weevil, about 12 mm long with a swollen, rounded abdomen, and long, thin, elbowed antenna. It is active at night, feeding on the edges of leaves producing a characteristic indentations. During the day it hides in the mulch, at the base of plants or in loose soil near plants. They feed on a wide range of crops and wild plants. They can be a problem to young papaya plants when present in large numbers.

What to do:

- **Hand picking and destruction is possible.**

Systates weevil
The systates weevil (*Systates* spp.) on papaya. The weevil feeds on leaves, making characteristic notch-like indentations to the leaf margin
© A.M. Varela, icipe

Root-knot nematodes (*Meloidogyne incognita*)

These infest papaya. Feeding nematodes cause root swellings or root galls, resulting in yellowing and premature abscission of the leaves. Infestation by nematodes reduces growth and yield. In nurseries, severely infested seedlings wilt and die.

What to do:

- **It is important to use clean land, and not to replant papaya in the same field.**

Root-knot nematodes
Root-knot nematode galls (here on tomato roots). Affected plants are normally stunted and eventually wilt and die. The most characteristic symptom is formation of root galls (knots) and these can be seen with the naked eye. Affected roots rot.

Information on Diseases

Damping-off and root rot

These are caused by the soil-borne fungi *Phytophthora parasitica, P. palmivora* and *Pythium aphanidermatum*. *Phytophthora* and *Pythium* also occur in the orchard, causing root rot.

Stem and fruit rots are produced on papaya. Infected young fruits develop water-soaked lesions that exude milky latex. These fruits may eventually shrivel and fall off the trunk. Infected trees show yellowing of leaves, which later collapse and hang limply around the trunk before falling. Small roots are generally absent and large ones show a soft, wet decay extending towards the trunk. At that stage, the lateral roots and taproots are entirely destroyed and a foul odour often emanates from diseased trees. Stem cankers, which develop most frequently in the top of the stem where the fruit is borne, induce fruit and leaf fall. These fungi may also cause trunk rot of mature trees. Infected trees eventually die.

Plants are susceptible at all ages but roots of young seedlings are most susceptible.

What to do:

- **Good soil aeration**
- **Good drainage and hygiene are important to control these fungi in the orchard as well as in the nursery.**
- **If possible do not replant pawpaw on the same land.**
- **Copper based fungicide treatments at the very beginning of first symptoms can reduce fruit rots.**

However, it is very sentive to copper fungicides. For more information on [copper click here.]

Fruit rot
White fungal crusts of white mycelium associated with fruit rot of papaya (*Phytophthora palmivora*).

Ripe fruit rots

Several fungal pathogens are involved in fruit decay. They include *Colletotrichum gloeosporioides* (*Glomorella cingulata*), *Alternaria tenuis*, *Phomopsis caricae-papayae* and *Ascochyta caricae*.
Symptoms first appear as brown, superficial discolourations of the skin. These develop into circular, more or less sunken spots and tend to occur in a group on the outer exposed side of the fruit and often join to form a large rotted area extending deep into the flesh. The fungi causing ripe fruit rots live on dying leaf stalks and produce spores, which spread to the fruit particularly during wet weather.
Several of these fungi, especially, *Colletotrichum gloeosporioides*, may infect green fruit and remain dormant in the tissues until ripening when they develop rapidly. They constitute a big post-harvest problem especially during transport and storage.

What to do:

- A 20-minute hot-water dip at 45°C reduces post-harvest decay.
- Spray fruit with hot water at 54°C for 3 minutes

- **Destroy rotten fruit**
- **Practise early harvesting**

Ripe fruit rot
Ripe fruit rot on Papaya
© Illustration courtesy of http://www.padil.gov.au use with permission.

Powdery mildew (*Oidium caricae*; *Sphaerotheca humili*)

Young crown leaves show light green patches covered by a white powdery growth. Fruits develop circular, white patches on the surface. As the fruits develop, the white mould disappears leaving grey-scarred areas. The disease is particularly severe on immature tissue. The white mildew produced on leaves and fruits, contains large numbers of spores, which are spread to adjacent trees by wind and rain.

What to do:

- **Collect and destroy fallen diseased leaves**
- **Spray wettable sulphur. However, sulphur should not be applied when it is very hot as it may cause leaf scorch. Alternatives to the use of sulphur are baking powder, neem extracts and white mineral oil plus soap solution**

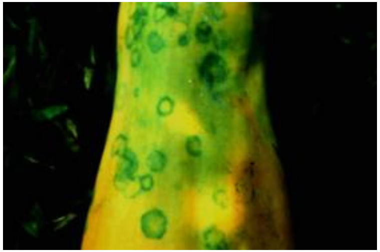
Powdery mildew
Powdery mildew (here on upper surface of an okra leaf).
© A. M. Varela, icipe

Papaya ringspot potyvirus

It is a devastating virus disease. In Africa, it occurs in Kenya, Nigeria, Tanzania and Uganda. 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. The virus is spread by aphids and it is also mechanically transmitted.

What to do:

- **Plant in isolation**
- **Remove and destroy infected plants**
- **Avoid interplanting with cucurbits, which are also a host of PRSV**
- **Use tolerant cultivars.**
- **Papaya mosaic potexvirus is another virus disease transmitted by aphids. Therefore, control aphids as soon as they are visible with soap sprays, neem or pyrethrum.**



Papaya ringspot potyvirus
Papaya ringspot potyvirus (PRSV) on papaya fruit
© A.A. Seif, icipe

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Information of www.infonet-biovision.org

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Sugarcane

Sugarcane
Scientific name: *Saccharum officinarum* L.
Family: Monocotyledonae: Poaceae
Local names: Miwa (Swahili)
Pests and Diseases: African armyworm Gummosis Leaf scald Mealybugs Pineapple disease Purple witchweed Ratoon stunting disease Rats Red rot of sugarcane Stemborers Sugarcane common rust Sugarcane mosaic potyvirus Sugarcane scale Sugarcane smut Termites Couch grass, Witchweed

General Information and Agronomic Aspects

Sugarcane provides over 50% of the worlds sugar requirements as it can grow in any country where it is not exposed to frost. The main product of sugarcane is sucrose, constituting about 10% of the crop. Sucrose is a highly valued food and sweetener but also serves as a preservative for other foods. Moreover, it provides the basis for various food products and beverages.
Sugarcane is chewed in all of the producing countries because of its sweet cell juice. Sugarcane juice is obtained by pressing the sugarcanes, and is mostly used to sweeten

Geographical Distribution of Sugarcane in Africa

foodstuffs, but can also be consumed as fresh or fermented juice. The byproduct of sugar production - molasses - is used in distilling alcohol and as an important cattle feed additive. Sugarcane can even be produced to provide motor fuel alcohol or ethanol as is the case in Brazil. Presently, the worldwide theme is on biofuels, and sugarcane is one of the major contenders. Cane tops can be used as livestock feed.

Organic sugar cane is mostly cultivated on small farms of 0.1-3 ha. The work is carried out manually, or with the help of animals. Only ripe sugarcane is cut down during the harvest. Cut off leaves and unripe plants are left on the plot. In this way, the field is never cleared, and the soil is constantly covered by a thick layer of mulch. Such systems make sustainable cultivation of sugarcane possible, also on relatively sloping ground.

Total area in Kenya under sugarcane production in 2005 was 144,765 hectares with a total production of sugar of 488,997 tonnes , and a national consumption of 695,622 tonnes, so Kenya has a national shortage in sugar production. However, the deficiency in Kenya, is primarily, due to old technology used in sugarcane companies resulting in high cost of production, and that is why Kenya cannot compete with Sudan. Sudan is one of the biggest sugarcane producers in world and number one in Africa.

Climate conditions, soil and water management

Good site conditions are necessary for successful organic cultivation. Under natural conditions, the plant seeks its place in an eco-system amongst the canopy, and therefore needs to reach above the additional crops. Relatively wet conditions tend to cause more difficulties in an organic cultivation system than do sites that are too dry. This is due to a more involved mechanical tilling of weeds, and also to the difficulties the shoots have in developing. Altitudes of 0-1700 m and pH of 5.0-7.0 are suitable.

Ideal site conditions are met with average temperatures of 20 to 28ºC and little fluctuation between night and

day. The ideal amount of rainfall is around 1500-1700 mm annually, with a drought occurring during harvesting. Harvesting during wet conditions gives a lot of transport problems. The soil should be deep, humus-rich, well aerated and drained. On black cotton soils cambered beds and ditches may be necessary.

Propagation and Planting

Generally, sugarcane is vegetatively propagated with cuttings of mature stalks, and true seed is only used for breeding of new cultivars. Each cutting or seed sett usually has 2-3 buds. The cuttings are put down horizontally and covered with a thin layer of soil. The leaves and top ends of seed cane can also be removed in the field, the buds are then allowed to germinate on the standing cane stalk. When the new shoots have reached a certain length, the cane is cut into setts and planted. These pre-germinated setts are excellent planting material, but vulnerable during handling and transport and very labour intensive to produce.

Crop rotation / Intercropping

In contrast to perennial field cultivation of sugarcane, the nursery fields need to follow a strict regime of crop rotation, in order to prevent infestation by soilborne diseases and pests, such as, e.g., nematodes, sugarcane smut (*Ustilago scitaminea*) and red rot of sugarcane (*Glomerella tucumanensis*). In problem cases, treatment of the seedlings with hot water can be effective. Sugarcane smut (*Ustilago scitaminea*), black rot (*Ceratocystis paradoxa*) and nematodes can be successfully managed with a 20 to 30 minute hot water treatment at 52°C, although this temperature may not be exceeded. Hot water treatment is only economically feasible for nursery stock. Heat treatment even when well done reduces germination percentage and the reduction depends on the variety being treated. Heat treated cane cannot be planted straight into commercial fields for two reasons: its germination is likely to be poor and so much cane would be involved that the treatment would be prohibitively expensive. Heat treated setts are therefore planted in nurseries which are harvested about a year later to provide planting material for the commercial fields.

The seedlings are planted in rows in pre-prepared furrows (furrow depth ca. 40 cm). On conventional sugarcane cultivations, the average distance between the rows is 150 cm (120 cm - 180 cm). On organic

sugarcane cultivations, the best results have been achieved with double rows (40-50 cm gap between two single rows and 110-180 cm distance to the next double row). It is necessary to plant legumes on newly developing organic plantations.

Every new plantation should be fertilised with organic material. The organic fertiliser must be well decomposed, so that no fires can be caused by it. It should be spread as near to the plants as possible, so that all nutrients that are released are immediately available to the plants' roots. The broad middle gap between the rows of new plantations is for the sowing of legumes. On farms with enough labour available for the manual harvest, these can be common bean or in drier areas cowpea or other *Vigna* species.Alternatively white clover is an excellent fixer of nitrogen and covers the soil very well, smothering most other weeds.

