

A synthesis of the work of the Regional Coffee Wilt Programme 2000-2007

Coffee Wilt Disease in Africa

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CABI

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Foreword

The purpose of this technical report is to synthesize the findings of the various projects that were carried out by the Regional Coffee Wilt Programme (RCWP) during the years 2000–2007, which was developed in response to the rapidly worsening disease status in the four African countries affected. As such, the report represents the current ‘state-of-the-art’ of our knowledge about this serious disease.

The report estimates that coffee wilt disease (CWD) has resulted in at least US\$1 billion in lost earnings to farmers over the last 15 years, which means that it represents one of the greatest natural disasters ever to afflict coffee production. Although the programme has now ended, the disease remains and will inevitably spread if further action is not taken.

We therefore urge decision makers in all African coffee-producing countries to study the findings of this report and take adequate steps to ensure that this disease is finally brought under firm control.

We gratefully acknowledge the support of our donors – CFC, EU and DFID, as well as the collaboration of many agencies and networks, whose names appear frequently in this volume. Especial thanks go to Caleb Dengu (CFC) for continued support and encouragement.

Noah Phiri and Peter Baker

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Abbreviations: Fx, *F. xylarioides*; Fo, *F. oxysporum*; Fso, *F. solani*; Fst, *F. stilboides*; Fl, *F. lateritium*; Ca, *C. arabica*; Cc, *C. canephora*; Ce, *C. excelsa*; Et, Ethiopia; Ug, Uganda; DRC, Democratic Republic of Congo; Tz, Tanzania; Gu, Guinea; CAR, Central African Republic; IC, Côte d'Ivoire; FEA, French East Africa. 48
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Principal Contributors

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Any mistakes and misinterpretations in this report are solely the responsibility of the authors.

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Acronyms and Glossary

ACRN	African Coffee Research Network
AFLP	Amplified fragment length polymorphism
a.i.	Active ingredient
Anamorph	The asexual form of the fungus
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
Ascomycete	CWD is a member of this family of fungi, one of four main groups of fungi which are described by the morphology of their structures for sexual reproduction. Sexual spores are formed within a characteristic structure called an ascus
ASIC	Association Scientifique Internationale du Café
asl	Above sea level
ATCC	American Type Culture Collection
BS	Biological species
CA	Cereal agar
CABI	CAB International
CABI-ARC	CAB International-Africa Regional Centre
CABI-UKC	CAB International-UK Centre
CAR	Central African Republic
Catimor	Hybrid of Caturra variety with the Hibrido de Timor, the latter a natural hybrid of Arabica and Robusta
CBD	Coffee berry disease
CBS	Centraalbureau voor Schimmelcultures
CFC	Common Fund for Commodities
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement
CLA	Carnation leaf agar
CLR	Coffee leaf rust
CNRA	Centre National de Recherche Agronomique Côte d'Ivoire
COREC	Coffee Research Centre, Uganda, now CORI
CORI	Coffee Research Institute, Uganda formerly COREC
CORNET	Coffee Research Network
COWIDI	Development of a long term strategy based on genetic resistance and agroecological approaches against coffee wilt disease in Africa

CPP	Crop protection programme
CWD	Coffee wilt disease
DA	Development assistants
DFID	Department for International Development, UKAid
DRC	Democratic Republic of the Congo
DSMZ	Deutsche Sammlung von Mikroorganismen und Zellkulturen GmbH
EAFCA	East African Fine Coffees Association
EARO	Ethiopian Agricultural Research Organization, Ethiopia
ECA	East and Central Africa
EDF	European Development Fund
EIAR	Ethiopian Institute for Agricultural Research
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
FFS	Farmer field school
F_{st}	Fixation index, a measure of population differentiation based on genetic polymorphism data, e.g. SNPs or microsatellites. It is a special case of the F -statistic. F_{st} is the proportion of the total genetic variance contained in a subpopulation (the S subscript) relative to the total genetic variance (the T subscript). Values can range from 0 to 1. High F_{st} implies a considerable degree of differentiation among populations
GDP	Gross Domestic Product
GfC	<i>Gibberella fujikuroi</i> complex
GHG	Greenhouse gas
GiC	<i>Gibberella indica</i> complex
GxC	<i>Gibberella xylarioides</i> complex
Heuristic search	When a number of individual strains need to be classified, the number of possible trees connecting them starts to rise astronomically. A computer program such as PAUP performs a heuristic search which estimates the shortest tree, obtained by starting with one strain and adding others in order to find, through a large number of iterations, the shortest tree
IACO	Inter-African Coffee Organization
ICO	International Coffee Organization
ICPM	Integrated Crop and Pest Management
Incidence of CWD	A term used in surveys to denote the percentage of farms infected with CWD
INCODEV	European Research Cooperation for Development

