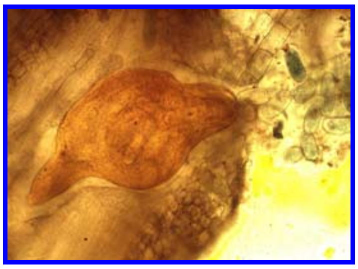
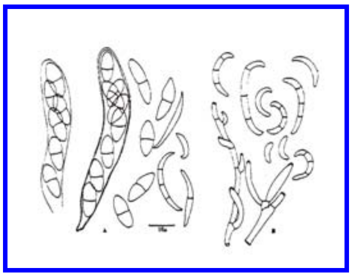
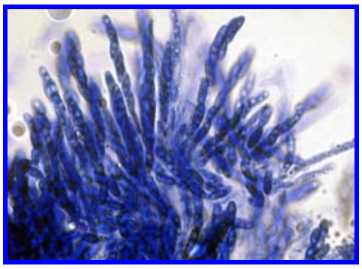
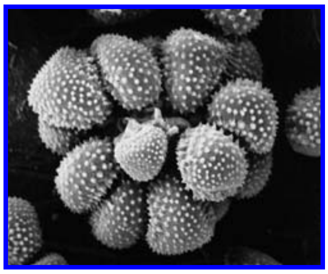
Pests and Diseases of Coffee in Eastern Africa: A Technical and Advisory Manual







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Part 1

INTRODUCTION

Coffee is grown in more than 50 countries around the world and, although utilised in a number of ways, is produced primarily for consumption as a beverage by more than one third of the world's population. It is a major commodity on the global market and provides a source of revenue for many millions of people concerned with cultivation, marketing, export and processing of the crop. Globally, Brazil is the biggest exporter of coffee, providing 25 million bags (each 60 kg) in 2003, which accounted for more than 30% of world coffee exports. Although many species of coffee exist, commercial production is based principally on two, *Coffea arabica* and *Coffea canephora*. These are often referred to as arabica coffee and robusta coffee, respectively. More than 60% of global coffee production is based on *C. arabica*. This species is considered to produce beans of higher quality and therefore demands a higher market value. However, *C. canephora* is better suited to warmer and more humid tropical environments than *C. arabica* and, also able to withstand more adverse conditions, is often grown at lower altitudes. Furthermore, *C. canephora* is generally more resistant to coffee pests and diseases.

Over the last two decades the level of coffee production has gradually increased, largely due to liberalisation of markets, while the price of coffee on the world market has declined and has become more prone to fluctuations. This has implications for those involved in the coffee commodity chain, including coffee farmers who still endeavour to produce a crop of acceptable quantity and quality but for reduced economic returns. Under such conditions farmers find it increasingly difficult to acquire those resources required for good crop management. Achieving satisfactory control of prevailing pests and diseases, one of many factors that producers must take into consideration, becomes increasingly difficult.

Coffee is an important commodity for Africa, Uganda being the biggest exporter (2.5 million bags in 2003). As in other parts of the continent, and indeed across the world, the majority is produced by smallholder farmer families that tend to have little in the way of resources to manage their farms. In these situations women often take responsibility for day-to-day running of the farm, the income from coffee being used for everyday needs including the purchase of food, clothing and medicine, payment of school fees and cultivation of other crops. Fortunate farmers may be in a position to raise cattle, goats, chickens or other animals for production of milk, eggs and meat and as source of manure. In terms of tackling pest and disease problems, resource-limited smallholder farmers are heavily reliant on the use of cultural management practices, ensuring a vigorous crop though application of mulch and manure, monitoring pest and disease levels and ensuring good sanitation, as opposed to the use of artificial fertilisers and chemical pesticides. In some cases coffee is produced on larger scale monocultures that, due to higher income levels, tend to be more mechanised, have trained staff, rely more heavily on fertilisers and chemical pesticides and may have irrigation systems. Here the possibilities for applying more complex and expensive approaches to management are much greater.

In Africa, as elsewhere, coffee farmers are continuously threatened by a range of pest and disease problems. Many of these are minor in terms of the damage they cause and their effect on yield and quality. However some, such as coffee berry disease, coffee leaf rust and coffee wilt disease (tracheomycosis), can be very serious indeed and can have a major impact not only on individual farmers but on the economy of countries or regions heavily dependent on coffee for foreign exchange earnings. Coffee wilt disease, for example, has been known to exist in Africa since the 1920s but renewed and widespread outbreaks of the disease since the 1990s has already led to considerable losses in Uganda, where more than 14 million trees have been destroyed, and in the Democratic Republic of Congo. Once established on a farm this disease is very difficult to control. Given the perennial nature of coffee, some pests and diseases are able to survive and multiply throughout the cropping season and are always present on the coffee crop, although their populations and hence their effect on the crop may vary through the year. Others may only visit and attack coffee during periods when conditions are favourable. Either way, the damage they cause and their impact on crop yield and quality can be considerable. White coffee stem borer, coffee wilt disease, parasitic nematodes and root mealy bug, for example, can and often do kill a coffee plant. Coffee berry borer, green scales, leaf rust and brown eye spot, however, will have more of a debilitating effect on plant growth, by causing defoliation for example, and can seriously affect berry quality.

It is vital that farmers are aware of the threats presented by pests and diseases and of appropriate steps that may be taken to help prevent their occurrence and to tackle them should they become problematic. The aim of this manual is to better inform farmers, directly or indirectly, of a number of the more major pests and diseases that threaten coffee production in eastern Africa and, as a consequence, to better empower them to take action as and when required. The manual makes reference to ten pest and disease constraints, selected for inclusion on the basis of those identified and prioritized by participants[1] at a Coffee Research Network (CORNET) Regional Coffee Stakeholders' Workshop held in Nairobi in October, 2004. A summary of the priorities emerging from this workshop is provided in Appendix 1. All of the constraints identified at the workshop are covered. For each, the manual provides a description to help with constraint diagnosis and identification of the causal organism. Information is provided on their importance (e.g. economic importance, coffee types affected), geographic occurrence,

[1] Participants were from eight countries (Burundi, DRC, Ethiopia, Kenya, Madagascar, Rwanda, Tanzania and Uganda) and represented coffee farmers, processors, marketers, regulatory bodies, policy makers, civil society and development agencies

biology and ecology (including survival, spread and life cycle of the causal organism) and on known approaches to management. These are supported by photographic illustrations principally of the organisms and the symptoms they induce on coffee. Detailed descriptions of the morphology of the relevant fungal and insect organisms is also provided, although this is intended more for the benefit of those who already have some knowledge and experience of these aspects and who also have access to microscopes and other equipment required to observe the organisms in detail. The manual has been produced in a use friendly format and principally to meet the needs of service providers, including agricultural extension. However, it may also be suitable for direct consultation by some farmers.

Where possible, an integrated approach to pest and disease management (IPM), involving use of a combination of cultural, biological and/or chemical measures should be considered and followed. Such an approach has advantages in terms of, for example: avoiding or minimising use of chemical pesticides that are often costly and also damaging to other organisms, man and the environment; promoting crop growth and vigour, thereby helping plants to tolerate pest damage and fight off infections; and helping to maintain biodiversity and utilise natural organisms against those organisms responsible for pest and disease outbreaks. For each pest and disease included in the manual, the various management measures known are addressed in order to facilitate development of an IPM approach. Where appropriate, control measures recommended in eastern Africa are incorporated, along with measures applied elsewhere that may be applicable to the region. Some information is also provided on possibilities for management that may currently be under investigation but show some promise.

Mike Rutherford
February 2006

Part 2

COFFEE PESTS

Coffee Berry Borer

IMPORTANCE

The beetle *Hypothenemus hampei* is commonly referred to as the Coffee Berry Borer (CBB), and is the only serious pest of the coffee bean in field grown coffee. This beetle originated in Africa but has now spread, through trade, to all of the major coffee producing countries of the world. It is now so widespread and causes such damage that it is widely considered to be the most important pest of coffee. In 1994/5, for example, CBB infested 650,000 hectares of coffee in Colombia, reduced national crop production by 1.5 million bags and cost an estimated US$ 100 million.

CBB is known to occur in Burundi, Democratric Republic of Congo, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Sudan, Uganda, Tanzania and Zimbabwe. It attacks *C. arabica* grown at lower altitudes, *C. canephora* and forest coffee, and becomes less of a problem in tropical areas above 1500 m.a.s.l. While coffee is its primary host, the pest has been known also to feed on the seeds and berries of other plants, including the pods of legumes. Attack by CBB can result in premature fall of berries and hence total crop loss. In other cases the berries may remain attached until harvest but the beans are reduced in weight, of lower quality and their flavour is adversely affected. As such, their commercial value is reduced.

DESCRIPTION

The CBB is a small black beetle about 2 mm in length and 1 mm wide. As the adult female bores into the green coffee berries to lay its eggs, occurrence of the pest can be recognised by the presence of small, round entrance holes about 1 mm in diameter and almost always close to the apex (tip) of large green or ripened berries. The female then bores a short distance into a bean where she lays her eggs and where the young insects (larvae) develop. Usually only one entrance hole is present on a berry but, when berries are scarce, several holes may be made as a number of females try to enter. They also bore into the tissues of younger berries but, finding them unsuitable for breeding purposes (because the endosperm is undeveloped) they either wait there for some weeks or they leave. A proportion of these prematurely attacked berries will rot due to bacteria and fungi contaminating the berry through the entrance hole. Mature beans that have been damaged develop a distinctive blue-green discoloration and may contain numerous small white and legless larvae, the head of which is brown.

Larvae of the coffee berry borer, H. hampei, *and damaged coffee*

bean.
Photo courtesy Jim Waller, CABI

As the eggs are laid over several weeks, the larvae within any one berry will be at various stages of development (see 'BIOLOGY AND ECOLOGY' below). Where premature fall of coffee berries is observed this may be due to attack by CBB, but these losses are often not attributed to CBB by the farmer.

Side view of adult coffee berry borer. Photo courtesy Georg Goergen, IITA

Side view (scanning electron micrograph) of adult coffee berry borer. Photo courtesy Peter Baker, CABI

BIOLOGY AND ECOLOGY

The female bores into the hardened and maturing coffee bean where it lays about 30 whitish eggs per berry over a period of about 20 days. The eggs hatch 6 to 8 days later to produce the white larvae. The larvae feed by tunnelling through the tissues of the beans to create more spacious areas (galleries) off the main tunnel. Over a period of about three weeks they pass through either two (in the case of the male) or three (in the case of the female) stages of development (instars) before pupating to become adults. The period from egg laying to adult takes between 25 and 35 days. Some of the new generation of borers will stay in the berry, mate with each other and start the next generation. When food resources in the berry are becoming exhausted the newly developed adult females leave the berry and fly from tree to tree to find a suitable site to lay their eggs. However, they wait for an environmental trigger before leaving the berry. The most common trigger is rainfall – when the berry is moistened by rain it causes numerous females to leave the following day during the late morning and afternoon. High temperatures will also cause the adults to leave. The male beetles do not fly and remain within the berry where they fertilise other females.

The adult female has been known to live for long periods of up to 282 days, the male only 103 days. CBB is therefore able to survive between crops even where there is only one crop per year. It usually does this by staying in the berry in which it developed until triggered to leave. Infestations may be maintained between peak cropping periods by the insect breeding in over-ripe berries remaining on the tree or in those that have fallen to the ground. This has important implications with regard to CBB control, as described below. Low temperature and low humidity limit survival of the beetle and its ability to breed, and partly explain why CBB is less problematic at higher altitudes.

Management

Control of CBB has always been difficult and costly. While cultural, chemical or biological approaches are suggested below, all have drawbacks in terms of efficiency or cost and no single approach applied on its own is entirely satisfactory. Combining two or more approaches (e.g. cultural practices and biological control), as part of an integrated pest management (IPM) package, may have a greater impact and should therefore be considered. Where possible this combination should be based on non-chemical measures or minimising the use of chemicals. Cultural methods, particularly sanitation, prompt harvesting and collection of mbuni from beneath trees, should be given high priority when control of CBB is being considered.

Cultural control

As the CBB survives between cropping periods in old dry berries remaining on the tree and ground, removal and destruction of these (e.g. by burning or boiling) is one of the most effective ways of reducing beetle numbers and hence controlling the pest. Berries should not be left to dry on the tree and any old berries should be removed before a main flowering to prevent carry over from one crop to the next. It is especially important to carry out this sanitation practice before rains arrive after a prolonged drought, as in these conditions there may be as many as 100 females per berry waiting for rain to trigger their dispersal. Mature berries should also be harvested frequently and efficiently to minimise the number remaining on the tree or falling to the ground. If possible this should be done every two weeks during peak fruiting periods and monthly at other times. A large piece of material or mat may be placed on the ground to collect berries that fall during harvesting. Berries should also be checked routinely and any with small holes opened to verify whether the bean has been damaged or is discoloured, as this indicates attack by CBB. Berries on the lower branches and those that have fallen on the ground are more likely to be infested.

While these manual practices can be beneficial they are laborious and time consuming. If possible farmers should try to determine whether they are cost effective by comparing crop yield and value when they are practiced as opposed to when plants are left unchecked.

In some cases CBB is believed to be more prevalent in damp or shady conditions, but this will depend on local conditions. This pest tends to occur in patches and those trying to control it should spend time evaluating field populations in relation to local conditions. Once it is established that certain areas are more prone to attack, it can be recommended to the farmer that special attention be given to these areas.

Biological control

A number of important natural enemies of the CBB, *H. hampei*, are known to occur in Africa. Of these, four parasitic wasps have been investigated for biological control purposes: *Cephalonomia stephanoderis*, *Heterospilus coffeicola*, *Phymastichus coffea* and *Prorops nasuta*. *P. nasuta* is found widely in eastern Africa. These parasites attack the eggs, larvae, pupae or adult stages of CBB, and like their host, the female remains within the berry to guard her brood. They have been shown to reduce CBB numbers but will not eradicate the beetle completely. *P. coffea* is unusual in that it attacks the adult stage and its potential for mass release, to attack adults before they damage the berry, is being studied. However there is still no commercially available wasp control agent and this is likely to remain the case for years to come.

