Sustainable Integrated Management of Whiteflies as Pests and Vectors of Plant Viruses in the Tropics

CIAT
Centro Internacional de Agricultura Tropical
[International] Center for Tropical Agriculture

Phase I:
Sustainable Integrated Management of Whiteflies as Pests and Vectors of Plant Viruses in the Tropics

A System-wide IPM Initiative Project

A Proposal for **DANIDA**
Danish International Development Agency

CG Convening Center **CIAT**
Centro Internacional de Agricultura Tropical

Collaborating CG Centers

ICIPE
International Center for Insect Physiology and Ecology

IITA
International Institute of Tropical Agriculture

AVRDC
Asian Vegetable Research Development Center

CIP
Centro Internacional de la Papa

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List of Acronyms

AHI	African Highland Initiative
ARC	Agricultural Research Corporation, Sudan
ARI	Advanced Research Institute
AVRDC	Asian Vegetable Research and Development Center, Tanzania
BARS	Bvumbwe Agricultural Research Station, Malawi
BBA	Biologische Budesanstalt fur land und Fortwirtschaft, Germany
CATIE	Centro Agronomico Tropical de Investigacion Enseñanza, Costa Rica
CENTA	Centro Nacional de Tecnologia Agropecuaria, El Salvador
CGIAR	Consultative Group on International Agricultural Research (or CG System or CG)
CIAT	Centro Internacional de Agricultura Tropical
CINVESTAV	Centro de Investigacion y de Estudios Avanzados, Mexico
CIP	Centro Internacional de la Papa
CORPOICA	Corporacion Colombiana de Investigacion Agropecuaria, Colombia
EAP	Escuela Agricola Panamericana Honduras
ESARC	East and Southern African Regional Center (IITA)
ESCaPP	Ecologically Sustainable Cassava Plant Protection Project (IITA)
FOFIFA	Centre National de la Recherche Apliquee au Developpement Rural, Madagascar
GIS	Geographic Information System
GTZ	Gesellschaft fur Technische Zusammenarbeit, Germany

HORTI Horticultural Research and Training Institute, Tanzania

IARC International Agricultural Research Center

ICIPE International Center for Insect Physiology and Ecology, Kenya

ICTA Instituto de Ciencia y Tecnologia Agricola, Guatemala

IISV Instituto de Investigaciones de Sanidad Vegetal, Cuba

IITA International Institute of Tropical Agriculture, Uganda

INIAP Instituto Nacional Autonomo de Investigaciones Agropecuarias, Ecuador

INIFAP Instituto de Investigaciones Forestales yAgropecuarias, Mexico

INRAB Institut National de Recherche Agronomique du Benin

IPM integrated pest management

IRA Institut de Recherche Agronomique

ISA Instituto Superior de Agricultura, Dominican Republic

JIC John Innes Centre, UK

KARI Kenya Agricultural Research Institute

LARS Lunyangwa Agricultural Research Station, Malawi

NARO National Agricultural Research Organization, Uganda

NARS National Agricultural Research System

NPPS National Plant Protection Service, Belize

NRCRI National Root Crop Research Institute, Nigeria

NRI Natural Resources Institute, UK

PPRSD Plant Protection and Regulatory Services Division, Ghana

PROFRIJOL	Programa de Frijol Centro Americano, Guatemala
PRONATHAR	Programa de Frijol de Haiti
TARO	Tanzania Agricultural Research Organization
UA	University of Arizona-Tucson, USA
UFL	University of Florida, USA
UNA	Universidad Nacional Agraria, Nicaragua
UW	University of Wisconsin-Madison, USA
VRU	Virology Research Unit (CIAT)
WF	whitefly
WTV	whitefly-transmitted virus

1.0 Summary:

Title Sustainable Integrated Management of Whiteflies as Pests and Vectors of Plant Viruses in the Tropics

Short Title Whitefly IPM Project

Project Goal

To improve living conditions of rural families through the effective management of whiteflies, resulting in increased crop production and a safer environment

Project Purpose

To reduce crop losses due to whitefly feeding damage and whitefly-transmitted viruses

Abstract

In the past decade, whiteflies (Homoptera Aleyrodidae), as pests and vectors of plant viruses, have become one of the most serious crop protection problems in the tropics The result has been devastating crop losses for small-holder producers and unprecedented insecticide abuse There is urgent need to develop IPM systems that would reduce insecticide use and help reestablish the ecological equilibrium by means of non-chemical approaches to whitefly control, such as biological and microbial control, or crop varieties with increased resistance to whiteflies (WFs) and whitefly-transmitted viruses (WTVs) One of the principle obstacles to achieving IPM solutions has been the isolated and uncoordinated fashion in which researchers have been working The Whitefly IPM Project proposes to organize a network for researchers in the tropics who are working on whiteflies and whitefly-transmitted viruses, promote the standardization of research methodologies among researchers, and facilitate the collecting of critical, missing data in order to adapt, develop and implement effective IPM packages for whitefly and virus management

Title Phase I Network Formation, Diagnosis and Analysis for IPM of Whiteflies in the Tropics

Short Title Phase I Whitefly IPM Project - Diagnosis and Analysis

Goal Phase I

To reduce environmental degradation, due to the excessive insecticide use, and reduce threats to food security, resulting from whitefly and WTV damage

Purpose Phase I

To gather, generate and analyze, through scientific and grower networks, baseline data relevant to the diagnosis and characterization of whitefly and WTV problems in the tropics, in order to propose a sound research agenda for improved understanding of pest and disease dynamics, IPM development and IPM implementation

Introduction

The problems caused by whiteflies as pests and vectors of plant viruses have been recognized for more than 100 years However, until recently serious whitefly damage had been limited to a few crops in particular geographic areas, e g whitefly pests of cotton in the Sudan and Central America, African cassava mosaic disease (ACMD) in Africa, tomato yellow leaf curl virus (TYLCV) in Israel, bean golden mosaic virus (BGMV) in Brazil In the past decade, this scenario has changed dramatically Whitefly pest infestations in cotton in Central America have become so severe that cotton production has completely collapsed in some countries (e g Nicaragua), and whiteflies have become new pests in other crops (e g tomato, cabbage) The historically damaging whitefly-transmitted viruses (WTVs), such as ACMD, TYLCV and BGMV have extended their range And, other WTVs are emerging in new crops and geographic zones, globally

The whitefly problem has become so serious worldwide, that the popular press has referred to whiteflies, such as *Bemisia tabaci*, as "the Pest of the Century" Whitefly pests and vectors have become one of the main target of insecticidal sprays in many parts of the tropics Excessive reliance on chemical pesticides has resulted in the systematic destruction of natural enemies that were formerly effective in providing natural control, whitefly populations with high levels of insecticide resistance, and the creation of new secondary pest problems Whiteflies provide a classic example of the "pesticide treadmill" The insecticide abuse, as well as exacerbating the pest problems it was intended to address, has become a serious threat to the environment, as well as a health hazard to producers and consumers And, as a result of both magnitude of the whitefly problems, and the ineffectiveness of insecticidal spraying, food security is at risk in several eco-regions

The fundamental problem is that producers in the tropics are using chemicals, many of them banned in developed countries, as insurance against the possibility of a devastating crop loss from whiteflies and WTVs Producers reason that as long as it is profitable, and better alternatives are not available, spraying is a good investment As indicated by CIP (1995) "It is a case of pay and spray and stay in business"

There is an urgent need to develop Integrated Pest Management (IPM) systems that would reduce insecticide use and help reestablish the ecological equilibrium by means of non-chemical approaches to whitefly control For whitefly pests this implies identifying the principal crop hosts, establishing economic injury levels (EILs), and developing new approaches to maintain whiteflies below the EIL For whitefly vectors, however, the traditional IPM approach will not suffice Vectors must be studied and managed within an epidemiological framework, i e , study and analysis of the whitefly-transmitted virus system, with IPM intervention strategies resulting from the epidemiological analysis

In recognition of the crucial importance of IPM to sustainable agricultural development, the Consultative Group on International Agriculture (CGIAR or CG System), has been working to establish a coordinating mechanism for IPM To this end, the CG formed a System-wide IPM Programme, guided by an Inter-Center Working Group on IPM Within this System-wide IPM Programme the International Center for Tropical Agriculture (CIAT) in Cali, Colombia was designated as the convening center to organize a Whitefly IPM Task Force and to prepare a proposal on Sustainable Integrated Management of Whiteflies as Pests and Vectors of Plant Viruses in the Tropics

A meeting of the System-wide Whitefly IPM Project Task Force was held at CIAT, in Cali, Colombia from February 13-15, 1996, with representatives from CG International Agricultural Research Centers (IARCs), National Agricultural Research Systems (NARS), and Advanced Research Institutions (ARIs) The Task Force defined a goal, purpose, outputs and activities for the project (Figure 1)

The Whitefly IPM Project is complex in nature and broad in scope Accordingly, the proposal presented here is for a start-up phase (Phase I), which will undertake the formation of a research network for whiteflies and WTVs in the tropics, extensive diagnosis and characterization of the WF/WTV problem, and, several critical analyses and IPM activities to prepare for Phase II of the Whitefly IPM Project (see the shaded areas of Figure 1)

Based on the Whitefly IPM Task Force Meeting, and within the framework of an eco-regional problem approach it is proposed that Phase I of the System-wide Whitefly IPM Project should consist of four sub-projects (Figure 2)

1 Whiteflies as pests in the tropical highlands of Latin America,
2 Whiteflies as vectors of viruses in legumes and mixed cropping systems in the tropical lowlands of Central America, Mexico and the Caribbean,

3 Whiteflies as vectors of viruses in vegetable and legume mixed cropping systems in eastern Africa and
4 Whiteflies as vectors of viruses in cassava and sweetpotato in Africa

Duration Phase I

Two years, from January 1997 to December 1998

Budget Summary

The total budget requested for Phase I of Whitefly IPM Project is US $1,372,376

Project Partners

Phase I will include scientists from 5 CG International Agricultural Research Centers (CIAT, ICIPE, IITA, CIP and AVRDC), 25 NARS institutions in 22 countries in Africa and Latin America, and 6 Advanced Research Institutions from the United Kingdom, Germany and the United States

Coordinating scientists

Leader, CIAT Pest and Disease Mangement Unit	Dr Anthony C Bellotti (CIAT)
Project Coordinator	to be hired
Coordinator Sub-project 1	Dr Cesar Cardona (CIAT)
Coordinator Sub-project 2	Dr Francisco Morales (CIAT)
Coordinator Sub-project 3	Dr S Sithanantham (ICIPE)
Coordinator Sub-project 4	Dr James Legg (IITA)

2.0 Project Background:

History of Whiteflies as Pests and Vectors in the Tropics

Whiteflies as pests and vectors

Although Mound and Halsey (1978) have catalogued 1156 species of described whiteflies (Homoptera Aleyrodidae), only a limited number of whitefly species are commonly found infesting plants of economic importance (Table 1, Martin, 1987, Caballero, 1992) Based on geographic distribution, host plant range, density on host plants, and difficulty of control in Central America and Colombia, Caballero (1992) classified

Two (2) whitefly species as key pests

- *Bemisia tabaci* (Gennadius)
- *Trialeurodes vaporariorum* (Westwood), and

Five (5) species as important pests

- *Aleurotrachelus socialis* Bondar
- *Trialeurodes variabilis* (Quaintance)
- *Bemisia tuberculata* Bondar
- *Trialeurodes abutiloneus* (Haldman), and
- *Aleurocanthus woglumi* Ashby

Three (3) whitefly species have also been confirmed as vectors of plant viruses in four virus families (Table 2, Duffus 1987, Padidam *et al* , 1995, Fauquet & Martelli, 1995) Undoubtedly, the most important whitefly is *Bemisia tabaci*, as a vector of geminiviruses

Although few whitefly species are important pests and vectors, the damage that they cause to crop hosts is devastating Whiteflies are phloem (sap) feeders They cause direct damage in some hosts by extracting large quantities of sap The honeydew which they excrete, as a result of the copious sap intake, serves as a substrate for sooty mold fungi which can also damage hosts by blocking photosynthesis Sooty mold can also discolor harvestable fruits and fiber, affecting the quality of produce e g snap beans, vegetables, cotton lint The whitefly-transmitted viruses (WTVs) are among the most destructive plant viruses, early virus infection often results in total crop loss

Table 1 Whitefly species commonly found infecting plants of economic importance (Martin, 1987, Caballero, 1992)

Whitefly Species	New World	Old World
Acaudaleyrodes citri (Priesner & Hosny)		X
Africaleurodes coffeacola Dozier		X
Aleurolobus barodensis (Maskell)		X
Aleurolobus niloticus Priesner & Hosny		X
Aleurolobus olivinus (Silvestri)		X
Aleurocanthus citriperdus Quaintance & Baker		X
Aleurocanthus cocois Corbett		X
Aleurocanthus delotti Cohic		X
Aleurocanthus spiniferus Quantaince		X
Aleurocanthus woglumi Ashby	**X**	**X**
Aleurocybotus indicus David & Subramaniam		X
Aleurocybotus setiferus Quaintance & Baker		X
Aleurodicus cocois (Curtis)	X	
Aleurodicus destructor (Mackie)		X
Aleurodicus dispersus Russell	X	X
Aleurodicus dugesii Cockerell	X	
Aleurodicus linguosus Bondar	X	
Aleuroglandulus malangae Russell	X	
Aleurothrixus floccosus (Maskell)	X	X
Aleurotrachelus cacaorum Bondar	X	
Aleurotrachelus socialis Bondar	**X**	
Aleurotrachelus trachoides (Back)	X	X
Aleurotuberculatus neolitseae Takahashi		X
Aleurotuberculatus psidii (Singh)		X
Aleyrodes lonicerae Walker		X
Aleyrodes proletella Linnaeus	X	X
Bemisia afer Priesner & Hosny		X
Bemisia giffardi (Kotinsky)		X
Bemisia tabaci (Gennadius)	**X**	**X**
Bemisia tuberculata Bondar	**X**	
Ceraleurodicus altissius (Quaintance)	X	
Ceraleurodicus ingae (Baker)	X	

Whitefly Species	New World	Old World
Dialeurolonga communis Bink Moenen		X
Dialeurolonga elongata (Dozier)		X
Dialeurolonga simplex Takahashi		X
Dialeuropora decempuncta (Quaintance & Baker)		X
Dialeurodes citri (Ashmead)	X	X
Dialeurodes citrifolii (Morgan)	X	X
Dialeurodes kirkaldyi (Kotinsky)	X	X
Lecanoideus giganteus (Quaintance & Baker)	X	
Leonardius lahillei (Leonardi)	X	
Metaleurodicus cardini (Back)	X	
Neomaskellia andropogonis Corbett		X
Neomaskellia bergii (Signoret)		X
Orchamoplatus citri (Takahashi)		X
Orchamoplatus mammaeferus (Quaintance & Baker)		X
Parabemisia myricae (Kuwana)	X	X
Siphoninus phillyreae (Haliday)		X
Tetraleurodes acaciae (Quanintance)	X	X
Tetraleurodes andropogon (Dozier)		X
Tetraleurodes mori (Quaintance)	X	
Trialeurodes abutiloneus (Haldman)	**X**	
Trialeurodes floridensis (Quaintance)	X	
Trialeurodes ricini (Misra)		X
Trialeurodes vaporariorum (Westwood)	**X**	
Trialeurodes variabilis (Quantaince)	**X**	
Xenaleurodes broughae Martin		X

