CROP PROTECTION PROGRAMME

Promotion of current knowledge on pests of coffee in East Africa

R8513 (ZA0726)

FINAL TECHNICAL REPORT

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Executive Summary

The primary purpose of the project was to collate current knowledge on the major pests and diseases of coffee in Eastern and Central Africa, and to utilise this knowledge to develop an up-to-date learning and advisory manual suitable for uptake and application by coffee stakeholders in the region. A secondary component was to review data from field and screen house trials established in Uganda to investigate aspects of coffee wilt disease (CWD) in relation to on-farm management of the disease. Both aims were achieved in that a comprehensive coffee manual comprising a series of fact sheets, each referring to a specific pest or disease, was produced. Pests and disease selection was based largely on the outputs of a regional coffee stakeholder workshop held in the region in 2004, at which the major constraints in the region were identified and prioritized nationally by participants. For each constraint, the manual provides a description (to aid diagnosis) and information on importance, occurrence, biology and ecology and management. This is supported by photographic depictions. The manual was produced in a use friendly format and principally to meet the needs of service providers including agricultural extension services and other national/regional agricultural advisory organisations involved in outreach programmes. However, it is also considered appropriate for direct uptake by some farmers. It may be consulted directly or utilised, wholly or in part, as an information resource to support other approaches to knowledge transfer, including training programmes.

Data acquired from a number of trials to investigate the epidemiology of the coffee wilt pathogen, *Fusarium xylariodes*, revealed that the pathogen can survive in field soil and stored coffee wood and remain infective to newly planted, susceptible coffee seedlings for up to eleven months and four months respectively. Previous suspicions that wounding of healthy coffee trees with a machete previously used on trees affected by CWD is sufficient to cause CWD development were also confirmed. These findings, which have been incorporated into the coffee manual, have significant implications with regard to measures taken to manage the disease, specifically with regard to whether and how affected plant material should be used (e.g. as firewood), as well as the impact of leaving fallow periods between coffee plantings and cultivating alternative crops.

The project activities have resulted in the acquisition and collation of existing and new knowledge on pests and diseases as major constraints to coffee production. This knowledge, now packaged in a format suitable for immediate dissemination and uptake, will be of fundamental importance to coffee producers. It will empower farmers, albeit largely through the efforts of intermediaries, to make more informed decisions, to implement up to date measures to control constraints they encounter and to have increased confidence that these measures will have a positive impact. This in turn will lead to more effective control of prevailing major pest and disease problems, such as CWD, and to improvements in the quantity and quality of coffee produced. As such, a vital source of revenue for millions of resource-poor farmers, traders, processors, exporters and other stakeholders in the farming community may be maintained. It will ultimately contribute to, and help to stabilise, national economies and will be of benefit to the well being of the region as a whole.

Background

Coffee production in East Africa is a major industry, contributing to national economies, providing a major source of foreign exchange earnings and, as a cash crop, supporting the livelihoods of millions involved in cultivation, processing and marketing. However, cultivation of coffee is constrained by a wide range of pests and diseases, including coffee wilt disease (CWD), coffee berry disease (CBD), coffee leaf rust (CLR), coffee stem borer (CSB) and coffee berry borer (CBB). Many of these coffee pests (*sensu lato*) routinely cause extensive crop damage and significant losses while some are threatening to eliminate coffee production in some areas, destroy the livelihoods of millions of resource poor farmers and undermine national economies. A re-emergence of CWD, for example, is causing major damage to robusta coffee in Uganda, Democratic Republic of Congo and Tanzania, and also to arabica coffee in Ethiopia. In Uganda coffee is the premier export, the industry being worth approx. US$350 million and accounting for up to 55 % of foreign exchange. Ethiopia is the centre of origin of coffee and the leading producer of arabica coffee in Africa (4.3 million bags in 2003). Exports from coffee constitute 63% of the total foreign exchange earnings of Ethiopia. Recent surveys showed that CWD is present in most of the coffee growing areas of these 2 countries, where 90% and 30% of the farms in Uganda and Ethiopia, respectively, were found to be infected. The disease is spreading in both countries. CBD, caused by the fungus *Colletotrichum kahawae*, can cause yield losses of up to 80%. Coffee quality may also be adversely affected, whereby berry diseases and boring insects such as CBB may cause discoloration, blemishes and physical destruction, while CWD disease often causes premature berry ripening. CBB and antesia bugs reduce coffee bean and coffee liquor qualities, while red blister disease has led to drying, over-ripening and impartment of off-flavours. Coffee stem borer (*Monochamus leuconotus*) is a serious pest of coffee at altitudes of below 1700 masl, causes yield loses of over 25% and may kill trees of less than three years.