Other natural predators of CBB include ants, birds and fungi. In recent years much attention has been given to the use against CBB of the fungus *Beauveria bassiana* as a spray to replace chemicals. This particular fungus is well known as a predator of insects, is found naturally in soils under humid conditions and has been closely studied for its ability to control a range of insect pests. When spores of the fungus come in contact with the insect they germinate and grow over it, eventually killing it. In humid climates the fungus can cause high CBB mortality as a natural epizotic. *B. bassiana* is already available commercially for control of a range of other insect pests, but the final result of its use on CBB is often disappointing and evidence that it is cost-effective is largely lacking. Production of high quality, viable spores of the fungus in sufficient concentration, well formulated and distributed, are also challenging requirements that unfortunately few developing countries can provide.

Insect traps

Recent advances in traps baited with an alcohol and turpene mixture are reported to be effective in controlling CBB, though convincing long-term efficacy trials are lacking for most countries. Mechanical traps have been developed in Central America where some are commercially available. These and homemade traps do show some promise but require testing in eastern and central Africa and again should not be used alone but form part of an integrated management programme with other measures.

Chemical control

Due to the toxicity of many insecticides, their damaging effects on the environment generally and their possible detrimental effects on natural enemies of CBB, including the parasitic wasps mentioned above, careful consideration should be given to their use. It is often preferable to apply insecticides only when infestations are serious and cannot be controlled by other measures. Chemical control of CBB previously relied on insecticides such as dieldrin and BHC (benzene hexachloride) but these have been largely replaced by endosulfan, chlorpyrifos, fenitrothion and fenthion. However, all of these chemicals are toxic to humans and other animals and, without protective equipment and careful use, spraying of coffee trees would prove hazardous. Endosulfan was traditionally used for CBB control and would appear to be the most effective chemical, but it is also now being withdrawn due to problems with safety and resistance in the borer. In particular, there are major health concerns for those applying the chemical who can become highly contaminated when spraying tall trees on difficult terrain. Furthermore, and as mentioned above, CBB spends much of its life protected within the coffee berry. If used, pesticide must therefore be applied before the insect bores into the berry to be effective, so timing is crucial. Effectively this means spraying before the endosperm has developed which means applying probably no later than 100 days after flowering. The amount of chemical used and the risks associated with their use may be reduced by spot application as opposed to spraying.

White Coffee Stem Borer

IMPORTANCE

The beetle *Monochamus leuconotus* (known previously as *Anthores leuconotus*) is commonly referred to as the white coffee stem borer, white stem borer or white coffee borer. This pest is endemic to Africa and has been reported in Angola, Burundi, Cameroon, Democratic Republic of Congo, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, South Africa, Tanzania, Zambia, Uganda and Zimbabwe. In southern Africa yield losses as high as 25% have been reported with more than 80% of coffee farms affected. Although white stem borer can survive and breed on all species of coffee, as well as a number of other Rubiaceous trees and shrubs, it is most severe on *C. arabica*, particularly at altitudes below 1700 m.a.s.l. It is often, therefore, a serious problem on coffee in eastern Africa.

Yellowing and chlorosis of leaves on a coffee tree due to infestation by white coffee stem borer. Photo courtesy Noah Phiri, CABI

DESCRIPTION

Conspicuous holes in the stem of the tree, about 1 cm in diameter, indicate that coffee stem borer has attacked a tree. Other symptoms include rings on the stem where the bark has been removed (eaten) by the larvae, and the presence of wood shavings ('frass') on the ground next to the stem. Yellowing and chlorosis of the leaves, which then wither and fall ('die-back'), are also common although these symptoms can also be caused by other problems. Coffee trees cultivated on shallow or eroded soils or near shade trees are more likely to be attacked by white coffee borer. Younger trees are also more prone to damage - those less than two years old are often killed. Trees more than three or four years old trees will suffer damage in terms of chlorosis and wilting of leaves and, while they may not be killed, will have such poor yields that they are often not worth keeping.

Adult white coffee stem borer. Photo courtesy Rory Hillocks, NRI

The adult beetle is 3.0-3.5 cm long and has a grey body with a dark brown mark (patch) on either side of its back towards the end of the wing cases. The head and thorax are dark in colour and it has very long and obvious antennae (2 - 3 cm in length).

A number of other stem bores also occur on coffee and are briefly described below under '*Other Borers of Importance*'.

Biology And Ecology

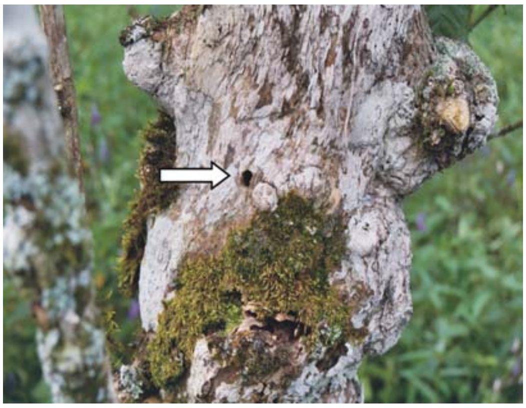
The adult female lays her eggs, at a rate of one or two per day over about a month, under the bark of the stem of the coffee tree and usually within 50 cm of the stem base. The eggs, cream coloured and about 5 mm long by 2 mm wide, hatch after about three weeks to produce creamy-white, flattened larvae. Mature larvae are between 3 and 5 cm long, legless and taper from about 1 cm wide at the head to about 0.5 cm wide at the tail.

Larva of coffee white stem borer burrowing in a coffee stem. Photo courtesy Noah Phiri, CABI

The larvae move under the bark and feed on it to form rings around the stem. This is known as 'ring barking'. They continue moving towards the base of the tree before boring into the wood where they remain for two years. During this time they pass through a number of stages of development ('instars'), becoming more yellow and cylindrical in shape. The fully-grown larva creates a large chamber ('gallery') in the stem where it pupates for 2-4 months to become an adult beetle.

Destruction of coffee stem bark ('ring-barking') caused by coffee white stem borer. Photo courtesy Noah Phiri, CABI

Adult beetles emerge from the stem about one to two weeks after the onset of the rains. They emerge by cutting a small circular hole about 1 cm in diameter to the exterior. They climb to the canopy of the tree where they feed on the green bark of shoots, leaf stalks and the skin of green berries before flying off to mate with other beetles. The females, after mating, crawl from the canopy back down to the stem to find a suitable site in the bark for laying her eggs.



Exit hole (arrowed) in coffee tree stem made by coffee white stem borer.
Photo courtesy Mike Rutherford, CABI

The larvae, by feeding on the bark and tunnelling into the wood, cause the most serious damage to the tree. Their feeding also weakens the plant, leading to the yellowing and chlorosis of the leaves and die-back. The adult beetles cause little damage, only feeding on the bark of branches.

Management

White stem borer is not easy to control. Previously, the pest was effectively managed through application of the chemical pesticides aldrin or dieldrin. These were applied to the stem with a brush or sprayer, often as a band around the stem. However, these pesticides are no longer used due to their hazardous effects on the environment and non-target organisms, and also their risk to the user. As few alternative and cost-effective chemicals have become available, current management is based largely on cultural practices.

Cultural control

Well-maintained coffee trees are less likely to be attacked by white stem borer. It is therefore wise to keep trees healthy and vigorous by, for example, providing adequate nutrition. This reduces the likelihood of attack, helps to minimise levels of infestation and also reduces the extent of damage. Maintaining healthy and vigorous trees will also help to prevent attack by other pests and diseases.

Smoothing the bark of the tree to a height of about 0.5 metres[2] from ground level to remove cracks in the bark will discourages adult females from laying their eggs. This can be done using a rough cloth, a dried maize cob, a stick or even a knife, but care must be taken not to damage the wood under the bark. Inserting a wire spoke into the tunnels made by the borer may also kill larvae that are already in the stem. Infested trees should also be uprooted and destroyed, preferably by burning infested tress before the onset of rains and hence before the adults emerge from the stem to find a partner and mate.

Although labour intensive, wrapping the base of tree stems with banana fibre provides a physical barrier and helps to prevent eggs being laid in the bark and larvae boring into the tree.

Biological control

White stem borer has a number of natural enemies that may be responsible for heavy rates of mortality observed in the pest. The larvae may be attacked in their galleries by woodpeckers and ants, while a species of the insect parasitoid *Aprostocetus* can parasitise the eggs and the pupae of the borer. Preliminary testing of the fungus *Beauvaria bassiana* for biological control has been investigated in South Africa with some promising results. No commercial biological control products appear to be available.

Chemical control

In cases where implementation of the cultural management measures is not successful, the white stem borer may be controlled by applying insecticides such as Regent® 200SC (Fipronil) to the surface of the lower 0.5 metres[2] of the main stem with a brush. Timing of application is important, as the insecticide should be applied just before the start of the rains. Application of a solution (10%) of lime has also been found to be effective and is more environmentally friendly than chemical pesticides.

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[2] Fifty centimetres is recommended, as borers are generally active below this height. However, treatment to a height on the stem above the uppermost point at which holes are usually observed is preferably.

In Kenya, any one of the following are recommended for treating stems:

- 1000 ml of Ultracide (Supracide) 40% in 20 litres of water
- 750 ml of Decis 2.5% EC in 20 litres of water
- 700 ml of Dursban 48% EC in 20 litres of water
- 1000 ml Ethion (Rhodocide) 50% EC in 20 litres of water adding

15g of methylene blue should be added to each treatment. The treatments should be repeated after one year and not applied to green stems or leaves.

Other chemical insecticides have been applied as stem paints or by pouring into the holes made by the stem borer. These include the use of chlorpyrifos in Zimbabwe, which is much safer to use than many other chemicals, including aldrin and dieldrin, and is more environmentally friendly. The chemicals fipronil and imidacloprid have also proved effective in field trials in Malawi. A fumigant paste containing aluminium phosphide ('Gastoxin') and injected into the holes have been found to be effective against other types of stem borer of coffee and cocoa in experimental tests in Ghana and Brazil. This may also be effective for white stem borer in eastern Africa, and is reasonably safe to use, but its overall suitability would need to be assessed.

OTHER STEM BORERS OF IMPORTANCE

Yellow-headed Borer (*Dirphya nigricornis*)

Also known as the orange stem borer, this borer only attacks *C. arabica* and is generally a minor pest in eastern and southern Africa. However, serious infestations have occurred in parts of Kenya (Taita Hills) and northern Malawi. It is also known to occur in Tanzania. Eggs, which are brown, are laid singly under green bark near the tips of primary branches. The hatching larvae bore into the branch and move downward into the main stem, leaving a row of holes along the branch (sometimes on the underside). Wood shavings ('frass') are usually visible outside the holes. Affected branches are weakened, the tips wilt and they may break under the weight of developing berries.

The adult beetle is slender, about 2.5-3.0 cm long and has long antennae. The body is brown and the head, thorax and first quarter of the wing cases yellowish-orange. Larvae are about 5 cm long, reddish-brown initially but becoming yellowish-orange as they mature. The pupa is about 3 cm long. Yellow-headed borer should be controlled at the first signs of attack by removing and destroying affected branches. In Kenya the lowermost hole is enlarged and dilute insecticide (e.g. Ultracide, Decis, Dursban or Ethion) poured or squirted into the hole.

Black Borer (*Apate monachus* and *Apate indistincta*)

Black borer is a minor pest, the adult stage entering the stem on the sunny side of the tree, perhaps as low as ground level, and tunnelling upward. The hole is usually cleanly cut and circular. The beetle is black, its head being held under the thorax, and up to 2 cm long. Only the adult beetle occurs on coffee, the eggs, larvae and pupae presumably developing on another host. Should control of black borer become necessary, this may be achieved by pushing a piece of cloth or cotton wool soaked in insecticide (e.g. Ultracide, Decis, Dursban, Ethion) or alternatively a wire spoke, into the tunnels.

Green Scales

Importance

Insects that belong to the Coccoidea are known as 'coccids'. Coccids considered to be important pests of coffee are scales insects (scales) and mealybugs. Coffee mealybugs are described in the following fact sheet. Scales, like mealybugs, are small insects that feed on plants by sucking the sap. In doing so they deplete the plant of vital nutrients required for growth and may cause it to become weak. While feeding, scales also inject saliva that is toxic to the plant and may cause discoloration and deformation of leaves and other plant parts. Globally, economic losses (including costs of control) attributed to all scale insects have been estimated to be US$ 5 billion per year.

While a number of scale insects are dependant on coffee as a source of nourishment, only a few of these will cause noticeable damage.

A general description of scales and their ecology and biology is provided below, followed by a more detailed description of green scales, considered to be the most important scales of coffee in Africa. Brief descriptions are also provided for a number of other scales considered to be of some importance.

General Description Of Scales

The nymph and adult, winged female are the stages of the scale insect's life cycle that are usually observed on a plant and are capable of causing damage. They feed on the plant by puncturing the bark with a short tube (stylet) and sucking the sap. Once they find a suitable feeding site and begin to feed they become attached to the plant and do not move or move very slowly. They also develop a tough scaly covering to their body that provides protection. Scale insects can multiply rapidly, especially in dry weather, while their numbers are reduced by prolonged or heavy rainfall. When infestations are heavy scale insects can cause considerable losses. The leaves of infested trees become yellow and droop while the roots become stunted.

Scales excrete sap on the surface of the plant as clear, sugary and sticky 'honeydew'. A black, sooty fungal mould will often grow on the surface of the honeydew. Scales are also often associated with ants that feed on the excreted honeydew and, in return, protect the scales from predators. Ants attend most scales considered to be of economic importance. The presence of a black, soot-like coating on coffee leaves and other plant parts, and/or or ants running about on plant surfaces, are therefore clear indications of infestation by scales.

Sooty mould on leaves infested by green scale.
Photo courtesy Dr S. D. Sawant

The male form, which in some species is rare, is generally a small, winged insect. It has reduced or non-functional mouthparts, rarely feeds and is therefore of minor importance as a pest.