Bold type denotes species of significant agricultural importance

Table 2 Plant viruses transmitted by whiteflies (Duffus, 1987, Padidam *et al*., 1995, Fauquet & Martelli, 1995)

Closteroviruses	
Beet pseudo yellows virus (BPVY)	*Trialeurodes abutilonea*
Cucumber yellows virus (CuYV)	*Trialeurodes vaporariorum*
Diodea vein chlorsis virus (DVCV)	*Trialeurodes vaporariorum*
Lettuce infectious yellows virus (LIYV)	*Bemisia tabaci*
Carlaviruses	
cowpea mild mottle virus (CPMMV)	*Bemisia tabaci*
Potyviridae	
sweet potato mild mottle virus (SPMMV)	*Bemisia tabaci*
Geminiviridae, Subgroup III	
Abutilon mosaic virus (AbMV)	*Bemisia tabaci*
African cassava mosaic virus (ACMV)	*Bemisia tabaci*
bean calico mosaic virus (BCMV)	*Bemisia tabaci*
bean dwarf mosaic virus (BDMV)	*Bemisia tabaci*
bean golden mosaic virus (BGMV)	*Bemisia tabaci*
East Africa cassava mosaic virus (EACMV)	*Bemisia tabaci*
pepper huasteco virus (PHV)	*Bemisia tabaci*
potato yellow mosaic virus (PYMV)	*Bemisia tabaci*
squash leaf curl virus (SLCV)	*Bemisia tabaci*
Texas pepper virus (TPV)	*Bemisia tabaci*
tomato golden mosaic virus (TGMV)	*Bemisia tabaci*
tomato leaf crumple virus (TLCrV)	*Bemisia tabaci*
tomato leaf curl virus (TLCV)	*Bemisia tabaci*
tomato mottle virus (TmoV)	*Bemisia tabaci*
tomato yellow dwarf virus (TYDV)	*Bemisia tabaci*
tomato yellow leaf curl virus (TYLCV)	*Bemisia tabaci*
tomato yellow mosaic virus (ToYMV)	*Bemisia tabaci*

History of whiteflies and geminiviruses

In Africa, *Bemisia tabaci* has been regarded as a pest and vector in cotton in the Sudan since the 1930s (Kirkpatrick, 1931) With the advent of resistant cotton varieties, *B tabaci* was considered a manageable early-to-mid-season pest However, the use of wide-spectrum insecticides, with accompanying adverse effects on the indigenous natural enemies, elevated *Bemisia tabaci* to a serious all-season pest, causing leaf drop by direct feeding, reduced number of bolls and sticky cotton lint from the production of honeydew (Lopez-Avila, 1986)

Bemisia-transmitted African cassava mosaic disease (ACMD) was first described in 1894 In East Africa, the disease was not reported to cause serious losses until the 1920s In West Africa, it was first recorded in the coastal areas of Nigeria Sierra Leone, and Ghana in 1929 and had spread northward by 1945 ACMD is now reported from all cassava-producing countries in Africa (Fauquet & Fargette, 1990) Although an old problem, and despite much research, ACMD remains prevalent in many parts of Africa and is currently causing a serious epidemic in Uganda

In Latin America, *Bemisia tabaci* was recognized as a minor insect pest of cotton in Central America in the 1950s By the 1970s the use of insecticides converted *B tabaci* into a key cotton pest, second in importance to the boll weevil

The whitefly-transmitted bean golden mosaic virus (BGMV) was first described as causing a minor disease (5-10% prevalence) of bean in Brazil (Costa 1965) In the early 1970s, the area of soybeans, a principal reproductive host for *Bemisia tabaci*, greatly increased in Brazil By the mid-1970s, Brazil was suffering severe outbreaks of BGMV with estimated yield losses of 48-85% (Costa & Cupertino, 1976) BGMV came to be considered as the limiting factor for dry season bean production in certain areas of central-southern Brazil (Costa, 1975)

Although the problems caused by *Bemisia tabaci*, both as pest and vector, have been recognized for more than 100 years, serious damage had been limited to few crops in particular geographic areas This scenario has changed over the past decade Whitefly pest infestations in cotton have become so severe that cotton production has completely collapsed in some countries (e g Nicaragua) and whiteflies have become new pests in other crops (e g tomato, cabbage) The known WTVs (ACMD, BGMV, TYLCV) have extended their geographic range And other WTVs are emerging in new crops and geographic zones, globally

The whitefly problem has become so serious, worldwide, that the popular press has referred to *Bemisia tabaci* as "the Pest of the Century"

CG Initiative on Whitefly IPM

In recognition of the crucial importance of Integrated Pest Management (IPM) to sustainable agricultural development, the Consultative Group on International Agricultural Research (CGIAR or CG System), has been working to establish a coordinating mechanism for IPM To this end, representatives of ten International Agricultural Research Centers (IARCs) and the Chairman of the IPM Working Group, met at The Hague in The Netherlands, on February 22-24, 1995 The participants of this meeting recommended that the CG System form a System-wide Programme on Integrated Pest Management, guided by an Inter-Center Working Group on IPM to function as the steering committee, coordinated by IITA The concept was approved by the CG and the initiative formally launched as the System-wide Programme on IPM (SP-IPM) at the beginning of 1996 Key issues to be tackled by the Programme have been identified and Task Forces, each led by a research center with special expertise in the relevant field, have been established to address each issue To-date, 11 Inter-Center IPM task forces have been established as part of the System-wide Programme on IPM The International Center for Tropical Agriculture (CIAT) in Cali, Colombia was designated as the convening center to organize the Inter-Center Whitefly IPM Task Force and to formulate the Inter-Center proposal on Sustained Integrated Management of Whiteflies as Pests and Vectors of Plant Viruses in the Tropics

A Task Force Meeting for the Inter-Center Whitefly IPM Project was held at CIAT, in Cali, Colombia from February 13-15, 1996 The objectives of the meeting were a) to discuss the outputs and activities that should be proposed for the project, and b) to discuss a structure for the global Whitefly IPM Project, as well as how to link and coordinate the institutions that would be involved in the project

The Task Force Meeting included 24 participants representing CG International Agricultural Research Centers (IARCs), National Agricultural Research Systems (NARS), and Advanced Research Institutions (ARIs) After considerable discussion on the nature of the whitefly problem, the Task Force agreed that it was possible to define three whitefly problems that should be prioritized 1) whiteflies as pests in mixed cropping systems in tropical highlands, 2) whiteflies as vectors in mixed cropping systems in low to mid altitudes of the tropics, and 3) whiteflies as vectors and pests of the semi-perennial cassava The first problem focuses on whiteflies as direct pests in annual crops in the highlands The second problem focuses on whiteflies as vectors of plant viruses in annual crops, especially legumes and vegetables, in the tropical lowlands And, the third problem focuses on whitefly pests and vectors in a semi-perennial staple crop, cassava

There was general consensus among the Task Force on the project goal, purpose, and the outputs Project activities were discussed extensively, and general agreement was reached Also Based on the Whitefly IPM Task Force Meeting and within the CG framework for an eco-regional problem approach (Bouma *et al* , 1995), it is proposed that Phase I of the Inter-Center Whitefly IPM Project should consist of four sub-projects (Figure 2)

1 Whiteflies as pests in the tropical highlands of Latin America
2 Whiteflies as vectors of viruses in legumes and mixed cropping systems in the tropical lowlands of Central America, Mexico and the Caribbean,

3 Whiteflies as vectors of viruses in vegetable and legume mixed cropping systems in eastern Africa, and
4 Whiteflies as vectors of viruses in cassava and sweetpotato in Africa

Innovativeness

Collaboration

Informal international and regional networks for whiteflies and WTVs already exist (e g , International Bemisia Working Group, GeminiNET, European Chapter of the International Organization for Biological Control, the U S Research and Action Plan Network, Latin American Whitefly and Geminivirus Network) However, these networks essentially serve as information exchange Numerous calls have been made for increased international collaboration and coordination on WF and WTV research (e g Thresh *et al* , 1994, van Lenteren, 1994) The objective of the CG Tropical Whitefly and WTV Network is to go beyond information exchange to achieve a collaborative research agenda on whiteflies and WTVs

The Inter-Center links at the heart of this project should ensure that technology and knowledge generated in one Center will be made available to other Centers, and their NARS/ARI collaborators

Integration

The objective of the CG Tropical Whitefly and WTV Network is not only to establish a collaborative research project, but also to integrate research across disciplines and eco-regions Research on whitefly pests and whitefly-transmitted viruses has not been truly integrated in the past Whiteflies and WTVs represent a complex problem spanning multiple crops, geographic regions and disciplines A compartmentalized approach that focuses on single crop from the viewpoint of one discipline will bring neither understanding nor solutions The WF/WTV problems demand a transdisciplinary, pan-tropical approach This project will attempt such an approach, and if successful, will set a precedent for whitefly/WTV research and for the System-wide IPM Programme

Standardization

One of the most serious obstacles to research progress on whiteflies has been the diversity of research methodologies, to an extent that similar data sets cannot be compared For that reason, significant attention and funds have been devoted to standardizing methodologies for activities in Phase I An initial investment in standardization will greatly increase the value of the data that is gathered and generated

Analysis

A further obstacle to research progress has been the limited qualitative and quantitative analysis that has been carried out on whitefly and WTV systems Analytical tools (e g GIS analysis, mathamatical models) are cost-effective investments In an ever-increasing context of limited resources, preliminary qualitative and quantitative analyses will acquire increased importance as a justification for research programs

Intended Beneficiaries

The immediate beneficiaries of Phase I of the project will be a) IARC scientists b) NARS scientists, c) small holder farmers, and d) donor agencies Additional, indirect beneficiaries will be the general community of whitefly and WTV scientists and government policy makers

CG-IARC scientists

The System-wide IPM Programme was created in order to strengthen Inter-Center collaboration, by facilitating the interchange of experienced human resources on IPM problems of mutual, global concern CG-mandated crops and eco-regions are being affected, worldwide by whiteflies and WTVs The research capacity of CG scientists will be strengthened through the Whitefly IPM Project in many ways For instance, experience in the epidemiology and management of vegetable and legume viruses and whitefly pests in Latin America, exchanged with eastern Africa, may help prevent the insecticide-induced environmental problems observed in Latin America Exchange of WF-resistant cassava varieties between Latin America (CIAT) and Africa (IITA) should strengthen the African breeding programs in their search for resistant cassava varieties The new Central American AVRDC program, which will set up a program of breeding against WTV in tomatoes and peppers, should benefit from this project through improved understanding of the specific identity and distribution of the tomato and pepper viruses responsible for the on-going epidemics in Central America Standardization of research methodologies across centers, will increase the value of the research results for all IARC scientists

NARS scientists

Scientists from national programs in 22 Latin American and African countries are expected to participate in this project (Appendix A) NARS scientists in Latin America have already recognized the need for standardized research methodologies and have begun working to standardize protocols (Hilje, 1996) This project will support and extend those efforts The improved understanding of whitefly pest and WTV problems, in each of the participating countries, along with the recommendations for IPM research and interventions, which will result from Phase I of this project, will be useful to NARS as they set up, prioritize or re-set national research agendas

Small-holder producers

The special phytosanitary activity to produce virus-free cassava planting material is expected to immediately and directly benefit the small-holder cassava producers in the ACMD epidemic areas of Uganda, and neighboring countries at risk from the epidemic In addition, the collection and exchange of information on crop protection practices for whiteflies is expected to be of immediate use to small holders cultivating legumes, vegetables, in Latin America and Africa

Donor agencies
In the present context of reduced and limited funding, it is critical that donor agencies have access to objective data and recommendations for funding prioritization As a result of Phase I, donor agencies will have a set of recommendations for prioritized IPM research and interventions, which they will be able to use as guidelines for funding allocations

The scientific community
The scientific community at large will benefit by participating in the standardization of critical research methodologies, by increased information flow and improved access to colleagues in the tropics, as well as the information that those colleagues have previously generated (grey literature) and the information generated by the project

Government policy makers
At present, little or no attention is being paid by many local authorities to the ever increasing problem of insecticide abuse It is hoped as a result of the findings of this project, changes in government policies regarding the sale, storage, distribution and use of insecticides for whitefly control may occur

Phase I Justification

Sub-project 1 Whiteflies as pests in the tropical highlands of Latin America

Approximately 10% of the world's population lives in the main highlands and mountainous areas of the developing world (the Andes of South America, the Africa highlands, and the Himalayas) The management of resources in those ecosystems affects an additional 40% of the world's population which inhabits adjacent areas such as Inter-Andean valleys in the Andean Zone Traditionally, people in the highlands have been marginalized from major development efforts, with significant repercussions on poverty, migration, social unrest as well as environmental deterioration, *in situ* and downstream (IFPRI, 1995, IDRC, 1996)

Environmental degradation
One major issue regarding the welfare of those living in highland areas of Latin America is environmental degradation caused by excessive pesticide use It is well known that insecticide consumption in the developing world is increasing rapidly It was initially thought that increases in insecticide use in Latin America were mainly due to the growth of plantation crops, an important source of export revenue (Bellotti *et al* , 1990) However, as stressed by Whitaker (1993), the developing country share of the world agrochemical usage, currently valued at US$ 10 6 billion, is forecast to rise from 19% in 1988, to an estimated 35% by the year 2000 Much of this growth stems from a wider and more intensive use of chemical protection by smallholder farmers

Unfortunately up to 45% of insecticide use in the developing world is represented by highly toxic insecticides Excessive reliance on chemicals has resulted in the emergence of pests that have built resistance to the insecticides, threatening the sustainability of cropping systems Chemical abuse has also resulted in the systematic destruction of natural enemies that were once effective in providing reliable natural control Moreover, insecticide abuse has become a serious threat to the environment as well as a health hazard to producers and consumers

The fundamental problem is that farmers in hillside areas of Latin America are using chemicals, many of them banned in developed countries, as an insurance policy against the possibility of a devastating crop loss from insect pests and diseases Farmers reason that as long as it is profitable, and better alternatives are not available, spraying is a good investment As indicated by CIP (1995) "It is a case of pay and spray and stay in business"