INERA	Institut National des Etudes et de la Recherche Agricole (DRC)
IPGRI	International Plant Genetic Resources Institute
IRAD	Institute de Recherche Agricole pour le Développement, Cameroon
ISAR	Institut des Sciences Agronomique du Rwanda, Rwanda
JARC	Jima Agricultural Research Centre, Ethiopia
JAU	Jima Agricultural University, Ethiopia
KARI	Kawanda Agricultural Research Institute
l	Litre
LARI	Lyamungu Agricultural Research Institute
LZARDI	Lake Zone Agricultural Research and Development Institute
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries, Uganda
MAC	Ministry of Agriculture and Cooperatives, Tanzania
NaCRRRI	National Crops Resources Research Institute
NARO	National Agricultural Research Organisation, Uganda
NARS	National Agriculture Research System
NCRS	National Coffee Research Systems
NGO	Non-governmental organization
NPK	Nitrogen, phosphorous and potassium
OCIR-CAFÉ	Office des Cafés, Rwanda
ONC	Office National Du Café (formerly the Office Zaïrois du Café, OZACAF) DRC
<i>P</i>	Probability
PCR	Polymerase chain reaction
PDA	Potato-dextrose agar
PEA	Project Executing Agency
PIA	Project Implementing Agency
PSA	Potato Sucrose Agar
RAPD	Random amplification of polymorphic DNA – a type of PCR where segments of DNA are amplified at random. Large numbers of DNA fragments are so formed which are then examined for patterns in the fragments that may be characteristic of individual strains
RCWP	Regional Coffee Wilt Programme
RFLPs	Restriction fragment length polymorphisms
SCR	Sidama Coffee Research Sub Centre, Ethiopia
Severity of CWD	A term used in surveys to denote the percentage of trees infected by CWD

Acronyms and Glossary

s.l.	<i>Sensu lato</i> – in the broad sense
SG	Sterility Group
SNA	Synthetic nutrient agar
SNNP	Southern Nations, Nationalities, and People's Region, Ethiopia
SNP	Single nucleotide polymorphisms
sp.	Species (plural – spp.)
SPSS	Statistical Package for Social Scientists
SSR	Single sequence repeats, also called microsatellites. These are short sequences of the base pairs (building blocks) of DNA that repeat themselves and are characteristic of a particular species or strain and hence can be used as markers to distinguish between strains
TACRI	Tanzania Coffee Research Institute, Tanzania
TCB	Tanzania Coffee Board
Teleomorph	The sexual form of the fungus
TWA	Tapwater agar
UCDA	Uganda Coffee Development Authority, Uganda
UCL	Université Catholique du Louvain, Belgium
UCTF	Uganda Coffee Trade Federation
UNIKIN	University of Kinshasa, DRC
UPGMA	Unweighted pair group method with arithmetic mean, also known as average linkage method – a simple hierarchical clustering method used for the creation of phylogenetic trees

Executive Summary

This report summarizes the findings of the Regional Coffee Wilt Programme (RCWP), 2000 to 2007.

The programme was funded by the Common Fund for Commodities (CFC), the European Union (EU), and Department for International Development (DFID), with the contribution of participating countries, Democratic Republic of Congo (DRC), Ethiopia, Rwanda, Tanzania and Uganda, as well as research support from the Centre de Cooperation Internationale en Recherche Agronomique pour le Développement (CIRAD) and the Université Catholique du Louvain (UCL). The programme was implemented under the supervision of the International Coffee Organization (ICO), and executed by CAB International Africa.

Coffee wilt is a major production constraint in DRC, Uganda and increasingly in Ethiopia too. Although the situation is improving in Uganda, the disease still represents a major threat to production in these and the neighbouring countries.

The project carried out a wide range of activities and represents a major advance in our understanding of the disease.

However, much further work is required to bring this disease under control, and eventually eradicate it. Principal findings and recommendations are given below.

The Countries

- CWD is present in four African countries – DRC, Uganda, Tanzania and Ethiopia, and absent from the other countries surveyed – Rwanda, Côte d’Ivoire and Cameroon.
- The CWD epidemic in DRC and Uganda represents the most severe natural disaster ever to befall African coffee, with total losses to small farm incomes exceeding US\$1 billion.
- The modern outbreak started in DRC, where it was first detected in the 1970s.
- The disease was first detected in Uganda in 1993; by the end of 2000 it had spread to all Robusta zones of the country.
- Ugandan Robusta production reached a peak in 1996 and then fell steadily to 2005, where it attained only 42% of peak production; Arabica production over the same period rose by 39%. It is very likely that most or all of the fall in Robusta was due to CWD. No other natural event in Africa’s coffee history comes close to matching this severity.
- CWD was first detected in Ethiopia in 1957. For many years it was a minor disease; however, it has now spread widely through the coffee zones, to the point that it is now regarded there as of similar importance to coffee berry disease.

