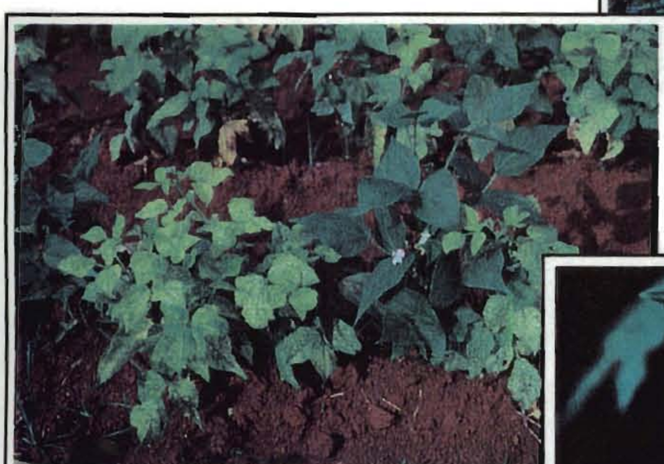
Sustainable Integrated Management of Whiteflies as Pests and Vectors of Plant Viruses in the Tropics



Progress Report

CIAT
Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

SUSTAINABLE INTEGRATED MANAGEMENT OF WHITEFLIES AS PESTS AND VECTORS OF PLANT VIRUSES IN THE TROPICS

DANIDA PROJECT

PHASE 1:
NETWORK FORMATION, DIAGNOSIS AND ANALYSIS FOR INTEGRATED PEST MANAGEMENT OF WHITEFLIES IN THE TROPICS

PROGRESS REPORT
AUGUST 1998

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LIST OF ACRONYMS

ACIAR	Australian Center for International Agricultural Research
ACMD	African cassava mosaic disease
ACMV	African cassava mosaic virus
ARI	Advanced Research Institute
AVRDC	Asian Vegetable Research and Development Center
BBA	Biologische Bundesanstalt fur Land- und Fortwirtschaft (Germany)
BGMV	bean golden mosaic virus
BMZ	Der Bundeministerium fur Wirtschaftliche Zusammenarbeit und Entwicklung (Germany)
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza (Costa Rica)
CdTV	chino del tomate virus
CGIAR (CG)	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical (Colombia)
CIP	Centro Internacional de la Papa (Peru and Uganda)
CINESTAV	Centro de Investigación y de Estudios Avanzados (Mexico)
CORPOICA	Corporación Colombiana de Investigación Agropecuaria
Danida	Danish International Development Agency
EACMV	East African cassava mosaic virus
EMBRAPA	Empresa Brasilera de Pesquisa Agropecuaria
ELISA	enzyme-linked immunosorbent assay
ESARC	Eastern and Southern Africa Regional Centre
ESCaPP	Ecologically Sustainable Cassava Plant Protection Project
FPR	Farmer Participatory Research
GIS	Geographic Information System
GTZ	Gesellschaft fur Technische Zusammenarbeit (Germany)
FAO	Food and Agricultural Organization of the United Nations (Italy)
IARC	International Agricultural Research Center
ICIE	International Center for Insect Physiology and Ecology (Kenya)
IDB	International Development Bank
INISAV	Instituto de Investigaciones de Sanidad Vegetal (Cuba)
IITA	International Institute of Tropical Agriculture (Uganda)
INEGI	Instituto Nacional de Estadística, Geografía e Información (Mexico)
INIAP	Instituto Nacional Autónomo de Investigaciones Agropecuarias (Ecuador)
INIFAP	Instituto de Investigaciones Forestales y Agropecuarias (Mexico)
IPM	Integrated Pest Management
JIC	John Innes Centre (UK)
MFAT	Ministry of Foreign Affairs and Trade (New Zealand)
NARO	National Agricultural Research Organization (Uganda)
NARS	National Agricultural Research System
NORAD	Norweigan Agency for Development
NPPS	National Plant Protection Service (Belize)
OFDA	Office of Foreign Disaster Assistance (of the USAID)
PAGE	polyacrylamide gel electrophoresis