The beans do not only supply nitrogen, but are also an important source of food, and therefore useful to the economics of the plantation. Foliage of beans or legumes should be incorporated into the soil surface for best nitrogen effect.

Seed setts are planted in a narrow planting furrow, which should have good tillage. They are covered with a thin layer of soil from the inter-row. These planting furrows can be made on flat land or on the bottom of an irrigation/drainage furrow. In wet sites, planting may be on the top of the ridge between the furrows. Irrigation water is usually applied before or immediately after planting. A nursery of one ha is needed to plant 8 to 10 ha of cane.

Recommended varieties for Kenya by zone:

Nyanza sugar belt		Awendo/Trans Mara		Mumias/Nzoia/Busia	
Variety	Yield potential T cane/ha	Variety	Yield Potential T cane/ha	Variety	Yield Potential T cane/ha
CO 421	87.3	CO 421	32.2	CO 945	114

CO 331	93	CO 331		NCO 376	103.4
CO 617	102.7	CO 617	180	CO 421	103.1
CO 945	100	EAK 70-97	156	EAK 69-47	94.9
EAK 70-97	109.2	CO 945	97.5		
EAK 71-402	89.4				
EAK 69-47	100				

Husbandry

Weed control is carried out manually. Where sufficient labour is available, weeding is carried out at 3-4-week intervals with 3-4 weedings per season.

As sugarcane is a heavy producer of plant material, the soil under continuous ratoon crops need heavy fertilisation in order for yields not to decrease. Phosphorus in the form of rock phosphate or SSP should be applied in heavy doses at planting (40-50 bags/ha) and same amount again for each new crop. In organic systems, nitrogen has to come from natural nitrogen fixation of legumes or in the form of compost/manure/slurry, which then also is needed in heavy applications.

Irrigation water, if necessary, is supplied every 2-4 weeks to the cane rows in the case of furrow irrigation, and to the cane on flat land or in small furrows in the case of sprinkler irrigation. When the cane grows taller, more water has to be applied, but intervals between the applications need not always be shortened.
In most cane fields the cane rows are earthed up 1-2 times by hand. In the end the cane stands on ridges separated by furrows. This practice stimulates root growth, consolidates the cane stools and improves drainage on the heavy clay soils. On the lighter textured soils it helps against early lodging of cane and can prevent erosion (if the direction of the furrows is along the contours of the land).

Diversification strategies

The ideal method is to cultivate sugarcane in a crop rotation system, yet for economical reasons, this is often difficult. Therefore, the good self-tolerance of sugarcane, the planting of legumes, the creation of sufficient compensatory tracts and niches, as well as a comprehensive fertilisation management system all have to help replace a lack of crop rotation on organic cultivations.

Green manure plants in existing sugarcane crops

On older plantations, a covering layer of legumes can quickly be obtained by sowing directly after the harvest. The seeds and re-growing sugar cane will form a compact, green mass that can be lightly worked into the soil after 3 months, before the seedbed is prepared for the new sugar cane. At sites with a strong growth of weeds, it may be worthwhile planting a second type of fast growing green manure plant. For sowing it may help to break over the sugar cane and afterwards apply one or two sowings of green manure plants. The green manure plants should be competitive, and able to suppress any weeds that may appear. They should be non-climbing varieties, as these would be harmful to the sugarcane.

Sowing legumes in the middle rows

Directly following the harvest, rapid-growing legumes can be sown in between rows. These will die off after the sugarcanes has appeared.
In areas with light soils and sufficient irrigation water, cane is intercropped, for example, with maize, groundnut or soybean. In such cases, the intercrops are planted on the ridges and the cane is planted 3-4 weeks later in the furrows. If required, irrigation furrows with a depth of 25-30 cm and a spacing of 1.10-1.30 m are made for hand-cultivated cane.

Harvesting

In Kenya the planted sugarcane crop is ready for harvest at the age of 14 (coast) - 22 months (higher altitudes) and the ratoon crop at the age of 12 (coast) - 18 (higher altitude) months. Cut the cane as near o the ground as possible as the butt is the sugar-richest portion. To prepare for a ratoon crop, the stems will have to be trimmed down to ground level in order for new shoots to form well from their own roots.
The cane is cut and loaded manually, hand cut and grab-loaded or loaded in bundles by chains pulled by a

tractor. Because the sucrose is being decomposed quickly inside the sugarcane, it must be processed relatively quickly after harvesting.

In many sugarcane growing regions, a controlled burning-off of the sugarcane fields is practised. Before the actual harvest, the foliage of the sugarcanes is set alight. Quite often, the sugarcane is again burned down after the harvest, in order to make the field easier to work. However if the fire gets out of control, the problem of too much cane being ready for the factory will occur, as it needs to reach the factory within 72 hours after harvest.
Advocates of burning-off argue that: a) an increase in efficiency of sugarcane cutting of around 30% (the work is usually carried out by casual labourers at piece rates).
b) non-burnt sugar cane contains more foreign substances, making sugar processing less efficient.
c) working the soil is not hampered by the mulch layer. The mulch layer hinders the shoots, especially in wet climates.
d) pests and diseases are destroyed by the fire.
e) nutrients in the ash are made easily available.

A 'green harvest' of sugarcane on the contrary is to harvest the cane without burning-off, which is practised in some sugarcane cultivation regions. Organic sugarcane cultivation consciously rejects the burning-off method in favour of a "green harvest" for the following reasons:
a) the sugar cane biomass remaining after harvesting is the basis for long-term sugar cane cultivation.
b) mulch encourages nitrogen fixing.
c) mulch suppresses unwanted growth.
d) in combination with the measures outlined above, this method helps to improve the humus content and the structure of the soil.
e) the burning-off method causes a high loss of nutrients and energy that is caused by carbon and nitrogen compound gases escaping.

Information on Pests

African armyworm (*Spodoptera exempta*)

The African armyworm can cause serious crop losses. Armyworms may cause indirect injury to the taproot by cutting stems and/or consuming foliage above ground.

What to do:

- **Monitor regularly field margins, low areas where plants have lodged, beneath plant debris around the base of plants, on the ground, and underneath the plant leaves. Check daily young crops if conditions are known to be favourable to the pest.**
- **Spray Bt or botanicals such as neem and pyrethrum extracts. Spray when caterpillars are small. Once caterpillars are mature (about 3 to 3.5 cm long) they may have cause serious damage and it may no longer be economical to treat the crop. For more information on (neem click here, for pyrethrum click here and for Bt click here)**
- **Conserve and encourage natural enemies. For more information on natural enemies click here**
- **Practise field sanitation. For more information on field sanitation click here**

Armyworm caterpillar
African armyworm. Mature larvae measure up to 4 cm long and are generally black, heads faintly mottled with dark brown spots, and with light yellow stripes at their backs. They are characterized by the presence

of C-shaped dark spots along their backs (IRRI, 2001).
© University of Arkansas

Stemborers

Stemborers are the most important pests of sugarcane. Several species of stemborers attack sugarcane. The most important is the African stemborer.

1) The African sugarcane stalkborer (*Eldana saccharina*)
The adult moth has a wingspan of 30 to 40 mm. It has elongated, pale brown forewings, each with two small spots in the centre, and whitish hind wings with a short fringe. Adult moths congregate on the cane canopy at night, they are attracted to light and so populations can be sampled using light traps. Female moths lay batches of yellow, oval eggs behind the leaf sheath or in folds of dead leaves. Eggs become pink before hatching. Young caterpillars feed on the leaves eating away the upper layers of the tissue; this damage is known as windowing. Later, they penetrate into the stalks. Caterpillars usually burrow into single internodes. When burrowing in the stem, caterpillars push their excrement outside.

Large amounts of frass are often hanging from the exit hole made by caterpillars prior to pupation. Caterpillars are light brown to dark grey coloured with brown with very small dark coloured spots. Pupation takes place in the plants, in the stem or on the leaf sheath. At emergence, the moth leaves a large emergence hole in the stalk. Attacked plants are stunted; in severe attacks they may dry up and die. When very young plants are attacked "deadheart" results, followed by tillering of the plant.

Older plants or ratoon cane have internodes bored. Crop losses are hard to assess because they vary with the age of the cane. In unstressed, maturing cane, quite high numbers of borers may be present without serious crop loss, but where infested, stressed cane is left to stand from one season to the next, the loss may be total. This stemborer also attacks maize and sorghum.

2) The spotted cane borer (*Chilo sacchariphagus*)

It is a serious pest of sugarcane in the Indian Ocean Islands (Mauritius and Reunion), and also attacking sugarcane in Mozambique and South Africa.

What to do:

- **Adjustments to crop management are the most effective measures in the control of African sugarcane borer.**
- **Use borer-free planting material (setts).**
- **Check planting material for signs of stem boring, which may indicate the presence of caterpillar and/or pupae.**
- **Avoid plant stress, such as drought, since stressed crops are more prone to stemborer attack.**
- **Cut older canes out, as soon as possible after 12 months, because the numbers of borers accumulate as cane ages, especially after about nine months.**
- **Do not leave tops of plants in fields; in East Africa caterpillars of the African cane borer are largely found on the upper part of the plant, and these residue will maintain carryover population for the next growing season.**
- **Proper fertilization is important; in particular nitrogenous fertilizers have shown to influence stemborer attack. In South Africa, where the African sugarcane borer is a problem, a reduction in nitrogen fertilisation rate from 50 kg to 30 kg per hectare is recommended. However, the yield outcome should be considered when deciding in reducing nitrogen input, though nitrogen fertilisation enhances borer development it also enhances the plant's tolerance to borer attack, and the outcome in terms of yield may be positive.**
- **Trashing has been recommended for control of stemborers. De-trashing sugarcane crops during the fifth, seventh and ninth month of growth has been recommended in India for control of the spotted cane borer. Pre-trashing of mature cane reportedly reduces numbers of the African sugarcane borer by 30% or more (Carnegie, 1991).**
- **Burning attacked fields at harvest or burning of residual cane is sometimes suggested, as it is more likely to destroy the pests than trashing, However, there are concerns that it may do more harm than good by destroying natural enemies.**

- **Parasitic wasps and predators attack caterpillars of the African sugarcane borer. In particular Cotesia sesamiae is widespread. The introduced spotted cane borer is attacked by the parasitic wasp Cotesia flavipes introduced in the region for control of the spotted stemborer Chilo partellus. In Madagascar, parasitism of 60% of caterpillars of the spotted cane borer by this parasitic wasp has been reported (Kfir et al, 2002).**

Sugarcane borer
Damage of the African sugarcane borer, (*Eldana saccharina*) in the stalk.
© Courtesy of CIMMYT/www.agricomseeds.net


Sugar…


African su…


African su…


African su…


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Sugarcane scale (*Aulacaspis tegalensis*)

The adult scales are pear-shaped (females) to elongated (males). The scale mainly attacks stalks and leaf sheaths but can also be found on leaves as a result of crowding on the stalks. In the case of severe infestation, the cane stalks are almost entirely covered by scales. When gravid, the female's body is 1.8 mm long and 0.9 mm wide. After egg-laying, the female shrinks and loses her pink coloration. Eggs are laid under the females scale. Upon hatching the crawlers (young immature mobile stage) wander looking for a feeding site. They insert their needle-like mouthparts and suck plant sap and do not move again. They then develop a

thick, waxy scale cover.