In the early 1980s the greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), became a very serious pest of several hillside-grown crops in the Andes Major outbreaks occurred in 1987 1991 and 1994, in selected areas of Colombia, northern Ecuador and the Constanza Valley in Dominican Republic Recent work conducted by NARS and IARCs shows that the patterns of insecticide use against the greenhouse whitefly and the sweetpotato whitefly, *Bemisia tabaci* (Gennadius), in the Andean Zone and parts of the Caribbean, are changing rapidly and creating new insect problems For example, insecticide use by small bean farmers, which was negligible until 1975-77 (Schoonhoven & Cardona, 1980), has steadily increased and become excessive in Colombia and Ecuador Surveys conducted in two regions of Colombia and the northern part of Ecuador (CIAT 1994) revealed that 100% of 893 farmers surveyed sprayed their crops in an attempt to control the greenhouse whitefly Highest insecticide use occurs in the Sumapaz region of Colombia where farmers make an average of 11 1 applications per season

Most alarming, is the fact that some growers are spraying their crops up to 24 times in a crop cycle that lasts 90-100 days That is to say, insecticides are being used every 3-4 days Insecticide abuse on beans in Colombia (5 6 kg active ingredient per ha per season) is such that it compares with present insecticide consumption for cotton (6 2 kg active ingredient per ha per season), a crop that has traditionally been known as the worst offender in terms of insecticide use To make matters worst, 78% of insecticides used against whiteflies are classified within toxicological category I (highly toxic) and are usually applied in mixture with other insecticides, broad-spectrum fungicides, and foliar fertilizers Farmers do not usually take precautions when handling pesticides, and up to 24% of those surveyed admit that they have been intoxicated at least once in the past 10 years (CIAT, 1994)

In summary, whitefly pests have become the main target of insecticidal sprays in the highlands of Colombia, Ecuador and the Dominican Republic, including areas where there is no need to spray against these insects (Cardona *et al* , 1993) This is creating a very serious imbalance that has raised other insects (leafminers, pod borers) to major pest status In addition to further accelerating the development of resistance (Buitrago *et al* 1994) and eroding the ecological balance, the expanded use of pesticides increases crop production costs The combination of high resistance of various insect species to insecticides, the induced ecological imbalance and the increased production costs tend to undermine the sustainability of prevailing cropping systems in the region There is an urgent need to develop IPM systems that would reduce pesticide use and help reestablish the ecological equilibrium by means of non-chemical approaches to whitefly control

Sub-project 2 *Whiteflies as vectors of viruses in legumes and mixed cropping systems in the tropical lowlands of Central America, Mexico and the Caribbean*

Food security

The common bean (*Phaseolus vulgaris* L) is one of the main staple foods in Latin America, particularly among the rural and urban poor In Central America, beans are the most important source of protein, usually being consumed thrice a day Despite its relatively small area (498,368 km^2), Central America devotes twice as much of its geographical area to the cultivation of beans (735,000 ha), when compared to major bean producers of South America such as Brazil (>5,000,000 ha) Beans are also produced in some Caribbean islands, such as Cuba (26,000 t), the Dominican Republic (55,000 t) and Haiti (56,000 t) where they, too, play an important nutritional role in the diet of the lower socio-economic classes

Bean production in Central America and the Caribbean is characterized by small holdings cultivated by farmers with limited resources In El Salvador, for instance, 85% of the bean producers cultivate less than 14 ha, and 50% of these producers have holdings of less than 3 5 ha

Despite the large area planted to beans in Central America, average productivity is low (495 kg/ha) compared to the average yield expected (over 1,500 kg/ha) in most bean producing regions of the U S and other temperate countries in the world The main factor identified as responsible for the low bean productivity in Latin America has been the incidence of biotic constraints, particularly diseases

Bean golden mosaic geminivirus (BGMV), transmitted by *Bemisia tabaci*, is the most devastating viral pathogen of beans in tropical Latin America It is estimated that over 2,500,000 hectares are currently under attack by BGMV, and that at least one million hectares cannot be planted every year due to the likelihood of total yield losses, mainly during the dry seasons of the year, when whitefly populations reach a high peak (Morales, 1992) In beans infected by BGMV, 100% yield reduction can occur due to high incidence of floral abortion and pod deformation (Morales & Niessen 1988) Throughout Central America and the Caribbean Basin, figures for crop damage indicate that the BGMV infection can be devastating There is consensus that BGMV is the major biotic factor limiting bean production in Latin America

The urban poor are also affected by the scarcity or higher production costs of producing food staples in countries affected by whitefly problems The solution of these biotic constraints will make food staples available at lower prices, thus, benefiting the lower socio-economic stratum of the urban poor

Poverty alleviation

Food production is the primary source of income for 42% of the population in Central America and the Caribbean basin Many small-scale farmers, particularly in Central America, plant beans only to meet their food demands, and devote the rest of their limited land to the cultivation of cash crops, such as tomato, peppers or melon The epidemics caused by whitefly-transmitted geminiviruses in these crops, during the past decade, have often been devastating (Table 3 Figure 3, Anderson, 1996) In social terms, the income of growers has been substantially reduced and many growers, such as those in Zacapa (Guatemala), Zapotitan (El Salvador) and Sebaco (Nicaragua) have abandoned their plots of land

The welfare of developing countries and their low-income populace, is tightly linked to the existence of cash-earning commodities, principally agricultural products The loss of cash crops to whitefly-transmitted viruses is a factor contributing to the stagnation of social programs in developing countries

Environmental degradation

The two most frequently implemented tactics to protect crops against insect-transmitted viruses, including the whitefly-transmitted plant viruses, have been the use of virus-resistant varieties and the use of insecticides to reduce the population level of the insect vectors For bean golden mosaic geminivirus, despite the continuous screening of bean germplasm since 1972 no BGMV-immune bean genotype has been found to date Nonetheless, some genotypes have been used as sources of resistance Over the last two decades, CIAT has released more than 20 bean varieties demonstrating increasingly greater resistance to BGMV The improved (DOR) bean varieties currently deployed are demonstrating stable yields and resistance to BGMV under medium-level inoculation pressure

However, the resistance is not effective under high inoculation pressure Moreover, varieties of tomato, melon and peppers that are resistant to geminiviruses are not available Due to the considerable crop losses caused by whiteflies as pests or vectors of plant viruses, and the scarcity of resistant varieties, the use of highly toxic agrochemicals has been the whitefly control method of choice

Central America is exceptional in the intensity of pesticide use In the decade from 1980-1989, an average of 11 8 kg of pesticides per hectare of cultivated land was applied, the equivalent of 2 1 kg per person Corresponding figures for developed-economy countries were 2 7 and 0 6, respectively (FAO, 1993)

Populations of *Bemisia tabaci* have become so resistant that most insecticides are no longer effective For example, in the 1950s in Nicaragua, whitefly was controlled in cotton by applications of 0 36 l/ha of 48% methyl parathion Now, due to the resistance of *Bemisia tabaci* even 4 30 l/ha of the same insecticide is ineffective This has led to a series of damaging or potentially damaging practices increased number of applications, use of more costly and more toxic products, and the use of untested alternative pesticides

Figure 3

GEOGRAPHICAL DISTRIBUTION OF WHITEFLY BORNE VIRUSES IN CENTRAL AMERICA, MEXICO, AND THE CARIBBEAN BASIN (*)

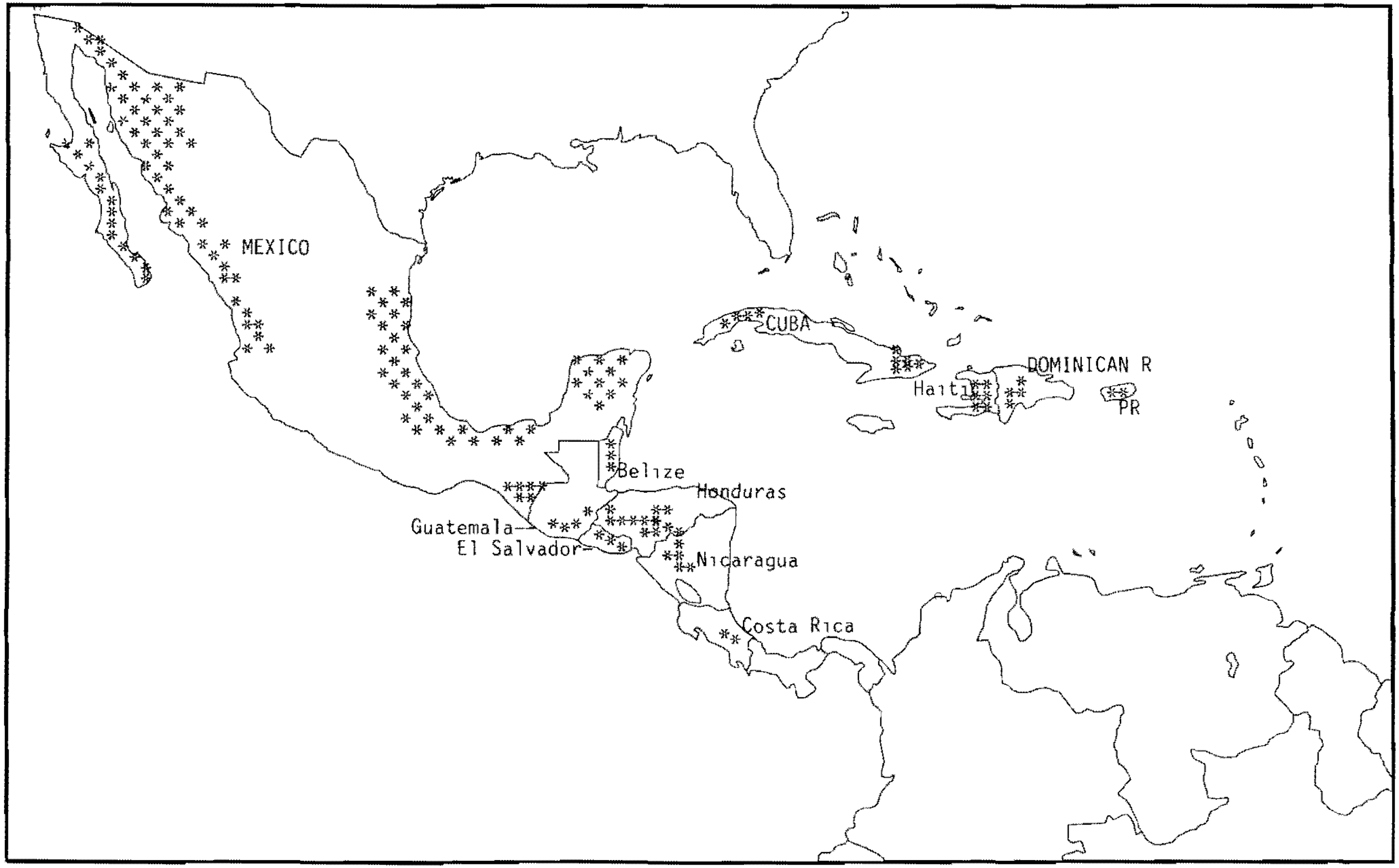


Table 3 Recent epidemics caused by whitefly-transmitted viruses in Central America, Mexico and the Caribbean (Anderson,1996)

COUNTRY - Zone	Crop	Year / Season	Affected Area (ha)	Disease Incidence	Yield Loss (%)	Economic Loss (millions)
DOMINICAN REPUBLIC						
San Juan de la Maguana	beans	Dec Feb		high		
Azua	tomato melon	1988				$US 10
Azua	tomato melon eggplant peppers	1988			35	
Azua North Northwest	tomato	1989 1995				$US 50
Azua	tomato	1988 1989 1989 1990 1990 1991 1991 1992 1992 1993 1993 1994 1994-1995			20 25 40 45 35 40 25 30 75 80 90 95 20	
North Northwest	tomato	1988 1989 1989 1990 1990 1991 1991 1992 1992 1993 1993-1994 1994-1995			5 5 10 10 15 15 80 50 15	
CUBA						
Holguin	beans	1989 1990 1990 1991	1 000 1 000		100 100	

COUNTRY - Zone	Crop	Year / Season	Affected Area (ha)	Disease Incidence	Yield Loss (%)	Economic Loss (millions)
CUBA (cont d)	beans tomato	1990 1991 1990 1991			23 5 30 8	
	beans tomato	1990 1993 1990-1993	20-33% 25 35%			
MEXICO Northwest	beans	Sept Mar Jan Jun			20 30 50 90	
South	beans				50-100	
	tomato peppers	1988 1989	70 000		57	
Yucatan	tomato peppers	1989			52	
North Yucatan South Yucatan	peppers	1989			55% 30%	
Mexicali Valley Baja California San Luis Rio Colorado Sonora	melon watermelon sesame sesame cotton	1991-1992	1 500 150 3 000 3 500 23 800		100 100 100 partial 0 5 paca/ha	$60 new pesos
	cotton	1992			50	$40 new pesos
Sonora	tomato squash potato cotton	1994	10 000			

COUNTRY - Zone	Crop	Year / Season	Affected Area (ha)	Disease Incidence	Yield Loss (%)	Economic Loss (millions)
BELIZE	tomato sweet peppers hot peppers		75 100 %			
GUATEMALA South East	beans	1989			9 000 T	
HONDURAS La Libertad	beans	1989			10 100	
Comayagua	tomato	1992	462		100	$US 4 6
Olancho	cotton	1991	1 750	80 100%		
El Paraiso Cortes	peppers				80 100	
EL SALVADOR San Andres	beans	Nov -Dec		100%		
NICARAGUA Boaco	beans	1990			82	
Sebaco	tomato peppers	1990-1991 1991 1992 1991 1992			20 50 30 100 30 50	
COSTA RICA Central Valley	beans	1991	35%			
	tomato peppers cucurbitaceas				20 80 10 90 40 60	

In beans in Guatemala, Dardon (1993) reported that in addition to the application of systemic pesticides at planting, the bean crop receives 12-15 applications of pesticide for whitefly control Bean producers, in Nicaragua, report that the traditionally recommended pesticides no longer offer whitefly control The insecticides which are still effective (e g Talstar, Herald) are extremely expensive, highly toxic, and their effectiveness does not last for more than several planting cycles Consequently, bean producers in Nicaragua are turning to the use of botanical insecticides and "repellents", e g chili tobacco, liquid soap, cooking oil, cattle slurry (Anderson *et al* 1993) These botanicals, particularly the use of cattle slurry, have never been tested for potential insect resistance or non-target effects Their impact on human health, beneficial insects and the environment is completely unknown

For vegetables, some producers are applying mixtures of up to four insecticides on alternate days (Salguero, 1993) In tomatoes in Nicaragua, whitefly control is so difficult that products, such as Polo, which are only registered for use in cotton, are used on tomatoes There are even reports that aracicides and wood preservatives are also being applied (Anderson *et al* , 1993) For melons the producers apply insecticides every 3 days, and almost half of the applications are against whiteflies Melons in Nicaragua receive 5-10 applications per growing season