GREEN SCALES

Of the green scales, *Coccus viridis*, *Coccus celatus* and *Coccus alpinus* occur on coffee in the tropics and do cause significant losses in some regions. *C. viridis* is one of the most widespread of coffee scales as it is present in virtually all of the major coffee-producing countries. It is also the most serious coccid pest of coffee. However, although widespread throughout eastern Africa (Democratic Republic of Congo, Ethiopia, Kenya, Madagascar, Tanzania and Uganda), *C. viridis* has only been found at low altitude (below 1200 m.a.s.l.) and, unlike in some countries of Asia and South America, is not considered to be a serious pest. *C. viridis* has a very wide host range that not only includes *C. arabica* and *C. canephora* but also citrus, cocoa, cassava, mango, guava and tea. It prefers to feed on the underside of leaves and on green shoots, but will also attack berries and twigs when infestations are heavy.

The closely related species *C. alpinus* and *C. celatus* are more restricted in their distribution and have a narrow host range. *C. alpinus* only occurs in eastern and central Africa (Democratic Republic of Congo, Ethiopia, Kenya, Malawi, Tanzania, Uganda and Zimbabwe), but may be found at altitudes above 1200 m.a.s.l. Local outbreaks have occasionally caused damage to *C. arabica*, particularly seedlings and young trees, in the East African highlands.

The third species, *C. celatus*, has been observed on coffee in Kenya, Tanzania, Sudan and Uganda and can again cause localised but limited damage. *C. celatus* is, however, a serious problem on coffee in some other parts of the world, particularly Papua New Guinea where it has reached epidemic proportions.

Note: *C. viridis*, *C. alpinus* and *C. celatus* are very similar in morphology. While it is possible to distinguish the three species, this requires some knowledge of key characteristics and may require the assistance of a specialist.

Green scales may attack plants in the vegetative, flowering, fruiting or post-harvest stages of growth. They are likely to been seen on the underside of leaves (especially along leaf veins), near the tips of shoots and sometimes on berries. Mature adult female green scales are about 2-3 mm long, flat, oval and pale green in colour. The insect skin is soft and the edge of the body very thin. Infestations are visible as immobile or slow moving rows or clusters of scales on the plant surface.

Green scale, black sooty mould and attendant ants on a coffee branch and berries. Photo courtesy FAO [3]

Biology and ecology

The female green scale insect lays up to 500 eggs under its body

[3] Winston, E., Laak, Op de Laak, J., Marsh, T., Lempke, H. and Chapman, K. (2005). Arabica coffee manual for Lao-PDR. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand.

which hatch within a few hours to release young, active insects (‘crawlers’). Although the young insects have three pairs of legs they generally remain under the mother for several days where they undergo three stages of development (nymphal instars). Each instar is also flat and oval but larger and more convex than the preceding one. The insect then moves from the mother and finds a suitable position under leaves, on shoots and occasionally on berries where it will settle and feed. Crawlers may move from tree to tree and can be responsible for high levels of scale dispersal. Once settled, they remain in the same position until they die, usually between three and seven months after hatching.

Coffee infested by green scale in Kenya. Photo courtesy CABI, UK

Management

Scale insects and other coccids are closely associated with ants attracted to the honeydew secreted by the scales. By attending and protecting the scales from predators and parasites the ants allow them to reproduce more freely, resulting in greater damage to the coffee plant. Indeed it is suspected that severe infestations only occur when ants are in attendance. Some measures to control scales are therefore aimed at breaking this association.

Regular inspection of trees is important in order that infestation can be identified at an early stage and management approaches implemented swiftly and before insect numbers become too high.

Cultural and biological control

Trees should be provided with optimum nutrition (mulch, fertiliser and well rotted manure) to maximise growth, vigour and resistance to attack by scale and to minimise damage and yield loss. New planting material should be inspected to ensure that it is free of infestation by scales, and for signs of honeydew or sooty mould. Badly infested branches and leaves trailing on the ground should also be cut off and destroyed to prevent insect spread, while stripping/removal of unwanted sucker growth should be carried out regularly.

Green scales are attacked by a wide range of predators and parasites, including a number of fungi, parasitic wasps and ladybirds. Some of these are available commercially. To maintain levels of parasites, it may be beneficial to leave coffee prunings on the ground rather than remove them, as this will allow parasites to emerge. Unfortunately scales are attended by ants that collect as food the honeydew excreted by the scales. In return they protect the scales against predators. Once ants are prevented from attending the scales, the parasites and predators can control an infestation of scales more quickly and much more effectively.

Green scale infected by the fungus Verticillium lecanii.
Photo courtesy Dr S. D. Sawant

Fungal parasites, such as *Cephalosporium lecanii* and *Verticillium lecanii*, will grow more rapidly under conditions of high humidity. Under such conditions they can act more quickly to reduce scale numbers. Conversely, they will be less effective when conditions are dry. *C. lecanii* is particularly effective in controlling scale insects.

Chemical control

Various oils, including refined white oils, and soap solutions were previously used to control scale infestations, as they had the effect of suffocating the insects. If used, it is important that they cover the infested area. A band of grease or thick oil, across which neither scale insects nor ants could walk, was also used to prevent scale insects reaching the foliage. In order to prevent damage to the tree, the grease or oil was smeared on greaseproof paper and not directly onto the bark. These measures are, however, of limited use if any branches touching the ground, adjacent weeds or mulch provide bridges for the insects to pass to the tree.

Stems may also be banded with chemical pesticides, which also kill or prevent scales from moving up the tree and prevent ants from attending, and hence protecting, the scales. Care should be taken with regard to selection of pesticides, as some of these are also toxic to beneficial predators and parasites. Dieldrin was previously used for this purpose but has now been withdrawn, and more recent replacements are costly. In East Africa banding trees with any of the following formulations is recommended:

- Dursban (chlorpyrifos) 48% EC (at a rate of 700 ml in 20 litres of water) plus 15g methylene blue
- Decis (deltamethrin) 2.5% EC (750 ml in 20 litres of water) plus 15 g methylene blue

Fenitrothion, a broad spectrum, contact organophosphorus insecticide, may also be effective and is relatively low cost.

The band ay be either painted or sprayed onto the tree and should be at least 15 cm wide. If trees are too small to band satisfactorily the insecticide mixture should be sprayed on to the collar of the tree and on a small area of mulch placed 15 cm from the stem.

Other Scales Of Importance

Armoured Scales

Armoured scales are scale insects where, unlike green scales, the adult female is protected by a clear wax coating. Armoured scales, including the Star Scale or Yellow-fringed Scale (*Asterolecanium coffeae*) also occur in eastern Africa and are among only a few pests that can kill a coffee tree. They are visible along the stems and branches and cause withering and slow death (‘die-back’) of the plant. They generally produce more eggs (up to 900) than green scales and the nymphs leave the mother as crawlers. Star Scale occurs in eastern Africa and, although usually a minor pest on *C. arabica*, can cause serious problems at altitudes below 1700 m.a.s.l. The adult female lays about 50 eggs and is part red-brown and part yellow when the eggs are about to hatch. The emerging crawlers are yellow, flat and oval shaped. No parasites are known for this scale. Star Scale was previously controlled by applying an emulsion of white oil to block the insect breathing pores and the hole from which the crawlers emerge. Older branches, but not young green bark, may also be treated (painted) with tar oil. Infested trees should also be well pruned.

Black Line Scale (*Ischnaspis longirostris*)

Black Line Scale, also known as Black Thread Scale, is present in eastern Africa and occurs on many crops. While it can attack coffee, it is not considered to be a serious pest of the crop. Leaves, shoots and berries can become encrusted with very large populations. Leaves become mottled with discoloured patches and curl downwards while shoot growth is inhibited, resulting in some yield reduction. The adult female is 3-4 mm long, slender, black and shiny with a slightly wider posterior (rear) and lays yellow eggs. The first instar sheds its skin that clearly remains attached. Chemical control is not usually required. Several types of beetle present in eastern Africa are effective predators.

Coffee Root Mealybug

IMPORTANCE

Insects that belong to the Coccoidea family are known as 'coccids'. Coccids considered to be important pests of coffee are scale insects (scales) and mealybugs. Scales are described in the preceding fact sheet. Mealybugs, like scales, are small insects that feed on a plant by sucking the sap. In doing so they deplete the plant of vital nutrients required for growth and berry formation and may cause it to become weak. A number of mealybugs are dependant on coffee as a source of nourishment, but only a few of these will cause noticeable damage.

Mealybugs can attack the aerial parts of coffee and those within the genus *Planococcus*, including *P. citri*, *P. kenyae* and *P. lilacinus*, are pests of coffee wherever the crop is grown around the world. However, mealybugs may also occur on roots. These are known as root mealybugs and are among the most important mealbugs of coffee in Africa. Root mealybugs have been known to cause severe damage to the crop, especially in parts of Kenya. In eastern Africa the coffee root mealybug has inflicted serious damage on *C. arabica* and *C. canephora*, particularly older or weakened trees, and is described in more detail below.

NOTE ON NAMES

The mealybug occurring on coffee roots in Africa and generally referred to as coffee root mealybug has usually been identified as *Planococcus citri*[4] (in some cases the names *Pseudococcus deceptor* or *Pseudococcus coffeae* have also been used). However, *P. citri* is commonly found on the aerial parts of plants including citrus and coffee, and is generally referred to as the citrus mealybug. Furthermore, it has been shown that mealybugs living on the roots cannot establish on aerial parts of plants and indeed recent studies suggest that the coffee root mealybug, although similar to *P. citri*, *P. deceptor* and *P. coffeae*, does differ from them morphologically. Indeed the root mealybug previously thought to be *P. citri* has now been identified as a new species *Planococcus fungicola* which, based on records under other names, appears to be distributed in Kenya, Tanzania, Uganda, Zimbabwe and possibly DRC. *P. fungicola* is therefore the species that has been known in Africa for many years as the coffee root mealybug. A second new root mealybug species, *Planococcus radicum*, has also been identified in Tanzania (and Nigeria in West Africa) and is superficially similar to *Planococcus kenyae*, a species common on aerial parts of coffee.

DESCRIPTION[5]

[4] Alternatively known as *Pseudococcus citri* in parts of Asia

[5] Differentiation of the three coffee root mealybug species *Planococcus fungicola*, *P. radicum* and *P. lilacinus*) by morphological characters is very difficult. As such, only a general description of the morphology of coffee root mealybug is provided to help in determining whether the pest is

The nymph and adult, winged, female are the stages of the root mealybug's life cycle that are usually observed on a plant and that cause damage. Infestations are visible on the surface of coffee roots as a mass of white insects usually covered with a layer of greenish-white fungus. Close examination of the insects under the fungus shows them to be small and soft bodied, with a very simple form of protection in the form of a white dusty coating with ridges of wax along the insect's body.

Coffee mealybug.
Photo courtesy FAO [6]

Unlike scales, they are capable of moving freely on the plant throughout their lifetime. The segmentation of the mealybug's body is clearly visible as are, in contrast to scale insects, their legs and antennae. Infested roots are often stunted and ants may be in attendance, feeding on sap (honeydew) secreted by the mealybugs. Leaves of the plant may become yellow and wilt.

The male form, which in some species is rare, is generally a small, winged insect. It has reduced or non-functional mouthparts, rarely feeds and, as such, is of little importance as a pest.

Biology And Ecology

Like scale insects, mealybugs feed on the plant by puncturing the plant tissues with a short tube (stylet) and sucking the sap. The coffee root mealybug, as its name suggests, lives on the roots of coffee plants and, at least in the case of *P. fungicola*, is usually associated with a soil fungus, *Diacanthodes novoguineensis* (also known as *Polyporus coffeae*). The fungus grows over the roots and over established mealybug colonies to form a distinctive casing lined with white mycelium and wax. This casing possibly provides protection to the mealybug while the fungus may feed on honeydew excreted by the mealybugs or sap leaking from the damaged plant root. It may also gain access to the root tissues through areas of damage caused by the mealybug. While the mealybugs may be found on roots in the absence of the fungus, the fungus does not occur on roots in the absence of the mealybug.

Root mealybugs, as with scales, are often associated with ants. Indeed, ants have been implicated in initial infestation of coffee roots in that they remove outer dead bark from the plant near soil level and therefore provide a point of access for the mealybugs to feed. The mealybugs move downwards to feed on the roots and become covered with the fungus, but remain accessible to the ants that may also feed on excreted honeydew and provide protection from predators.

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present. For identification to species level, the assistance of a mealybug specialist should be sought.

[6] Winston, E., Laak, Op de Laak, J., Marsh, T., Lempke, H. and Chapman, K. (2005). Arabica coffee manual for Lao-PDR. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand.

Clumps of coffee root mealybug on the roots of coffee in Uganda. Photo courtesy Georgina Hakiza, NARO, Uganda

Mealybugs can multiply rapidly, especially in dry weather. Their numbers are reduced by prolonged or heavy rainfall. When infestations are heavy, mealybugs can cause considerable losses. The damage caused by the mealybug and the loss of sap from the plant results in the leaves wilting, turning yellow and falling from the plant. Yield may be greatly reduced and all, or part, of the plant may die.

MANAGEMENT

Cultural control

New planting material should be inspected to ensure that it is free of infestation by mealybug, and for signs of honeydew or sooty mould. Trees that are old, weak, receiving inadequate nutrition or are otherwise stressed (e.g. by drought) are more susceptible to mealybug attack and should be provided with adequate nutrition in the form of fertiliser, mulch or well-rotted manure to enhance growth and vigour. Those growing in soils deficient in potassium and with little exchangeable calcium and a pH below 5.0 are particularly susceptible to attack. In Uganda, the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) recommends application of 100 g Single Super Phosphate fertiliser plus 50 g NPK (25.10.10) fertiliser per tree to enhance vigour[7]. Provision of fertiliser or other nutrition should be supported by application of chemical pesticides (see below) where possible.

Infested trees that have been growing poorly for some time or are suffering severe damage due to mealybugs and have yellow or brown leaves should be replaced (preferably by uprooting and burning to destroy the insects and hence prevent further spread).