Crawlers can be dispersed considerable distances by wind or movement of vegetation by field workers and transport. This scale is a serious pest of sugarcane causing yield loss (both of canes and sugar content) and making extensive replanting necessary. Yields losses of over 30% percent have been reported in Tanzania (Bohlen, 1973).

What to do:

- **Use of clean planting material will delay scale population build-up. Washing or hot-water treatment kills the scales.**
- **Practice plant sanitation in pruning infested plants. In many cases, the crawler stage (dissemination life stage) can be spread from plant to plant by pruning equipment or by infested clippings that are not discarded properly. A good practice is to clean pruning equipment before moving to new plants and to destroy infested clippings. Uproot and burn heavily infested sugarcane plants.**
- **Scales are usually attacked by parasitic wasps; leave alternate infested plants to allow this wasps to survive and to built-up.**
- **Spray of white oils (foliage and truncs) is effective against young scales. However, care should be taken, since mineral oils may be phytotoxic.**

Scale
Round female scale and elongate immature males on a leaf (here the related Mango scale, *Aulacspis*

***tubercularis*). Its 1.5 to 2mm long.**

Pink sugarcane mealybug (*Saccharicoccus sacchari*)

The adult female is pinkish and it is elongated, oval to round in shape, and about 7 mm long. This mealybug is usually found in colonies on the stem beneath the sheath but is sometimes found on the stem just below ground level, on the root crowns, on the stem buds, and underneath the leaves. The leaves often turn red at the bases as a result of mealybug attack. Sooty moulds often develop in severe infestations and ants feed on honey dew excreted by the mealybugs. This mealybug is often present in very large numbers, which excrete a considerable amount of honeydew.

Damage is partially caused by the insect sucking the plant sap, which may lead to stunting and yellowing, thin canes, death of young shoots and impaired growth when mealybugs are present in high numbers, but direct damage rarely causes yield loss in sugarcane. Most damage is caused by honeydew excreted by the mealybugs and the gums exuded from the wounded parts, which interfere with the synthesis of raw sugar juice leading to filtration and clarification problems, lower quality of the syrup and reduced crystallisation. Severe attacks decrease the general vitality of the plants, which become more susceptible to diseases.

What to do:

- **Cultural methods such as destruction of crop residues and trash; clean cultivation; and use of uninfested planting material is the best way of controlling this pest.**

Mealybugs
Here a related species of the sugarcane mealybug (on the image see the cassava mealybug (*Phenacoccus manihoti*). Female mealybugs are 0.5 -1.4 mm long and their body is usually covered with a waxy secretion.

Termites (*Amitermes* spp., *Pseudacanthotermes* spp., *Macrotermes*spp., *Odontotermes* spp., *Microtermes* spp. and *Ancistrotermes* spp.)

Occasionally termites can be a problem by attacking the seed pieces or the roots and stems of established plants. Yield losses can be very high. In Sudan losses of 18 per cent have been recorded and in Central Africa losses of 5-10 per cent are common. In Nigeria plant germination failure of up to 28 per cent has been reported. The most common damage to sugar cane is the destruction of the planting material (setts).

What to do:

- **Deep plow or tillage to expose termites to desiccation and to predators, thus reducing their number in the crops. Pre-planting tillage also destroys the tunnels built by termites and restricts their foraging activities.**
- **Dig mounds and destroy the queen.**
- **Destroy mounds. Mounds may also be flooded or burnt with straw to suffocate and kill the colony.**
- **Spray plant extracts, such as those of neem, wild tobacco and dried chili.**
- **Conserve natural enemies. Ants are important termite predators. Attract ants to the field by placing**

protein-based baits in the field near the plants.

- **Remove residues of previous cereal crops (sorghum, millet and maize). Plant residues left in the field serve as food for termites, which may infest the new crop.**

Termites
Termites (*Coptotermes formosanus*)

Rats (*Rattus* spp.)

Every 5-6 years there are explosions in rat population size, mainly attacking food crops and sugarcane.

What to do:

- **Do not kill mongoose, snakes, owls and other birds as they are very good predators of rats.**

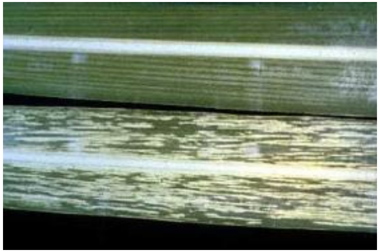
Information on Diseases

The sugarcane mosaic potyvirus (also called mosaic of abaca) (SCMV)

It causes systemic infection of the sugarcane plant: the whole plant, including roots, contains virus. The symptoms (mosaic and/or necrosis) are observed on the leaves and sometimes the stems. Sometimes the whole plant is stunted. The classical symptoms are contrasting shades of green on a background of paler green to yellow chlorotic areas. It is aphid transmitted and also through infected planting material.

What to do:

- **Attempts to eradicate SCMV by rouging infected plants have rarely been successful. Rouging by digging out may be useful in maintaining mosaic-free seed plots of cane if the level of infection is lower than 5%.**
- **A close relationship exists between ants and aphid vectors of sugarcane mosaic virus. Ants can carry the aphids from one sugarcane plant to another, from grass to cane and from cane to grass. Presumably, ants also reduce natural predators and parasitoids of aphids, which would exert better control.**
- **Because aphids which transmit sugarcane mosaic virus come from outside as well as inside the sugarcane crop, take care to reduce the build up of the vector species in the vicinity. Crops of maize and sorghum are hosts of vectors and should not be grown near infected sugarcane crops.**
- **Alter the times of planting and harvesting so that they do not coincide with high aphid vector populations.**



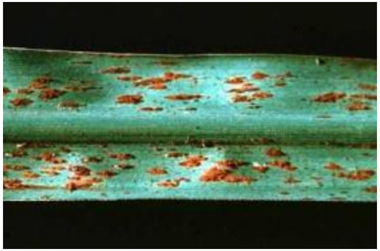
Sugarcane mosaic virus
Severely strains of sugarcane mosaic virus infection on sugarcane compared to a healthy leaf.
© K.C. Alexander (Courtesy of EcoPort, www.ecoport.org)

Sugarcane common rust (*Puccinia melanocephala*)

Initial symptoms of sugarcane common rust are elongate yellowish leaf spots, 1-4 mm long. On susceptible plants, the spots increase in size with a reddish-brown change in colour. Typical rust pustules form on the leaves. The elongate pustules are parallel to the venation of the leaf and measure 2-20 mm by 1-4 mm. Multiple pustules on leaves give a reddish appearance to plants from a distance.

What to do:

- **Control of sugarcane rust relies on planting resistant cultivars. Fungicides are neither practical nor economical for rust control.**



Common rust
Sugarcane common rust (*Puccinia melanocephala*)
© Mauritius Sugar Industry Research Institute

Red rot of sugarcane (*Glomerella tucumanensis* / *Colletotrichum falcatum*)

The fungus may infect any part of the sugarcane plant. It is most destructive as a rot of the stalk of standing cane, seed cuttings and/or stubble pieces remaining in the ground after the cane has been harvested. It produces long lesions on the leaf midribs. The lesions on the leaf midribs are dark or red. They may be short and discontinuous or long extending the length of the leaf. The centres become straw-coloured with age and are later covered with black powdery mass of spores of the fungus. However, the leaf lesions cause no serious injury to the plant but are important in the life cycle of the disease because they are sources of the

spores that cause infection of the stalk.

Affected plants turn yellow, shrivel and the upper leaves die. On splitting the stalk or seed cutting, the normally white or creamy-white internal tissues are reddened and the reddened area is cross-barred with white or light patches. Any sort of wounding causes a reddening of the stalk tissues next to the wound, but when diseased the characteristic red discolouration extends beyond the point of the wound. In advanced stages of rotting, the interior of the stalk darkens and the tissues shrink, leaving a cavity, which may be filled with mycelium (growth) of the fungus.

The disease is spread by wind and rain. It is also spread by planting infected seed cuttings and it is enhanced by injuries by sugarcane borers and sugarcane weevils.

What to do:

- **Disease management consists of planting disease-free cuttings, resistant varieties and minimizing hazards of injury by borers.**
- **Treatment of the seedlings with a 20-30 minute hot water treatment at 52°C can be effective, although this temperature should not be exceeded.**
  For more information on hot-water treatment click here.

Red rot of sugarcane
Sugarcane red rot (*Glomerella tucumanensis*) - Red spots on the midrib of the upper leaf surface develop

pale yellow to white centres, merging to cover the length of the leaf. Similar spots also occur on the leaf blades.

Pineapple disease (*Ceratocystis paradoxa*)

It is called pineapple disease because of the characteristic odour of the rotting cuttings, which is like that of decaying pineapples. The interior of affected seed pieces becomes sooty black. Eventually the vascular bundles (tissues conducting fluids in the plant) become fibrous strands in hollow blackened core.

In contrast to red rot (which is favoured by excessive soil moisture), pineapple disease is most destructive when cane is planted in dry soil. Another major difference is that the red rot fungus is not soil-borne and infection occurs before planting, whereas pineapple disease fungus lives in the soil.

What to do:

- **Best management options include planting resistant varieties and rotation.**

Pineapple disease
Reddening, followed by black areas of rot, on stems of sugarcane with pineapple disease caused by *Ceratocystis paradoxa*.

Sugarcane smut (*Ustilago scitaminea*)

he main symptom of smut is a long whip-like shoot covered with black spores contained in a silver coloured membrane. It emerges at the top of the stem in place of the inflorescence. Other symptoms include stunting and production of thin horizontal leaves. Smut is spread by infected cuttings and spores released from the whip-like shoot. Infection takes place through seed pieces and through axillary buds of the growing plant.

What to do:

- **Management measures consist of planting resistant varieties and hot water treatment of planting setts (50°C for 2 hours or 52°C for 20 minutes).**

Sugar cane smut
Sugar cane smut *Ustilago scitaminea*
© J. Kranz. Courtesy of www.ecoport.org

Ratoon stunting disease (*Clavibacter xyli* subsp. *xyli*)

This disease does have overt symptoms: There is a decrease in plant vigour and decline in yields, both of which are noticeable in ratoon crops. Red spots can sometimes be seen in vascular tissues, especially in the nodes. It can be spread by infected planting material and also through mechanical operations.