As with whitefly pests in the Neotropical highlands, whitefly vectors in the Neotropical lowlands have become a principal target of the insecticide applications There is an urgent need to develop IPM programs in order to manage whitefly vectors with minimal insecticide use

Sub-project 3 Whiteflies as vectors of viruses in vegetable and legume mixed cropping systems in eastern Africa

The highlands of eastern and central Africa constitute approximately 23% of the total land mass of the region The area is densely populated and is currently home to more than 100 million people (half of the total population) and is the major source of water for northern, eastern and central Africa The highlands provide half the food value for the region, making a major contribution toward the countries' GDPs They support diverse land uses and economic opportunities, in addition to food for domestic consumption, horticultural crops are largely grown in the highland areas and are a major source of foreign exchange for the countries in the region

The problem of whitefly-transmitted viruses on vegetables, found in Central America, Mexico and the Caribbean, is now beginning to emerge in eastern Africa *Bemisia tabaci* infests the more common vegetable crops in the subregion tomatoes (*Lycopersicon esculentum* Mill), eggplant (*Solanum melongena* L), okra (*Abelmoschus esculentus* (L) Moench) and chillies (*Capsicum annuum* L) The legume crops which are commonly grown in association with vegetables in the subregion include bean (*Phaseolus vulgaris* L), cowpea (*Vigna unguiculata* (L) Walp) and groundnut (*Arachis hypogaea* L) Until recently whiteflies were known to be minor or occasional pests on legumes However, the trend in Sudan indicates that whiteflies are becoming an important pest on beans

Tomato is one of the most widely cultivated vegetable crops in the region Production is predominantly by small-scale farmers for fresh consumption, and yields are generally low Small farmers obtain yields of 20t/ha while commercial farmers obtain over 100t/ha These low yields are due to various production constraints, particularly arthropod pest and diseases (GTZ 1995)

In October, 1995, 25 participants from Kenya, Mozambique, Tanzania, Uganda, Zambia and Zimbabwe met in a tomato planning workshop for southeastern Africa The workshop reviewed the past 15 years of research on tomato plant protection for each of the countries represented Workshop participants defined criteria of an important disease or pest as 1) high yield losses 2) widespread distribution, 3) high incidence, and 4) frequent occurrence Based on these criteria *Bemisia tabaci* was identified as the third most important arthropod pest after red spider mites and African bollworms (Table 4, Varela & Pekke, 1995)

Table 4 Priority ranking for whitefly on tomato in selected countries based on ranking of importance by national scientists in eastern and southern Africa (Varela & Pekke, 1995)

Country	**Whitefly Species**	**Whitefly Importance (1 = most important)**	**Others ***
Kenya	B tabaci	1	none
Malawi	B tabaci	2	mites
Uganda	B tabaci	4	thrips Helicoverpa leaf miner
Tanzania	B tabaci (as vector)	1	none
Zimbabwe	T vaporariorum	3	mites Helicoverpa
Mozambique	B tabaci	4	Helicoverpa leaf miner mites
Regional Priority	B tabaci	3	mites Helicoverpa

* Other insect pests perceived of as more important than whiteflies

Workshop participants could not prioritize the importance of viral diseases due to the lack of information from most countries, with the exception of Tanzania where *Bemisia tabaci*, as a vector of tomato yellow leaf curl virus (TYLCV) was considered the limiting factor for tomato production (GTZ, 1995) Subsequent survey work carried out by the AVRDC regional office in southeastern Africa has ascertained that TYLCV is also a serious problem in Malawi and Zambia Prior work conducted by INRA (France) also found TYLCV to be a threat to tomato production in the Sudan All commercial varieties of tomatoes grown in southeastern Africa are susceptible to TYLCV (R Nono-Womdim, pers comm) Control of whiteflies is based on the use of insecticides

Environmental degradation in this region is largely attributable to the indiscriminate and/or excessive use of broad-spectrum insecticides as part of the intensive crop protection system in industrial crops (especially cotton) The problems of insecticide resistance and pest resurgence although initially existant on these target crops, have extended to the other seasonal crops grown in rotation and/or combination with these crops, as in the case of whiteflies The increasing importance of horticultural production also brings with it the attendant strategy of pesticide-based protection in an effort to harvest damage-free produce Intensive use of insecticides in vegetable crops has become quite common in large areas of Sudan, Uganda, Kenya, Tanzania and Zimbabwe In a recent survey of vegetable farmers in Kenya it was found that the majority perceived that they would lose up to 90 percent of their harvest if they did not use insecticides These vegetable farmers are currently applying up to 19 sprays a season, with a significant proportion of farmers spraying 9-12 times per season (KARI-GTZ, 1994)

The increasing reliance on synthetic pesticides has already resulted in the destruction of natural enemies, leading to 'flare up' or 'resurgence' of pests Two examples of traditionally minor pests taking over as key pests are the whiteflies and mites In Sudan, the transformation of whiteflies as key pests, has not only affected vegetable crops like tomato (Dabrowski, 1994), but is more recently reported to also cause significant damage to legume crops The emergence of whiteflies and spider mites as major pests in several seasonal crops in the region is clearly a case of man-made' pests, due to the indiscriminate use of insecticides in some target crop systems It is evident that the adverse consequences of the "pesticide treadmill" are looming large on the vegetable ecosystem in this sub region of Africa And, any longer term erosion of the already thin ecological balance and biodiversity of beneficial insects in this subregion, if not promptly remedied through suitable alternatives to and rational use of pesticides, may lead to agroecological disasters which would greatly affect the economic and food security of the subregion

It is critical to begin work in eastern Africa so as to intervene with alternative whitefly crop protection measures, before the WTVs reach the severity currently encountered in the Neotropics

Sub-project 4 Whiteflies as vectors of viruses in cassava and sweetpotato in Africa

The problem of whiteflies on cassava in Africa is because of their role as plant virus vectors They are not pests of cassava and there has been little insecticide use

Food security

Cassava is the third largest source of carbohydrates for human food in the world, with an estimated annual yield of 153 million tons, and Africa is the largest center of production, 73 million tons of cassava were grown on 9 5 million hectares in Africa in 1994 (FAO, 1995) If one uses the definition that a staple food accounts for more than 200 calories per day per capita in the diet, then cassava is the second most important staple food, after maize in sub-Saharan Africa Nearly 200 million people or 40% of the Sub-Saharan Africa population relies on cassava And, in some countries people derive approximately 1000 calories a day, or 50% of daily food intake) from cassava (IITA, 1988)

Although Africa is the greatest producer of cassava, yields are low 7 7 tons per hectare in 1994 (FAO, 1995), compared with a potential of between 30 and 50 tons per hectare There have been major research successes in combating exotic pests which have devastated cassava in Africa following their introduction from South America Most prominent amongst these has been the biological control of the cassava mealybug The effective continent-wide management of this pest resulted in benefits to cassava farmers in Africa, calculated at $149(US) per $1(US) invested The indigenous African cassava mosaic disease (ACMD), however, is arguably responsible for even greater reductions in the continent's cassava yield than were attributed to cassava mealybug

Responses to an international questionnaire, sent to all cassava-producing African countries (Fauquet & Fargette 1987) showed that ACMD is present wherever cassava is grown (Figure 4) A survey of 20 farms in Ghana revealed an average 96% of plants infected Similarly, ACMD incidence exceeded 80% in some districts of Kenya, and nearly 100% in Ivory Coast Subsequently, the ESCaPP Project has identified ACMD as a key problem in Ghana, Benin, Nigeria and Cameroon, with overall incidences of infection of 72, 55, 82 and 66%, respectively

Figure 4 Distribution of African cassava mosaic disease (ACMD)

Table 5 Presence and relative importance of African cassava mosaic disease (ACMD) as estimated by agronomic services of different African countries that produce cassava (Fauquet & Fargette 1990)

Country	Principal biotic constraints to cassava	Crop losses due to ACMD
Benin	mosaic green spider mites	UNKNOWN
Burkina Faso	mosaic	UNKNOWN
Burundi	mosaic green spider mites mealybugs	40%
Congo	bacterial blight mealybugs green spider mites	UNKNOWN
Ghana	bacterial blight green spider mites	25%
Ivory Coast	mosaic green spider mites	up to 90%
Kenya	mosaic green spider mites bacterial blight	up to 70%
Liberia	mosaic green spider mites	35 50%
Malawi	mosaic green spider mites	UNKNOWN
Nigeria	mosaic	20 90%
Rep Cent Af	mosaic mealybugs	UNKNOWN
Rwanda	mosaic green spider mites	UNKNOWN
Senegal	saic mealybugs	UNKNOWN
Sierra Leone	mosaic mealybugs	UNKNOWN
Tanzania	mosaic green spider mites	UNKNOWN
Togo	mosaic	UNKNOWN
Uganda	mosaic green spider mites bacterial blight	55 87%
Zaire	bacterial blight mealybugs	up to 70%

Yield losses with individual cultivars have been reported from different countries to range from 16 to 100% (Table 5, Fauquet & Fargette, 1990, Thresh *et al* , 1994) Yield losses depend upon the mode and time of infection In Kenya, ACMD causes a loss of about 70% in tuberous root yield of plants derived from infected cuttings (Bock, 1982)

In 1988, reports were received of serious damage to cassava in northern Uganda Plants were severely affected by ACMD and resulted in such low yields that local food shortages and starvation occurred By 1989 a severe epidemic was reported in the West Nile Region of northwestern Uganda A comprehensive survey of cassava in the area revealed that the disease was spreading rapidly and causing crop failure By April 1992, most fields were 80-90% infected and cassava production had virtually ceased due to the poor yields of the diseased crops In some districts, the area planted to cassava decreased by 95% because farmers were aware of the futility of planting infected cuttings of the available varieties This epidemic has now covered much of Uganda and is extending southwards at a rate of 10 to 20 km per year It is estimated that over

150,000 ha of cassava growing land is abandoned, equivalent to over 2 2 million metric tons (US $440 million) This has caused food shortages and famine in a number of districts particularly in the eastern and northern regions where the crop has been a major staple The current epidemic in Uganda is a threat to cassava production in all neighboring counties (Otim-Nape *et al* 1996)

Sweetpotato (*Ipomea batatas* L), another important subsistence crop, tends to be grown in the same farming system as cassava Sweetpotato is particularly important in eastern Africa Uganda is the largest producer of sweetpotato, eastern Zaire, Kenya, Tanzania and Madagascar are also major producers (FAO, 1995)

Sweetpotato virus diseases have been identified as the main biological constraint to sweetpotato production in many countries in Sub-Saharan Africa (Geddes, 1991) *Bemisia tabaci* has been confirmed as a vector of sweet potato sunken vein virus (SPSVV) and sweet potato mild mottle virus (SPMMV) SPSVV combines as a complex with the aphid-borne sweet potato feathery mottle virus (SPFMV) to cause the severe disease known as sweetpotato virus disease (SPVD) Infection with SPVD stops plant growth, and infected cuttings usually result in no yield

Surveys of the incidence of SPSVV carried out in Uganda show that the virus is present in virtually all sweetpotatoes that show disease symptoms Large differences are present in the incidence of disease, however, even within the Ugandan Lake Victoria shore region, over 40% infection has been found in the south whereas almost no disease is found in the region bordering Kenya Curiously, low incidence of disease in sweetpotatoes coincides with the high incidence of ACMD in the cassava plantings

It is necessary to better-characterize the distribution and impact of ACMD and sweetpotato viruses in the cassava- and sweetpotato-growing belt of Africa In addition, special efforts, such as phytosanitation introduction of whitefly-resistant cassava clones and disease monitoring, should be continued to both understand and slow down the Uganda ACMD epidemic

State-of-Knowledge

Review of the documented literature

A review of the existing whitefly databases confirms the belief that most of what is known about whiteflies is based on studies of *Bemisia tabaci* and *Trialeurodes vaporariorum* (Byrne & Bellows, 1991) Specifically, a review of three agricultural data bases, for principal whitefly pest and vector species revealed the following number of publications from January 1990 to May 1996

Whitefly Species	Data Base		
	CAB	AGRIS	AGRICOLA
Bemisia tabaci	515	376	330
Trialeurodes vaporariorum	209	189	78
Aleurotrachelus socialis	3	1	1
Trialeurodes variabilis	3	2	1
Bemisia tuberculata	0	1	0

Content analysis of the CAB references for *Bemisia tabaci* and *Trialeurodes vaporariorum* for the same period of 1990 to 1996, showed that only 73 (10 1%) of the 724 documents referenced in the CAB database referred to whitefly work conducted in Latin America (42, 5 8%) or tropical Africa (31, 4 3%) Moreover, many of the findings of the whitefly and WTV research that has been carried out in Latin America and tropical Africa in the past decade are not readily accessible to the scientific community

Characterization and diagnosis of the problem

Despite the research that has been conducted on whiteflies in the past decade, our knowledge on tropical whitefly pests and vectors is inadequate Existing and available knowledge is largely a function of who has been able to obtain research funding, and where they have worked, rather than a reflection of the severity of the problem Our current state-of-knowledge is best described as partial and patchy

Sub-project 1

Although our understanding of *Trialeurodes vaporariorum*, as a pest of beans in the Andean zone is relatively advanced, there is virtually no information on the economic importance of the greenhouse whitefly as a pest of other economically important crops, e g tomato, potato, and vegetables, in the tropical highlands and InterAndean valleys The status of the insect as a pest needs to be better ascertained Actual yield losses have not been measured but it is known that farmers regard the insect as a major threat to these crops Surveys and observations (CORPOICA, unpublished surveys) indicate that insecticide use on potato is very high in Colombia and that tomato plantings are sprayed twice a week on a regular basis

Sub-project 2

The Latin American regional literature is replete with reports of epidemics believed to be caused by *Bemisia*-transmitted viruses However, quantitative data are scarce and variable (Table 3) The apparent lack of quantitative data (e g for Belize, Guatemala El Salvador) does not indicate the absence of whitefly-transmitted geminivirus epidemics, but rather that data have not been collected The data which do exist (Table 3) repeatedly report epidemics in beans, tomato pepper and melon, suggesting that these crops are the most seriously affected, often by devastating epidemics, on a regional level These data also appear to suggest that within countries epidemic "hot spots" for different crops are geographically distinct This may reflect different cropping patterns, or may be an artifact of partial data It is necessary to conduct a coordinated and systematic survey of disease incidence and yield losses and to estimate economic losses

The best example available of an attempt to characterize the behaviour of a geminivirus disease in Latin America, is the collective work on bean golden mosaic virus (BGMV) (Morales, 1994) For 11 countries in Latin America, maps are presented depicting the state-of-knowledge on spatial distribution of BGMV Accompanying texts provide additional detail on the temporal patterns of BGMV, i e , when during the year the epidemics seem to be most severe Even in this best-documented case, existing descriptive information is still quite incomplete, and analysis is lacking

Table 6 Geminiviridae species identified from food crops in the Caribbean Mexico and Central America