Recent initiatives on coffee pests and diseases (including a major, ongoing coffee rehabilitation and disease management programme in East and Central Africa) have provided new information on identification, distribution, severity, prevention and treatment. R8188 (ZA0505), for example, has shown that two geographically demarcated variants of the CWD pathogen have been identified, for example, one specific to robusta coffee, the other to arabica. Alternative, environment friendly pesticides have been developed for managing CSB, and improved targeting of these pesticides further enhances the specificity of this control method. Such findings may have major implications with regard to crop selection, for example, and the use of host resistance in particular and those involved in coffee production must be informed. At present, much of the information is fragmented and not readily available to farmers and those that inform them, including extensionists, NGOs, and an increasing range of private schemes by FairTrade, organic and other certification bodies, as well as traders such as Neumann Kaffee Gruppe and Dean's Beans Organic Coffee (activities in Uganda) who are becoming more involved in outreach and outgrower schemes.

Gichuru, E.K., Simons, S.A. and Oduor, G.I. 2003. Smallholder coffee farmers practices that affect integrated disease management in Kenya. Poster. 8th International Congress of Plant Pathology, Christchurch, New Zealand

Flood, J., Rutherford, M., Buddie, A. Brayford, D. Ashurst, J. Cannon, P., Hakiza, G. Byesse, D. and Kalonji-Mbuyi, A. 2003. *Fusarium* wilt of coffee in Africa - re-emergence of an old problem. Proceedings International Fusarium Symposium, Sydney, Australia, February 2003.

Oduor *et al*. 2003. Surveys to assess the extent and impact of coffee wilt disease in East and Central Africa. Final Technical Report, EU.

Oduor, G. 2000. Development of Coffee IPM components in Kenya. Final Technical Report Project R6782, DFID Crop Protection Programme, Natural Resources International.

Rosskamp, R., Tiemeier, J.M., Opitz, M., Mabe, A. and Ngategize, P. 2003. Feasibility Study: Kaweri Coffee Outgrowers Scheme. Project no. sx 92/18/01 –05. Draft Report, 12 June 2003.

Project Purpose

The main purpose of the proposed work was to synthesise current knowledge on the major pests of coffee in Eastern and Central Africa, and to develop an up-to-date learning and advisory manual suitable for subsequent uptake and application by extension and advisory services (incl NAADS), NGOs, CBOs, researchers and other stakeholders in coffee growing countries in Eastern and Central Africa directly or indirectly concerned with informing coffee farmers of improved approaches to coffee production and coffee health. Relevant information from various sources, including previous DFID/CPP funded research projects, would be collated and utilized to produce an up to date reference/technical manual on coffee pest and disease management. Extensive knowledge of direct relevance to improving coffee pest and disease management has been generated through CPP funded projects and a key objective of the project would be to utilize outputs of this work to inform development of the manual. A subsidiary purpose of the project was to review ongoing field trials established to assess differing approaches to coffee pest and disease management and to extract the maximum of useful new information to help establish state-of-art management for coffee production. Findings from these trials would be taken up to strengthen the manual and to help ensure that it's content is up-to-date and user-friendly.

Research Activities & Outputs

Output 1. Pest and disease constraints to coffee production identified and prioritised, knowledge required by stakeholders for effective pest management synthesised.

Activity 1.1 *Pest and disease constraints to coffee production identified and prioritised*.
Reference was made to a range of information resources[1] to provide an overview of the pest and disease constraints known to occur in Eastern and Central Africa and also, depending on the resource, to enable these to be prioritised for inclusion in the coffee manual. Of the resources consulted, emphasis for both constraint identification and prioritisation was placed on the outputs of a regional coffee stakeholders' workshop[2] held in Nairobi in October 2004. This workshop provided recent and collective opinions of a broad range of participants representing farmers, processors, marketers, regulatory bodies, policy makers, civil society and development partners at the forefront of coffee production and pest and disease management. Ten pest and disease constraints (white stem borer, coffee berry borer, green scale, root mealy bugs, parasitic nematodes, coffee leaf rust, coffee berry disease, coffee wilt disease, fusarium bark disease, red blister disease/brown eye spot disease) were identified and prioritised by national representatives for each of eight countries within the region, of which a summary table[3] is provided in Appendix 1. All ten constraints were selected for inclusion in the pest and disease manual.