What to do:

- **Its management involves planting resistant varieties and also hot water treatment of planting material (50°C for 2 hours or 52°C for 20 minutes). Heat-treated cane cannot be planted straight into commercial fields because its germination is likely to be poor. Secondly, for direct planting under commercial scenario, treatment of cane would be prohibitively expensive. Heat-treated setts are therefore planted in nurseries and harvested about a year later to provide planting material for commercial fields.**

Ratoon stunting disease
Discolouration of the nodal and internodal regions of sugarcane stem due to ratoon stunting disease (RSD).
© K.C. Alexander. Courtesy of www.ecoport.org

Gummosis (*Xanthomonas campestris* pv. *vasculorum*)

It is a primarily a disease of the vascular system. It got its name from slimy gum that oozes from cut ends of infected stalks. Yellowish streaks, usually dotted with red or brownish spots are produced on the leaves near the tips. These spots often widen to a V-shape towards the leaf tip. Top rotting may result when the terminal bud is attacked resulting to shooting of the lateral buds. The disease is transmitted in infected cuttings used for seed, knife cuts and other means of physical contacts.

What to do:

- **Management measures consist of use of disease-free planting material, resistant varieties and**

sterilization of cutting tools.

Leaf scald (*Xanthomonas albilineans*)

It is a vascular disease but differs from gummosis in that there is no oozing of gum from cut ends. Also leaf streaks due to leaf scald are different: they begin as sharply defined, narrow, white pencil stripes, which may extend the entire leaf length.

As the leaves grow older, the streaks tend to broaden and become more diffuse. There may be only one or several streaks on a leaf. Sometimes, instead of definite streaks, the entire shoot is chlorotic to nearly white. Affected plants become stunted and in advanced disease stage some shoots or the entire stool may suddenly wilt and die.

What to do:

- **Disease management measures for gummosis are applicable for leaf scald. Also heat treatment of planting for 3 hours at 50°C provides effective control.**

Leaf scald
Typical white streaking of the leaves found on sugaracane plants with leaf scald *Xanthomonas albilineans*

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Cotton

Cotton
Scientific name: *Gossypium* spp.
Family: Malvales: Malvaceae
Local names: Pamba (Swahili)
Pests and Diseases: African bollworm African cotton mosaic disease Anthracnose Aphids Ascochyta blight Bacterial blight Cotton leaf curl bigeminivirus Cotton leaf roller Cotton stainers Cutworms Damping-off diseases Fusarium wilt Helopeltis bugs Leafhoppers or jassids Other bugs Root-knot nematodes Spider mites Whiteflies Cotton semi-looper

General Information and Agronomic Aspects

Geographical Distribution of Cotton in Africa

Introduction

The cotton plant belongs to the Malvaceae family. Over 30 species have been discovered (among others: *Gossypium hirsutum L., G. barbadense L., G. arboreum L.).* Cotton as a tropical crop originates from several locations (southern Africa, south-east Asia and Peru). There are annual and two-year species, as well as perennial varieties. It produces a yellow, white and purple-red blossom, and is a hermaphrodite.

Varieties and countries of origin

World wide there are ca. 33 mill. hectares of cotton crops. Economically, the most important varieties are *Gossypium hirsutum* and *Gossypium barbadense*.

G. hirsutum:
- Upland cotton
- 80-90% of world market
- short to medium fibres (2-3 cm; middle stapled variety)

G. barbadense:
- Sea Island cotton
- 10-20% of global market
- high-quality, long to very long fibres (3-4 cm; long stapled variety)

In addition, the annual *G. herbaceum* or the hardy cotton bush *G. arboreum* produces fibres with a length of 1.8-2.2 cm. Long stapled varieties are cultivated mostly in Egypt and Peru. The middle stapled varieties from the USA, short stapled varieties in Asia *G. barbadense* is more susceptible to pests due to its long vegetation period *G. hirsutum*, that ripens far quicker (some varieties after only 150 days).

All of the cotton varieties with coloured fibres, formed from crossings between wild varieties (from Peru) and crops, have provoked a certain interest in the natural textile processing industry. Until now, mostly brown, green and beige varieties had been cultivated.

Organic cotton production is most widely spread in the USA (ca. 4000 ha). Yet ecological cotton projects also exist in Egypt, Argentina, Brazil, Greece, India, Mali, Nicaragua, Paraguay, Peru, Tanzania, Turkey and Uganda.

Uses and contents

Cotton can be seen as a classic dual purpose plant (fibres and oil). A harvest yielding 1000 kg of cotton/ha can be broken down thus:

- **ca. 320 - 420 kg fibres (raw cotton)**
- **ca. 200 - 250 kg seed cakes or flour**
- **ca. 100 - 150 kg oil**
- **ca. 200 kg shells**
- **ca. 20 kg retained seeds**
- **ca. 40 kg dirt**

The fibres (lint-fibres, lint) are used in the production of materials (threads, fabrics, etc.), whilst the linters (fluff separated from the cotton seeds) are used to produce cellulose fibres and other cellulose products, thick threads and stuffing materials, as well as being used for the production of paper.

Oil produced from the seeds can be used as edible oil, among other things. When oil is produced from the cotton seeds and pelleted feed used as fodder, care must be taken to remove the Gossypol that forms in the oil/cakes by heating it. Gossypol is poisonous to humans and animals with normal stomachs (e.g. pigs), only ruminants (e.g. cattle) can digest cakes containing Gossypol without a problem. The seed shells can be used as raw fodder for animals, as straw, dung or as fuel.

Low-grade oil is used in the manufacture of soap, lubricants, sulphonated oils and protective coatings. The seed cakes are used as fodder and manure. The seed shells can be used as raw fodder for animals, as straw, or as fuel.

Climate conditions, soil and water management

Cotton performs best in desert climates, under irrigation. It grows on lowland below 1000 m. The optimum temperature for germination is 34°C, for the growth of seedlings 24-29°C, and for later continuous growth 34°C. Low temperature increases the production of vegetative branches and extends the cropping period. Cotton is susceptible to frost. High temperature increases the number of fruiting branches and reduces the cropping period. Cotton is a sun-loving plant and cannot tolerate shade, particularly in the seedling stage. Reduced light intensity, caused by long-lasting overcast weather, shading from interplanted crops or too dense a stand, retards flowering and fruiting and increases boll shedding. Shedding of over 50% of squares, flowers or young bolls, due to early bollworm attack, drought or waterlogging, is normal. Upland cottons are day-neutral.

The crop will not tolerate very heavy rainfall and, where grown as a rain-fed crop, the average rainfall is usually 800-1200 mm. Adequate, but not excessive, moisture is required for early vegetative growth. The first flowering period requires relative dryness to speed up formation of fruiting branches. An increase in moisture is required for boll setting and renewed growth, followed by dry weather for ripening and harvest. Sufficient soil moisture is essential during the flowering period.
In the tropics most cotton is grown by smallholders who sell their seed cotton to the ginners. Ginneries may be privately, cooperatively or state owned.

Cotton can be grown on a variety of soils from light sandy soils to heavy alluvium and calcareous clays. Soils must be permeable to water and to roots to a depth of at least 100 cm, preferably over 150 cm, with pH 5.5-8.5. Cotton is one of the salt-tolerant crops.

Propagation and Planting

Site requirements

In its early stages of growth, cotton requires an arid climate with a plentiful supply of water. Afterwards, the

weather needs to be dry, especially after the capsules have opened, for if rain can enter at this stage it will have a detrimental effect on the quality. The vegetation period generally lasts around 180-220 days (varieties such as *G. hirsutum* that mature rapidly can be harvested after only 150 days). Very high yields have been reported from the arid areas of the CIS and in Egypt using irrigation.

Because cotton loves the heat, yet is also highly susceptible to frost, temperatures of around 26-28°C are ideal for its development. Lots of sun has a very positive effect during the blossoming and fruit setting periods, in cases of 50% and more cloud during the vegetation period it makes little sense to plant cotton. Cotton cannot withstand shade. Cotton is also a short-day plant, and such conditions will accelerate its growth. The correct climatic conditions are generally found between the 28° northern and 47° southern latitudes.

A strong wind can suck the fibres out of the capsules and blow them away. Today's varieties are tolerant with regard to salinity (up to a salinity of 0.5-0.6%). The soil's pH value should be between 6 and 8. In addition, cotton also requires deep, well-drained and ventilated soil, in order to properly develop its system of tap-roots (resistance to drought).

The site's elevation plays a large role when planting coloured varieties of cotton, because the intensity of the sun's rays has a strong effect. At least the green varieties tend to bleaching when the intensity increases too much (Peru).

Seeds and shoots
The fertilisation process is generative. Most wild Gossypium varieties are perennial. Annual varieties are most generally used for cultivation, which conclude their development cycle during one single vegetation period. Local and regionally produced seeds should be used, which will have developed a tolerance or resistance against the pests most commonly found in the region. Because the sale of seeds is usually controlled by government authorities, it is important to try to acquire untreated seeds of the desired variety early enough.

During the last few years, hybrid seeds have been developed that provide high yields. Yet this method makes

it impossible to use self-produced seeds from the crop, and a new supply of seeds must be bought for the next season.

Because cotton can be affected by various root and dumping off diseases, in certain cases, it is worthwhile considering pre-treating the seeds. In contrast to conventional cotton crops, only micro-organisms, which work antagonistically, are used. In Egypt, for example, the seeds are treated with Bacillus subtilis, Gliocladium penicilloides and/or a suspension of trichoderma. In order to improve the nutrient availability for the young plants in India, the seeds are additionally treated with azotobacter and bacteria strains capable of breaking down phosphorous.

Sowing methods
If the cotton is to be planted by machines, then the seeds need to be rid of the fluff that surrounds them (otherwise the seeds stick together). This is not necessary when the seeds are sown by hand. The temperature should not fall below 18°C. Temperature of 35°C is optimal. The seeds should be sown at a depth of maximum 5 cm.

The density depends upon the method utilised (manual or by machine). Bio-dynamic farmers in Egypt sow several seeds by hand every 20 cm into the prepared planting rows (distances between the rows 60-70 cm). Between three and four weeks later, the plants are inspected and all but the two strongest specimens removed. The plant population of rain-fed cotton of small-scale farmers in Tanzania is much lower. The farmers sow cotton by broadcasting the seeds on the flat land or in rows at a spacing of 90 cm between and 30 ? 50 cm in the rows. Some farmers sow also on ridges with the same spacing.