Biological control

Like scales, mealybugs are attacked by a wide range of predators and parasites, including a number of fungi, parasitic wasps, caterpillars and ladybirds. Some of these are available commercially. However, the mealybugs are attended by ants that collect as food the honeydew they excrete and, in return, protect the mealybugs against predators. If ants are prevented from attending the mealybugs the parasites and predators usually control an infestation quickly. Under conditions of high humidity fungal parasites grow more rapidly and therefore act more quickly to reduce mealybugs numbers, the fungus *Cephalosporium lecanii* being particularly effective. The fungi are much less effective in dry conditions. To maintain levels of parasites, it may be beneficial to leave prunings on the ground

[7] MAAIF (1995) Clonal Robusta Coffee Handbook, Part 111: Pests and Diseases and their Management. Entebbe, Uganda, Ministry of Agriculture, Animal Industry and Fisheries.

rather than remove them to allow parasites to emerge.

Chemical control

Control with chemicals is not easy due to the root mealybug being present on the roots of the plant and the presence of the protective wax and the fungal layer. Care should also be taken to use selective chemicals to avoid destroying naturally occurring predators and parasites of mealybugs. Soil may be scraped away from base of the plant and also the roots, if possible, a pesticide such as Furadan (carbofuran), Dursban (chlorpyrifos) or Mashal (carbosulfan) 10% granules applied at a rate of 10 g per tree, and the soil replaced. Treatment is more effective if applied during the early stages of attack. Infested trees that still appear healthy should also be treated.

Nematodes of Coffee

Note on names

The name 'Root-knot nematode' is used to refer to species of the genus *Meloidogyne*. When these nematodes develop inside the roots of plants, the infested roots swell and distort to form galls. In severe infestations of certain species of root-knot nematode, the individual galls may coalesce, parasitized roots becoming knotted and distorted in appearance – the characteristic symptom of attack and the origin of the common name of the pest.

Importance

There are over 80 described species of root-knot nematode and although some are host-specific, others are decidedly not and may attack a broad range of plants. In general, many of the coffee root-knot nematodes are only known to attack coffee and related plants, although there are also several species, such as *Meloidogyne incognita*, *M. hapla* and *M. javanica* that are much more polyphagous and indeed are serious pests on, for example, vegetable crops.

Root-knot nematodes cause extensive damage to coffee in countries such as Brazil where their impact has been well documented. African species of coffee root-knot nematode are, on the other hand, much less well known, five of the eight species known being described from Africa.

By attacking the roots and disrupting root function, these nematodes have an impact on the ability of the coffee tree to absorb water and nutrients. This is in turn reflected in a decline in the general health and vigour of the tree and hence yield and bean quality.

Eight species of root-knot nematode are known to attack coffee in Africa, probably the most important pests being *M. africana* and *M. decalineata* which are, however, apparently restricted to relatively few countries. Distribution patterns are not well known for many African countries, the most widely surveyed being Kenya, Tanzania and Zaire. Other root-knot species include *M. oteifae*, *M. megadora*, *M. incognita*, *M. hapla*, *M. kikuyensis* and *M. javanica*. *Meloidogyne decalineata* is recorded from Tanzania in eastern Africa, but also occurs in São Tomé in West Africa, where it may have been introduced with infested planting material.

Meloidogyne africana *galls on coffee roots in Kenya.*
Photo courtesy John Bridge, CABI

In the Kilimanjaro foothills and Usambra Hills of Tanzania, *M. decalineata* is the dominant species of root-knot nematode. Of the other species, *M. africana* is reported from Kenya and Zaire and is widespread in these countries; *M. oteifae* occurs in Zaire; *M. megadora* is recorded from Angola and Uganda; *M. kikuyensis* occurs in the Kilimanjaro foothills of Tanzania and has also been reported from South Africa, although not on coffee (coffee appears to be a poor host for this species, the original population being from kikuyu grass in Kenya); *M. javanica* occurs on coffee in Tanzania and Zaire; *M. hapla* in Tanzania and Zaire; and *M. incognita* in Tanzania and Ivory Coast. Unidentified species of root-knot nematode have been reported from coffee in Tanzania and other African countries, such as Zimbabwe.

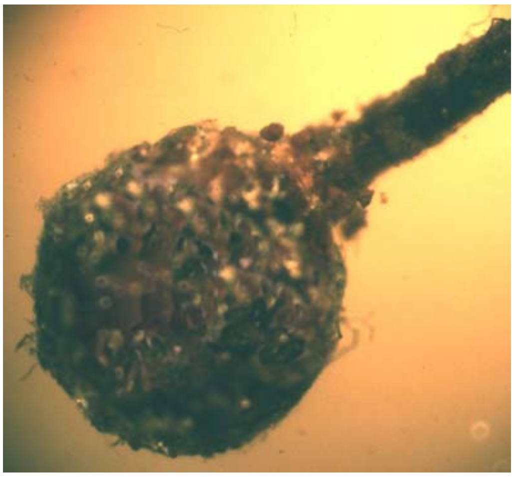
Meloidogyne decalineata *galls on coffee, Tanzania.*
Photo courtesy John Bridge, CABI

Of the known species, *M. africana*, *M. decalineata*, *M. oteifae*, *M. megadora* and *M. kikuyensis* are apparently indigenous to Africa, although there are unconfirmed reports in the literature of *M. oteifae* from Fujian, China, and *M. decalineata* from Argentina.

Accurate assessments of yield loss due to root-knot nematodes are not available, although estimates of 20% loss and above have been made for Tanzania.

Description

Root-knot nematodes are found both in the soil and within the roots of the host plant. The soil-living stages are very small, colourless, transparent worm-like animals and may easily be confused with the many other nematodes living in the soil. It is this stage that enters the plant root and then develops through a series of moults to form the mature female. Secretions produced by the developing nematode result in proliferation of the root parenchyma cells in the immediate vicinity of the nematode, thereby forming the swelling or gall that is so characteristic of these nematodes. The females are found within galls on the roots. The shape of the gall can be helpful in identifying the species present, although in coffee most root-knot galls have a similar appearance, being almost spherical and found near or at the root tips. The galls are actually swellings of the root tissue and serve to enclose and protect the enlarged females within. Attack by root-knot nematodes may facilitate invasion by pathogenic fungi such as *Rhizoctonia solani*.



Root-tip gall caused by Meloidogyne decalineata *in Tanzania.*
Photo courtesy John Bridge, CABI

Attack by *M. africana* and *M. decalineata* is usually characterised by the presence of small, more or less spherical, galls between 1-5 mm in diameter. With *M. decalineata* the galls are mainly found at the root tips.

Infested seedlings may be stunted and show proliferation of lateral roots behind the infected root tips.

Meloidogyne africana attacks *Coffea arabica* in Kenya, where it can be a serious pest both in nurseries and in the field, and *C. robusta* in Zaire. *Meloidogyne decalineata* attacks both *C. arabica* and *C. canephora* in Tanzania, causing root galling, chlorosis and reduced vigour and growth. *Meloidogyne oteifae* is reported to incite moderate sized galls on *C. robusta* in Zaire.

Identification of root-knot nematodes to species level is difficult as their morphology is relatively conserved yet variable within a species. It is clearly crucial that accurate identifications are made as this will impact upon the management strategies employed, particularly so where resistant or tolerant rootstocks are utilised as these are rarely effective against a range of pest species. The routine identification of members of the genus *Meloidogyne* is rapidly moving towards molecular methodologies.

Biology And Ecology

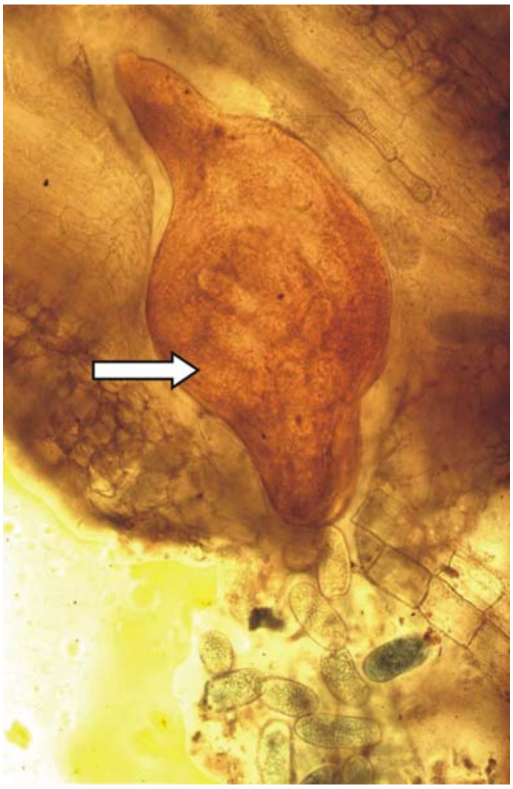
The basic life cycle of root-knot nematodes is relatively simple although the gall-inciting interaction of the parasite with the physiology of the host is complex. The mature female deposits many hundreds of eggs into a gelatinous egg-sac that may partially protrude from the root or be enclosed within the tissue of the gall. The infective juvenile nematode hatches from the egg and migrates through the soil until it finds a root of the host plant.
The juvenile then penetrates the root and settles down near the vascular cylinder, a position it will occupy for the rest of its life. As the nematode feeds it grows rapidly and moults. Although the infective nematode is vermiform (worm-like), the parasitic stages, which have a sedentary endoparasitic life style, rapidly swell as they absorb food from the plant.

Root-knot nematode infective juveniles. Photo courtesy John Bridge, CABI

The greatly swollen mature female is completely immobile, whitish in colour and usually more or less globose in form with a short, protruding, neck region at the anterior end. She produces hundreds of eggs which are laid into, and protected by, a clear jelly-like matrix secreted by the female – the egg mass.

Most root-knot nematodes are parthenogenetic (can reproduce without the need for males), although males may be produced when food supply is short, as when the host plant is weakened, or in cases of severe infestation when there is great competition between individual nematodes for the available food.

In coffee, the galls produced tend to be rather small and spherical in shape and are often restricted to the vicinity of the root tip. This is in contrast to galls on vegetables, for example, where the galls occur along the length of the root, often coalescing to form large, irregular, growths.



Female root-knot nematode (arrowed) in root. A number of laid eggs can be seen. Photo courtesy John Bridge, CABI

Root-knot nematodes on coffee are known to have other hosts. *Meloidogyne incognita*, *M. hapla* and *M. javanica* are, of course, extremely polyphagous pests and attack many vegetables and other crops. *Meloidogyne africana* is also reported to attack corn, cowpea, clove, potato and pyrethrum and *M. kikuyensis* has been found on cowpea and kikuyu grass. *M. decalineata* and *M. megadora* appear to be more host specific, although this may reflect a lack of research effort rather than fact.

MANAGEMENT

Cultural control

The best way to manage root-knot nematodes is to plant clean root-stocks into clean ground. This implies that the nurseries where the seedlings are raised must be scrupulous in practising excellent phytosanitary measures. Unfortunately, it is all too often the case that these nematodes, hidden in the roots of the plants or within the soil adhering to the roots, are unwittingly spread from infested nurseries to contaminate previously clean areas.

In the case of an infested plantation, control is made much more difficult by the sheer volume of soil in which the coffee roots, and hence the nematodes, occur.

As with other crops, good husbandry and adequate fertilization may assist the trees to partially overcome the effects of nematode attack and thereby help to minimize impact on yield parameters.

Heat treatment of soil
The soil in which the coffee seedlings are grown in the nurseries may be heat-treated prior to use so as to kill any nematodes present.

Chemical control
Chemical control of root-knot nematodes in tree crops is very costly because of the enormous volume of soil that must be treated in order to reduce the total nematode population to a reasonable level. In addition, root-knot nematodes have such a very high reproductive potential (a single female may lay several hundred or more eggs) that any surviving nematodes can rapidly build up to damaging population levels. For these reasons, chemical control of root-knot nematodes in tree plantations is rarely economic at the smallholder end of the production scale. Nematicide application also has a number of important safety and environmental considerations, including potential contamination of water supplies. Nematicide application has included both systemic and granular formulations, although the cost of these for smallholder coffee growers may be prohibitive.

Methyl bromide, an effective soil fumigant, was previously used in nurseries and the field, but this compound is currently being phased out from the market and is unlikely to be widely available for much longer.

Biological control
Although a lot of work has been done on biological control of root-knot nematodes in vegetable crops, few studies have been done on tree crops. In vegetables, the most common biological control agents are the bacterium, *Pasteuria penetrans*, and the fungus, *Pochonia chlamydosporia*. Both agents may be artificially cultured on a semi-industrial scale and then applied to the soil although, as repeat applications are usually necessary to maintain control of the target pest, these organisms are, at present, perhaps best regarded as biological pesticides rather than a self-perpetuating biological control agents.

Host plant resistance
Host plant resistance to nematodes has been widely studied in certain crops (such as banana or vegetables), although in coffee, most information comes from research in Brazil where the rootstock *Coffea canephora* C. 2258 has shown good resistance to *M. exigua* and resistance or tolerance to several populations of what was previously identified as *M. incognita* (recent research using

molecular techniques has shown that nematodes that were referred to as *M. incognita* in fact represent several, previously undescribed, species). Host resistance studies continue in Brazil and elsewhere in an attempt to limit the extensive damage caused by root-knot nematodes to coffee.

Grafting on to resistant rootstocks is yet to be fully exploited in Africa. There is limited evidence for root-knot nematode resistance in some African coffee lines, but much work remains to be done on this potentially useful and environmentally acceptable means of managing the impact of root-knot nematodes.

Part 3

COFFEE DISEASES

Coffee Leaf Rust

Importance

Coffee leaf rust (CLR), caused by the fungus *Hemileia vastatrix*, affects *C. arabica* (arabica coffee), *C. canephora* (robusta coffee) and *C. liberica* (Liberian coffee tree). It is the most important disease of *Coffea arabica*, the most susceptible of the three coffee species, and affects both yield quality and quantity. CLR first appeared in Sri Lanka in the 1860s but has since spread to most coffee growing areas of the world and is endemic to the major producing countries. It is present in every coffee growing country in Africa. The disease is potentially most damaging, and must therefore be controlled, wherever *C. arabica* is grown under warm and humid conditions at lower altitudes (below 1500 m.a.s.l.). In contrast, it is of little significance in the cooler areas of the East African Highlands above 1700 m.a.s.l.