- CWD is found in wild forest coffee, giving rise to concern that it may weaken the genetic base of the Arabica genome in Ethiopia, where the species evolved.
- In Ethiopia, the disease is particularly prevalent in plantation coffee, which may be linked to the intensive agronomic methods employed there.
- Overall, however, Ethiopian coffee production has increased in recent years and it seems likely that the Arabica version of the disease is somewhat less virulent than the Robusta disease, possibly due to a level of natural resistance in the heterogeneous coffee landraces.
- CWD was detected in Tanzania in 1996. It is currently restricted to the north-west of the country bordering Uganda. Severity of the disease is the least of the four affected countries and economic losses have been much smaller.

The Surveys

- Through extensive field surveys in Ethiopia, Uganda and Tanzania a very wide range of farming practices was found; in most cases, coffee was in a poor state, with very old trees (>50% over 15 years), poor soil fertility and consequent very low yields.
- Many farmers weed by machete and hoeing, both of which may tend to spread CWD; Ethiopian farmers especially control weeds by machetes that cause frequent cuts to the base of the main stem.
- Farmers practise farming of highly diversified crops; nine or more crops per farm is common. Across the countries, most think CWD is getting worse, and that coffee is becoming less important to them.
- The surveys suggest that the past few years have seen a marked reduction in inputs applied to coffee across the East African region.
- Farmers clearly found it difficult to understand the nature of the disease and their use of diseased coffee wood for a range of purposes confirms that many did not understand how the disease is propagated.
- Many instances were found of farmers removing diseased coffee wood from coffee plots to be sold or used in other fields, this presents a major route of infestation that must be stopped by increased training and quarantine inspections across frontiers.

Molecular Studies

- Powerful molecular identification methods have been used to differentiate between the different strains of CWD, which confirm the complexity of the disease.
- The strain of the disease currently affecting Robusta coffee in DRC, Uganda and Tanzania is identical to a strain isolated from DRC in 1960. There is no detectable genetic variation in this strain, making it very likely that the disease spread from a small initial outbreak in DRC. Arabica is not attacked by the disease in these three countries.

- It is likely, therefore, that CWD was never completely eradicated in DRC after the historical (mid-20th century) outbreak.
- The CWD found on Arabica in Ethiopia since 1957 is a different strain which does not attack Robusta and does not interbreed with the Robusta CWD strain.
- It is suggested that the Arabica and Robusta strains of CWD are in fact separate diseases that arose independently, most likely from undetected disease forms on wild coffee species or even non-coffee species.
- It is possible that a new outbreak could occur spontaneously at any time in the future. It is therefore recommended that all African coffee zones be regularly monitored to detect new disease events so that they can be quickly contained.
- A collection of more than 300 purified (monosporic) anamorphic (asexual form) and teleomorphic (sexual form) strains of CWD was assembled throughout the research programme. The collection will serve as a reference library for future studies.

Robusta Genotype Discoveries

- Robusta material was collected from Ugandan forest sites of Kibale and Itwara and genetic diversity analysed using SSR marker technology.
- The material was compared with cultivated genotypes from Kalangala Islands on Lake Victoria as well as Nganda and Erecta phenotypes.
- The genetic analysis revealed significant differences between the groups collected. The Ugandan genotypes were found to be sufficiently different from Guinean and Congolese types to represent new, genetically distinct diversity groups within the *Coffea canephora* genome.
- The variability inherent in the Ugandan Robusta genome therefore represents a very valuable resource for future breeding programmes.
- More collections from Uganda and other countries should be undertaken to maximize available genotypes for future breeding purposes.
- In Uganda, this valuable genetic resource is under threat from deforestation and CWD itself – it is urgent that steps are taken to collect and conserve this material in safe sites.

Screening Tests

- Various methods were evaluated to establish a simple, reliable and cost-effective way of evaluating resistance of coffee germplasm to CWD so that mass screening activities could be accomplished.
- Two methods were preferred: dipping of roots into a suspension of spores for about 20 min, and scraping the stem of seedlings with an infected scalpel.