Mechanical methods usually leave 70 cm (50-120 cm) between the rows and 20 cm (20-60 cm) distance between the seeds. When the harvest is done mechanically, varieties such as G. hirsutum that produce few branches are sown every 8-10 cm with a distance between the rows of 15-20 cm.

Cotton is either planted on flat soil, ridges or in furrows. Furrow drilling is employed mainly as a protection against quicksand. Ridges are used in soils, which are difficult to drain, and in regions with little rainfall, as

this eases irrigation and facilitate the seeping in of the water into the soil. Its disadvantages are more difficult sowing and tilling of weeds. The cotton is sown in the lower third of a ridge in high-content soils and the upper third for low content soils. The seeds should be watered as soon as possible after sowing.

During the first 3 weeks, the shoots can offer little resistance against weeds, but this improves until the thick crop growth has no more problems in the area. For this reason, a suitable position in the crop rotation, suitable soil cultivation method and preparation of the seed beds should be taken care of to prevent an excessive growth of weeds during the early growth phases. On irrigated soils, irrigation is carried out prior to sowing in order that the weed seeds germinate and grow. The resulting growth of weeds can then be easily removed by appropriately cultivating the soil, before the cotton is sowed. The final soil treatment before planting should include the spreading of compost.

For cultivation done using animal-drawn (oxen or water-buffaloes) implements time requirements are: 15 animal days and person-days/ha, or by hand: 50 person-days/ha. By two or four-wheeled tractors (150 kWh/ha).

The land should be prepared early and to a depth of at least 15 cm. To maintain soil organic matter, liberally apply or incorporate plant residues and animal manure during land preparation. Planting should be early, as soon as rainfall is adequate for the germination and growth of the crop. Cotton grown by smallholders is commonly planted with a delay, because the food crops are given priority. In hand planting, cotton is usually sown at a seed rate of 11-14 kg/ha and at a depth of about 25 mm with 3-6 seeds per hole in rows or ridges. Ridges are an advantage as they can be tied to conserve water under dry conditions and aid drainage under wet conditions. Thinning is done when the plants are 6-10 cm high, and two plants per hill are usually left. The optimum spacing depends on the size and fruitfulness of the plant permitted by local conditions. It also depends on the interactions between variety, soil and climate. The optimum spacing ranges from 80-20 to 100-40 cm, with one or two plants per hill. Plant densities may vary between 40,000 and 100,000 plants per ha, but are generally between 50,000 and 60,000 plants per ha.

Husbandry

Cotton seedlings are sensitive to competition from weeds. Weeds should be controlled early to prevent damage to the crop. Control weeds against the first flush of weeds before sowing and plant the seeds closely. Weed early and frequently. Place manure some 6 weeks after sowing. These measures help to reduce hand weeding to some 15 person-days (work of one person done per day) per ha. It also helps to reduce attack by pests harboured by weeds.

Irrigation

Intervals between irrigation should be 2-3 weeks on deep permeable sandy loams to heavy clays and less for very light, very heavy and shallow soils. The irrigation period should be 19 weeks. Excessive irrigation besides being a waste of water increases risk of disease incidence. Most irrigation is by gravity using furrows. Water saving is possible by alternate furrow irrigation or by handwatering with a hosepipe.

Nutrients and organic fertilisation strategies

Compost, decomposed animal dung and mulching material are used to supply the soil with sufficient organic material. This supports the cotton's growth. Potassium can be supplied by spreading wood ashes, and phosphorous by adding rock phosphate. Usually, the soil is prepared before the cotton is sown by spreading compost that is mixed with ashes and rock phosphate. In some areas, animal manure that has been composted is used for fertilisation. It should be applied inside the furrow close to the plant lines or in each plant hole. The above is only applicable to smallholder farmers. It is not practicable where cotton is a plantation crop as in Egypt, Sudan and Tanzania.

Crop rotation and intercropping

Cotton should not be grown for more than 3 years on the same field. It is important that cotton is grown in

rotation with other crops. This helps to improve and maintain soil fertility. Crop rotation and mixed cropping help prevent build-up of pest population, diseases and weeds. Cotton grows well in rotation with cereals, tobacco and legumes. Particularly good yields can be achieved when cotton is grown after pulses (soybean, chickpea, pigeon pea, groundnut etc.), horticultural crops like chillies or vegetables, and after sugarcane and wheat.

Cotton intercrops such as maize, sorghum, beans, and peanut create a natural balance of pests, natural enemies, and weeds in the cotton field environment. Maize or tobacco planted in every 20 rows of cotton attracts African bollworm. Sunflower or cowpea sown in every 5 rows of cotton attracts moths when planted as trap crops. Castor bean (*Ricinus communis*) attracts caterpillars. Rice when rotated with mungbean and cotton disrupts the life cycles of pests attacking these crops. However, the timing of planting of intercrops, trap crops, and border crops should be planned to flower at the same time with cotton.

Harvesting

In Africa generally, cotton is hand picked. This creates work for farmers' families or village labourers, usually women. It also produces clean seed cotton that can be ginned easily and cheaply in low-cost ginneries. One picker can harvest 25-40 kg of seed cotton per day depending on the availability of open bolls. Picking is very laborious. It should be done every 3-4 weeks, so that open cotton is not left in the field for too long which may result in a change of the colour and reduced the quality of the lint. It is then sorted into clean and stained cotton before marketing. Harvesting begins about 4 months after sowing, lasts for 2 months and 2-3 pickings are usually done.

Biological methods of plant protection

Preventative or combating methods are already known for all of the important pests and diseases that can occur on organic cotton plantations. In the long-term, it is safe to presume that a high level of pest and diseases will significantly diminish following the introduction of an organic cultivation system.

Yet this requires a successful plant protection management system. The farmer should inform himself in time:

- **Which important infection agents are present in the region,**
- **Which preventative strategies he wishes to implement against them on his site,**
- **Which combating measures exist against a heavy infestation,**
- **Which permitted resources are available for organic systems,**
- **How these are applied**
- **When it is correct time to apply them**
- **Whom he can turn to in an emergency (advice).**

The following preventative measures should thereby be strictly adhered to:

Selecting crop rotation
As cotton is not well compatible with itself, it is not advisable to have a larger ratio than 1/3 in the crop rotation. Other mallow plants (e.g. hibiscus) must be excluded from the rotation, or at least not planted on the same soil. It is also important to check that no cotton is grown on any of the neighbouring plots. On the whole, a diversified crop rotation works best.

Mixed crops with plants that act as a repellent
Mixed or strip cultivation with onions, garlic, chillies, chrysanthemums or hot peppers have proved their worth because of their repellent effect against, among others, bugs, white fly and cotton leafworm (*Alabama argillacea*). Rotted liquid manure can also act as a repellent (and be simultaneously used as a fertiliser).

Cultivation of trap crops
Trap crops manage to keep pests away from the cotton by offering a more attractive source of food. Strip cropping using lucerne (*Medicago sativa L.*) within the cotton plants is, for example, practised in the USA and Paraguay, in order to keep pests such as different bug species (*Dysdercus* spp., *Lygus* spp.), *Helicoverpa* spp., *Spodoptera littoralis, Platyedra gossypiella* and aphids away from the cotton.
Sowing sorgo before the cotton (on neighbouring plots) can help to build up a population of useful insects,

which can then combat cotton pests when they appear at an early stage (e.g. aphids).

A similar strategy can be followed by planting *Hibiscus esculentus* against the pest *Podagrica* spp., planting *Lablab niger L*. against the pests *Helicoverpa* spp., *Spodoptera littoralis* and *Bemisia tabaci*, or nasturtium against *Tetranychus cinnabarinus* (these are based on experiences culled from Turkey and in Sudan). During 9 years of organic cotton growing in Tanzania the experiences have shown that the most important cotton pest *Helicoverpa* spp. can be controlled with sunflower as trap crop to such an extend that the threshold for an economic application of insecticides is not reached in most cases. The recommended practice is to sow one row of sunflower around the cotton plot as a living fence and one row of sunflower all 10 meters in the plot. The sowing time has to be very close to the cotton sowing so that the sunflower will be in the flowering stage when the infestation period starts. The sunflowers attract the moths of *Helicoverpa* spp. to lay their eggs. The caterpillars are feeding on the sunflower however without destroying the production of sunflower seeds. So the farmers can get an additional income from the sunflower seeds.

The caterpillars on the sunflowers show also the phenomenon of cannibalism so that they reduce their number itself (Source: Dr. Braun, gtz-IPM project, personal communication, 1997).

The positive effects of sunflowers are also shown in the results of a study that was carried out by an entomologist on behalf of the GTZ-IPM project in Shinyanga. The researcher found out that in organic cotton plots with sunflowers were up to ten times more useful ants compared with cotton plots without sunflower. It is known that these ants are reducing the eggs and larvae of the African bollworm (*Helicoverpa armigera*). (Source: Varela, Ana (1996) "Ants as mortality factors of the African bollworm *Helicoverpa armigera* in smallholder cotton fields in Tanzania"). A booklet about the natural enemies of the African bollworm names especially the ant species *Myrmicaria* and *Pheidole* as important. 'On sunflower, ants were observed to reduce bollworms by as much as 85%.' (Source: van den Berg, H. + Cook, M.J.W., (1993) 'African bollworm and its natural enemies in Kenya', P. 33, CAB International + NRI, International Institute of Biological Control, Kenya Station). Many contracted smallholders in Tanzania confirm the positive effects on the cotton yield by cultivating sunflower as trap crop and even many conventional neighbours in the region started copying this cheap and easy method of preventive pest control.

Pigeon peas (*Cajanus cajan*) can also be a useful trap crop for pests like *Helicoverpa* spp. but it is not so easy to synchronise the flowering stage of the trap crop with the infestation period of the pest. The local pigeon pea varieties in Tanzania start the flowering too late to be an efficient trap crop. Early maturing varieties or sowing of pigeon peas in the previous year could resolve this problem. In the bioRe India project the pigeon peas are successfully use as trap crop in cotton.

Trap crops planted in autumn (e.g. maize) can be used in combination with a pheromone against hibernating boll weevils.

Leaving a strip of natural vegetation around the cotton plot can be useful against aphids and other pests.

Choosing a site
Cotton should be planted in healthy soil wherever possible. In principle, sites that are infested with weeds should not be sown with cotton, but first cultivated with an appropriate rotation crop in order to prepare it. Care should be taken that no cotton is planted in the neighbouring plots. Sowing time
The choice of when to sow plays an important role. Cotton sown too early will possibly become infested by the pest population that has already developed there. In Tanzania the late sown cotton is often attacked by African bollworm (*Helicoverpa armigera*) that developed on maize or sorghum plots. At the end of the season the risk of the late season pest cotton stainers (*Dysdercus* spp). is higher on late sown cotton while it is a minor problem on early sown cotton.