Crop losses are due to premature shedding of leaves (defoliation) that occurs following infection by the fungus. Defoliation, by reducing the growth potential of the plant, restricts the growth of new stems on which the following season's crop is to be produced. As such a disease outbreak in one year directly affects cropping the following year, and the disease has a gradual (and often unnoticeable) weakening effect on the plant over successive seasons. High disease levels can also affect the current season’s crop, resulting in defoliation, premature ripening of berries and production of poor-quality, 'light' coffee beans. When CLR reaches epidemic proportions cultivation of coffee can become uneconomic.

CLR can cause yield losses in excess of 75% where outbreaks are severe. The costs of controlling the disease are also high and, in relation to the decreasing returns from coffee, are increasing rapidly as a proportion of the crop value. The high costs are largely due to the reliance on fungicides, the use of which is estimated to cost, globally, between US$1 billion and US$3 billion per year.

*Total defoliation and ‘die-back’ of a coffee tree due to coffee leaf rust (*Hemileia vastatrix*). In this case disease pressure was high and no fungicide was applied to control the disease. Photo courtesy Noah Phiri, CABI*

The coffee leaf rust fungus is very variable and can exist in a number of physiological types, or ‘races’. Forty races have been identified in *Hemileia vastatrix* but others may exist. Many races can attack more than one species of coffee and also show specialisation to particular varieties of coffee within a species. The existence of such variability within the fungus, and the ability to produce new races, makes management of CLR more difficult, certainly where host resistance is concerned.

DESCRIPTION

CLR is recognised by the development of yellow or blotchy, orange powdery pustules, or lesions, on the underside of coffee leaves, with corresponding chlorotic patches on the upper side. Initially these are only 2-3 mm in diameter but, as the disease develops, they enlarge and can eventually become several centimetres in diameter. The pustules are made up of numerous small, yellow, powdery spores of the fungus called urediniospores. Young lesions may appear as small chlorotic spots before the spores are produced. As they become older their centre becomes necrotic (dead) and the spores are confined to the outer areas. On older leaves several lesions may also merge to produce irregular shaped lesions that cover much of the leaf surface. However, diseased leaves are usually shed before this stage is reached.

Young (above) and more mature (below) pustules of coffee leaf rust, Hemileia vastatrix, *on the underside of leaves of* C. canephora. *Photos courtesy Noah Phiri, CABI*

In humid conditions a parasitic fungus, *Verticillium lecanii*, may grow over the CLR lesions, giving them a pale appearance (see 'Biological control' below). On occasion, rust lesions may also be visible on berries and green stems.

Another key symptom of CLR is the premature shedding of leaves. This, in turn, can lead to berries being starved of vital nutrients, especially in heavily bearing trees, and ripening prematurely. Beans of affected trees may develop poorly and feel 'light'. As the plant diverts available nutrients from the vegetative parts of the plant to the developing berries, a condition known as 'overbearing dieback' may result. This is denoted by necrosis (death) of the shoot that commences at the tip of the twigs, but gradually spreads backwards through the older tissues and main branches. Dieback can result in death of the whole branch or stem and eventual death of the entire tree. CLR tends to be more severe on heavily bearing trees, and can lead to a cycle of seasons of severe disease followed by seasons of primarily vegetative growth and very poor cropping.

Leaves of C. canephora infected with Hemileia vastatrix*. Note the orange pustules almost covering the entire leaf surface.*
Photo courtesy Noah Phiri, CABI

Another species of *Hemileia*, *H. coffeicola*, is similar to *H. vastatrix* and also affects coffee. However, *H. coffeicola* is of less importance and is restricted to the more humid areas of Africa. Unlike *H. vastatrix*, it causes a powdery rust of *Coffea* species where the urediniospores are scattered across the entire surface of the leaf and do not form in pustules.

Biology And Ecology

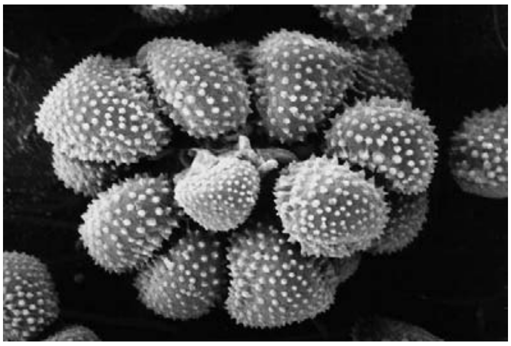
CLR is most severe on *C. arabica*, which is very susceptible to the disease, and under warm and humid or wet conditions as these aid initial infection, growth of the fungus and urediniospore production. In order to germinate urediniospores of *H. vastatrix* require liquid water and a temperature between 15°C and 28°C. In eastern Africa most infection of coffee plants seems to occur at night when the duration of wetness is adequate and can support spore germination. Within hours the new fungal mycelium developing from the spore penetrates the coffee leaves and grows within the plant. Fresh spores are usually produced on this mycelium between two weeks and two months after leaf infection. Young leaves that are not fully expanded are resistant to infection while mature leaves are most susceptible, especially on heavily bearing trees or branches.

The rate of disease development depends on a number of factors including levels of inoculum, temperature, rainfall and the density of foliage on the tree. Development is very rapid shortly after the onset of the rainy season and reaches a peak (as does defoliation) after the rains have finished. *H. vastatrix* is dispersed primarily by wind and rain splash but spores may also be dispersed or carried from one farm to another by people, insects and animals should they come into contact with spore producing lesions. Although the disease is not usually seed-borne coffee berries and seeds may become contaminated by urediniospores that are then carried elsewhere.

Identification of *H. vastatrix* based on fungal morphology

Although the pustules caused by CLR can only be seen very clearly on the coffee plant, the individual spores and fungal mycelium can be clearly observed only with the aid of a microscope. Where this is available the rust pustules are seen to have many individual groups, or clumps, of fungal mycelium mixed with uredioniospores. These clumps are known as uredinia and are densely scattered across the pustule, resulting in the powdery appearance of pustules. Within the uredinia the urediniospores are produced in spherical clusters at the ends of filaments. The urediniospores are packed together like segments of an orange, giving each spore a kidney-like shape, curved with short spines on one side and smooth and flattened on the other (hence the name *Hemileia*, which means 'half smooth'.

The urediniospores measure 18-28 x 28-36 µm, and are yellow with an attachment scar on their smooth surface. Another form of spore, the teliospore, may also be produced in the uredinia of the fungus. These are almost spherical or turnip shaped and 20-25 µm in diameter.



High power magnification of a uredinium of H. vastatrix *with maturing urediniospores produced in spherical clusters and packed like segments of an orange. Photo courtesy Jim Waller, CABI*

For a full description of the morphology of the fungus refer to; *Laundon, G. F. and Waterston, J. M (1964) C.M.I. Descriptions of Pathogenic Fungi and Bacteria Set No. 1, Number 1*, published by CAB International.

Management

Coffee rust is managed primarily through application of chemicals (fungicides) and the use of resistant varieties.

Chemical control

Fungicides are widely used for control of CLR, although the advent of apparently durable resistance in 'Catimor' coffee hybrids is now enabling resistant cultivars to be deployed. The timing of fungicide application is critical for controlling CLR, with maximum effect being achieved through application before the start and during the early period of the rainy season. It is important that fungicide is reapplied should the previous application be washed off by rainfall.

The primary aim of fungicide application is to protect the underside of the leaves, where the fungus is most likely to penetrate the plant, at times when conditions are favourable for disease development. Such protection usually requires regular applications throughout the rainy season. If fungicides are available, spraying regimes are also usually provided to suit local conditions and other factors. Specific spraying techniques (e.g. ultra low volume, or ULV) have also been developed to help ensure that leaf surfaces are adequately covered during application to fully protect them. Such techniques also tend to reduce the volume of fungicide required, and hence overall costs. In Africa growers should consider the need to control other diseases such as coffee berry disease and the consequences on these of using fungicides for CLR control.

Fungicides should be applied for controlling CLR once a disease threshold is reached. This threshold is when either 5% (i.e. 1 in every 20) or more of the coffee leaves show even a single pustule three months after flowering or when an average of two or more pustules are present on each diseased leaf. Fungicides used for the control of CLR are either protectant (kill the fungus on coming into contact with it on the surface of the plant), which are mostly copper based, or systemic (move within the plant and act once the fungus enters the plant tissues). The common copper fungicides used for control are:

Cuprous oxide 50% Cu WP (red copper e.g. Copper Nordox) applied at a rate of 3.8 kg per hectare.

Cupric hydroxide 50% Cu WP (blue copper e.g. Kocide 101) applied at a rate of 3.8 kg per hectare.

Cupric chloride 50% Cu WP (copper oxychloride or green copper e.g. Cupravit) applied at a rate of 7 kg per hectare.

All of the above three fungicides are applied at three week intervals, and the application rates shown are based on recommendations in eastern African.

Alternatively, a tank mixture comprising copper (5 kg of 50% WP copper oxychloride) plus half rate organic fungicide (e.g. 2 kg of chlorothalonil 75% WP), normally used to control coffee berry disease, is also suitable for controlling CLR.

Should 20% or more of the leaves develop pustules then the systemic triazole fungicide Bayleton 25% EC, which contains triademefon, should be sprayed at a rate of one litre per hectare.

Resistant varieties

Coffee varieties that are resistant to coffee rust and also produce high yields and quality beans are available. A number of 'Catimor' varieties that have durable resistance to most races of CLR are now widely planted in many countries. They include 'Catimor 129', 'Catimor 128' and five other Catimor types being grown in Malawi and many other countries in Africa. In addition, coffee variety 'K7' is tolerant to coffee rust, while 'Ruiru 11', a new hybrid derived from Catimor and now widely planted in Kenya, is resistant to both CLR and coffee berry disease. Unfortunately new races of *H. vastatrix* that are able to overcome resistance in new hybrids continue to emerge.

Cultural control

Cultural practices can have an indirect but beneficial effect in terms of CLR control. For example, wider spacing and appropriate pruning help by preventing prolonged wetness and increasing penetration of fungicides sprayed into the tree canopy. It is also known that the severity of rust is lower under shaded conditions possibly because fully exposed trees, by producing higher yields, become more susceptible to the disease. Appropriate shade management may also therefore be of some benefit.

Hyperparasitic fungi growing over Hemileia vastatrix *lesions on a leaf of* C. arabica *coffee.*
Photo courtesy Noah Phiri, CABI

Biological control

There are no commercial biocontrol strategies for controlling CLR. However, fungal parasites of the rust pathogen, such as *Verticillium lecanii* and a number of *Darluca* species, occur on CLR pustules in coffee fields. Although their effect on disease development is not clear they may be of some benefit. Some insects and mites also feed on the rust spores but again are not used purposefully for CLR control.

Coffee Berry Disease

IMPORTANCE

Coffee berry disease (CBD), which affects *Coffea arabica*, is caused by the fungus *Colletotrichum kahawae*. It is endemic to Africa and was first recorded in western Kenya in 1922. Since then the disease has spread to most *C. arabica* growing countries on the continent and is currently known to occur in Angola, Burundi, Cameroon, Central African Republic, Democratic Republic of Congo (DRC), Congo, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Tanzania, Uganda, Zambia, and Zimbabwe. CBD has not been observed outside Africa.

CBD can cause considerable yield losses of up to 75% when not adequately controlled. Even though application of fungicides to control the disease can result in yields being doubled, losses of up to 30% can still occur when attack is severe. Yield losses occur as a result of shedding and/or destruction of infected berries, which become mummified (dry, wrinkled and decayed, with a hard skin). The pathogen can infect berries at the pinhead, expanding, mature green and ripe stages of development, as well as flowers. However, most losses are due to infection of the green expanding berries, between four and six weeks after flowering, when they are most susceptible, and also under wet conditions. Crop losses may therefore vary from year to year depending on weather conditions. Berries are most resistant at the 'pinhead' stage (first month) and when fully mature (at 16-18 weeks from the time of flowering). Active lesions develop on the berry and expand until the whole berry is affected. The beans are destroyed and the berries turn black and either drop or remain on the coffee plant as mummified berries. Some of the berries drop off after developing a few active lesions.

Coffee berries infected by C. kahawae. *Note the mummified coffee berries (black). Photo courtesy Noah Phiri, CABI*

Coffea arabica is the major host for *C. kahawae*. The disease has not been observed on other coffee species, including *C. canephora* and *C. liberica*, in the field nor on wild coffee. Disease lesions have been known to develop on these species, but only when plants are artificially inoculated under controlled conditions.

DESCRIPTION

The characteristic symptom of CBD is the development of small, water-soaked lesions on young, expanding berries that rapidly become dark brown or black and slightly sunken. They enlarge to cover the whole berry within about a week, which eventually rots.

Under humid conditions, masses of pale pink spores become visible on the surface of lesions. These symptoms, collectively known as 'anthracnose', are typical of CBD. Another characteristic of the disease is the shedding of berries from branches at an early stage of disease development. Lesions may also occur on young berry stalks, causing them to be shed before lesions appear on the berry itself.

The dark, sunken lesions are generally referred to as 'active' lesions.

Typical dark sunken lesions and 'active' lesions (arrowed) of coffee berry disease on green coffee berries.
Photo courtesy Noah Phiri, CABI

However, pale, corky brownish lesions may also develop, mostly on young pinheads and mature green berries. These lesions are known as 'scab' lesions and, as pinhead and mature green berries are more resistant to CBD, their development is due to a resistant reaction to infection. Scab lesions may heal completely, or may remain dormant until the berry becomes susceptible again (as it begins to ripen) when they may develop into active lesions. Scab lesions also develop when weather conditions are not favourable for disease development, for example when the weather becomes dry and hot, and on unsprayed coffee.