Executive Summary

- Standard concentrations and exposure times were established. Spore concentrations as low as 13 spores per millilitre were sufficient to cause seedling mortality.
- Collections of wild Robusta from Kilangala and Itwara forests showed a high level of resistance to CWD.
- In Uganda, a very wide difference in susceptibility to field grown clones was found, from 0 to 96% mortality.
- Among available Tanzanian Robusta material, the highest level of resistance was found in the Maruku germplasm collection, but more fieldwork needs to be carried out to further evaluate this.
- At the University of Kinshasa, studies reveal a range of resistance among the tested material with several genotypes showing substantial levels of resistance with levels of mortality less than 10% 5 months after inoculation. Overall the mortality rates found in screening in DRC tend to be lower than for similar studies in Uganda and Tanzania.
- The most resistant Arabica genotype tested was a Catimor variety.
- None of the tested Ethiopian Arabica cultivars displayed a repeatable low mortality (less than 20%), suggesting that presently there are no Arabica genotypes currently available that are highly resistant to CWD.
- One CWD strain from the historical outbreak (DSMZ62457) was found to cause at least some mortality of seedlings of three *Coffea* species: *C. canephora*, *C. Arabica* and *C. liberica*. However, no currently extant CWD strain exhibits this lack of specificity.
- It is concluded that the Ethiopian Arabica CWD would present a serious threat to Arabica production in other countries if it spread, as has happened with Robusta CWD.

Breeding a Resistant Variety

- A breeding programme in Uganda has screened thousands of Robusta plants for resistance to CWD.
- The initial screening produced over 1500 lines potentially resistant to the disease.
- Further screening and agronomic trials have reduced this to seven final candidates for release to farmers in 2010.

Field Studies

- CWD transmission through wounding of coffee with an infected machete was studied in the field and screen house. Some evidence of transmission in the field was seen but further tests are needed as well as improvement in experimental procedure to develop a standard technique that can reliably deliver a dose of infective inoculum.

- CWD transmission from infected wood to adjacent uninfected seedlings was confirmed in screen house trials, suggesting that leaving infected wood near uninfected trees in the field is a significant infection pathway.
- CWD transmission from infected soil to healthy seedlings potted in that soil was also confirmed, with high infectivity lasting at least 3 months and declining subsequently.
- Further fieldwork is required to assess the extent of the infectious period of the soil under a range of ambient conditions, but from this study a period of at least 1 year fallow land before planting is advisable to avoid reinfection.
- Preliminary results of screening insects as possible CWD vectors could find no evidence that they carry the disease, although they were found to be carrying spores of other *Fusarium* diseases.
- Results to test whether other crop and weed plants might harbour CWD all proved negative, strongly suggesting that no common plant growing in the vicinity of coffee in Uganda harbours CWD.
- The spread of CWD through observation Robusta plots was studied in Uganda.
- There was no clear indication of a general spread of infection across fields, which might be expected if the disease was water- or wind-borne.
- There was evidence, however, that once established in a plot, the subsequent spread of infection is from tree to neighbouring tree, since the disease gradually spreads outwards from initial foci of single-tree infections.
- The means of this spread is still unknown but most likely involves transmission through the soil.
- Statistical analysis suggests that an infected tree can cause infection to trees up to 10m distance, i.e. three rows away. Hence, eradication of isolated trees in a healthy plot should also include removal of neighbouring trees to stand a good chance of halting an infection.

On-farm Trials

- In Ethiopia, DRC, Tanzania and Uganda, on-farm participatory trials and classical research station trials were carried out using a number of possible techniques to prevent CWD infection.
- Through pre-initiation workshops, farmers were consulted about the treatments to be applied and some of their suggestions incorporated into the experiments.
- The most salient result was that ways to limit the use of machetes or slashers seemed to have the most effect on lowering incidence of CWD.
- Fungicide stem applications and herbicide sprays also showed promise in some cases, but may be too expensive for many of the poorest farmers.

Training

- A major effort was undertaken in CWD-affected countries to train a range of coffee stakeholders, especially extension staff, trainers of trainers and farmers.
- A total of 2578 extensionists were trained as trainers and farmer field school (FFS) facilitators.
- Training techniques involved classroom sessions, participatory group discussions, outdoor on-farm practical sessions (hands-on discovery-based learning), group-building exercises, experience sharing by coffee extension staff and working with farmers.
- Extension workers in selected CWD hot spots and those located in the vicinity of on-farm trials were specifically trained on FFS group extension methodology, in addition to technical training on CWD identification and management.
- Based on the training of trainers work, slightly more than 1 million farmers were trained by extensionists from 2002 to 2007.