Mulching of harvest residues
Careful mulching of the remains of a cotton harvest can help prevent the survival of pests (e.g. *P.gossypiella* in seeds and boll weevil, *Anthonomus grandis*). In the case of heavy infestations with wilting diseases, such as bacterial blight (*Xanthomonas malvacearum*), Anthracnose (*Glomerella gossypii*), verticillium-wilt (*Verticillium alboatrum*) or fusarium-wilt (*Fusarium oxysporum*) it is recommended to remove the residue and then apply for composting.

Sufficient, balanced supply of nutrients
A plant that receives balanced nutrients is more vigorous, and therefore less susceptible to infestation. As already mentioned, supplying too much nitrogen will lead to an infestation by pests.

Choosing a variety
It is hereby important to choose varieties adapted to the site conditions, and that are resistant to, or can tolerate, the main pests. In addition, general varieties have proven their worth that matures quicker, thereby shortening the time span they can be infested. Gossypol-free are not so well suited to organic plantations because Gossypol (just like other terpenoide chemical compounds) has a repellent effect on certain insects (e.g. against *Helicoverpa* spp., *Spodoptera* spp. and *Pectinophora* spp.).
How easy or difficult it is to choose a suitable variety show the examples from Tanzania and India.
While in Tanzania there is only 1 cotton variety per production zone the bioRe farmers in India use 9 out of more than 50 different varieties according to their specific needs and preferences. It follows a list with the advantages and disadvantages of the varieties used in India, which shows the different aspects that can be important for the decision.

Planting of boundary areas
Planting 2-3 rows of trees or hedges along the boundaries provides a habitat for birds, improves climatic conditions and reduces the amount of water needed for cotton.

Checking the infestation level of cotton pests
In Tanzania the gtz-IPM project has developed a method to check the infestation level of the key pest *Helicoverpa armigera*. The method is called 'scouting' and it works by counting the squared buds on 30 plants of 1 acre. If the number of squared buds comes up to 15 the economic threshold is reached and the farmers are advised to spray an insecticide. The organic farmers then apply an oily formulation of neem. This 'scouting' method works much faster than looking for the pests itself and helps to avoid many applications of insecticide (in organic and in conventional farming).

Light traps allow seeing the start of pests moving into the cotton plot and at the same time reducing the

number of moths laying eggs on the cotton plant. In Tanzania the the fields at rate of one per acre for about two hours after sunset. The reduction of moths can help to reduce the number of sprayings.

Direct combating measures

Direct methods of combating pests are also available for organic plantations, yet are only to be used in emergencies (and not as preventatives). It is necessary that the cotton, and any pests which may eventually develop, should be regularly inspected in order to be able to decide whether a direct method is to be used or not (see chapter above).

If the critical threshold is reached and there is an immediate threat for the cotton harvest the organic farmers need to have insecticides available that are allowed in organic farming. There are several botanical insecticides, which proofed to be efficient against important cotton pests.

In India the bioRe farmers can choose among 3 commercial neem formulations and the self-made preparations made with crushed neem seeds. In Tanzania the farmers can get one neem formulation imported from Kenya and another from India to control *Helicoverpa armigera*. Against the late season pest *Dysdercus* spp. the farmers use a locally formulated Pyrethrum preparation with black wattle extract (*Acacia mearnsii*) as UV-light stabilisator.

Beside the neem products there are also some other plants that can be useful to produce botanical insecticides. In Tanzania the Ukiriguru Research Institute tested with promising results an emulsion of *Jatropha curcas* oil against *Helicoverpa armigera*. In Mali it has been tested against Sorghum pests and a report from Malawi states: 'The oil and aqueous extract from oil (active principle probably phorbol ester) has potential as an insecticide, for instance in the control of 4 insect pests of cotton including cotton bollworm (Solsoloy 1995) and on pests of pulses, potato and corn.' (Malawi Agroforestry Extension Project Marketing & Enterprise Program Main Report, Publication No. 47, page 46, July 2002).

In West African countries like Bénin and Mali the farmers are experimenting with mixtures of plant extracts and other ingredients. Experiences from Bénin give the following recommendations for 1 ha:

3 sprayings during early season with a preparation of
1.5 kg pounded neem seeds in water, fermenting over night and then filtered
1 litre cow urine
20 papaya leaves
local soap diluted in water
total of 10 litres

Then later in the season the following preparation without cow urine in order to avoid excessive vegetative growth:
2 kg pounded neem seeds in water, fermenting over night and then filtered
5 cloves of garlic
20 papaya leaves
local soap diluted in water
total of 10 litres

Since 1999 organic cotton growers in Mali use a mixture of neem and 'Npeku' oil (*Lannea microcarpa*) as botanical insecticide. The preparation for 1 ha is done as follows:
- 500 g grounded neem seeds in 10 litres of water for 3 to 5 days and then filtered
- Add 40 to 160 ml of 'Npeku' oil (according to plant stage, see table below) and mix well to get an emulsion

Instead of the 'Npeku' oil the organic cotton farmers in Mali take also the oil of 'KOBI' (Carapa procera) in the same way.

Yellow traps, pyrethrum and also sulphur extracts do not work specifically enough (useful insects are also affected). For this reason, these preparations should only be used when absolutely necessary, and when no other alternatives are available.

Information on Pests

General Information

Preventative or combating methods are already known for all of the important pests and diseases that can occur on organic cotton plantations. In the long-term, it is safe to presume that a high level of pest and diseases will significantly diminish following the introduction of an organic cultivation system.

Direct methods of combating pests are also available for organic plantations, yet are only to be used in emergencies (and not as preventatives). It is necessary that the cotton, and any pests which may eventually develop, should be regularly inspected in order to be able to decide whether a direct method is to be used or not (see chapter above).

Examples of Cotton Pests and Organic Control Methods

Root-knot nematodes *(Meloidogyne* spp.)

Several species of root-knot nematodes attack cotton roots. Infested plants are often stunted and leaves yellow. Galls or knots are formed on the roots. Infestation can be particularly serious in light soils. Nematode infestation predisposes plants to *Fusarium* wilt infection.

What to do:

- **Practice crop rotation with crops not related to cotton (e.g. cereals) whereby cotton is cropped once every 3 or more years.**

Root-knot nematodes
Root-knot nematodes (*Meloidogyne incognita*) affected plants are normally stunted and eventually wilt and die. The most characteristic symptom is formation of root galls (knots) and these can be seen with the naked eye. Affected roots rot.

Helopeltis bugs (*Helopeltis schoutedeni* and *H. anacardii*)

Other bugs feeding on cotton include Helopeltis bugs, blue bugs and cotton lygus and the cotton seed bug.

Cotton Helopeltis (*Helopeltis schoutedeni*)
Helopeltis bugs are up to 10mm long and have very long antennae. They are bright red (females) or yellowish-red (males) in colour. The bugs prefer to feed on young plant tissue of leaves, shoots, peduncles and petioles. The toxic saliva injected during sucking causes pale brown necrotic patches. The leaves and the stems of the plants are twisted. The lesions on the leaves often drop out leaving holes as if attacked by chewing insects. The green boll wall is also attacked showing dark, circular, sunken lesion.

What to do:

- **Bugs, in particular adults are difficult to control since they can readily move from neighbouring crops or wild plants into the cotton crop.**
- **Do not interplant cotton with crops that are host for Helopeltis bugs, such as cashew, tea, sweet potato,**

guava and mango.

- Monitor the crop regularly. Helopeltis attack occurs very suddenly and great vigilance is very important to control this pest, particularly during the rainy season or when water is available leading to flushing (production of young shoots) when Helopeltis populations normally build up.
- Natural enemies are important in the control of bugs. Conserve natural enemies. Weaver ants build nests on cashew trees providing good protection against this and other bug pests. The most important are parasitic wasps attacking bug eggs; ants, which feed on eggs and nymphs; and various predacious bugs, spiders, birds and parasitic flies.
- Neem products reportedly reduce feeding by some bugs.
- Since bugs are late season pests early sowing and picking is recommended to reduce bug attack.

Helopeltis bug
Helopeltis bug. Real size: 6 to 10 mm long.
© F. Haas, icipe

 

Helope Helope

Bugs (Blue bug, cotton lygus, cotton seed bug)

Other bugs feeding on cotton include blue bugs and cotton lygus and the cotton seed bug.
Blue bugs (*Calidea degrii*, *Calidea bohemani*)

The adults are large bugs, 8 to 17 mm long by 4-8 mm broad, and strikingly coloured, with red or orange underneath and the upper surface bright metallic blue or green with black spots. They suck the seeds of unopened bolls causing staining of the cotton lint in a similar way as stainer bugs; as a result the development ceases and the boll aborts.

Blue bugs seldom breed on cotton; they usually invade cotton when the bolls are well formed, from other host plants, for instance sorghum, sunflower, castor and many wild hosts such as crotalaria and hibiscus.

Cotton lygus (*Taylorilygus vosseleri*)

The adult bugs are up to 5mm long and pale green to light brown in colour. The nymphs are green. Adults and nymphs prefer to suck young leaf buds, flower buds and bolls. The toxic saliva causes the flower buds to turn yellow and drop off. Leaves, which have been attacked in the bud stage, later show a ragged appearance with many irregular holes. The cotton lygus is an early season pest.

Cotton seed bug (*Oxycarenus hyalinipennis*)

These bugs are small (4 to 6 mm), and blackish in colour. Their wings are transparent. They attack open or damaged pods mainly at the end of the growing season. It is a late season pest, which mainly appears when the bolls have opened. Nymphs and adults suck the seeds. Feeding by large numbers of bugs reduces considerable the germination rate, seed weight and oil quality. The lint is not affected.

What to do:

- **Bugs, in particular adults are difficult to control since they can readily move from neighbouring crops or wild plants into the cotton crop.**
- **Natural enemies are important in the control of bugs; the most important are parasitic wasps attacking bug eggs; ants, which feed on eggs and nymphs; and various predacious bugs, spiders, birds and parasitic flies.**
- **If heavy outbreaks of the cottonseed bug occur, the cotton should be picked as soon as the cotton bolls mature.**
- **Neem products reportedly reduce feeding by some bugs.**
- **Since bugs are late season pests early sowing and picking is recommended to reduce bug attack.**

- **Tanzania: Pyrethrum formulation with black wattle extract as UV light stabilisator**

Cotton seed bugs
Cotton seed bugs(*Oxycarenus hyalinipennis*) (here on okra)

Cutworms (*Agrotis segetum* and the cotton leafworm, *Spodoptera littoralis*)

Caterpillars cut seedlings at ground level. They can be found in the soil up to a depth of about 5cm around the plant host. Caterpillars of the cotton leafworm are up to 45 mm long. Their colour varies from yellowish white to bluish grey and greyish brown. On the dorsal side of the caterpillars there are usually two rows of triangular black spots. These spots can be absent with the exception of those at the fore and hind part of the body. Although the caterpillars feed mainly on leaves, they occasionally cut plants and attack fruits.