PCR	polymerase chain reaction
PROFRIJOL	Programa de Frijol Centro Americano
REDCAHOR	Red Colaborativo de Investigación y Desarrollo de Hortalizas para América Central, Panamá y República Dominicana
SP-IPM	Systemwide Programme on Integrated Pest Management
SPCSV	sweet potato chlorotic stunt virus
SPFMV	sweet potato feather mottle virus
SPMMV	sweet potato mild mottle virus
SPVD	sweet potato virus disease
SWP	sweet potato
TYLCV	tomato yellow leaf curl virus
USAID	United States Agency for International Development
UV	Uganda variant of African cassava mosaic virus
WF	whitefly
WTV	whitefly-transmitted virus

EXECUTIVE SUMMARY

In March of 1996, the Danish International Development Agency (Danida) invited CIAT to submit a proposal for the start-up phase (Phase 1) of the Whitefly IPM Project. Phase 1 focuses on the formation of a network of professionals working on whiteflies, whitefly-transmitted viruses and crop management for these pests in the Tropics; and the establishment of a collaborative research agenda by which whitefly problems in the Tropics can be better characterized. The objective 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/virus research should be carried out, and what research should be prioritized.

Geographically, the Danida Project is carrying out work in 12 Latin American and 10 African countries, to better characterize:

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 and Southern Africa, and
4). Whiteflies as vectors of viruses in cassava and sweet potato in sub-Saharan Africa.

The Project funds, totaling US$1,200,000, were received by CIAT in March of 1997. During March and April 1997, the Project and Sub-project Coordinators revised the Coordination and Sub-project budgets. From April toAugust, 1997, Memoranda of Understanding were written and signed between the collaborating CGIAR centers, and NARS, to formalize the working relations of this Project. Project funds were transferred to IITA and ICIPE in late August 1997, and subsequently to NARS of all sub-projects. Project operations began in October - November 1997.

Thus, the information in this progress report represents the efforts of the past year. Understandably, due to factors such as time of cropping seasons and human resources availability, different activities are in different states-of-progress. Much of the field survey information is still being processed and analyzed. Nonetheless, significant progress has already been made in a short period of time.

Coordination. A document entitled "Standardization of Methods for Whitefly IPM Project Activities" was prepared by the Coordination Team, in consultation with other whitefly and geminivirus experts. The first draft of the Methodology Guide was completed in April of 1997, pilot-tested in Colombia and Uganda and modified accordingly. The Methodology Guide has been translated into Spanish, French and Portuguese and circulated to project partners. It is also being used by colleagues (e.g. Brazil) at present, not formally involved in the Whitefly IPM Project.

A World Wide Web homepage for the CGIAR Whitefly IPM Project, is being developed. The homepage will serve to inform the broader scientific community as to the progress and information being generated by the Project and link the Whitefly IPM Project homepage and to other WWW whitefly homepages. Specifically, the Web page will provide information on: the Whitefly IPM Task Force, the research projects contributing directly to the Project Work plan; a listing of the formal collaborators in the Project; the Standardization of Methods for Whitefly IPM Project activities, and the documentation project.

The documentation project consists of a searchable database of the grey literature and a directory of professionals working on whiteflies and whitefly-transmitted viruses, in the Tropics. A keyword list, compatible with the CABI Thesaurus, has been drawn up. Over 1100 citations of nonconventional literature (the grey literature) on whiteflies and whitefly-transmitted viruses in Latin America and Africa have been identified and obtained for introduction into the searchable database. To promote and facilitate communication among colleagues, a directory of professionals actively working on whiteflies and whitefly-transmitted viruses in the tropics is being compiled, to accompany the citations in the searchable database. At present, 375 professionals have been entered into the directory, based on information provided in the grey literature documents and workshop lists. Profiles are being mailed to colleagues to verify and update the information.

Subproject 1. Field survey work has been completed. Producer interviews are being analyzed. Preliminary findings point to several important conclusions. The dogma has been that *Bemisia* was found 0 to 1000 m and *Trialeurodes* above 1000 m, with numerous reports that *Bemisia tabaci* was expanding its range upwards. Survey work along altitudinal transects, from sea level to over 2500 m, showed that *Bemisia tabaci* is found from 0 to 920m, and *Trialeurodes vaporariorum* is found from 730m to 2740m. Many of the agricultural valleys in Colombia are found at the midaltitudinal levels (700-900 m) where mixed populations would be present. Based on these findings, altitudinal transects are also being carried out in Costa Rica and Tanzania.