Activity 1.2 *Collate and distil available information, including that generated by previous DFID CPP funded research, on prioritised constraints (identified under 1.1 above).*

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[1] Key resources included books (e.g. Wrigley, G. 1988. Coffee. London, UK: Longman Press) and other literature materials, electronic databases (e.g. CABI Crop Protection Compendium), reports of DFID/CPP funded research projects and outputs of a coffee stakeholder workshops held inn Nairobi in 2004.
[2] The Regional Coffee Stakeholders' Workshop was held at the Nairobi Safari Club between 27th and 29th October 2004, and was organised to allow participants to 'deliberate on the outcome of constraints analysis and build consensus on the constraints/opportunities in the coffee sub-sector within the region and the requisite themes, sub-themes and projects to alleviate the constraints'.
[3] Although Appendix 1 also shows cumulative scores for all countries, these have been calculated only to provide an indication of ranking in terms of regional priorities and as additional information for this report.

In order to produce the manual, relevant information was sought from an extensive range of sources. These included: books, coffee reviews and journal articles; the CABI Crop Protection Compendium, CAB Abstracts and other electronic databases; internet websites, including those of CGIAR; fungal and insect description sheets, including the CMI Descriptions of Plant Pathogenic Fungi and Bacteria; and various reference manuals published for the purposes of pest and disease diagnosis and organism identification. Current management recommendations for pests and diseases provided by agricultural ministries, farmer associations, advisory services, research organisations and other bodies, including those in Eastern and Central Africa, was also sought as were the personal views of experts in relevant disciplines. Reference was also made to the outputs (e.g. Final Technical Reports) of recent DFID-funded research initiatives, specifically projects R6782, R7942, R8188, R6807, R8204, R6028, R7246 and R6812 funded by the Crop Protection Program, to ensure that relevant new knowledge was taken into consideration. The most relevant and up to date information was extracted, collated and utilised to compile a specific section, or fact sheet, on each constraint for inclusion in the manual.

Activity 1.3 *Collect, analyse and interpret data from ongoing field research on CWD.*

As part of CPP project R8188, a number of small scale trials[4] were established at field sites and in the screen house at the Coffee Research Institute (CORI), Kituza, Uganda, to investigate:

(i) the duration over which soil obtained from a field site affected by CWD remains infective to newly planted seedlings following removal (uprooting) of affected coffee trees from the site

(ii) similarly, the duration over which wood pieces cut from a CWD affected tree and placed on sterile soil remain infective to newly planted seedlings

(iii) whether wounding of healthy, mature coffee trees with a machete previously used to cut wood from a tree affected by CWD was sufficient to cause CWD on those trees

As part of this project, data collected from these trials was collated, summarised and interpreted to provide up to date observations on findings. It revealed that, in summary, soil collected monthly from affected sites could remain infective to newly planted susceptible, six month old coffee seedlings for a period of up to 11 months after tree removal. Wood pieces remaining on soil for up to four months could also act as a source of infection. Of the six mature trees wounded by a machete previously used on CWD trees in May 2004 four have since developed symptoms of CWD, three of which have been killed by the disease. Of six trees wounded in a similar manner but with a machete cleansed with 'JIK' disinfectant beforehand, none have developed CWD. The findings suggest that great care must be taken with regard to the use of farm implements and that these should be cleansed by farmers (e.g with disinfectant or in a fire) to destroy pathogen inoculum after using on CWD affected trees and certainly prior to using on trees that appear healthy. While they also provide an indication of the period for which areas affected by CWD would remain infective to newly planted and susceptible coffee, it remains unclear as to when it may be safe to replant. A similar situation arises in relation to infectivity of coffee wood.

It should however be noted that some difficulties were encountered with these trials that unfortunately led to premature termination of a number and observations being more limited than anticipated. New trials have been established at CORI but it will be some months before further meaningful data is available.