What to do:

- **Remove weeds in and around the fields as a preventive measure to reduce the number of sites where the moths can lay eggs. Do this at least 2-3 weeks before planting.**
- **Plough and harrow fields properly before planting to destroy eggs and expose caterpillars to birds, ants and other predators.**
- **Apply neem cake or de-oiled castor cake before sowing.**
- **Encourage the presence of birds with trees and hedges. Also promote natural enemies like spiders,**

ground beetles and lacewing.

- Interplant with onion, garlic, peppermint or coriander, this will act as a repellent to cutworms.
- Sunflowers can be planted as trap crops.

Cutworms
Black cutworm (*Agrotis ipsilon*). Early instars are about 7 to 12 mm long. Fully grown caterpillars are 35 to 50 mm long.
© Ooi P., Courtesy of Ecoport (www.ecoport.org)

The cotton aphid (*Aphis gossypii*)

Cotton aphids are about 1-3 mm long, and variable in colour from yellow to yellowish green or very dark (almost black) with two cornicles (projections) on the rear end and long antennae. They suck sap preferably from tender shoots and the underside of young leaves. Feeding by aphids may result in crinkling and cupping of leaves, defoliation, square and boll shedding and stunted growth.

Honeydew (a sugary liquid) excreted by aphids accumulates on the upper surface of leaves and sooty mould develops. Honeydew can contaminate the fibre if the bolls are open, causing problems in processing the lint.

What to do:

- The cotton aphid is attacked by a range of natural enemies; the most important are ladybird beetles,

hoverflies, lacewings and parasitic wasps. They usually keep aphids under control.

- **Healthy cotton plants can tolerate a fairly high number of aphids.**
- **Avoid plant stress by giving neither too little nor too much manure. Avoid water stress and water logging.**
- **Intercrop cotton with maize or sorghum to create a natural balance of pests and natural enemies.**
- **Use yellow water or sticky traps.**
- **Spraying maybe necessary in the case of high aphid infestation or if the honeydew affects the lint in open bolls. If this is the case, use plant extracts such as neem leaf and seed extracts, ginger rhizome extract, and custard apple leaf extract for control of aphids.**
- **3% potassium soap in acute cases; ii extreme cases nicotine extract, neem, chilli, garlic, Lantana camara**

The cotton aphid
Cotton aphid (*Aphis gossypii*) on the underside of a cotton plant.
© Ronald Smith (Courtesy of EcoPort, www.ecoport.org)

Whiteflies (*Bemisia tabaci*)

Whiteflies (*Bemisia tabaci*) suck the sap of leaves. Feeding weakens plants and may lead to yellowing and wilting, premature leaf shed and reduced plant growth, affecting the quality and quantity of yield. Severe attack may kill young plants. Honeydew excreted by whiteflies and sooty mould that develops subsequently can affect the fibre quality considerably and cause problems in processing the lint.

The whitefly is a vector of important virus diseases on various crops including cotton. It transmits the cotton

leaf curl virus and the African cotton mosaic disease. Attacks are common during the dry season, and usually recede with the onset of rains.

What to do:

- **Whiteflies are attacked by parasitic wasps and predators. Conservation of these natural enemies is important.**
- **Yellow sticky traps are useful for monitoring whiteflies, and may help to control low populations.**
- **3% potassium soap in acute cases**
- **Plant traps: Lablab niger; Trichogramma chilonis Ishii; Brinckochrysa scelestes**

Whiteflies
Whiteflies (*Bemisia tabaci*) under leaf. Adult whiteflies are about 1mm long.

Leafhoppers or Jassids (*Empoasca* spp)

Adult leafhoppers are small (2 to 3 mm long), long and thin. The wings are held roof like over the abdomen. They are pale green to yellowish green in colour, shiny and more or less transparent. The legs are slender with bristles. The nymphs resemble the adults but are smaller and do not have fully developed wings. Adults and nymphs suck sap from the leaves, remaining on the underside during the day, but also moving to the upper surface during the evening; when disturbed they run sideways rapidly to reach a shady part of the host

plant.

Feeding by leafhoppers causes discolouration, and leaf curl, the outer zone of the leaf turn yellow to reddish and whiter later. Heavy leafhopper infestation may retard plant growth and cause severe yield losses. Cotton fields attacked by leafhoppers are easily recognisable form some distance, owing to their reddish or purple colour ("hopperburn").

What to do:

- **Use resistant varieties. A number of very hairy varieties have been bred, which are considerable less prone to leafhopper attack than those varieties whose leaves are not or only sparingly covered with hairs. By planting such resistant varieties damage by leafhoppers can be avoided to large extent. In Tanzania, the release of the Ukiriguru varieties resistant to leafhoppers and to bacterial blight played a major role in the increase in annual crop production.**
- **Early sowing helps if the cotton plants have past the most susceptible plant stage during the period after the rainy season, when leafhopper population is at its peak.**
- **Repellent plant extracts from: neem, chilli, garlic and Lantana camara**

Leafhoppers
Leafhopper. Adults are small, about 2.5 mm long. Picture shows *Empoasca fabae*.

The cotton leaf roller (*Haritalodes (Sylepta) derogata*)

The moths are about 15 mm long with a wingspan of 25-30 mm. They are yellowish-white with black and brown spots on the head and thorax and a series of dark-brown wavy lines on the wings. Caterpillars are dirty pale green and semi translucent and up to 30 mm long when fully grown. Moths lay eggs on the underside of leaves. Young caterpillars feed initially on the underside of leaves, but older caterpillars spin or roll leaves together, and eat the leaf margins, causing the leaves to curl and droop. They pupate in the leaf roll or in debris on the ground.

The leaf roller is a common pest, which may cause considerable local damage. In extremes cases, the cotton plants may be almost completely defoliated, as a result the growth of the plants is stunted, and the bolls ripe prematurely leading to yield reduction.

What to do:

- **The leaf roller is usually controlled by natural enemies, particularly parasitic wasps, spiders and praying mantis.**
- **Removal and destruction of eggs, caterpillars, pupae and rolled leaves help to reduce damage.**

Leaf roller
Caterpillar of the leaf roller (*Haritalodes derogata*)

Spider mites (*Tetranychus* spp; cotton red mite *Oligonychus gossypii*)

Spider mites feed on the lower surface of leaves. Adults are about 0.6mm long. As a result the leaf surface appears tan or yellow and the upper surface has a speckle or mottled appearance. A close inspection of the lower leaf surface shows the mites as tiny moving greenish or reddish speckles. Heavily infested leaves turn yellow, curl up, dry and are shed. Mites produce large amount of webbing. In heavy infestations a fine web may cover the leaves. Plants may die when infestation is severe, particularly in hot dry conditions.

What to do:

- **Provide good plant growing conditions, in particular enough water; water stressed plants are prone to mite damage.**
- **Avoid the use of broad-spectrum pesticides, which kill natural enemies and may result in outbreaks.**
- **Avoid planting next to infested fields.**
- **Sulphur preparations**

Spider mites
Spider mites *Tetranychus* spp; cotton red mite *Oligonychus gossypii*) on cotton leaf. Adults are about 0.6mm long.
© O.P. Sharma, NCIPM, New Delhi. India, Bugwood.org

Bollworms (*Helicoverpa armigera*, *Earias spp* and *Pectinophora gossypiella*)

Bollworms are among the most serious cotton pests. They feed in the bolls, damaging lint and seed and causing considerable reduction in yield and quality. The main bollworms are the African bollworm (*Helicoverpa armigera*), spiny bollworms (*Earias* spp) and the pink bollworm (*Pectinophora gossypiella*). Caterpillars of the false codling moth (*Cryptophlebia leucotreta*) are sometimes found boring in the bolls.

The African bollworm (*Helicoverpa armigera*) bores into the boll often with the hind part of the body exposed outside the boll. If younger bolls are attacked they normally show a yellowish colour and the bracteoles open out (flared square). One caterpillar can damage a number of bolls and buds by moving from one to the other. Infested bolls and buds drop prematurely.

2) Spiny bollworms (*Earias biplaga / Earias insulana*)
The adults are moth, about 12 mm long with a wingspan of about 20-22. The forewings are white, peach, metallic green to straw yellow in colour according to the species. Fully-grown caterpillars are up to 18 mm long. Their body bears numerous fleshy spines. Caterpillars vary in colour from brown and deep orange to grey and yellow. Caterpillars bore into flower buds, young shoots and maturing bolls. Hollowed tender shoots whither and die.

3) The pink bollworm (*Pectinophora gossypiella*)
The moths are small (about 8-9 mm long) with grey brown or brown forewings covered with dark spots. The hind wings are whitish, broader than the fore wings, and have a long fringe on the posterior margin. The pink caterpillars are up to 15 mm long and have two broken transverse red bands on each segment of the body. This is usually a late season pest.
The caterpillars bore into the flower buds and young bolls causing shedding. Caterpillars feeding on flowers spin the petals together, causing the formation of what is called "rosette flowers" which do not open up. The bolls open prematurely and may also rot or drop to the ground. The most important damage is caused by caterpillars penetrating bolls, where they feed on the seeds and soil the lint with frass and excrements. The pest is carried over to the next season and crop as a diapause-caterpillar mainly within the cottonseeds.

What to do:

- **Practise field hygiene. Remove and destroy old crops and plant debris after harvesting or let cattle graze in the field after the picking is over.**
- **Crop rotation with plants not related to cotton (avoid kenaf, okra, abutilon and other malvaceas) may help to reduce attack by the pink bollworms and the spiny bollworm, but it is unlikely to be effective against the African bollworm, since this pest feed on many different plants.**
- **Mixed cropping helps to reduce attack by bollworms; plant composition and combinations are important to optimise the benefits. Some plants may act as trap crops and/or may attract natural enemies that will then predate on bollworms.**
- **In Tanzania, early sowing of Ukiriguru varieties is strongly recommended. These varieties have the ability to compensate for early crop loss of fruiting points caused by either physiological stress or by the African bollworm, provided soil moisture and nutrients are not limiting. Thus, the early sown cotton (sown between the end of November and end of December) may lose its bottom crop, but can compensate later by producing a crop during the main rains in March-April. If bollworms attack later, then the early sown crop would have set its main crop and will therefore escape damage (Nyambo et al., 2003).**
- **Encourage natural enemies like ladybird beetles, lacewings, spiders etc.**
- **Direct control measures are spraying with neem spray or a garlic-chilli-onion-repellent and Bt. For more information on neem click here. For information on Bt click here**
- **In Malawi and Zimbabwe, thresholds based on egg numbers have been used successfully in cotton since 1961. Spraying was recommended at an average of one egg per two plants in twice-weekly counts. In the Sudan Gezira, over two eggs or caterpillar per 18 plants, and in Australia two eggs per metre of row were used as thresholds (CABI, 2000). It has been argued that control thresholds based on damage are easier to use and more economical than those based on pest density. In the case of cotton, damaged buds are easier to detect and sample than either eggs or small caterpillars. Studies in Tanzania indicate that spraying at damage threshold of 10 to 20% would give adequate protection to the crop. Further fine-tuning of damage thresholds should be concentrated during the first four weeks of flowering when most of the damage by this pest occurs. (Kabissa, 1989).**
- **Bollworms can also be removed by hand picking. This helps when their numbers are low and in small fields.**

African bollworm
Larvae of African bollworm (*Helicoverpa zea*) feeding on cotton.