Bean		
BcaMV	Mexico	Loniello *et al* 1992
BGMV	Dominican Rep	Galvez *et al* 1977
	Mexico	Galvez *et al* 1977
	Guatemala	Galvez *et al* 1977
	El Salvador	Galvez & Castaño 1976
	Nicaragua	Rojas *et al* 1994
BDMV	Nicaragua	Zamora 1996
Tomato		
TYLCV Is	Dominican Rep	Polston *et al* 1994
		Nakhla *et al* 1994
	Cuba	Gonzalez & Valdes 1995
		Ramos *et al* 1996
TLCV	Mexico	Paplomatas *et al* 1994
TPV	Guatemala	Maxwell 1995
tomato geminivirus	Belize	Polston (unpublished)
tomato geminivirus I	Guatemala	Maxwell 1995
	Honduras	Maxwell 1995
	Nicaragua	Maxwell 1995
tomato geminivirus II	Guatemala	Maxwell 1995
TYMV	Costa Rica	Maxwell 1995
Peppers		
TPV	Mexico	Bravo *et al* 1995
	Nicaragua	Maxwell 1995
PHV	Mexico	Torres Pacheco *et al* 1993
pepper geminivirus	Belize	Polston (unpublished)

BCaMV bean calico mosaic virus
BGMV bean golden mosaic virus
BDMV bean dwarf mosaic virus
TYLCV tomato yellow leaf curl virus
TLCV tomato leaf crumple virus
TPV Texas pepper virus
TYMV tomato yellow mottle virus
PHV pepper Huasteco virus
PYMV potato yellow mosaic virus

Table 6 presents the geminiviruses identified to-date, from bean, tomatoes, and peppers in Central America, Mexico and the Caribbean In addition to BGMV, which has been identified in Central America since the mid-1970's, bean calico mosaic virus (BCaMV) has been identified from Mexico (Loniello *et al* 1992), and bean dwarf mosaic virus (BDMV) has recently been identified from Nicaragua (Zamora, 1996) Our knowledge of the geminiviruses infecting tomato and peppers in the region has increased greatly in the past five years Tomato geminiviruses, distinct from those already named and accepted by the International Committee on Virus Taxonomy (ICTV), have been identified from tomatoes in Central America These geminiviruses have been sequenced but have not yet been named (Maxwell, 1995), and are referred to as tomato geminivirus I and tomato geminivirus II Although geminiviruses have been detected in cucurbits in the Dominican Republic (J K Brown, unpublished), Guatemala (Alvarado *et al* 1990, Moran, 1994), Honduras, El Salvador, Costa Rica (Polston unpublished Valdivia, Perring & Polston, cited in Caballero & Rueda, 1993), and Nicaragua (J K Brown & P K Anderson unpublished 1987), identifications appear to be lacking

Despite the advances in WTV identifications in the region, it remains uncertain as to which WTVs are responsible for the epidemics, some of which may be caused by mixed infections In Guatemala, 81% of the tomato samples tested, were found to have mixed infections of tomato geminiviruses I and II (Maxwell, 1995) WTVs must be linked to the observed epidemics, in order to determine which virus pathosystems should be prioritized for epidemiological study

Sub-project 3

As noted previously, the participants of the tomato planning workshop for southeastern Africa, were unable to prioritize whitefly-transmitted viruses due to lack of information from most countries However, they felt that there is a need to assess the importance of WTVs in the region (GTZ, 1995) The preliminary results of a survey of major vegetables in southern Africa indicate that tomato yellow leaf curl virus (TYLCV) is a very important tomato disease (Nono-Womdim, pers comm) However, there is a lack of quantitative information on the distribution and extent of yield loss due to TYLCV, and other WTVs, in the region across the target crops in vegetable and legume based cropping systems There is a critical need for baseline information as a prerequisite for prioritizing and planning the strategies for sustainable pest management interventions

Sub-project 4

Current knowledge suggests that two cassava mosaic geminiviruses occur in Africa with partially-overlapping distributions (Hong *et al* , 1993, Swanson & Harrison, 1994) East African cassava mosaic virus (EACMV) has been identified from coastal East Africa, Madagascar, Malawi and Zimbabwe, and African cassava mosaic virus (ACMV) from West and Central Africa and from western Kenya and Tanzania Both viruses are transmitted by *Bemisia tabaci* Recent evidence, however, suggests that this classification may be an oversimplification New research suggests that the ACMD epidemic in Uganda may be caused by a geminivirus distinct from both EACMV and ACMV A novel biotype of *B tabaci* may also be involved (Gibson *et al* , 1996)

Although SPSVV is believed to be the most damaging virus of sweetpotato throughout Africa, outside of Uganda there is no information on the incidence of SPSVV In the Lake Zone of Tanzania, for example, viral diseases were commonly reported during farmer surveys (Kapinga *et al* , 1995) Likewise, the incidence of SPMMV has only been surveyed in Kenya with a mean infection rate of about 25% (Wambugu, 1991) or 10% (Carey *et al* , 1996), in

Uganda (Carey *et al* , 1996) and to a very limited extent in Tanzania Although sweetpotato viruses are known to occur widely in sweetpotato producing areas of Africa there is virtually no detailed information on their incidences or yield losses

Despite the devastating pest outbreaks and epidemics being caused by WFs and WTVs, our knowledge in the tropics is quite incipient Without first generating a clearer picture of the nature and extent of the whitefly problem, it will be impossible to develop rational IPM programs

3.0 Phase I Description:

There was a consensus, by the Whitefly IPM Task Force, on the project goal, purpose and outputs for the Inter-Center Whitefly IPM Project (Figure 1, Work Breakdown Structure) The following description represents Phase I of the Inter-Center Whitefly IPM Project Accordingly, the goal and purpose for Phase I are more restricted (Figure 5) With respect to outputs, Phase I will focus on the formation of an international network for whiteflies and WTVs in the tropics (Output 1), and an extensive characterization and diagnosis of the whitefly and WTV problem in the targeted eco-regions (Outputs 2, 3, and 4) In addition, several activities to prepare for Phase II are proposed (Output 5)

Phase I Goal

To reduce environmental degradation due to the excessive insecticide use, and reduce threats to food security which are resulting from whitefly and WTV damage

Phase I Purpose

To gather, generate and analyze, through scientific and grower networks, baseline data relevant to the diagnosis and characterization of whitefly and WTV problems in the tropics, in order to propose a sound research agenda for improved understanding of pest and disease dynamics, IPM development and IPM implementation

Phase I Outputs

1 International network for whiteflies and WTVs in the tropics established

2 Socio-economic and environmental impact assessed

3 Epidemiological characterization initiated

4 Agronomic characterization initiated

5 Preliminary studies for Phase II conducted

Outputs and Activities

The objective of Phase I of the project is to gather and analyze the data which already exist, and to generate a limited, additional, critical database, in a standardized fashion, such that qualitative and quantitative analyses will indicate where further whitefly/WTV research should be carried out, and what research should be prioritized Communication and information exchange will be critical to the success of the project

Figure 5

Work Breakdown Structure
Phase I of Whitefly IPM Project

Project Goal

To reduce environmental degradation due to the excessive insecticide use and reduce threats to food security resulting from whitefly and whitefly transmitted virus damage

Project Purpose

To gather generate and analyze thourgh scientific and grower networks baseline data relevant to the diagnosis and characterization of whitefly and WTV problems in the tropics

puts	**Output 1** International network for Wfs and WTVs in the tropics established	**Ouput 2** Socio economic and environmental impact assessed	**Ouput 3** Epidemiological characterization initiated	**Output 4** Agronomic characterization initited	**Output 5** Preliminary studies for Phase II conducted
vities	1 1 Development of an electronic conference for communication between collaborators 1 2 Creation of a project homepage on the INTERNET WWW 1 3 Standardization of methodologies for activities in Outputs 2 through 4 1 4 Publication of a bibliography of the grey literature on WFs and WTVs 1 5 Publication of a directory of WF and WTV researchers 1 6 Dissemination of project research results through the CG system	2 1 Identification of WF and WTV affected zones in each target area 2 2 Estimation of disease incidence and yield losses due to WFs and WTVs in affected areas 2 3 Determination of WF related crop protection costs and crop production costs in affected areas 2 4 Survey of pesticide use against WFs and WTVs in affected areas 2 5 Determination of insecticide resistance levels in target regions 2 6 Identification of agricultural policies and policy environment in target regions	3 1 Identification of WF reproductive hosts 3 2 Identification of WF species and biotypes 3 3 Identification of WTVs in affected areas 3 4 Identification of efficient WF natural enemies	4 1 Characterization of cropping systems cropping patterns and cropping intensity 4 2 Characterization of crop varieties and agronomic practices 4 3 Characterization of agro ecology and agro meteorology of target regions	5 1 Development of GIS 5 2 Conducting of critical area analysis using GIS 5 3 Conducting of preliminary quantitative analyses of key WTV pathosystems 5 4 Production of ACMV free planting stock for Uganda 5 5 Improvement of ACMV resistant varieties 5 6 Epidemiological monitoring for ACMV

Note Output 1 refers to overall Phase I coordination Outputs 2 - 5 are relevant to all sub projects

Output 1 *International network for whiteflies and WTVs in the tropics established*

The importance of information collection and exchange was clearly articulated in a technical planning workshop held at ICRAF in Nairobi Kenya in June 1993 The workshop was attended by 33 NARS researchers trainers and development workers, 31 IARC scientists, training and information specialists, and donor representatives The working group identified key priority areas for information, including access to local knowledge, spatial and numerical data, up-to-date research information and efficient communication mechanisms among partners The working group circulated an information needs assessment questionnaire among the workshop participants The results were used as a tool for priority setting, and led to the priority rating presented in Table 7 (African Highlands Initiative, 1994) The information priorities defined by the ICRAF workshop appear to state, equally-well, the information needs for the whitefly scientific community working in the tropics

Activity 1 1 Development of an electronic conference for communication between collaborators

Efficient communications among collaborators of the Whitefly IPM Project is critical While many NARS scientists do not have access to INTERNET, most have electronic mail capacity An (email) electronic conference will be set-up, and moderated by the Project Coordinator, as a vehicle for linking sub-project coordinators, IARC and NARS scientists In addition to facilitating project logistics, the conference will be used to convey bibliographic databases and updates Project Coordination will assist those collaborators who do not have email capacity in getting on-line

Activity 1 2 Creation of a project homepage on the INTERNET WWW

The Project Coordinator, in conjunction with the System-wide IPM Programme Coordinator and the CIAT Communication Head, will develop a World Wide Web homepage for the System-wide Whitefly IPM Project The homepage will serve, generally, to inform the broader scientific community as to the progress and information being generated by the project Specifically, the project homepage will include linkages to other WWW whitefly homepages

a University of Wageningen, European Chapter of the International Organization for Biological Control (IOBC),
  Dr Joop van Lenteren (http //www spg wau nl/ento)
b Whitefly Research at the University of Arizona
  (http //gears tucson ars ag gov/wcrl/wwwghome html)
c University of California Kearney Agricultural Center Whitefly Information
  (http //www uckac edu/whitefly/index htm)
d United States Department of Agriculture Whitefly Knowledgebase
  (http //www ifas ufl nt2/wfly/index html)
e GeminiNET, electronic conference Dr Claude Fauquet

Table 7 Priority ratings of information needs assessed among the participants of the Technical Planning Workshop, Nairobi (African Highlands Initiative, 1994)

Information	Priority Rating *
1 Access to bibliographic database	82%
2 Regular current awareness service	80%
Information on current research	
3 Access to local knowledge	79%
4 Access to GIS	74%
State of the art reviews	
Access to photocopies loans	
5 Information on who-is doing what	73%
6 Access to numerical data base	70%
7 Annotated bibliographies	67%
8 Newsletters	67%
9 Training in scientific communication	55%
Training in information management	

* These percentages reflect views of a diversified audience where the main category consisted of researchers (36) followed by program planners or project designers (17) persons involved in training/education (13) policy makers (4) and extensionists (2)

Activity 1 3 Standardization of methodologies for activities in Outputs 2 through 4

Preliminary work will be undertaken to gather written protocols for each of the activities proposed in Outputs 2, 3, and 4 Experts in each area will be consulted A document with clear instructions on proposed methodologies, protocols and surveys will be produced At the onset of the project, before actual field work begins, regional workshops will be held in Latin America (at CIAT) and in Africa (at ICIPE) with NARS participants and ARI collaborators to discuss and, where necessary, modify the proposed protocols

Funding allocations to all participating collaborators will be contingent on their acceptance of the standardized methologies

Activity 1 4 Publication of a bibliography of the grey literature on WFs and WTVs

In addition to the CAB, AGRIS, and AGRICOLA databases cited above, numerous bibliographies and collective works on whiteflies and WTVs have been published and are widely available (e g Cock 1986, Ohnesorge & Gerling, 1986, Gerling 1991, Gerling & Mayer, 1995, Butler *et al* 1995) These publications primarily document the work that has been carried out by researchers in the developed countries of North America, Europe and the Middle East

However, a tremendous amount of the research has also been conducted on whiteflies and WTVs in the tropics This information has not been available to the larger scientific community, either because it has been published in local journals, proceedings of regional meetings, and in-house documents, or it has been published in a language other then English

A bibliography of the so-called "grey literature" for whiteflies and WTVs in the tropics will be developed and made available to the WF/WTV community, to complement the existing bibliographies

Activity 1 5 Publication of a directory of whitefly and WTV researchers

To promote and facilitate communication among colleagues, a directory of researchers actively working on whiteflies and whitefly-transmitted viruses in the tropics will be compiled, to accompany the grey literature publication discussed above

Activity 1 6 Dissemination of project research results through the CG System

The research findings of this project will be analyzed and published in book form The book will be a collective work, presenting the results for each participating country and for each topic (e g insecticide use, biotypes, natural enemies) Participating scientists (NARS, IARCs and ARIs) will co-author the chapters for which they assisted in collecting or analyzing data

Summaries of the research findings will also be made available through the electronic conference and WWW project homepage

Output 2 Socio-economic and environmental impact assessed

The original intent of the project, with respect to problem characterization and diagnosis, was to select several whitefly pest and virus "hot spots", to serve as model sites, in which intensive survey work for diagnosis and characterization would take place However, preliminary discussion and analysis indicated that our collective knowledge is extremely uneven

Criteria for the selection of hot spots included a) economic importance of the WF/WTV problem, b) pesticide use against the whitefly problems, c) availability of relevant databases (e g land use, meteorological data), d) capacity to conduct work (e g institutional support and infrastructure, accessibility, safety), and e) donor interest As indicated in Sections 2 4, our knowledge of the areas affected by whiteflies and the etiology of the problem is currently patchy which reflects the history of research rather than the problem, *per se* When we consider additional criteria, such as insecticide use existence of databases, etc , our ability to select and prioritize hot spots for further work becomes even weaker