Previously, the focus of research in the highlands has been the common bean (*Phaseolus vulgaris* L.). Field work surveying a broader range of crops verified that in the highlands common bean is the most important host of *Trialeurodes vaporariorum*, followed by tomatoes, and potatoes to a much lesser degree. Thus, a pest management focus of *Trialeurodes vaporariorum* on *Phaseolus vulgaris* for the Andean highland region is justified.

Subproject 2. Because of the production crises that whitefly-transmitted viruses have caused throughout Mexico, Central America and the Caribbean over the past two decades, there has been a tremendous amount of information generated and a large number of professionals involved in whitefly work in this region. Thus, the primary focus has been on gathering and analyzing existing information. More than 600 citations have been collected and are being analyzed. In addition, standardized field survey work has been completed in Guatemala and Honduras, and supplemental collections from throughout the region are being processed.

From literature analysis it is clear that there are at least 3 bean-infecting geminiviruses, 17 tomato-infecting geminiviruses, 3 pepper-infecting viruses and geminivirus detections in melons, and cotton. Preliminary results from the field surveys indicate that over 90% of the bean samples collected are infected by geminiviruses, but the detection rate for geminiviruses in horticultural crops is lower: only 75% and 35% of the samples collected for tomato and pepper, respectively are infected with geminiviruses. There are other plant viruses affecting horticultural crops, which the producers are confusing with geminiviruses. Conversely, newdetections of geminivirus in tobacco and soybean are being made. The B biotype of*Bemisia tabaci* is prevalent throughout the region.

A Geographic Information System for the region has been set up for the data frm Mexico, Central America and the Caribbean. Base maps (to the municipal level), and climatic maps have been completed. Development of crop use maps is advancing, but is slow due to the general lack of information on the geographical distribution of horticultural crops in the region. A separate database for the biological data (geminiviruses, whitefly species and biotypes, host plants, natural enemies) has been established. Once data from the literature and field surveys has been entered, this will be fed into the GIS.

Field work indicates that the diversity of IPM responses by the producers is much greater than originally anticipated and much more localized than expected (and it appears that the localization is a function of the research interests and biases of the local scientists/ agronomists/extension agents). A major step forward can be taken by gathering the diverse IPM tactics, and after epidemiological analysis, re-formulating them into a series of improved IPM packages that can be adapted depending upon the local socio-economic constraints. This can be done while needed research moves forward and continues to feed into the process of improved IPM options.

Subproject 3. As whitefly research is incipient at ICIPE, it was necessary to establish basic facilities and human resources for the Project work. A laboratory has been dedicated to the whitefly research, and a research team has been formed. ICIPE has also taken leadership in promoting the formation of an African Whitefly Network.

Field surveys have been initiated in all four partner countries. However, El Nino flooding severely affected the ability to access many sites. Survey work will continue in 1998. Nonetheless, preliminary findings are interesting.

Based on 354 whitefly collections, *Bemisia tabaci* is the most common whitefly species, but *Bemisia afer*, *Bemisia hirta*, *Aleyrodes proletella*, *Trialeurodes* *vaporariorum* and *Trialeurodes recini* were also found. More species of whitefly have been found to occur in the region than are been reported from the literature. The B biotype of *Bemisia tabaci* has been identified from Sudan.

Adults of Bemisia tabaci are commonly found on tomatoes, but do not reproduce on tomatoes, except in the Sudan. Identification of the most important reproductive hosts for *Bemisia tabaci* is a priority.

Bemisia-transmitted tomato yellow leaf curl virus (TYLCV) is found throughout the region. Perceived on-farm losses due to tomato geminiviruses were up to 40% in Malawi, 50% in Kenya, 75% in Tanzania and 100% in Sudan. Yield losses for tomatoes are high and often result in crop abandonment. Sudan suffers up to 75% crop loss, annually, in okra, watermelons/melons, peppers and *Vigna/Phaseolus* bean. Kenya and Tanzania are also finding problems on these crops, suggesting that the work should be expanded to include a mixed crop framework.