Africa bo…


Spiny boll…


Pink bollw…

Cotton stainers (*Dysdercus* spp.)

Several types of bugs attack cotton. They are late season pests; they usually attack during the flowering and fruiting stages of the crop. The most important are the cotton stainers.

Stainer bugs are between 14 and 24 mm long. They are bright red, yellow or light grey with an orange tinge depending on the species, and with black bands. Stainer bugs are late season pests; they appear when the bolls are ripening. Female lay whitish yellow eggs in moist soil or in crevices in the ground. They hatch to produce reddish-orange nymphs. Initially the nymphs are wingless, but wings develop gradually as the nymphs grow.
The nymphs are found together in the area where the eggs have been laid and later disperse to look for food. Both nymphs and adults feed on the bolls, but adults cause the most serious damage. They pierce through the boll and suck the seeds reducing germination capability and the quality of the seed oil and the cake.

Furthermore, they cause severe indirect damage by transmission of a fungus (*Nematospora* sp.), which leads to internal boll rot and stain of the lint with typical yellow colour, hence the name 'cotton stainers'. The nymphs feed mainly on seeds in open bolls reducing the seeds's oil content and their germination capacity. Severe bug attack affects yield, oil content and the marketability of the crop.

What to do:

- **Cotton stainers are attacked by a range of natural enemies; the most important are assassin bugs, ants, spiders, birds and parasitic flies.**
- **Caging chickens in cotton plots using chicken wire may control cotton stainers; about 15 birds will keep about 0.1 ha free of stainer bugs. This is a good option for small plots grown next to the homestead.**
- **Preventive control measures are sanitation; remove cotton plants and all its debris as well as ratoon cotton as soon as harvesting is over. Keep stores clean. Cotton should be grown strictly as an annual with a close (dead) season. Hand pick and destroy the bugs, this is feasible in small plots and at the beginning of infestations, and will help to reduce population density.**
- **Custard apple leaf extract is recommended for control of these bugs (PAN).**
- **The baobab tree is one of the main host plants of stainer bugs. If cotton is grown where baobab occurs, the soil and trunk of the baobab tree should be sprayed to kill the nymphs hatching from eggs laid around the stem.**
- **Tanzania: Pyrethrum formulation with black wattle extract as UV light stabilisator**

Cotton stainer
Cotton stainer (*Dysdercus* spp.) nymphs (two to the left) and an adult cotton stainer.

Information on Diseases

General Information

Diseases in cotton are of less importance than pests. The most common diseases are bacterial blight (*Xanthomonas axonopodis* pv. *malvacearum*) and *Fusarium* wilt (*Fusarium oxysporum* f.sp. *vasinfectum*).

Examples of Cotton Diseases and Organic Control Methods

Bacterial blight (*Xanthomonas axonopodis* pv. *malvacearum*)

The disease attacks seedlings, leaves, stems and bolls. Seedling attack, usually called seedling blight, results in small, round, water-soaked spots on the cotyledons as they emerge from the seed coat. The spots furnish inoculum (disease source) for the developing true leaves. Leaf spots are translucent, water-soaked, angular and bordered by veins. Affected leaves become browned and blackened. Spread of the bacteria along leaf veins is commonly called vein blight. Affected veins appear black. Younger leaves are more susceptible to vein blight than mature, old leaves.

In older plants black lesions may develop on the stems. These lesions girdle the stem and may cause breaking of the stem when windy. This symptom is known as black arm. Infected bolls have round, shiny lesions, which later become sunken, browned and finally blackened. Infected bolls become deformed and open prematurely. Fibre in diseased bolls is usually stained.

The disease is carried over season to season on infected crop debris and diseased seeds. Spread of the disease is through use of infected seeds and in the field by wind-blown rain water.

What to do:

- **Plant resistant varieties (e.g. Albar 51; Albar G501; BPA; BP 52; SATU; S 2950)**
- **Use disease-free seeds**
- **Practise crop rotation of at least 3 years with cereals or legumes**
- **Practise good field sanitation**

Bacterial blight
Bacterial blight blackening of veins (here on okra)
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Fusarium Wilt (*Fusarium oxysporum* f.sp. *vasinfectum*)

The earliest symptoms on seedlings and young plants are the yellowing and browning of cotyledons and leaves. The affected parts finally die and fall off. The bare stem blackens and dies.

In older plants symptoms are stunting, followed by leaf yellowing, wilting and dropping of most of the leaves. A characteristic symptom is the browning and blackening of the woody tissue below the bark. When a stem or branch is cut crosswise, brown discolouration is usually seen in a ring just beneath the bark. The wilt fungus survives in the soil and it is also seed-borne. Infection is often associated with nematodes.

What to do:

- **Plant resistant varieties (e.g. UK 61; UK 77; UK 91)**
- **Use disease-free seeds**
- **Liming of the soil may help to reduce wilt incidence**
- **Crop rotation is not effective in controlling Fusarium wilt but it may reduce nematode population in the field. Nematodes are associated with Fusarium wilt as they cause injury to the roots and therefore facilitate Fusarium infection.**

Fusarium wilt
Wilting (here of okra plant) due to Fusarium wilt
© A.M. Varela & A.A.Seif, icipe

Anthracnose (*Glomerella gossypii*)

It is caused by the fungus *Glomerella* (*Colletotrichum gossypii*). It is the primary cause of seedling blight, boll rot and fibre deterioration (staining) in all humid cotton growing areas. Seedlings affected by blight are killed before or after they emerge (damping-off).
Symptoms of seedling blight on cotyledons are usually diseased areas on margins or small reddish or light coloured spots. Diseased seedlings show reddish-brown lesions below ground. The lesions may be on one side of the stem or they may surround it and extend down the root. On the bolls the disease appears as small, round, water-soaked spots, which enlarge, become sunken and brownish in colour. In wet weather, the spots are covered with a sticky mass of fungal spores pinkish in colour.
Boll infection is often associated with wounds made by boll weevils. The lint and seeds are rapidly invaded

once the disease gets through the husk of the boll. Affected lint is stained.
The disease survives on old rotten bolls, crop refuse in the field and on the seeds. It is spread on diseased seeds. Infection is favoured by moderate temperatures and high moisture.

What to do:

- **Use disease-free seeds**
- **Practise crop rotation**
- **Practise good field hygiene**

Anthracnose
Anthracnose (*Glomerella gossypii*) on cotton bolls (*Gossypium hirsutum*)
© Jürgen Kranz (Courtesy of EcoPort, www.ecoport.org)

Ascochyta blight (*Ascochyta gossypii*)

The disease is caused by fungus *Ascochyta gossypii*. It may manifest as seedling blight, a leaf spot, a stem canker, and as a boll spot. The first symptoms are small, round, white, purple-ringed spots on the cotyledons and lower leaves. The spots become somewhat elongated and raised on the upper surface. Later they change to a light brown, the purple ring around the outside disappears, and the diseased tissue often falls out. The upper small leaves, petioles and buds are often infected, and the plant dies. The almost bare stems, with a few small leaves at the tip, are characteristic of the disease at the later growth stages.

Stem infection, which occurs only during consecutive days of cloudy, wet weather, leads to the formation of lesions, which may reach several centimetres in length, with cracks and ragged edges. The centre of these lesions becomes pale, liver-coloured and covered with tiny black dots (bodies of fungal spores, conidiomata). Cankers may encircle the stem and kill the distal parts. Flowers are not attacked, but mature lint can be destroyed. Lint may show a grey discolouration with conidiomata in half-opened bolls.

The disease is favoured by long periods of rain and cool weather. It is also seed-borne.

What to do:

- **Use disease-free seeds**
- **Practise crop rotation with crops non-related to cotton (e.g. cereals)**
- **Practise good field sanitation and cultivation practices which destroy drop residues are also recommended**

Ascochyta blight
Ascochyta spots (here on snowpea leaves)
© A.M. Varela, icipe

Damping-off diseases

Cotton seedlings are subject to attack by several fungal and bacterial diseases. These include the anthracnose fungus (*C. gossypii*), Ascochyta blight (*A. gossypii*), wilt fungus (*F. o.* f.sp. *vasinfectum*), bacterial blight (*X. a.* pv. *malvacearum*), *Pythium* spp. and *Rhizoctonia solani*.

The latter is particularly serious where soil temperatures are low and wet weather prevails at planting. *Rhizoctonia solani* causes sore shin disease of cotton seedlings. Attacked seedlings develop dark to reddish-brown cankers on the stems near the soil line. The cankers encircle the stems or penetrate so deeply that the plants fall over and die.

What to do:

- **Use disease-free seeds**
- **Avoid planting during cold, wet weather**

African cotton mosaic disease

The disease causative agent is still unknown but it is associated to whitefly-transmitted geminiviruses, based on symptomatology typical of begomoviruses and the demonstration of its transmissibility by the whitefly *Bemisia tabaci*. The disease is widespread in Africa south of the Sahara. Disease symptoms include irregular leaf mottling (chlorotic patches), reduced flower production, boll shedding and stunting of infected plants.

What to do:

- **As with most insect-vectored plant viruses, the disease pressure may be reduced by routine sanitation practices.**
- **Also remove infected residues; this helps to reduce disease inoculum (source) and assists in lowering vector populations**

- **Remove seasonal weeds adjacent to cotton fields and ditch banks in irrigated areas**

Cotton leaf curl bigeminivirus

Leaves of infected cotton curl upward or downward often accompanied by foliar discoloration and mosaic. These leaves may bear leaf-like enations (growth) on the underside along with vein thickening. Plants infected early in the season are stunted and yield is reduced drastically. The virus is transmitted by whiteflies (*Bemisia tabaci*).

What to do:

- **Plant resistant varieties (e.g. B6L; L1530; XL1; X1730A)**
- **Eliminate weeds in and near cotton fields. This may have some advantage in reducing virus and insect vector reservoirs**

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