Activity 2 1 Identification of WF and WTV - affected zones in each target eco-region

In each of the participating countries, agricultural professionals and producers will be interviewed in order to obtain a more complete picture of which (geo-political) zones and which crops are believed to be suffering losses due to whiteflies and WTVs

Activity 2 2 Estimation of disease incidence and yield losses due to WFs and WTVs in affected areas

Once specific crops within specific zones have been identified, then disease incidence or yield losses will be estimated Disease incidence or yield loss estimates will provide relatively objective indications of the severity of the pest problem, as well as relative importance of the whiteflies as production constraints across geographic zones and crops

Activity 2 3 Determination of whitefly-related crop protection costs, and crop production costs in affected areas

Additional data on the costs of protecting crops against whiteflies and WTVs, and crop production costs for the crops being affected, will indicate the relative economic importance of whiteflies and WTVs

Activity 2 4 Survey of pesticide use against WFs and WTVs in affected areas

Information on the pesticides used against whiteflies and WTVs (how much, which insecticides, when) will indicate the producers' perception of the problem These data will also indicate which crops and zones require priority attention, in order to minimize insecticide abuse

Activity 2 5 Determination of insecticide resistance levels in target regions

In zones where whitefly populations are highly resistant to insecticides, the rate of the "pesticide treadmill" can be expected to accelerate It will be of critical importance to develop, and prioritize, non-chemical alternatives for vector management and crop protection in those zones

Activity 2 6 Identification of agricultural policies and policy environment in target regions

Understanding government agricultural policies will indicate the relative feasibility of IPM implementation, in whitefly-affected zones For example, government insecticide subsidies, which make excessive and unwarranted use of pesticides economically feasible, often undermine IPM efforts, IPM success would be expected to be more difficult in countries where insecticides are subsidized

The documentation of disease incidence and yield losses, production costs, pesticide use and agricultural policies, during Phase I, will also serve as *ex-ante* baseline data for evaluation of project impact during the final phase of the project

Output 3 Epidemiological characterization initiated

Activity 3 1 Identification of whitefly crop reproductive hosts

Bemisia tabaci (Gennadius) is regarded as an extremely polyphagous species, characterized by its extensive intercrop movement (Butler *et al* 1986) Greathead (1986) lists 506 plant species that have been recorded as host plants for *Bemisia tabaci*, worldwide However, empirical and experimental data suggest that *Bemisia tabaci* populations do not reproduce freely among all available cultivated hosts

In Phase I, identification of the principal cultivated reproductive hosts, will form the basis for further sampling of whitefly species and whitefly biotypes This information will also be important for subsequent stages of the project (IPM development and implementation) It will not be possible to effectively implement crop protection tactics aimed at source reduction (e g biological control efforts), if we do not understand which plant species are the principle reproductive hosts for whitefly pests and vectors

Activity 3 2 Identification of whitefly species and biotypes

Specific crop plants often support several species of whiteflies (R Caballero, unpublished data, Krafka & de Mata, 1995) It is necessary to ascertain which species of whiteflies are present on the principal hosts

In 1986, a new biotype of *Bemisia tabaci*, referred to as the poinsettia biotype or the B biotype, was discovered in the United States (Simone *et al* 1986) The B biotype is spreading in Latin America (Brown, 1993, Brown & Bird, 1995) Of epidemiological importance is the knowledge that the B biotype of *Bemisia tabaci* has a broader host range, higher fecundity (Bethke *et al* 1994) and a greater dispersal capacity (Byrne, 1995) than the A biotype

And not surprisingly there are reports of additional biotypes in Latin America Distinct biotypes of *Bemisia tabaci* have also been reported from Africa in the Ivory Coast (Burban *et al* 1992) and Uganda (Legg *et al* , 1994, Legg, 1996) However, the majority of information available on biotypes is based on allozyme electrophoresis (Costa & Brown, 1991, Wool *et al* 1989 1993, 1994), which does not have adequate resolving and analytical power Systematic biotype analysis, using molecular traits, for populations of *Bemisia tabaci* and *Trialeurodes vaporariorum* is needed, as the basis for further comparative studies on critical biological and epidemiological parameters

Activity 3 3 Identification of WTVs in affected areas

Although many WTVs have been identified as the causal agents for regional epidemics, there are many zones in which it is not understood which WTVs are responsible for the epidemics still observed Once the epidemic areas are identified then the whitefly species and WTVs must be verified If it is not clear what viruses and whitefly species are causing the outbreaks, then basic (epidemiological) studies cannot be planned rationally Likewise, virus identification is necessary for sound breeding programs

Activity 3 4 Identification of efficient WF natural enemies

Knowledge of whitefly parasitoids, predators and entomopathogens is growing However, it is not at all clear which of the potential biocontrol agents are most common in the field It is now necessary to survey, not only to identify the whitefly natural enemy complexes but also, in order to determine which of the commonly reported natural enemies are most prevalent in the field

Output 4 Agronomic characterization initiated

Activity 4 1 Characterization of cropping systems, cropping patterns and cropping intensity

Spatial and temporal patterns, for crops related to WTV epidemics and WF outbreaks, will be critical input for GIS analysis It will be necessary to describe when and where these crops are planted as well as the land tenure patterns

Activity 4 2 Characterization crop varieties and agronomic practices

Some of the disease and pest outbreak patterns that are observed, may be explained by the crop varieties or specific agronomic practices used

Activity 4 3 Characterization agro-ecology and agro-meteorology of target regions

Although published and unpublished data on population dynamics exist, the analysis of these data has been quite superficial The predominant theories in the literature point to rainfall and temperature as explanatory factors for population fluctuations More precise and complete agroecological and agrometerological databases are necessary in order to take advantage of available whitefly data sets Meteorological stations as well as national weather services and international data bases can be utilized to obtain the key climatological data, e g precipitation, temperatures

Output 5 Preliminary studies for Phase II conducted

... 1 Development of GIS

... Information System (GIS) offers the opportunity to integrate and analyze multiple ... will be established by creating a base map, and a series of data maps (e g ... ive host plants, target crops of interest, disease incidence and yield loss, ... ots, agro-meteorological data, etc) Development of a GIS in Phase I will ... ticated regional analyses in Phase II of the project

... of critical area analysis

... ill be possible to use overlay methodologies to conduct a critical ... lysis involves creating classifications for each map, assigning ... us classifications, combining the values and creating a product map ... on from the individual maps This analysis will indicate and prioritize ... hot spots, where intensive characterization and diagnosis, as well as ... al field studies, should be carried out in Phase II of the project

...ity 5 3 Conducting of preliminary quantitative analyses of key WTV pathosystems

Mathematical models for the analysis of within-field spread of insect-transmitted viruses, including WTVs, exist and have been previously proposed as important tools for analyzing whitefly-transmitted geminiviruses in annual crops (Anderson, 1993, 1994) Preliminary mathematical analysis indicates a) which necessary information is completely lacking for the pathosystems or regions of interest, and b) which parameters are most sensitive, i e which parameters will have the most impact on pathogen spread or crop damage, and should therefore be prioritized for further research or intervention Such an analytical process serves as the basis for defining and prioritizing an experimental research agenda for further epidemiological studies

As a result of Activity 5 1, 5,2 and 5 3, it should be possible to define a) which critical areas, or hot spots, should be prioritized for further study, b) which pathosystems within the critical areas should be prioritized, c) which biological and ecological parameters need further study, and d) which crop protection/intervention strategies appear to be most promising The data which is gathered or generated, and then analyzed in Phase I, will provide an objective basis for defining Phase II activities

However due to the severity and urgency of the African cassava mosaic virus epidemic in Uganda, it is proposed that several critical IPM activities be initiated during Phase I, rather than waiting until Phase II when most of the IPM development and implementation activities will take place

Activity 5 4 Production of ACMV-free planting stock for Uganda

Before other ACMV control measures can be considered, it is first essential to establish virus-free stocks of planting material Such material was introduced into northern Uganda However because of a shortage of ACMV-free stems farmers planted the new cuttings either adjacent to or mixed with the original heavily infected stands Rapid infection of the new crops occurred and within 10 months all fields were again severely affected It is necessary to select, multiply and distribute virus-resistant varieties in ACMV-epidemic areas of Uganda

Activity 5 5 Improvment of ACMV-resistant varieties

In the severe ACMV epidemic conditions prevalent over much of Uganda, IITA ACMV-resistant varieties, such as 30572, have been shown to provide good yields, whereas local varieties produced virtually nothing

In South America there has already been some success in developing cassava varieties with resistance to whiteflies At CIAT more than 3000 cassava cultivars, mostly land races or traditional farmers' varieties, have been evaluated in the laboratory and field, for resistance to *Aleurotrachelus socialis*, the major whitefly species causing yield losses in cassava South America (Bellotti *et al* , 1983, Bellotti & Vargas, 1991) Moderate to high levels of resistance have been identified and germplasm is available for breeding programs and for evaluating resistance to other whitefly species, such as *Bemisia tabaci*

Most breeding programs have emphasized either insect pest resistance or virus resistance Exchange of germplasm between IITA and CIAT would allow breeding to follow a novel strategy of combining both pest and virus resistance Of particular interest are recent reports that *Bemisia tabaci* is reproducing on cassava in Cuba and Mexico *Bemisia tabaci* has not been known to reproduce on cassava in the Americas (Costa & Russell, 1976) If a new biotype of *Bemisia* is moving onto cassava in the Americas, then the introduction of ACMV resistance into American cassava varieties would be a prudent and important step towards the solution of any problem that may arise

Activity 5 6 Epidemiological monitoring for ACMV

In Uganda, plots of "healthy" cassava will be planted at a number of localities along two north-south transects running across the apparent "front" of a severe ACMV epidemic Patterns of ACMV spread into these plots and whitefly populations will be monitored, as will the disease incidence in farmers' cassava fields surrounding the experimental plots Results from this epidemiological work, which will be repeated twice a year for a period of three years, when combined with molecular characterization of whiteflies and virus isolates, should contribute towards an explanation for the severity and apparent southwards expansion of the current cassava mosaic epidemic in Uganda

The second group of studies will aim to examine differences in the rate of spread of ACMD into plots of disease-free cassava in different countries and agro-ecologies It will be coordinated by ESCARC and ESCaPP and conducted in Ghana, Benin, Nigeria, Cameroon, Uganda, Kenya and Tanzania A standard set of cassava varieties will be planted in each of the main cassava-producing agro-ecologies in each country, and rates of spread of ACMD and whitefly numbers will be compared Characterization of whitefly and virus samples collected from trial sites, collection of meteorological data and monitoring of incidence of cassava mosaic in surrounding fields should facilitate the explanation of differences in rates of spread observed Information obtained from these studies should help to determine the most appropriate intervention measures, both for countries affected and threatened by the Ugandan ACMD epidemic and elsewhere, where ACMD is prevalent

Figure 6 Chronogram of Activities

Project Outputs and Activities	* PD	Year 1 - 1997 Q1	Year 1 - 1997 Q2	Year 1 - 1997 Q3	Year 1 - 1997 Q4	Year 2 - 1998 Q1	Year 2 - 1998 Q2	Year 2 - 1998 Q3	Year 2 - 1998 Q4
1 0 International network for WFs and WTVs in the tropics established									
1 1 Development of an electronic conference		■							
1 2 Creation of a project homepage on the INTERNET WWW		■							
1 3 Standardization of methodologies for activities in Outputs 2 & 4		■							
1 4 Publication of a bibiliography of the grey literature on WFs and WTVs					■				
1 5 Publication of WF & WTV researcher directory					■				
1 6 Dissemination of project research results through CG System								■	■
2 0 Socio-economic and environmental impact assessed									
2 1 Identification of WF and WTV affected areas			■	■	■				
2 2 Estimation of yield losses due to WFs and WTVs on affected areas			■	■	■				
2 3 Determination of WF related crop protection costs and crop production in affected areas			■	■	■				
2 3 Survey of pesticide use against WFs and WTVs			■	■	■				
2 5 Determination of insecticide resistant levels			■	■	■				
2 6 Identification of agricultural policies and policy environment			■	■	■				
3 0 Epidemiological characterization initiated									
3 1 Identification of WF reporductive hosts WF species and biotypes			■	■	■	■	■	■	
3 2 Identification of of WF species and biotypes			■	■	■	■	■	■	
3 3 Identification of WTVs in affected areas			■	■	■	■	■	■	
3 4 Identification of effficient natural enemies			■	■	■	■	■	■	

* *Previously Done*

Project Outputs and Activities	*	Year 1 - 1997				Year 2 - 1998			
	PD	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
4.0 Agronomic characterization initiated									
4.1 Characteization of cropping systems patterns and intensity			■	■	■				
4.2 Characterization of crop varieties and agronomic patterns			■	■	■				
4.3 Characterization of agroecology and agrometeorology of targetr regions			■	■	■				
5.0 Preliminary studies for Phase 2 conducted									
5.1 Development of GIS			■	■	■	■	■	■	
5.2 Conducting of critical area analysis using GIS							■	■	
5.3 Conducting of preliminary quantitative analyses of WTV pathosystems			■	■	■	■	■	■	
5.4 Production of ACMV-free planting stock for Uganda			■	■	■	■	■	■	
5.5 Improvement of ACMV resistant varieties			■	■	■	■	■	■	
5.4 Epidemiological monitoring for ACMV			■	■	■	■	■	■	

* *Previously Done*

4.0 Project Management: (see Figure 7)

Responsibilities and Activities

Cross-project scientific support and coordination

This project will be managed within the framework of the CG Inter-Center Whitefly IPM Project, Sustainable Integrated Management of Whiteflies as Pests and Vectors of Plant Viruses in the Tropics CIAT has been designated as convening center for this Inter-Center Project and, as such, will serve as overall coordinator and executing agency for the DANIDA Phase I Project, assuming responsibility for progress reporting to DANIDA Structurally the Whitefly IPM Project will fall under the umbrella of the CIAT Pest and Disease Mangement Unit (Dr Anthony Bellotti, Leader) The project will be coordinated and overseen by a Project Coordinator (to be hired)

At the Task Force Meeting held at CIAT, Cali, Colombia, from February 13-15, CG-scientist coordinators for each of the sub-projects were also proposed, and have since been approved by their home institutions Sub-project coordinators will be responsible for coordinating and overseeing activities within their sub-project, ensuring that agreed-upon methodologies are respected, allocating and administering the funding necessary to carry out those activities and coordinating activities with the Project Leader and Project Coordinator

The Work Breakdown Structure of the Phase I of the Whitefly IPM Project is presented in Figure 7

Coordination and structure of Sub-project 1

Coordination of Sub-project
Centro Internacional de Agricultura Tropical (CIAT), Colombia,
Dr Cesar Cardona (Entomologist)