However, many of the virotic tomato samples collected have tested negative for TYLCV, suggesting that there may also be a complex of indigenous tomato-infecting geminiviruses in the region, similar to that found in Latin America. A scientific exchange between Project virologists is planned for early 1998 to share diagnostic techniques for general geminivirus detection. Other, interesting patterns are emerging, which need further exploration. TYLCV has not been identified from Western Kenya (ca. 1100 m). But at higher elevations (ca. 1500-1800 m), where it should be less likely to occur, the incidence of TYLCV is high.

Subproject 4. Field surveys have been completed in 7 of the nine partner countries. Kenya and Tanzania will be completed in 1998. Interview data has been analyzed for Uganda. Western Africa and the rest of Eastern Africa data are currently being analyzed.

The disease front for the severe African cassava mosaic disease (ACMD) epidemic has been defined. Based on this knowledge, generated from the Phase 1 survey work, additional funding has been obtained to multiply and deploy the new elite lines of ACMD-resistant cassava. They will be planted ahead of the epidemic front, in an attempt to slow down and contain the epidemic, which is currently spreading at the rate of about 20 km per year, and now threatens Rwanda, Burundi, NW Tanzania and additional area in Western Kenya.

The new "Uganda variant" geminivirus seems to be pushing out the old ACMV virus. Mixed infections have been detected. But the distribution and the presence of separate African cassava mosaic geminiviruses, as well as mixed infections, needs better characterization.

With ACMD affecting cassava production, and declining banana production, sweet potato in becoming more important as a food security crop in the region. Phase 1 field survey work has shown that in addition to sweet potato weevils, sweet potato viral diseases are also a production constraint in southwestern Uganda and northwestern Tanzania, indicating the priority areas for deployment of resistant sweet potato varieties and screening work. Interestingly, in Northeastern Uganda, there is not much virus pressure, suggesting that these two areas would provide an instructive comparative study.

Based on over 200 whitefly samples, *Bemisia tabaci* is the predominate whitefly species on cassava and sweet potato. However, *Bemisia afer* is more prevalent in the southern area (e.g. Madagascar) than previously believed.

Parasitism is estimated at 30-60%, for *Bemisia tabaci* in cassava. *Encarsia transvena* is the most abundant parasitoid. *Encarsia formosa* and *Eretmocerus* spp. have also been found. However, parasitism has been difficult to evaluate in the extensive survey. Additional, intensive survey work targeting the biological control agents, is necessary as this may offer an important vector management component for this cropping system.

Phase 1 has been instrumental in defining the overall importance of the problem as well as the diagnostics, research and implementation needs. Phase 1 improved knowledge, gave a more reliable assessment of damage, IPM practices and what other IPM problems need to be studied, and the importance of the role for extension.

In less than one year, a coordination network has been developed, methodologies standardized, literature and field surveys conducted, biological samples diagnosed, regional epidemiology characterized and mapped, databases for literature and biological data developed, and a GIS established. All data collection will be finished in 1998, and analysis completed in early 1999. The publication of a book, to serve as the final report for Phase 1, is planned for mid-1999.

Additional donor support and linkages. In response to concerns regarding Project sustainability, The Coordination Team of the Whitefly IPM Project, and the Management Team of the Coordinating Center have been successfully pursuing other linkages with the objective of constructing a constellation of donors to support the global Whitefly IPM Project. .

ACIAR has approved approximately US$200,000 (1999-2001) to begin a Phase 1-type characterization for whiteflies as pests and vectors in 8 Asian countries. This makes the CGIAR Whitefly IPM Project, truly pantropical.

The USAID Office of Foreign Disaster Assistance (OFDA) has granted US$150,000 (1999-2000) to IITA for the "Emergency Programme to Combat the Cassava Mosaic Disease Pandemic in East Africa". The objective of this disaster assistance is to boost production of cassava in Uganda, Kenya and Tanzania and enhance both short and longer term food security, through the implementation of an emergency program to multiply and disseminate mosaic resistant cassava.