Output 2. *Pest management advisory and learning manual developed and available for onward dissemination to coffee stakeholders.*

Activity 2.1 *Utilising information generated through activities 1.1-1.3, develop advisory/learning manual to convey the most up-to-date knowledge on priority pests and diseases of coffee.*

[4] For further information and full details of methodology refer to FTR for project R8188, submitted to CPP January 2005

A coffee pest management manual was produced principally to meet the needs of service providers such as agricultural extension services, national and regional agricultural advisory bodies, community based organisations (CBOs) and non-governmental organisations (NGOs), but the needs of research based organisations that have a role in providing advice on coffee management were also taken into consideration. Furthermore, the manual was intended to be of direct benefit to some farmers, namely those proficient in English. As such, it provides a broad but concise overview of each pest and disease with science orientated information kept to a minimum. For each pest and disease, information is provided on importance (e.g. economic, coffee types affected), geographic occurrence, description (to aid diagnosis and organism identification), biology and ecology (including survival, spread and life cycle) and approaches to management (e.g. cultural, chemical, biological). These are supported by photographic depictions principally of the organisms and the symptoms they induce on the coffee crop (an example fact sheet, on parasitic nematodes, is provided in Appendix 2). A glossary of terms referred to in the manual is also provided. The manual is therefore suitable for direct consultation as a reference manual or may be utilised, wholly or in part, as an information resource in farmer field schools or other training sessions.

Contribution of Outputs to developmental impact

Through the project activities, comprehensive information required for the successful management of the major pests and diseases in Eastern and central Africa has been collated and prepared in a format suitable for uptake by potential beneficiaries. New knowledge on specific aspects of coffee wilt disease, currently causing extensive and widespread damage in Uganda DRC, Ethiopia and parts of Tanzania, has also been acquired, will contribute towards improved management of the disease and has been incorporated into the coffee manual. The project outputs will be of considerable benefit, in the first instance, to agricultural extension and other organizations providing of support and advisory services. However, they will ultimately benefit the many millions of resource poor farmers and commercial farmers are at the forefront of efforts to ensure that a coffee crop of sufficient quantity and quality is produced, and on which their own livelihoods and those of other stakeholders involved in the coffee commodity chain are so dependant. The coffee manual will help to expand on the level of knowledge of coffee pests and disease within the coffee community and will empower growers in particular to make more informed decisions with respect to crop management.

The coffee manual, as the primary output of this project, has been produced principally with constraints to coffee production in Eastern and Central Africa in mind, and is available for reproduction and wide scale dissemination within the region. The information it contains is suitable for uptake by farmers, as ultimate beneficiaries, directly in some cases but more likely by a number of indirect approaches, such as farmer field schools (FFS) and other farmer training programmes. CFC, for example, has supported training of extensionists in Uganda on approaches to training farmers. It may also be accessed, and the information conveyed to farmers, by intermediary service providers, through extraction and use of relevant material for the preparation of other reference/advisory materials and teaching aids e.g. posters, fact sheets and video. Information may also be conveyed through the mass media, radio being a principal means by which farmers acquire information on crop management and threats to production, while many farmers also now access rural Telecentres and Datecs sources of information. The project outputs will support the development of co-ordinated local, national and regional strategies and policies by organisations such as the Uganda Coffee Development Authority (UCDA, under whom the entire coffee extension in Uganda falls), the Coffee Research Institute (CORI), the Coffee Research Network (CORNET), the Uganda National Agricultural Research Organisation (NARO) and the International Coffee Organisation (ICO) to reduce the overall impact of coffee pests, thereby helping to stabilize productivity of coffee grown by smallholder farmers in the target countries.

The project was limited by resources in terms what it could achieve. Support, including financial, is now required in order that the outputs may be taken up in an appropriate manner. In the first instance, this should be through reproduction and dissemination of the manual directly or by communication of the knowledge it provides by alternative means (e.g. via service providers and training initiatives). This necessitates priority being given by local, national and regional policymakers, continued institutional inputs and funding being made available. FFS established under the CFC-funded coffee wilt project, for example, may use the outputs of this proposed project to ensure continuity of its current initiatives in Eastern and Central Africa. The EU-funded Coffee Research Network (CORNET) also runs beyond 2007 and, with the generation and dissemination of demand-driven technologies and information falling within its remit, would provide a suitable extended pathway for this project. DFID, perhaps through the Knowledge Partnership initiative and under the new theme of 'Research Into Use', may also play an important future role.

Many of the pest and disease problems referred to in the manual and not unique to Eastern and Central Africa but are encountered in other parts of the continent and in major coffee producing regions further field, including Brazil and Colombia in South America and Vietnam in Asia. The information provided is therefore of direct relevance to producers in these regions and possibilities for uptake beyond the focus of this particular project should be given consideration.

Appendix 1

Table 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 regional coffee stakeholder workshop, Nairobi, October 2004

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 borrers				3					**3**
Green scales				3					**3**
Root mealy bugs								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

†† Red blister disease and brown eye spot disease are synonomous

Appendix 2

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 East 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.