Dissemination

- A total of 487,700 items of information materials about CWD were produced during the course of the RCWP, and disseminated throughout coffee regions of Ethiopia, Uganda, Tanzania, DRC and Rwanda.
- Materials included leaflets, posters, calendars, T-shirts, coasters, pens and exercise books.
- Printed material was produced in a total of 13 languages.
- Over 250 radio broadcasts were made in five countries reaching a potential audience of tens of millions.
- Over 30 scientific papers and conference presentations were prepared.

Principal Recommendations

1. Establish an international task force to regularly visit coffee-producing countries to carry out farm surveys, collect plant material for subsequent analysis, conduct training and interview plant protection personnel, so that any information of an emerging threat reaches decision makers quickly and can be acted upon in a timely fashion at minimal cost. This should include countries that are currently CWD-free. We are confident that if such a facility had been available since the 1970s, it would have detected the disease at a much earlier date and control measures could have been instigated before it became the billion-dollar problem that it is now.
2. Carry out regular socio-economic surveys to continuously evaluate the status of African coffee.
3. Studies should be commissioned on *Fusaria* of wild coffee and other species to learn more about the origins of the disease.
4. Regular surveys should be instigated in coffee zones most likely to be next invaded by CWD to look for signs of the disease.
5. An international workshop should be convened to discuss quarantine services in the region with a view to major upgrading of facilities, training and ways in which this can be funded.
6. A contingency plan is needed for special emergencies such as regional unrest or natural disasters, when large populations suddenly move across borders bringing plant material with them, e.g. a rapid reaction team to organize incineration of plant materials brought with refugees when they cross borders.
7. A new and detailed survey should be carried out to update our knowledge on the status of CWD in Ethiopia, to know ways in which farmers are coping, the amount of diseased wood being moved around (especially south towards Kenya) as well as an assessment of quarantine activities at the Ethiopia–Kenya border. Much more too needs to be understood about the great range of severity of the disease in Ethiopia and how much of this is related to natural resistance to the infection and how much to agronomic or other factors.
8. A workshop should be conducted with national and international experts to discuss CWD in Ethiopia with the aim to review options and prepare a research, control and/or eradication strategy for Arabica CWD – if at all possible this disease should be eliminated before it escapes Ethiopia.
9. Further collections of Robusta material from forest areas in Uganda should be made and conserved in Uganda and other countries in order to maximize the probability that this material is permanently available for future breeding activities.
10. A workshop should be organized to discuss the threats to Ugandan Robusta diversity and what can be done to protect it. Subsequent to the workshop, a conservation plan should be drawn up and funds sought to implement it.
11. Commission a short study of the present CWD situation in Tanzania as well as a detailed account of the various monitoring and eradication activities carried

out there in recent years to understand the reasons for the reduced impact of the disease in this country with the view to learning lessons that other countries could build upon in their attempts to halt the advance of the disease.

12. Further funds are required to support long-term breeding activities in Uganda as well as DRC and Tanzania, in order to be able to continue to produce new lines to broaden the genetic basis of resistance to the disease and closely monitor the field performance of the new clones.
13. Multi-site, multi-year on-station and on-farm evaluations of the various options to prevent infection in all affected countries. These need to be part of a bigger plan to revitalize African smallholder coffee.
14. A rapid test should be developed to detect the presence of CWD which can distinguish it from other *Fusarium* species.
15. Conduct more research to discover genetic markers for CWD resistance in the coffee genome.
16. In addition, more research to study the genetic variation of the CWD disease complex should be carried out.
17. There should be a substantial upgrading of disease recognition and research facilities in Africa.
18. For urgent matters such as a spreading disease, project development, approval and start-up activities all need to be streamlined. We suggest that a special fund is required that could be sourced to initiate activities quickly without the time lags that are customary in getting a major international project started.
19. A much greater investment in research and extension is required in all countries. It is probably too ambitious to create a cadre of scientists that can carry out long-term field and laboratory studies in all countries, but a few regional centres of excellence should be supported, together with a basic level expertise in detection, identification and monitoring activities in all countries, backed by a reliable source of long-term funding.
20. An international conference to review progress and discuss what needs to be done next – essentially the work reported here could be regarded as Phase 1 of the project, Phase 2 needs to develop and role out wide-scale control programmes as well as expanded research to follow up on potentially fruitful lines of investigation. Phase 3 could be to eradicate the disease or arrive at a situation where the problem is maintained under tight control.
21. A major programme of activities to revitalize African coffee is required since control of CWD alone will not be enough to change the direction of African coffee. This would look at all aspects of coffee growing, and develop a range of activities to develop sustainable coffee strategies for long-term revival of the crop.