The USAID Collaborative Research Grants Program has granted US$63,000 (1998-1999) for studies on biological control of whiteflies pests, by indigenous natural enemies, for major food crops in theNeotropics. The principal objective of this project is to continue exploration of indigenous parasitoids and determine the efficiency of indigenous South American parasitoids against whiteflies pests on cassava.

The New Zealand Ministry of Foreign Affairs and Trade (MFAT) has granted US$300,000 (1998-2000) to CIAT (core substitution funds) for the project Sustainable Integrated Management of Whiteflies through Host Plant Resistance, to be carried out in conjunction with New Zealand Crop and Food Research. From previous research at CIAT, a cassava variety (Ecuador 72), which is highly resistant to cassava whiteflies has been identified. The objective of the MFAT-funded project is to study the mechanism and genetics of this resistance, to map the genes for whitefly resistance in cassava, and develop molecular markers for subsequent use in the improvement of African, Latin American and Asian cassava germplasm.

A project proposal to BMZ is pending. CIAT has submitted a Special Project to BMZ (US$900,000, 1999-2001) on Alternative Management Strategies for Whitefly-transmitted Geminiviruses Affecting Horticultural Crops in Central America, Mexico and the Caribbean. The objective of the BMZ project, if funded, will be to configure and evaluate epidemiologically-effective IPM packages of alternative whitefly management tactics, in a set öf pilot zones, utilizing participatory research/technology transfer methodologies.

The financial support from Danida for Phase 1 of the CGIAR Whitefly IPM Project has been essential, as a validation of the worthiness of this Project, and to attract further donor support. The preliminary results of Phase 1 have provided valuable, objective, data to support many of these proposals. It is also becoming clear that funding for the two ends of the research continuum (upstream-molecular and downstream-applied), will be much easier to obtain than funding for the field and laboratory research on pest and disease dynamics which are so necessary to the success of this Project. In addition, it is evident that as Project funding and linkages expand, the Project coordination becomes an increasing challenge. Continued Danida support for overall Project coordination and basic research activities will be of strategic importance to the success of the global Whitefly IPM Project.

I. BACKGROUND AND CONTEXT

A. Background

The Systemwide Programme on Integrated Pest Management (SP-IPM) was established by the Consultative Group on International Agricultural Research (CGIAR) in recognition of the crucial importance of integrated pest management to sustainable agricultural production and environmental protection. In March 1994, representatives of ten International Agricultural Research Centers (IARCs) and the Chairman of the Inter-Center IPM Working Group met at As, Norway. The participants at this meeting recommended that the CG System form a System-wide Programme on Integrated Pest Management (SP-IPM), with the Inter-Center IPM Working Group to function as the steering committee. To date, the IPM Working Group has approved 12 Inter-Center IPM initiatives, including whitefly IPM.

In 1995, the International Center for Tropical Agriculture (CIAT) was designated as the convening center to formulate a systemwide proposal on Sustainable Integrated Management of Whiteflies as Pests and Vectors of Plant Viruses in the Tropics (Whitefly IPM Project). To that end, a Whitefly IPM Task Force was convened at CIAT from February 13-15, 1996. After three days of discussion, the 26-member Task Force reached consensus on the nature of the whitefly problem in the Tropics and what actions were needed.

The Task Force agreed that it was possible to define three whitefly problems in the Tropics that should be prioritized:

1) whiteflies as pests 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 direct pests in cassava.

The Task Force also agreed upon the Goal and Purpose of the Project, was able to reach consensus on the Outputs of the Project, and defined which activities should be undertaken to achieve each Output. Based on this consensus, a work breakdown for the Whitefly IPM Project was constructed (**Fig. 1**).

B. Danida Phase 1 Whitefly Project

After the Task Force meeting, in March of 1996 the Danish International Development Agency (Danida) invited CIAT to submit a proposal for the start-up phase (Phase 1) of the Whitefly IPM Project. Phase 1 focuses on Outputs 1 and 2, as defined in the work breakdown structure (**Fig.1**); that is, the formation of a network of professionals working on whiteflies, whitefly-transmitted viruses and crop management for these pests in the Tropics, and the establishment of a collaborative research agenda by which whitefly problems in the Tropics can be better characterized. Geographically, theDanida Phase 1 Project focuses on work in 12 Latin American and 10 African countries (**Fig. 2**).