Coffee berry disease 'scab' lesions (arrowed) on coffee berries.
Photo courtesy Noah Phiri, CABI

CBD can also cause a 'brown blight' on ripening berries, denoted by dark, sunken lesions typical of the anthracnose enveloping the red berry. Under very wet weather conditions CBD may also cause brown lesions to develop on flower petals. In addition, it can attack seedling hypocotyls of *C. arabica*.

Coffee berry disease lesions on green berries. Note fungal sporulation (arrowed) on lesion of the berry in the centre. Photo courtesy Noah Phiri, CABI

C. kahawae may be found on coffee in association with another species of *Colletotrichum*, *C. gloeosporioides*. However, this species is non-pathogenic or only weakly pathogenic and will only infect ripe coffee berries. The two fungi are genetically and physiologically different. *C. gloeosporioides* may also cause anthracnose of ripe coffee berries, but in this case the coffee beans are not destroyed. This pathogen is therefore of less importance than *C. kahawae*, although infection can cause problems when pulping the berries.

Identification of *C. kahawae* based on fungal morphology

When isolated from CBD lesions and grown on an artificial growth medium (2% malt agar, MA) at 25°C, *C. kahawae* colonies appear densely floccose, grey to dark olive-grey and dark greenish on the reverse. With successive sub culturing colonies become more variable, often paler or brownish.

The detailed structure of the CBD fungus, *C. kahawae,* can only be clearly observed with the aid of a microscope. Where this is available the spores (conidia) are seen to be produced from simple hyphae, with no formation of acervular condiomata, Conidia are unicellular, straight, cylindrical, invariably guttulate, rounded (obtuse) at the apex and 12.5-19.0 x 4.0 µm. Appressoria are moderately abundant, pale to medium brown, circular or slightly irregular, 8.0-9.5 x 55 x 6.5 µm, often becoming complex.

Fungal mycelium and conidiaspores of C. kahawae, *the coffee berry disease pathogen. Photo courtesy Jim Waller, CABI*

For a full description of the morphology of the fungus refer to; Waller, J. M., Bridge, P. D., Black, R. and Hakiza, G. (1993) Characterization of the coffee berry disease pathogen, *Colletotrichum kahawae* sp. nov. *Mycological Research* **97**: 989-994.

Biology and Ecology

The fungus over-winters on the maturing bark of coffee twigs together with other species of *Colletotrichum*, such as *C. gloeosporioides* and *C. acutatum*. The maturing bark of coffee twigs has been shown to have the highest population of *C. kahawae* in comparison to immature, green bark, older bark and berries. It constitutes, therefore, the primary source of inoculum for seasonal CBD outbreaks that develop after flowering and at the beginning of the rains, especially if no infected berries have remained on the tree. As the season progresses and developing berries become infected they become more important as a source of inoculum. Where crops overlap, as in countries with bi-modal rainfall pattern such as Kenya, levels of inoculum can remain high.

Weather conditions are critical in development of CBD. Adequate moisture is essential as the spores (conidia) of *C. kahawae* are dispersed by water and also require liquid water or 100% relative humidity for germination. This implies that CBD epidemics should be expected in areas where rainfall is generally high or during years of high rainfall in otherwise dry areas. Temperature is another important factor in that temperatures between 12°C and 30°C are also required for conidia to germinate, the optimum being 22°C. The host plant tissues may be infected within five hours of germination. The ideal conditions for CBD development can therefore vary at different altitudes and from country to country. In Kenya spore production by *C. kahawae* was greatest between 1700 and 1900 m.a.s.l., while in Malawi CBD occurs between 1300 and 1800 m.a.s.l. (although the highest altitude at which coffee is grown in Malawi is 1800 m.a.s.l.).

MANAGEMENT

CBD can be controlled through cultural measures, chemical application, use of resistant varieties and biological control. A number of these differing approaches should be considered as part of an integrated approach to control. Chemical control is considered as essential in most countries, with copper based fungicides, as well as organic eradicant/protectants such as chlorothalonil and dithianon, being very effective. A number of resistant varieties are also now available.

Cultural control

Cultural management practices can indirectly control CBD. Providing wider spacing and ensuring that trees are pruned appropriately helps to prevent prolonged wetness and high relative humidity following periods of rainfall (conditions that are ideal for CBD development). These practices are also beneficial to fungicide application, as they open up the coffee bush to allow effective penetration of spayed fungicide. Pruning is, however, not recommended for dwarf and semi-dwarf varieties such as Catimors. In shaded coffee the canopy of the trees should be prevented from becoming too dense.

Any infected berries remaining on the tree can act as a source of inoculum. All berries including dried berries ('mbuni') should therefore be removed at the end of the cropping season to prevent them acting as a source of inoculum for the new crop.

Chemical control

A number of fungicides are available for controlling CBD, but the use of chemicals is costly. Copper based fungicides are relatively cheap, very effective against CBD and also give protection against coffee leaf rust. The most economical approach is to use a tank mixture containing half the normal rate of copper fungicide (5 kg of 50% WP copper oxychloride) and half the normal rate of organic fungicide (2 kg chlorothalonil 75% WP). Other fungicides which give good control of CBD are:

Dithianon 76% WP
Anilazine 75% WP
Cobox 50% WP
Funguran 50% WP
Procida Bordeaux Mixture 25% Cu WP

Tank mixtures are used in many countries for controlling CBD, including Malawi, Zambia, Kenya and Zimbabwe. Fungicides should be applied every three to four weeks during the rainy season to protect developing berries.

Resistant varieties

Coffee varieties resistant to CBD are available. They include Ruiru 11, Hibrido de timor, Rume Sudan, K7 and several Catimors. Ruiru 11 was bred in Kenya with vertical resistance to the CBD pathogen. It is high yielding and also resistant to coffee leaf rust. Rume Sudan, although highly resistant, is of poor quality and probably not suitable for commercial production. In addition, a single-tree selection, 'Nyika', was developed in Malawi from Catimor 129 and is recommended for use in that country.

Biological control

Components of the microbiota (fungi and bacteria) on coffee plants have been tested against *C. kahawae*, a number of which have shown very high levels of antagonism. However, these have not yet been developed as commercial biocontrol agents. It has also been established that applying fewer than the recommended number of sprays or lower rates of fungicide than recommended for control of CBD results in increased disease severity, due to elimination of natural antagonists that compete with *C. kahawae* on the twigs and berries. In most cases it is therefore advisable not to apply any fungicides if it is known that application at the recommended rates is not possible (due to costs, for example).

Coffee Wilt Disease

IMPORTANCE

Coffee Wilt Disease (CWD), also known as 'fusarium wilt' or 'tracheomycosis', affects *Coffea arabica* and *Coffea canephora* as well as wild coffee species. It is a vascular wilt disease caused by the fungus *Fusarium xylarioides.* This is the asexual stage (anamorph) of the fungus, *Gibberella xylarioides* being the sexual stage (teleomorph).

*Coffee tree partially affected by coffee wilt disease (*F. xylarioides*). Photo courtesy Mike Rutherford, CABI*

CWD has been known to occur in Africa for more than 70 years, having first been reported in Central Africa Republic (CAR) in 1928. It subsequently caused extensive losses to production of *C. canephora* and *C. excelsa* in CAR, Cote d'Ivoire (where more than 50% of the coffee producing area was destroyed) and the Democratic Republic of Congo (DRC), but was successfully controlled by the use of host resistance. However, the disease has again become a serious problem in some countries in eastern Africa where it has already caused considerable damage to *C. canephora* in Uganda and DRC. In Uganda, for example, 14 million trees have been killed since the disease re-emerged in 1993. CWD is also causing problems on *C. canephora* in Kagera region, north west Tanzania. In Ethiopia the disease occurs on *C. arabica* where, again, severe losses have been experienced in some areas. Recent evidence suggests that the current outbreak on *C. canephora* developed in northeast DRC before spreading to Uganda and then Tanzania. The disease is not present on *C. arabica* in Uganda, DRC and Tanzania, or on *C. canephora* in Ethiopia. Unlike many other diseases of coffee CWD will quickly kill the tree.

DESCRIPTION

Yellowing, folding and inward curling of the leaves are among the first signs of CWD. The leaves feel limp to the touch, then dry up and become brown and eventually drop off, leaving affected trees completely leafless.

First signs of coffee wilt disease – leaves wilt, droop, become dry and fall leaving only the berries intact.
Photo courtesy Mike Rutherford, CABI

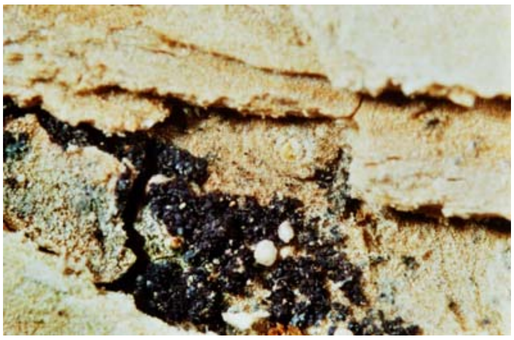
Affected branches may turn black-brown or blackish and become dry. These symptoms, collectively referred to as 'dieback', often start on the branches on one side of the tree but rapidly spread to the entire tree. Berries on infected trees turn red prematurely and appear to ripen early.

Curling and drying of leaf on a coffee tree caused by coffee wilt disease. Note also the blackening ('dieback') of the stem. Photo courtesy Julie Flood, CABI

The fungus invades and blocks the water conducting system (xylem) of the plant, preventing the movement of water upwards from the roots. This water shortage causes the visible signs of wilting, dieback and early ripening of berries that are associated with CWD.

Premature ripening of coffee berries due to coffee wilt disease. Note also the blackening of the branch.
Photo courtesy Julie Flood, CABI

The bark on the trunk, especially near the base of the tree, may become swollen and have many vertical or spiral cracks. Towards the end of the rainy season small black structures (perithecioid ascomata, also known as 'perithecia') resembling soil particles may be produced on the bark, usually at the base of the plant and sometimes in the cracks. The ascomata contain spores (ascospores) of the fungus. Although the spores cannot be seen with the naked eye they enable the fungus to spread to other coffee plants and to survive in the soil or on dead plant material. In the roots a moist, black rot may develop.



Production of perithecioide ascomata ('perithecia') of the coffee wilt pathogen in the crevices of tree bark. Photo courtesy Julie Flood, CABI

Some of these symptoms, such as yellowing of the leaves, may be due to other causes, including drought and diseases induced by other species of *Fusarium*. However, a unique symptom of CWD is the development of blue-black discoloration of the wood directly beneath the bark. This can be seen when the bark is removed, and is usually most pronounced towards the base of the stem.

Blue-black staining of wood beneath the bark at the base of a tree affected by coffee wilt disease.

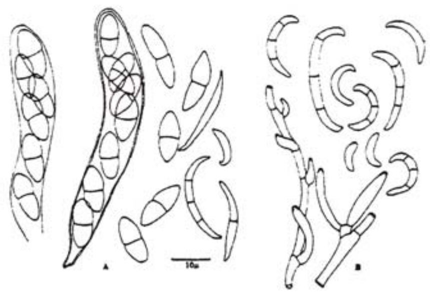
Photo courtesy Mike Rutherford, CABI

The coffee plant may be affected by CWD at any stage of its development. Young plants may be killed within a few weeks of initial infection. Older trees usually die within between six and fifteen months of the first symptoms appearing, some within just three months. By the time CWD symptoms are seen it is too late to save the plant. For this reason some farmers call this disease 'coffee AIDS'.

Blue-black staining of wood beneath the bark on a section of stem affected by coffee wilt disease.
Photo courtesy Mike Rutherford, CABI

Identification of *F. xylarioides* based on fungal morphology

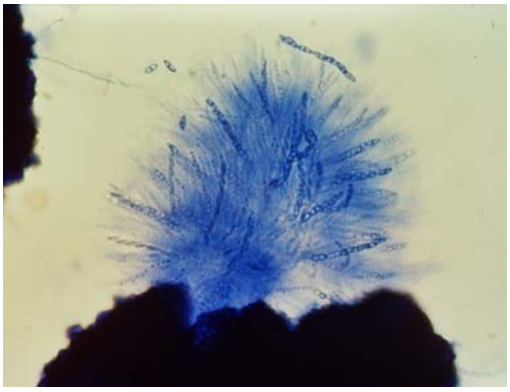
Although the symptoms caused by CWD can be very obvious the fungus causing the disease, *F. xylarioides*, can only be closely observed and identified with the aid of a microscope. Where this is available, colonies grown on potato sucrose agar (PSA) are characterised by the production of strongly curved, unicellular microconidia that are produced in slimy masses on short conidiogenous cells on the vegetative mycelium. Strongly curved but larger macroconidia, fusoid or falcate in shape and having two or three septa, are produced in a similar manner.



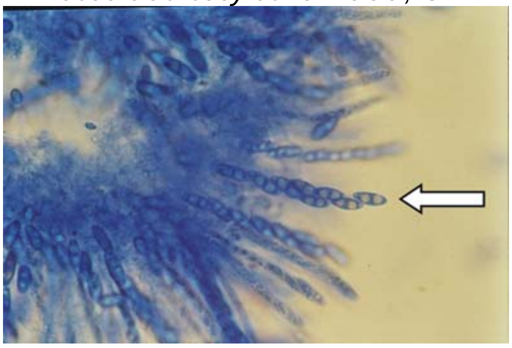
Diagrammatic representation of ascospores of F. xylarioides *containing two-celled asci (left) and characteristically curved conidia (right)*

The teleomorph, *G. xylarioides*, develops on affected coffee plants under conditions of high humidity or rainfall, forming globose ascomata that contain numerous cylindrical asci. Each ascus contains eight ascospores, each ascospore having two cells. Cultures of the fungus tend to develop a bluish-violet tinge.

For a full description of the morphology of the fungus refer to *Booth, C. and Waterston, J. M. (1964) C.M.I. Descriptions of Pathogenic Fungi and Bacteria Set No. 3, Number 24*, published by CAB International.