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

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

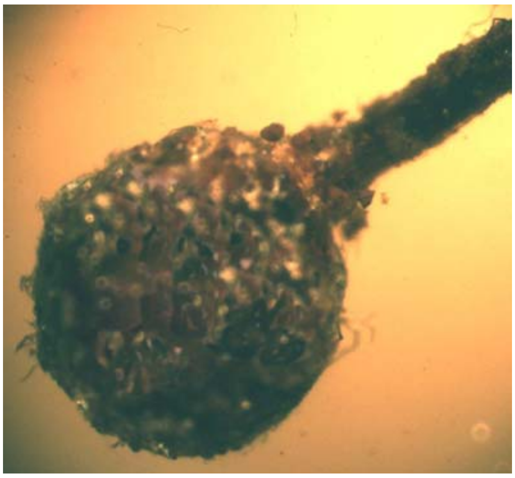
Of the known species, *M. africana*, *M. decalineata*, *M. oteifae*, *M. megadora* and *M. kikuyensis* are apparently indigenous to Africa, although there are unconfirmed reports in the literature of *M. oteifae* from Fujian, China, and *M. decalineata* from Argentina.

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.

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.

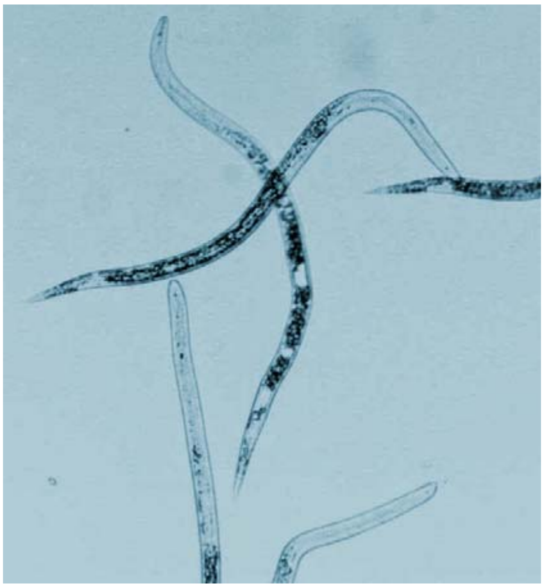
DESCRIPTION

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



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

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



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

enlarged females within. Attack by root-knot nematodes may facilitate invasion by pathogenic fungi such as *Rhizoctonia solani*.

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 & ECOLOGY

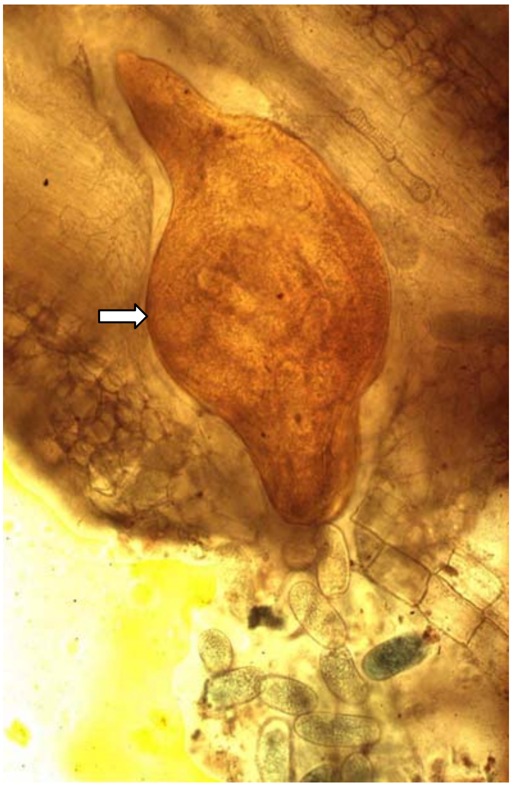
The basic life cycle of root-knot nematodes is relatively simple although the gall-inciting interaction of the parasite with the physiology of the host is complex. The mature female deposits many hundreds of eggs into a gelatinous egg-sac that may partially protrude from the root or be enclosed within 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 or worm-like, the parasitic stages, which have a sedentary endoparasitic life style, rapidly swell as they absorb food from the plant.

The greatly swollen mature female is completely immobile, whiteish 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 and 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 (arrow) in root. A number of laid eggs can be seen. Photo courtesy John Bridge.

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

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.

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 small-holder 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 small-holder 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.