Fig. 1. Work breakdown structure for CGIAR Whitefly IPM Project, indicating Danida-funded activities.

Sustainable integrated management of whiteflies as pests and vectors of plant viruses in the Tropics

Program 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, and reduce environmental degradation due to excessive pesticide use, leading to more sustainable and environmentally sound agricultural systems

Outputs / *Activities*

Formation of international whitefly network

- Develop linkages between regional whitefly networks
- Develop an electronic communication network for CG Centers and collaborators in the IPM Whitefly Project
- Standardize methodologies for identification and diagnosis, experimental research, on-farm participatory research and impact assessment
- Publish bibliography of the grey, and other relevant, literature on whiteflies and whitefly-transmitted viruses
- Disseminate research results through CG System electronic and printed media, and publications

Diagnosis and characterization of whitefly problems and target areas

- Identify whitefly and disease affected areas
- Survey farmers' perception of whitefly problem and their crop protection practices, using farmer participatory methods
- Collect baseline data on yield loss, pesticide use and resistance levels, and production costs
- Identify whitefly species and biotypes and virus strains encountered
- Assess prevalence of natural control agents, including entomopathogens
- Characterize cropping systems, cropping patterns and cropping intensity in target areas
- Characterize agro-ecology, including agrometeorology, and socio-economy of target region
- Identify agricultural policies and policy environment in target areas
- Survey whitefly populations, disease incidence and production practices

Improved understanding of pest and disease dynamics

- Conduct GIS analysis of target eco-regions
- Develop analytical tools, including mathematical models, for analysis of pest and disease dynamics
- Conduct necessary research on the biology, behavior and ecology of pests, vectors, viruses, host plants and beneficials
- Conduct comparative studies on whiteflies and viruses to study the nature and extent of inter-population variation
- Analyze climatological parameters affecting whitefly numbers and virus spread
- Collect and analyze data on whitefly population dynamics
- Develop pest and disease predictive models
- Develop and standardize culturing methodologies for whiteflies and natural control agents
- Map geminivirus plant resistance genes
- Determine components of pest and disease resistance and their epidemiological implications

Management strategies and tactics developed and tested through participatory methods

- Conduct epidemiological analysis of most efficient intervention strategies
- Conduct economic analysis, in eco-regional target areas, of feasible intervention tactics
- Develop and evaluate phytosanitary measures
- Develop and evaluate whitefly and virus resistant germplasm
- Develop and evaluate cultural control tactics
- Develop and evaluate biological control agents and tactics
- Evaluate alternate, safer chemical control agents
- Formulate, implement and validate IPM systems in eco-regional target areas, using farmer participatory methods
- Verify and validate pest and disease forecasters in eco-regional target areas, using farmer participatory methods