Asci emerging from an ascomata of F. xylarioides *(above) and magnification of asci showing two-celled ascospores (below, arrowed).*
Photos courtesy Julie Flood, CABI



Biology And Ecology

Unlike many species of *Fusarium* causing diseases on plants, *F. xylarioides* appears to be a pathogen specific to coffee. It causes extensive necrosis of the water conducting vessels that results in wilting and death of the plant. The pathogen is considered to be an endemic soil inhabiting fungus. It can remain viable in soil and infected wood and retain its ability to infect coffee for at least 11 months. How it survives for prolonged periods is unclear as the fungus, unlike some other species of *Fusarium*, rarely produces thick-walled resting spores (chlamydospores). It is possible that ascospores produced in the ascomata may act therefore as survival spores.

Spores of *F. xylarioides* may be dispersed by wind, in rain splash, during flooding and by human activity. In the case of wind, this may allow spread over long distances. Although it has been suggested that the fungus may be carried on coffee berries and by insects, such as stem borers, recent research suggests that this is unlikely. The fungus infects coffee plants through the roots or through wounds made in the stem. It has also been shown that wounding with farm implements contaminated with spores of the fungus, during pruning and mechanical weeding for example, can result in spread of the disease. On entering the host plant the fungus spreads upward through the water conducting vessels (xylem). Once a tree has become affected by CWD adjacent trees subsequently start to develop symptoms, usually within just a few months. Ascomata may be observed on the bark towards the end of the rainy season and on dead and decaying coffee plant material.

Recent genetic studies suggest that two different forms (variants) of *F. xylarioides* are responsible for current CWD outbreaks in eastern Africa. The first is found on *C. arabica* in Ethiopia, while the second is found on *C. canephora* in Uganda, DRC and Tanzania. Screen house and glasshouse trials undertaken in Africa and Europe and involving artificial inoculation of coffee plants have also shown that host specificity is operating in that the variant currently present in Ethiopia can cause symptoms of CWD only on *C. arabica* while the variant in Uganda, DRC and Tanzania can cause symptoms only on *C. canephora*. Neither of the two variants can attack both coffee species. Some variation was also noted in the extent to which different isolates of the fungus caused symptoms on different coffee lines within each of the two coffee species. Both variants also show some genetic differences to isolates obtained from CWD affected coffee during earlier outbreaks in CAR, Cote d'Ivoire and Guinea. Research also suggests that, despite the presence of a sexual phase in the fungus, the two variants are sexually incompatible. This incompatibility may have led to the limited genetic variability and apparent host specificity within the pathogen, and to the apparent geographic separation of the two variants.

Of possible alternative hosts investigated, the pathogen has only been recovered from within the roots of banana in Uganda. However, as yet symptoms of CWD have not been observed on field grown crops other than coffee.

MANAGEMENT

Regulatory control

Strict quarantine measures, involving restrictions on the movement of coffee materials (seedlings, beans, husks etc) from affected area, are necessary to prevent entry of CWD to disease free areas. For countries bordering affected countries, import of coffee material should be discouraged until the risk of infection is known. Cordon sanitares, involving the destruction of all affected coffee in border areas and encouragement of farmers to grow crops other than coffee, may be established to prevent disease spread.

A cause for concern amongst farmers is the spread of the disease between *C. arabica* and *C. canephora* plants. At present the variant of CWD in Uganda, DRC and Tanzania only attacks *C. canephora* while the variant in Ethiopia only attacks *C. arabica*. However, should the variant present in Ethiopia spread to other countries it could cause considerable damage to *C. arabica*.

Cultural control

Current recommendations are largely based on preventing introduction of CWD to a farm and, where it is already present, limiting spread within the farm and onward spread to other farms. On disease free farms introduction of CWD can be prevented by replanting with plants raised from disease-free cuttings and seed collected from within the farm. Where planting material is obtained from elsewhere, this should be obtained from official distributors or from areas that are known to be free of the disease.

On farms where CWD is already present, affected trees provide focal points for further infection and should be uprooted and burnt. Trees adjacent to affected trees should also be uprooted and burnt even if they appear healthy since they may already be infected by the fungus. Trees must be destroyed were they are uprooted and not dragged through healthy trees as this will spread the disease. Storage and use of wood from affected trees, as firewood for example, should also be avoided. Uprooting and burning is most effective when disease symptoms are recognised quickly and only one or a few trees are affected. In such cases the farmer may save some of the crop. If the farmer delays then infected trees act as a source of inoculum and will rapidly infect other trees and the entire crop may be lost. Following destruction of diseased trees the land should be left fallow or an alternative crop grown. Unless planted with a resistant cultivar, replanting with coffee should not be carried out for at least two years to allow inoculum of the fungus in soil to decline. While replanting with coffee will allow production of coffee to continue, it will be several years before new planting are sufficiently mature to yield a crop. Preventing introduction of CWD or taking swift action to destroy trees that develop symptoms is therefore the best way of minimising overall losses.

On large plantations, spread of CWD from one area to another may be prevented by clearing a strip of land, up to several hundred metres wide, ahead of the disease front. An alternative crop may be planted in this strip.

Any wounding of the tree, especially in the stem near soil level or in the roots, will allow the fungus to gain entry. Great care should be taken, therefore, to minimize damage when weeding and pruning with a machete, hoe or other implement. Livestock should also be prevented from feeding on and around the trees, especially the stem. If possible, all tools should be sterilized in a fire or with disinfectant (e.g. 'JIK') before moving from one tree to another. Treating wounds with disinfectant or a suitable fungicide may also be effective, especially if applied soon after the wounds are made.

Resistant varieties

The use of resistant cultivars offers the best option for long-term control of CWD. Development of breeding programmes is essential to allow screening and selection of resistant coffee types that may be multiplied and distributed as planting material to farmers. During the serious CWD outbreaks in western and central Africa in the 1950 and 1960s, uprooting and destroying trees, followed by replanting with resistant cultivars of

C. canephora, proved very successful in eradicating the disease.

A renewed search for resistance to CWD amongst cultivated varieties and wild coffee (growing in forest parks, botanic gardens and coffee museums, for example) has begun as part of national selection programmes. Trials to screen coffee for resistance are now underway in Uganda, DRC, Tanzania and Ethiopia, supported by similar research in Europe. In Uganda, surviving plants obtained from CWD 'hot spots' are being screened, as are 'Arabusta' types (crosses between resistant *C. arabica* and susceptible *C. canephora*). The mechanisms responsible for resistance in the coffee plant and how resistance is inherited are also being studied in Africa and Europe and should improve the prospects for producing resistant material in the future.

If practical, uprooting and replanting affected *C. canephora* with *C. arabica* should help to contain CWD in Uganda, DRC and Tanzania. Similarly, CWD in Ethiopia could be prevented or restricted by replacing *C. arabica* with *C. canephora*.

Chemical control

Chemical control is unlikely to be effective as the pathogen is known to live in the soil or inside the plant, making it hard to target even with systemic fungicides. Even if effective, the use of systemic fungicides would be costly and probably uneconomic, and would have undesirable environmental effects.

Coffee Bark Disease

Importance

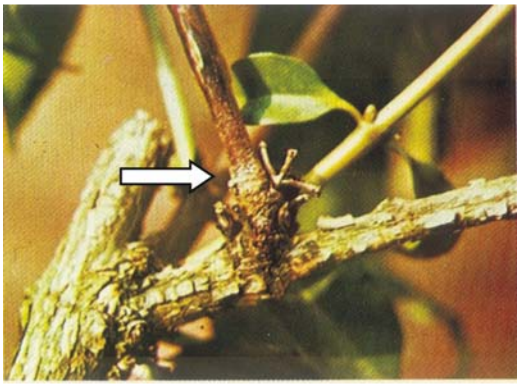
Coffee bark disease, also known as 'Fusarium bark disease' and 'Storey's bark disease', only appears to affect *Coffea arabica*. The disease is caused by the soil borne fungus *Fusarium stilbioides*. This is the asexual stage (anamorph) of the fungus, the sexual stage (teleomorph) being *Gibberella stilboides*. Coffee bark disease can be highly destructive and was first described in Tanzania in 1932 and subsequently in Malawi, where it caused serious economic losses and reached epidemic proportions in the 1950s and 1960s but was largely controlled through selection of resistant cultivars in the 1970s. The disease has been reported to occur in Burundi, Ethiopia, Kenya, Madagascar, Rwanda, Tanzania and Uganda.

Description

Symptoms of coffee bark disease may develop on a coffee tree in several different ways. These are referred to as 'Storey's bark disease', 'scaly bark', and 'collar rot'. The three conditions, all of which may not necessarily develop on a tree at any one time, are described in detail below.

1. Storey's bark disease

In green stems a slightly sunken disease lesion with a water-soaked margin develops near the stem base and expands to eventually girdle the stem. The lesion may be cinnamon to tawny olive, darkening to brown-brown and in moist conditions may bear pink spore masses. All tissues below the lesion and as deep as (and including) the cambium are killed. Where bark is present, this remains intact and may obscure an underlying lesion.



Lesions and constriction at the base of a coffee branch caused by Storey's bark disease (F. stilboides). *Sporulation of the fungus is also visible (arrowed).*
Source: Clowes et al., 1989[8]

Within days or even months after complete girdling the foliage wilts and dies. In some cases a constriction forms at the base of suckers or secondary branches and, being a weak point, the sucker or branch eventually breaks off. Storey's bark disease may take a year or more to develop, more mature stems tending to be more tolerant.

[8] Clowes, M. J., Nicoll, W. D. and Shelley, R. S. [Eds.] (1989) Coffee Handbook for Malawi. Tea Research foundation of Central Africa, Mulanje, Malawi. pp. 224

Coffee stems affected by Storey's bark disease. Note the constrictions on the stems. Photo courtesy Jim Waller, CABI

2. Scaly bark

Scaly bark usually occurs as a result of mature main stems being infected through wounds left after pruning laterals. The bark on the main stems, usually at a pruning scar, rises up and becomes flaky. Here too lesions caused by the disease may be hidden by overlying bark. On young wood scaly bark is often associated with cankerous regions round the base of branches or suckers. If dieback does not develop stems and branches may survive infection. However, fungal spores forming on infected wood may spread to and infect suckers, leading to suckers being killed when infected trees are being regenerated.

Degeneration of a coffee tree affected by scaly bark. Photo courtesy Jim Waller, CABI

3. Collar rot

A cankerous lesion, known as collar rot and similar to that described on suckers, develops round the base of the trunk and the trunk appears constricted. Collar rot may develop due to the fungus spreading downwards from infected suckers. Leaf yellowing and general dieback develop from the top of the tree, which are ultimately killed.

Note: Care should be taken to avoid confusion between coffee bark disease and two other coffee diseases caused by *Fusarium* species. *F. xylarioides* causes coffee wilt disease, and is described in a separate fact sheet. *F. solani*, also a soil borne fungus, causes a root rot and wilt in which the roots are killed and a reddish, purple or brown discoloration forms in the wood. *F. solani* usually attacks plants growing under poor conditions.

Identification of *F. stilboides* based on fungal morphology

The fungus responsible for coffee bark disease, *F. stilboides*, cannot be seen by the naked eye and can only be observed and identified with the aid of a microscope. Where this is available, colonies grown on potato sucrose agar (PSA) are characterised by the production of long, narrow macroconidia, straight to slightly curved with up to ten separate cells. Microconidia are not generally produced. Sporodochia, cushion-like masses of fungal mycelium bearing a spore mass, are usually produced.

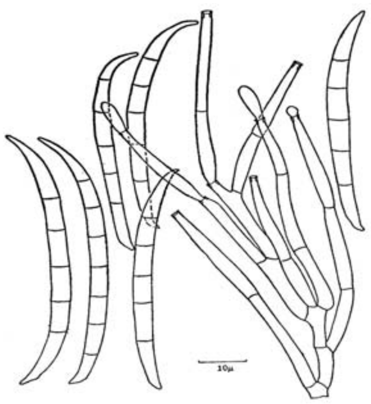
Chlamydospores, thick walled resting spores, are absent in the mycelium but present in conidia. Cultures of the fungus tend to develop a red colour and have 'fluffy' aerial mycelium with orange sporodochia.

For a full description of the morphology of the fungus refer to

Booth, C. and Waterston, J. M. (1964) C.M.I. Descriptions of Pathogenic Fungi and Bacteria Set No. 3, Number 30, published by CAB International.

Biology and Ecology

The fungus *F. stilboides* is widespread on coffee throughout the world. It is most commonly found as a member of the mycobiota on the surface of plant tissues or as a secondary invader of damaged or moribund berries. When causing coffee bark disease the fungus often acts as a secondary invader, especially of damaged berries and often in association with *C. coffeicola* (as berry blotch), overbearing and sun scorch, and appears to cause disease when plants are under adverse environmental conditions. In Kenya, for example, the detrimental effects of the disease were enhanced by the presence of the yellow-headed borer and hot, dry conditions. The pathogen can survive in the bark and aerial parts of the tree and can infect roots but, unlike *F. xylarioides*, cannot survive for long periods in soil other than in plant debris.



Diagrammatic representation of condiophores and macroconidia of F. stilboides *(above) and actual growth of the fungus (below). Photo courtesy Mike Rutherford, CABI*

Management

Cultural control

As with coffee wilt disease (CWD), once trees are affected by coffee bark disease they will be killed. Cultural management practices are therefore similar to those for CWD. The most appropriate approach is to prevent introduction of the disease and, should it become present, to prevent or restrict on-farm spread between trees. Introduction of coffee bark disease to healthy farms should therefore be avoided by ensuring that planting material is obtained from official distributors. If obtained from other sources, especially farms, ensure that these are located in areas known to be free of the disease and that the material has been raised from disease-free cuttings or seed collected.

On farms where CWD is already present, affected trees act as sources of infection and should be uprooted and burnt. Trees must be burnt were they are uprooted and not dragged through healthy trees as this may spread the disease. Storage and use of wood from affected trees, as firewood for example, should also be avoided. Uprooting and burning is most effective when disease symptoms are recognized quickly and only one or a few trees are affected. In such cases the farmer may save some of the crop. If the farmer delays then infected trees may act as a source of inoculum and may infect other trees until the entire crop is lost. Following destruction of diseased trees the land should be left fallow for at least a month (but preferably a minimum of six months) and/or planted with resistant coffee or an alternative crop (e.g. legume cover crop) before *C. arabica* is replanted. Avoid handling affected trees in wet conditions as spores of the fungus may be transferred more readily.