National Agricultural Research System Participation
Corporacion Colombiana de Investigacion Agropecuaria (CORPOICA), Colombia,
Dr Aristobulo Lopez-Avila
Instituto Nacional Autonomo de Investigaciones Agropecuarias (INIAP), Ecuador,
Ing Oswaldo Valarezo
Instituto Superior de Agricultura (ISA), Dominican Republic,
Dr Colmar Serra

Coordination and structure of Sub-project 2

Coordination of Sub-project
Centro Internacional de Agricultural Tropical (CIAT), Colombia,
Dr Francisco Morales (Virologist)

Regional Coordinators
Centro Agronomica Tropical de Investigacion y Enseñza (CATIE), Costa Rica,
Dr Luko Hilje, Central American and Caribbean Whitefly Network Coordinator
Centro de Investigacion y de Estudios Avanzados (CINESTAV), Mexico,
Dr Rafael Rivera-Bustamante
Instituto Superior de Agricultura (ISA), Dominican Republic,
Dr Colmar Serra
Programa de Frijol Centro Americano (PROFRIJOL), Guatemala,
Dr Rogelio Lepis, Coordinator

National Agricultural Research System Participation
Instituto de Investigaciones de Sanidad Vegetal (IISV), Cuba,
Dr Gloria Gonzalez
Programa de Frijol de Haiti (PRONATHAR), Haiti,
Ing Emanual Profete
Instituto de Investigaciones Forestales y Agropecuarias (INIFAP), Mexico,
Ing Ernesto Lopez
Ing Rafael Salinas
Instituto de Ciencia y Tecnologia Agricola (ICTA), Guatemala,
Dr Victor Salguero
National Plant Protection Service (NPPS), Belize,
Ing Orlando Sosa
Escuela Panamericana (EAP), El Zamorano, Honduras,
Dr Allan Hruska
Centro Nacional de Tecnologia Agropecuaria (CENTA), El Salvador,
Ing Joaquin Larios
Universidad Nacional Agraria (UNA), Nicaragua,
Ing Gregorio Varela

Advanced Research Institute Participation
University of Arizona-Tucson (UA), USA
Dr Judith Brown
University of Florida (UFL), USA
Dr Jane Polston
University of Wisconsin-Madison (UW), USA,
Dr Douglas Maxwell

Coordination, structure and responsibilities within Sub-project 3

Coordination of Sub-project
International Center for Insect Physiology and Ecology (ICIPE), Kenya,
Dr Srinivasan Sithanantham (Entomologist)

Other CGCenter Participation
Asian Vegetable Research and Development Center (AVRDC), Tanzania,
Dr Remi Nomo-Wodim (Virologist)

National Agricultural Research System Participation
Agricultural Research Corporation (ARC), Sudan,
Dr M A Ahmed (Entomologist)
Kenya Agricultural Research Institute (KARI), Kenya,
Mr Davis Thou
Horticultural Research and Training Institute (HORTI), Tanzania,
Mr Ignas S Swai
Bvumbwe Agricultural Research Station (BARS), Malawi
Mr Patrick T Khonje

Advanced Research Institute Participation
John Innes Center (JIC) United Kingdom,
Dr Peter Markham

Coordination and structure of Sub-project 4

Coordination of Sub-project
International Institute of Tropical Agriculture (IITA), Uganda,
Dr James Legg (Virologist)

Other CG Center Participation
Centro Internacional de la Papa (CIP), Uganda,
Dr Nicole Smit

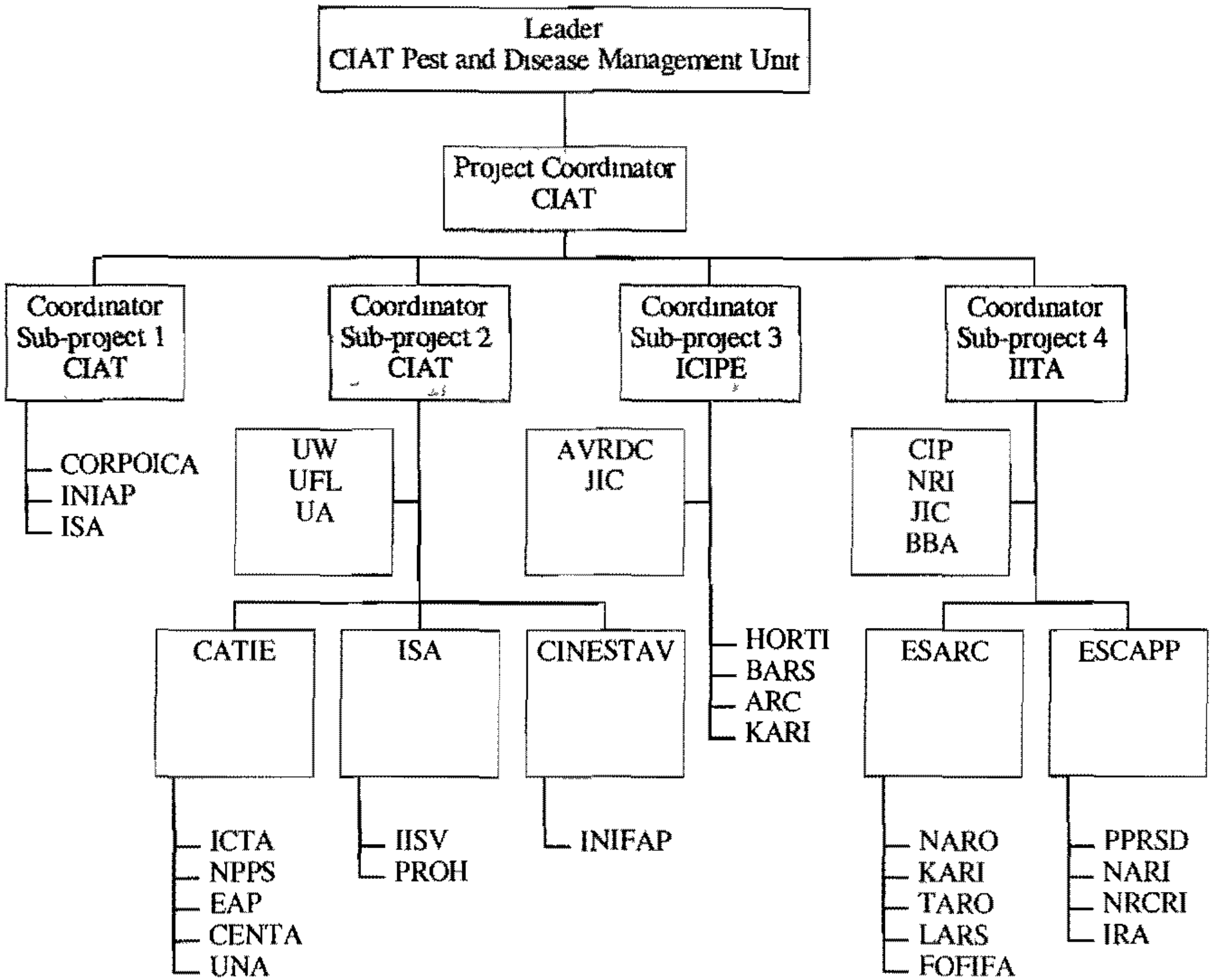
Regional coordinators
International Institute of Tropical Agriculture (IITA), Benin,
Dr Braima James

National Agricultural Research System Participation
National Agricultural Research Organization (NARO), Uganda,
Dr William George Otime-Nape
Plant Protection and Regulatory Services Division (PPRSD), Ghana,
Dr Anthony Cudjoe

National Root Crop Research Institute (NRCRI), Nigeria,
Dr T N C Echendu
National Agricultural Research Institute of Benin (NARI), Benin,
Dr N G Maroya
Agricultural Research Institute (IRA) Cameroon,
Dr J Ambe Tumanteh
Kenya Agricultural Research Institute (KARI), Kenya
Dr Joseph Kamau
Tanzania Agricultural Research Organization (TARO), Tanzania,
Dr Regina Kapinga
Lunyangwa Agricultural Research Station (LARS), Malawi,
Dr Jonathan Mkumbira
Centre National de la Recherche Apliquee au Developpement Rural (FOFIFA), Madagascar,
Dr Sahondramalala Ranomenjanahary

Advanced Research Institute Participation
Natural Resources Institute (NRI), United Kingdom,
Dr Michael Thresh
Dr John Colvin
Biologische Bundesanstalt fur land und Fortwirtschaft (BBA), Germany,
Dr J Vetten

Figure 7 Project Management Organigram



5.0 Budget:

The projected cost of Phase I is estimated at US $1,386 327 over 2 years (see Table 8 for budget summary) Funds are allocated among 5 CG Centers, 25 national program institutions in 22 countries of Latin America and Africa, and 6 advanced research institutions (see Appendix A for a list of participating institutions)

Budgets for sub-projects 1 - 4 are presented in Tables 9-12, respectively Field-based activities (Outputs 2 3 4) to be carried out by the national program institutions will require temporary workers, national travel, supplies and vehicle operations costs Necessary virus identifications for each sub-project will be carried out by the IARCS, in conjunction with ARIs where necessary International travel allowances have been allocated to the sub-project regional coordinators in order to provide necessary backstopping for field-based activities Variations in allocations to national institutions reflect variations in the size of the country, in-country travel and labor costs Additional funding has been allocated to Uganda for the development of ACMV-free planting stock and continued improvement of resistant varieties

Given the collaborative nature of this project and the network-building component (Output 1), a separate budget for cross-project scientific support is also presented (Table 13) This budget covers setting up and moderating an electronic conference for all project participants, creating and updating the WWW Homepage, organizing the regional and coordinators' workshops for methodology standardization, compiling and publishing the Directory of WF and WTV researchers, and the grey literature bibliography, and editing and publishing the final publication The budget covers the personnel and supplies for processing and identification of whitefly species and natural enemies as well as biotyping activities, for sub-projects 1 and 2 Honoraria are allocated for expert verification of insect specimen Funding for these later activities to be coordinated for sub-project 3 and 4 has been included in the sub-project 3 budget, coordinated by ICIPE

As explained previously in Section 4 , CIAT will assume overall coordination, i e , communication, logistical coordination administration and reporting, for Phase I A budget to run the coordination office is presented in Table 14

The indirect costs are calculated at 13% for all monies allocated to CIAT, 10% for monies transfered to ICIPE, and 4% for monies transfered to other CG Centers, NARS and ARIs

Table 8 Budget Summary (US $)

Sustainable Integrated Management of Whiteflies as Pests and Vectors of Plant Viruses in the Tropics

Item	Year 1	Year 2	Total
Sub project 1	94,924	71 900	166 824
Sub-project 2	148,000	126,500	274 500
Sub project 3	151 000	123 000	274,000
Sub project 4	99,430	102 570	202 000
Cross project	111,172	74 422	176 827
Coordination	80 405	79 422	159 827
Sub-total	684931	577814	1,253 978
Indirect costs			132 349 124,110
Total			1 386 327

Table 9 Budget for Sub-project 1
Sustainable Integrated Management of Whiteflies as Pests and Vectors of Plant Viruses in the Tropics

Item	Year 1				Year 2				Total
	CIAT	CORPOICA	INIAP	ISA	CIAT	CORPOICA	INIAP	ISA	
PERSONNEL									
• Support Staff	23 924				25 700				49 624
TOTAL PERSONNEL	**23,924**				**25,700**				**49,624**
TRAVEL									
• National	14 000	14 400	5 700	500	5 000	6 000	3 500	500	49 600
• International	2 400	2 500			1 000	1 500			7 400
TOTAL TRAVEL	**16,400**	**16,900**	**5,700**	**500**	**6,000**	**7,500**	**3,500**	**500**	**57,000**
OPERATIONS									
• Supplies and services	2 500	5 000	1 000	500	3 500	5 000	3 100	500	21 100
• Vehicle operations	7,500	7 500	2 000	500	4 000	4 000	2 600	500	28 600
• GIS services	5,000				5 500				10 500
TOTAL OPERATIONS	**15,000**	**12,500**	**3,000**	**1,000**	**13,000**	**9,000**	**5,700**	**1,000**	**60,200**
INSTITUTION TOTALS	**55,324**	**29,400**	**8,700**	**1,500**	**44,700**	**16,500**	**9,200**	**1,500**	
TOTAL BUDGET SUB-PROJECT 1				**94,924**				**71,900**	**166,824**

Table 10 Budget for Sub-project 2 Sustainable Integrated Management of Whiteflies as Pests and Vectors of Plant Viruses in the Tropics

ITEM	CIAT VRU	CIAT GIS	CATIE	CINESTAV	ISA	PRO FRIJOL	IISV	PRONAH
Year 1								
PERSONNEL								
• Support Staff	18 000	17 500						
TOTAL PERSONNEL	**18 000**	**17 500**						
TRAVEL								
National			1 500	3 000	1 000	2 000	1 500	1 000
• International	15 000		5 000		4 000			
TOTAL TRAVEL	**15 000**		**6 500**	**3 000**	**5,000**	**2 000**	**1 500**	**1 000**
OPERATIONS								
• Supplies and services	10 000	7 500	2 500	2 000	2 500	3 000	500	500
• Vehicle operations								
TOTAL OPERATIONS	**10 000**	**7 500**	**2 500**	**2 000**	**2 500**	**3 000**	**500**	**500**
INSTITUTIONAL DEVELOPMENT								
• Materials dev	3 000							
• Info dissemination	1 500							
TOTAL INST DEV	**4,500**							
Year 2								
PERSONNEL								
• Support Staff	19 500	35 000						
TOTAL PERSONNEL	**19 500**	**35 000**						
TRAVEL								
• National			1 500	3 000	1 000	2 000	1 500	1 000
• International	15 000		5 500		4 000			
TOTAL TRAVEL	**15 000**		**7,000**	**3 000**	**5 000**	**2 000**	**1 500**	**1 000**
OPERATIONS								
• Supplies and services	10 000	10 000	2 500	2 000	2 500	3 000	500	500
• Vehicle operations								
TOTAL OPERATIONS	**10 000**	**10 000**	**2 500**	**2 000**	**2 500**	**3 000**	**500**	**500**
INSTITUTIONAL DEVELOPMENT								
• Materialdevelopment	3 000							
Info dissemination	1 500							
TOTAL INST DEV	**4 500**							
TOTALS (YR 1 & 2)	**96 500**	**70 000**	**18 000**	**10 000**	**15 000**	**10 000**	**4 000**	**3 000**
TOTAL BUDGET								

ITEM	INIFAP	ICTA	MAG	EAP	CENTA	UNA	UA	UW	UFL
Year 1									
PERSONNEL									
• Support Staff				2 500					
TOTAL PERSONNEL				**2 500**					
TRAVEL									
National	2 500	1 500	700	1 500	1 000	1 500			
• International									
TOTAL TRAVEL	**2 500**	**1 500**	**700**	**1 500**	**1 000**	**1 500**			
OPERATIONS									
• Supplies and services	1 000	500	300	1 000	500	500	3 000	3 000	3 000
• Vehicle operations									
TOTAL OPERATIONS	**1 000**	**500**	**300**	**1 000**	**500**	**500**	**3 000**	**3 000**	**3 000**
INSTITUTIONAL DEVELOPMENT									
• Materials dev									
• Info dissemination									
TOTAL INST DEV									
Year 2									
PERSONNEL									
• Support Staff				2 500					
TOTAL PERSONNEL				**2,500**					
TRAVEL									
• National	2 500	1 500	700	1 500	1 000	1 500			
• International									
TOTAL TRAVEL	**2 500**	**1 500**	**700**	**1,500**	**1 000**	**1 500**			
OPERATIONS									
• Supplies and services	1 000	500	300	1 000	500	500	3 000	3 000	3 000
• Vehicle operations									
TOTAL OPERATIONS	**1 000**	**500**	**300**	**1 000**	**500**	**500**	**3,000**	**3 000**	**3 000**
INSTITUTIONAL DEVELOPMENT									
• Materialdevelopment									
Info dissemination									
TOTAL INST DEV									
TOTALS (YR 1 & 2)	**7 000**	**4 000**	**2 000**	**10 000**	**3 000**	**4 000**	**6 000**	**6 000**	**6 000**
TOTAL BUDGET									**274 500**

Table 11 Budget for Sub-project 3 Sustainable Integrated Management of Whiteflies as Pests and Vectors of Plant Viruses in the Tropics

Item	ICIPE	AVRDC	ARC	KARI	HORTI	BARS	JIC	TOTAL
Year 1								**Yr 1**
PERSONNEL								
• Support Staff	32 000						17 500	49 500
• Temporary	3 000	500	1 000	1 000	1 000	1 000		7 500
• Honoraria	10 000	2 000						12 000
TOTAL PERSONNEL	**45 000**	**2 500**	**1 000**	**1 000**	**1 000**	**1 000**	**17 500**	**69 000**
TRAVEL								
• National	3 000	1 000	2 500	2 500	2 500	2 500		14 000
• International	10 000	3 500						13 500
TOTAL TRAVEL	**13 000**	**4 500**	**2 500**	**2 500**	**2 500**	**2 500**		**27 500**
OPERATIONS								
• Supplies and services	6 000	2 000	1 500	1 500	1 500	1 500	5 000	19 000
• Vehicle operations	6 000	1 500	1 500	1 500	1 500	1 500		13 500
TOTAL OPERATIONS	**12 000**	**3 500**	**3 000**	**3 000**	**3 000**	**3 000**	**5,000**	**32 500**
INSTITUTIONAL DEVELOPMENT								
• Workshops	13 000							13 000
• Document Acquisitions	2 000							2 000
TOTAL INST DEVELOPMENT	**15,000**							**15 000**
CAPITAL								
• Office	7 000							7 000
TOTAL CAPITAL	**7 000**							**7 000**
Total Budget Yr 1	**92 000**	**10 500**	**6 500**	**6 500**	**6 500**	**6 500**	**22 500**	**151 000**
Year 2								**Yr 1 & 2**
PERSONNEL								
• Support Staff	35 000						18 500	103 000
• Temporary	3 000	500	1 000	1 000	1 000	1 000		15 000
• Honoraria	8 000	2 000						22 000
TOTAL PERSONNEL	**46 000**	**2,500**	**1 000**	**1 000**	**1,000**	**1 000**	**18 500**	**140 000**
TRAVEL								
• National	3 000	1 000	1 500	1 500	1 500	1 500		24 000
• International	8 000	3 500						25 000
TOTAL TRAVEL	**11 000**	**4 500**	**1 500**	**1 500**	**1 500**	**1,500**		**53 000**
OPERATIONS								
• Supplies and services	5 000	2 000	1 500	1 500	1 500	1 500	5 000	37 000
• Vehicle operations	5 000	1 500	1 500	1 500	1 500	1 500		26 000
TOTAL OPERATIONS	**10 000**	**3 500**	**3 000**	**3 000**	**3 000**	**3 000**	**5 000**	**63 000**
TOTAL BUDGET	**159,000**	**21 000**	**12 000**	**12 000**	**12 000**	**12 000**	**46 000**	**274 000**

Table 12 Budget for Sub-project 4 Sustainable Integrated Management of Whiteflies as Pests and Vectors of Plant Viruses in the Tropics

ITEM	ESA RC	ESCaPP	CIP	CIAT	PPRSD	NRCRI	INRAB	IRA	NARO	TARO	KARI	LARS	FOFIFA	NRI	BBA	TOTAL
Year 1																Yr 1
PERSONNEL																
• Senior Staff																
• Support Staff	5 280								1 000					2 400		8 680
• Temporary					300	300	300	300	300	300	300					2 100
TOTAL PERSONNEL	**5 280**				**300**	**300**	**300**	**300**	**1 300**	**300**	**300**			**2 400**		**10 780**
TRAVEL																
• National	3 000	700	3 500		3 500	3 500	3 500	3 500	6 000	4 700	3 500			1 000		36 400
• International	3 250	3 650												5 000		11 900
TOTAL TRAVEL	**6 250**	**4 350**	**3 500**		**3 500**	**3 500**	**3 500**	**3,500**	**6 000**	**4 700**	**3 500**			**6,000**		**48 300**
OPERATIONS																
• Supplies and services	1 700			4 000	700	700	700	700	4 000	700	700			500	6 000	20 400
• Vehicle operations	3 000	3 000			1 500	1 500	1 200	2 250	3 000	1 500	1 500			1 500		19 950
TOTAL OPERATIONS	**4 700**	**3 000**		**4 000**	**2 200**	**2,200**	**1 900**	**2 950**	**7 000**	**2 200**	**2 200**			**2 000**	**6 000**	**38 850**
Year 2																Yrs 1 & 2
PERSONNEL																
• Senior Staff																
• Support Staff	6 280	3 600			1 000	1 600	900	1 800	2 000	1 000	1 000			2 400		30 260
• Temporary	300	300			300	500	300	450	500	300	300					5 350
TOTAL PERSONNEL	**6 580**	**3 900**			**1 300**	**2 100**	**1 200**	**2 250**	**2 500**	**1 300**	**1,300**			**2,400**		**35,610**
TRAVEL																
• National	1 500	700	3 000		2 000	3 500	2 000	5 000	5 000	4 500	2 000	3 500	3 500	1 000		73 600
• International	5 450	3 650							1 000					5 000		27 000
TOTAL TRAVEL	**6 950**	**4 350**	**3 000**		**2 000**	**3 500**	**2 000**	**5,000**	**6 000**	**4 500**	**2 000**	**3,500**	**3 500**	**6 000**		**100 600**
OPERATIONS																
Supplies and services	1 500			3 000	20	30	20	30	4 000	20	20	700	700	500		30 940
• Vehicle operations	3 000	3 000			300	450	300	650	1 500	1 200	750	750	1 500	1 500		34 850
TOTAL OPERATIONS	**4 500**	**3,000**		**3 000**	**320**	**480**	**320**	**680**	**5 500**	**1 220**	**770**	**1,450**	**2 200**	**2 000**		**65 790**
TOTAL BUDGET SUB PROJECT 4	**34 260**	**18 600**	**6 500**	**7 000**	**9 620**	**12 080**	**9 220**	**14,680**	**28 300**	**14 220**	**10 070**	**4 950**	**5 700**	**20 800**	**6 000**	**202 000**

Table 13 Budget for Cross-Project Scientific Support

Item	Year 1	Year 2	TOTAL
PERSONNEL			
Support Staff	39 922	42 716	82 638
Honoraria	5 000	5 000	10 000
Total Personnel	**44 922**	**47 716**	**92 638**
OPERATIONS			
Supplies and services	14 250	14 250	28 500
Total Operations	**14 250**	**14 250**	**28 500**
PROJECT DEVELOPMENT			
Workshops	40 000		40 000
Materials development	2 000	13 000	15 000
Total Project Development	42 **52 000**	**13 000**	**55 000**
TOTAL	101 172 **111 172**	**74 966**	**176 138**

Table 14 Budget for Project Coordination

Item	Year 1	Year 2	TOTAL
PERSONNEL			
Senior Staff	57 140	61 150	118 290
Clerical Staff	8 665	9 272	17 937
Total Personnel	**65 805**	**70 422**	**136 227**
TRAVEL			
International	6 000	6 000	12 000
Total Travel	**6 000**	**6 000**	**12 000**
OPERATIONS			
Supplies and services	3 500	3 000	6 500
Total Operations	**3 500**	**3 000**	**6 500**
CAPITAL			
Office	5 100		5 100
Total Capital	**5 100**		**5 100**
TOTAL	**80 405**	**79 422**	**159 827**

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Appendix A Participating Institutions and Collaborating Scientists

International Agricultural Research Centers (IARCs)

Centro Internacional de Agricultura Tropical (CIAT)
Dr Anthony Bellotti (Entomologist)
Dr Cesar Cardona (Entomologist)
Dr Francisco Morales (Virologist)
Dr Lee Calvert (Virologist)
Apartado 6713
Cali, COLOMBIA

International Center for Insect Physiology and Ecology (ICIPE)
Dr Srinivasan Sithanantham (Entomologist)
P O Box 30772
Nairobi, KENYA

Asian Vegetable Research and Development Center (AVRDC)
Dr Remi Nomo-Wodim (Virologist)
Arusha, TANZANIA

International Institute for Tropical Research (IITA)
Dr James Legg (Virologist)
P O Box 7878
Kampala, UGANDA
Dr Braima James
PB 08-0932
Cotonou, BENIN

Centro Internacional de la Papa (CIP)
Dr Nicole Smit
c/o IITA
P O Box 7878
Kampala, UGANDA

National Agricultural Research Systems (NARS)

In Latin America
Instituto Superior de Agricultura (ISA)
Dr Colmar Serra
Avenida Presidente Antonio Guzman, Km 55
Apartado 166
Santiago, REPUBLICA DOMINICANA

Instituto de Investigaciones de Sanidad Vegetal (IISV)
Dr Gloria Gonzalez
Calle 110 #514 e/5taB y 5taF
Playa CP 11600
Havana, CUBA

Programa de Frijol de Haiti (PRONATHAR)
Ing Emmanuel Prophete
Post Box 121
Port-au-Prince, HAITI

Centro de Investigacion y de Estudios Avanzados (CINVESTAV)
Dr Rafael Rivera-Bustamante
P O Box 629
Km 9 6 Libr Norte Carr Irapuato-Leon
Irapuato, Guanajuato, MEXICO

Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP)
Ing Ernesto Lopez
Programa de Frijol
Veracruz, MEXICO
Ing Rafael Salinas
Campo Experimental "Valle del Fuerte"
Sinaloa, MEXICO

Programa de Frijol Centro Americano (PROFRIJOL)
Dr Rogelio Lepis
Oficina IICA
Primera Avenida 8-00
Zona 9
Guatemala, GUATEMALA

Instituto de Ciencia y Tecnologia Agricola (ICTA)
Dr Victor Salguero
Avenida de Reforma 8-60
Zona 9
Guatemala, GUATEMALA

National Plant Protection Service (NPPS), Ministry of Agriculture
Ing Orlando Sosa
Central Farm
Cayo District, BELIZE

Escuela Agricola Panamericana (EAP)
Dr Allan Hruska
Departamento de Proteccion Vegetal
ZAMORANO
Apartado 93
Tegucigalpa, HONDURAS

Centro Nacional de Tecnologia Agropecuaria (CENTA)
Ing Joaquin Larios
Apartado 773
San Salvador, EL SALVADOR

Universidad Nacional Agraria (UNA)
Ing Gregorio Varela
Km 12 1/2 Carr Norte
Apartado 453
Managua, NICARAGUA

Centro Agronomica Tropical de Investigacion y Enseñza (CATIE)
Dr Luko Hilje
Apartado 7170
Turrialba, COSTA RICA

Corporacion Colombiana de Investigacion Agropecuaria (CORPOICA),
Dr Aristobulo Lopez-Avila (Entomologist)
Apartado Aereo 240142 Las Palmas
Santafe de Bogota, COLOMBIA

Instituto Nacional Autonomo de Investigaciones Agropecuarias (INIAP)
Ing Oswaldo Valarezo
Casilla Postal 100
Portoviejo, Manabi, ECUADOR

In Africa
Plant Protection and Regulatory Services Division (PPRSD)
Anthony Cudjoe
P O Box M37
Accra, GHANA

Institut National de Recherche Agronomique du Benin (INRAB)
N G Maroya
BP 884
Cotonou, BENIN

National Root Crop Research Institute (NRCRI)
T N C Echendu
PMB 7006
Umdike, Umuahia
Abia State, NIGERIA

Institut de Recherche Agronomique (IRA)
J Ambe Tumanteh
IRA Ekona
PMB 25, Buea, CAMEROON

Agricultural Research Corporation (ARC)
Dr M A Ahmed (Entomologist)
P O Box 126
Wad-Medani, SUDAN

National Agricultural Research Organization (NARO)
Dr William George Otime-Nape
P O Box 7084
Kampala, UGANDA

Kenya Agricultural Research Institute (KARI)
Dr Joseph Kamau
NDFRC, Katumani
P O Box 340
Machakos, KENYA

Tanzania Agricultural Research Organization (TARO)
Dr Regina Kapinga
Ukiriguru ARI
P O Box 1433
Mwanza, TANZANIA

Horticultural Research and Training Institute (HORTI)
Mr Ignas S Swai
P O 1253
Arusha, TANZANIA

Lunyangwa Agricultural Research Station (LARS)
Dr Jonathan Mkumbira
P O Box 59
Mzuzu, MALAWI

Bvumbwe Agricultural Research Station (BARS)
Mr Patrick T Khonje
P O Box 5748
Limbe, MALAWI

Centre National de la Recherche Apliquee au Developpement Rural (FOFIFA)
Dr Sahondramala La Ranomenjanahary
BP 1690
Antananarivo, MADAGASCAR

Advanced research institutes (ARIs)

Biologische Bundesanstalt fur land und Fortwirtschaft (BBA)
Dr J Vetten
Messeweg 11/12
D - 38104 Braunschweig, GERMANY

John Innes Centre (JIC)
Dr Peter Markham
Department of Virus Research
Colney Lane
Norwich, Norfolk NR4 7UH
United Kingdom

Natural Resources Institute (NRI)
Dr Michael Thresh
Dr John Colvin
Central Avenue
Chatam Maritime
Chatam, Kent, ME4 4TB
United Kingdom

University of Arizona-Tucson (UA)
Dr Judith Brown
Department of Plant Sciences
Tucson, AZ 85721
USA

University of Florida (UFL)
Dr Jane Polston

5007 60th St E
Bradenton, FL 34203
USA

University of Wisconsin-Madison (UW)

Dr Douglas Maxwell
Department of Plant Pathology
1630 Linden Dr
Madison, WI 53706-1598
USA