The coffee bark disease fungus is likely to penetrate the tree through weak points in the bark, such as wounds cause during pruning and weeding, penetration by insects such as stem borers and feeding by livestock. Care should therefore be taken to minimize damage when weeding and pruning with a machete, hoe or other implement, especially in the lower part of the stem. Pruning cuts should be disinfected or preferably protected with copper fungicide paint. Livestock should be prevented from feeding on and around the trees. All tools should be sterilised in a fire or with disinfectant (e.g. 'JIK') before moving from one tree to the next. Trees should be kept free of weeds. If using herbicides, contact herbicides should be avoided and the herbicide should not come in contact with the base of suckers. Avoid mulching too close to trees and intercropping with dense, low lying crops such as beans as this may create conditions conducive to collar infection. Control heavy borer infestations.

In the case of Storey's bark disease newly exposed leaf scars may provide entry points for the fungus, while healthy shoots may become infected due to the fungus passing through stumps from a dead shoot. Stumping mature trees and ratoon pruning may therefore provide a means by which healthy shoots become attacked. Preventing leaf loss, for example by proving adequate nutrition and maintaining plant vigour, may also reduce the number of potential infection points.

As with many other diseases, coffee bark disease tends to be more prevalent where trees are grown in sub-optimal conditions. These include water stress in areas where rainfall is marginal, temperatures above 27°C, acidic soils and soils with low or imbalanced nutrients. Such conditions should be avoided by adjusting soil pH and nutrient content and maintaining good water management practices.

Resistant varieties

Coffee bark disease only appears to affect *C. arabica*. As such, the disease may be prevented or eradicated by cultivating coffee species other than *C. arabica* or inter-specific hybrids.

Brown Eye Spot Disease

Importance

Brown eye spot, also referred to as coffee leaf spot, coffee eye spot, brown eye spot, berry blotch or berry spot disease of coffee, is caused by the fungus *Cercospora coffeicola*. It flourishes in warm, humid conditions and occurs in all of the coffee growing areas of the world. Although it is the most widespread disease of *Coffea arabica*, brown eye spot rarely causes yield losses on this coffee species but can cause defoliation in, and reduce the vigour of, seedlings and young plants. In fact the disease appears to be more prevalent at lower altitudes and on *Coffea canephora*, possibly due to *C. canephora* being more susceptible. In eastern Africa brown eye spot disease is known to occur in Uganda and has also been reported in the Democratic Republic of Congo (DRC).

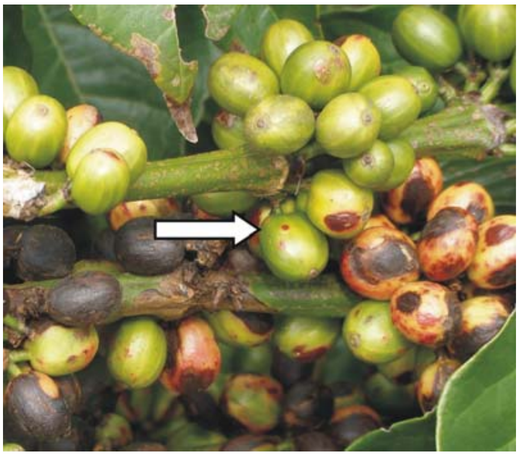
Brown eye spot on leaves of C. arabica. *Note the grey centre and yellow halo. Photo courtesy Noah Phiri, CABI*

The fungus causing brown eye spot has also been referred to by a number of other names: *Cercospora coffeae*, *Cercospora herrerana* and *Ramularia goeldiana*.

Description

Infection of coffee by *C. coffeicola* can lead to a number of conditions. On *C. arabica* it is first recognised by the appearance of small chlorotic spots on the leaves. These are usually more visible on the upper side of the leaf and gradually enlarge to become reddish-brown or brown with a greyish centre. The spots are circular or perhaps angular, may also develop a yellow margin ('halo') and are delimited by the main veins of the leaf. As the fungus begins to sporulate (produce spores) small olive green patches may develop in the grey centre of the spots.

C. coffeicola may also cause dark brown, patch lesions on the coffee berries, a condition known as 'berry blotch' but of minor importance. The lesions are often confused with those that develop due to coffee berry disease (caused by *Colletotrichum kahawae*, see separate fact sheet) but, unlike those of berry disease, are not of the sunken 'anthracnose' type. Development of berry blotch is often linked to sun scorch damage, which makes the berries more susceptible.

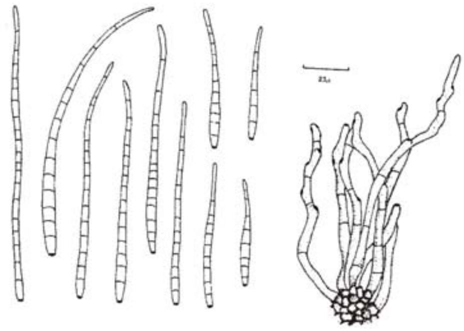


Red blister disease on coffee berries. Note lesion at early stage of development (arrowed). Photo courtesy Noah Phiri, CABI

Small red spots may also develop on both green and ripening berries, a condition referred to in Uganda as 'red blister disease'. The spots on the berries increase in size and coalesce to form dead blisters.

Identification of *C. coffeicola* based on fungal morphology

The morphology of *C. coffeicola* can only be clearly observed with the aid of a microscope. The fungus produces multiseptate conidiophores (20–275 × 4–6 µm) in groups of between three and thirty that arise from masses of hyphae (stromata) and may occasionally be branched, narrowed or bent like a knee. The conidiophores have distinct scars where conidia have become detached. Conidia are elongate (40–150 × 2–4 µm), multiseptate, needle-shaped and widest at the base. They are straight or rarely curved, pointed or bent like a knee and have a thickened scar at the point of attachment to the coniodiophore.



Diagrammatic representation of conidia (left) and conidiophores (right) of Cercospora coffeicola

Biology and Ecology

The brown eye spot pathogen, *C. coffeicola*, sporulates readily under more humid conditions. The spores, known as conidiospores (conidia), germinate and the emerging fungal thread (germ tube) grows along the leaf surface and enters the leaf on the underside through a stoma (a hole through which air passes into and out of the leaf). It continues to grow within the leaf until spots begin to develop, about four weeks after initial infection. Sporulation occurs about three weeks after the appearance of spots. Environmental conditions affect the rate of disease development. Germination may occur between at temperatures between 8°C and 30°C, although 27°C is optimum.

The spores of *C. coffeicola* may survive on the surface of leaves for up to two months, and may be spread by wind or rain-splash. Fallen leaves constitute a primary source of infection, especially at the end of the dry season. As with many diseases, the development of brown eye spot is enhanced in plants already under stress e.g. those deprived of essential nutrients or with insufficient shade.

Management

Control of brown eye spot is not usually necessary for mature *C. arabica* plants. However, control may be necessary for nursery plants by routine spraying with a protective, copper based fungicide (e.g. Bordeaux mixture) from the first leaf stage. In India, results from nursery trials have shown that captafol at certain concentrations provided better control of brown eye spot than the previously recommended carbendazim treatment, with good foliage retention and enhanced plant growth. Monthly applications of captafol (0.3% a.i.) are now being recommended for use in coffee nurseries in place of carbendazim.

Provision of adequate shade and nutrition can also be beneficial. In Nigeria, for example, coffee seedlings grown under partial shade showed lower incidence of brown eye spot than those under direct sunlight, which were very severely affected. They also showed better growth and retention of leaves.

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Glossary of Technical Terms

Abdomen	The hind-body of an insects
Acervular	Saucer-shaped
Aerial	In the air
Agar	A substance for making gels on which organisms, including fungi, can be grown
Allantoid	Slightly curved with rounded ends (sausage shaped)
Anamorph	The asexual form or state
Antenna (plural antennae)	In insects, a feeler or horn
Apex	Tip, end point
Appresorium (plural appresoria)	A structure formed by a fungus to allow attachment to host tissues before penetration
Ascospore	A fungal spore produced in an ascus
Ascus (plural asci)	A sac like cell of a fungus in which ascospores are produced
Bicellular	Having two cells
Brood	Offspring
Cambium	Plant tissues from which the wood and inner bark are formed
Canker	A sunken, necrotic lesion
Chlamydospore	A thick-walled conidium
Chlorosis	Partial or complete loss of normal green colour (in plants, usually referring to yellow or white)
Chlorotic	Lacking normal green colour (in plants, see 'chlorosis')
Coalesce	To group or grow together
Collar	The area between the roots and stem
Conidiogenous	Condium-forming
Conidiomata	Conidium-bearing structures
Conidiophore	A simple or branched hypha on which conidiospores are produced
Conidium (plural conidia)	A non-motile, specialised, asexual spore of a fungus usually produced for dispersal
Cordon sanitares	Restriction on movement into and out of an area to prevent an infectious disease spreading from it

Cultivar	A plant derived from a naturally occurring species and developed and maintained through cultivation
Defoliation	Shedding of leaves
Dieback	Necrosis (death) of a shoot, beginning at the tip and spreading back through the older tissues. The shoot may die.
Disease	A condition where the normal functions are disturbed or harmed, as shown by the development of symptoms
Disinfect	To remove infection by killing a parasite or pathogen
Disinfectant	An agent used to disinfect (see above)
Endemic	Permanently established in moderate or severe form in a given area e.g. a country
Endoparasitic	Internal parasite
Endosperm	The nourishing part of a seed, not incorporated in the embryo
Epizotic	A disease attacking many animals at the same time
Falcate	Curved like the blade of a sickle
Fallow	Land left untilled or unsown, not cropped
Filiform	Thread-like, very slender
Floccose	Cotton wool-like
Fungicide	A substance that kills a fungus
Fungus	One of the lowest groups of plants, not having chlorophyll
Fusoid, fusiform	Spindle-shaped
Gelatinous	Jelly-like
Germinate	Begin to grow
Globose	Spherical or almost spherical
Guttulate	Having one or more oil-like drops inside
Herbicide	A substance that kills a plant (usually used for weed control)
Hyaline	Clear, lacking dark pigment
Hypha (plural hyphae)	A single filament, or thread, of a fungus
Indigenous	Originating from, or native to
Infect	Attack, enter or establish a pathogenic relationship with another organism (e.g. a plant)
Infection	The process of becoming infected

Infested	Attacked by animals, usually insects
Inoculum	The substance (e.g. part of a fungus) used to contaminate or infect another substrate (e.g. a plant)
Insect	Small creature divided into a head, thorax and abdomen with three pairs of legs attached to the thorax
Insecticide	A substance that kills an insect
Instar	A stage in an insect's development between two successive moults
Larva (plural larvae)	An active but immature stage in an insect's development
Lesion	An area of diseased or damaged tissue
Macroconidium (plural macroconidia) *	Small, usually single celled conidium
M.a.s.l.	Metres above sea level (when denoting altitude)
Microconidium (plural microconidia) *	Large, often multi-celled conidium
Microbiota	All the micro-organisms present in an area
Moribund	In a dying state
Morphology	The science of form
Moult	To shed a skin or covering
Multicellular	Having many cells
Multiseptate	Having many cell walls, or partitions
Mycelium	A mass of fungal hyphae, or threads
Mycobiota	All fungi present in an area
Necrosis	Death (of cells or tissues)
Necrotic	Dead (cells or tissues)
Nematocide	A substance that kills a nematode
Obtuse	Blunt or rounded at the tip, not pointed
Parenchyma	Ordinary, soft, thin-walled tissues of a plant
Pathogen	An organism which causes disease
Pest	An animal which damages plants or other animals
Pesticide	A substance that kills a pest
Physiology	The science of the processes of life in animals and plants
Polyphagous	Consumes many different kinds of food

Pupa	An insect in the (usually inactive) stage of development between larva and adult
Pupate	To become a pupa
Ratoon	Emergence of new shoot(s) from the ground following harvest to form a new crop
Resistant	Suppresses or retards invasion by a pathogen
Septum (plural septa)	A cell wall or partition
Septate	Having a septum or septa
Sporodochium (plural sporodochia)	Cushion shaped structure comprising closely grouped conidiophores
Sterilise	Make free from living organisms
Stylet	A piercing part of an insect's jaw
Sucker	A new shoot arising from the underground part of a plant
Susceptible	May be affected by, or is prone to, disease
Symptom	A visible or detectable abnormality caused by a disease or disorder
Systemic	Spreading through all tissues (of a plant)
Teleomorph	The sexual form or state
Teleospore	A spore produced by the teleomorph, or sexual state
Thorax	The part of the body between the head and the abdomen
Unicellular	Having a single cell
Variety	Type or form
Vermiform	Worm-like

* Terms usually applied when a fungus produces conidia of two distinct sizes, some large and some small

Appendix 1

Constraints to coffee production, processing and marketing in the eastern and central Africa sub region as identified and prioritised in terms of importance by coffee stakeholders at a Coffee Research Network (CORNET) Regional Coffee Stakeholders' Workshop, 27-29 October 2004, Nairobi, Kenya

Disease/pest constraint	Priority rating†								Total
	Burundi	DRC	Ethiopia	Kenya	Madagascar	Rwanda	Tanzania	Uganda	
Coffee Leaf Rust (CLR)	2		1	2	3	3	3	3	**17**
Coffee Berry Disease (CBD)	3	2	2	3		1	3	3	**17**
Coffee Wilt Disease (CWD)	1	3	3	1			3	3	**14**
Nematodes	1	2	1	1	1		2	1	**9**
Fusarium Bark Disease	1		1	1	1	1	2	1	**8**
Coffee Berry Borer (CBB)				3				3	**6**
Red Blister Disease††								3	**3**
White Borer				3					**3**
Green Scales				3					**3**
Root Mealybugs								2	**2**
Brown Eye Spot Disease††								2	**2**
Total	**11**	**10**	**10**	**20**	**7**	**8**	**16**	**24**	**106**

† Scores 3, 2 and 1 correspond to high, medium and low priority respectively
†† Includes reference to red blister disease