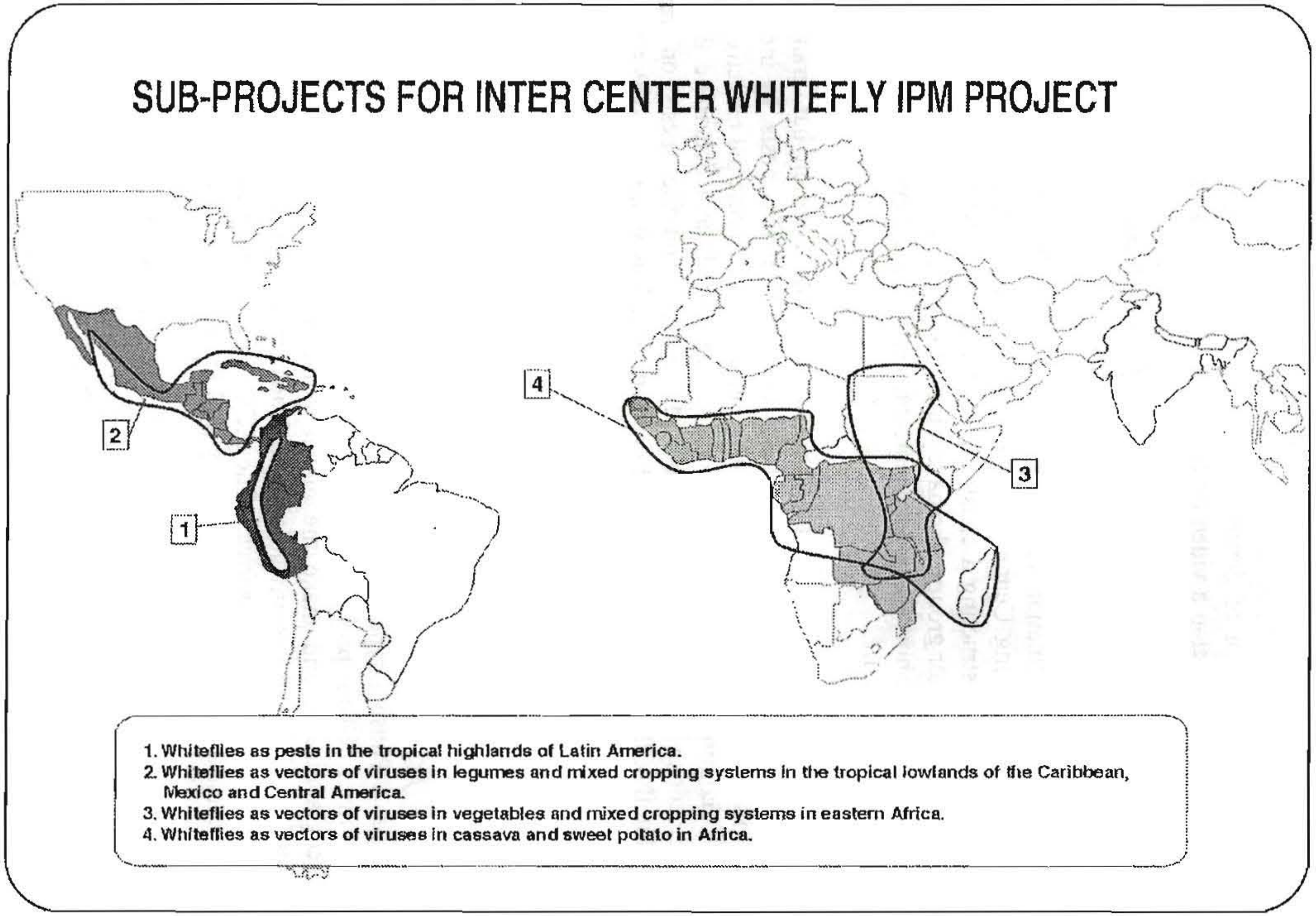
Strengthened NARS capacity in IPM research, policy formulation and implementation through information exchange and training

- Produce training and extension materials
- Provide policy recommendations on IPM implementation for whiteflies as pests and vectors
- Train NARS researchers in experimental methodologies
- Train NARS extension personnel and farmers in IPM methodologies and on-farm participatory research methodologies
- Disseminate IPM methodologies at national level through training courses, workshops and field days

Assessment of project impact

- Develop impact assessment methodologies
- Measure rates of adoption or adaptation of IPM systems by farmers, and evaluate constraints
- Assess impact of farmer participatory methodologies
- Assess impact of IPM measures and policy recommendations, specifically on yield loss, production costs and pesticide use

Fig. 2.   Subprojects of Danida Phase 1 Whitefly Project.



C. Expanding Donor Support and Linkages

Successful completion of a project with a geographical, scientific and management scope as broad as that of the Whitefly IPM Project, will require support from a constellation of donors. With that foresight, in 1996, Danida granted CIAT US$35,000 to develop a video on the whitefly problem as a visual tool for fund-raising efforts with other potential donors. Drs. Jorgen Jakobsen and Annie Enkegaard, as part of the proposal review process in late 1996, also voiced concern about how the global Whitefly IPM Project would proceed after Phase 1.

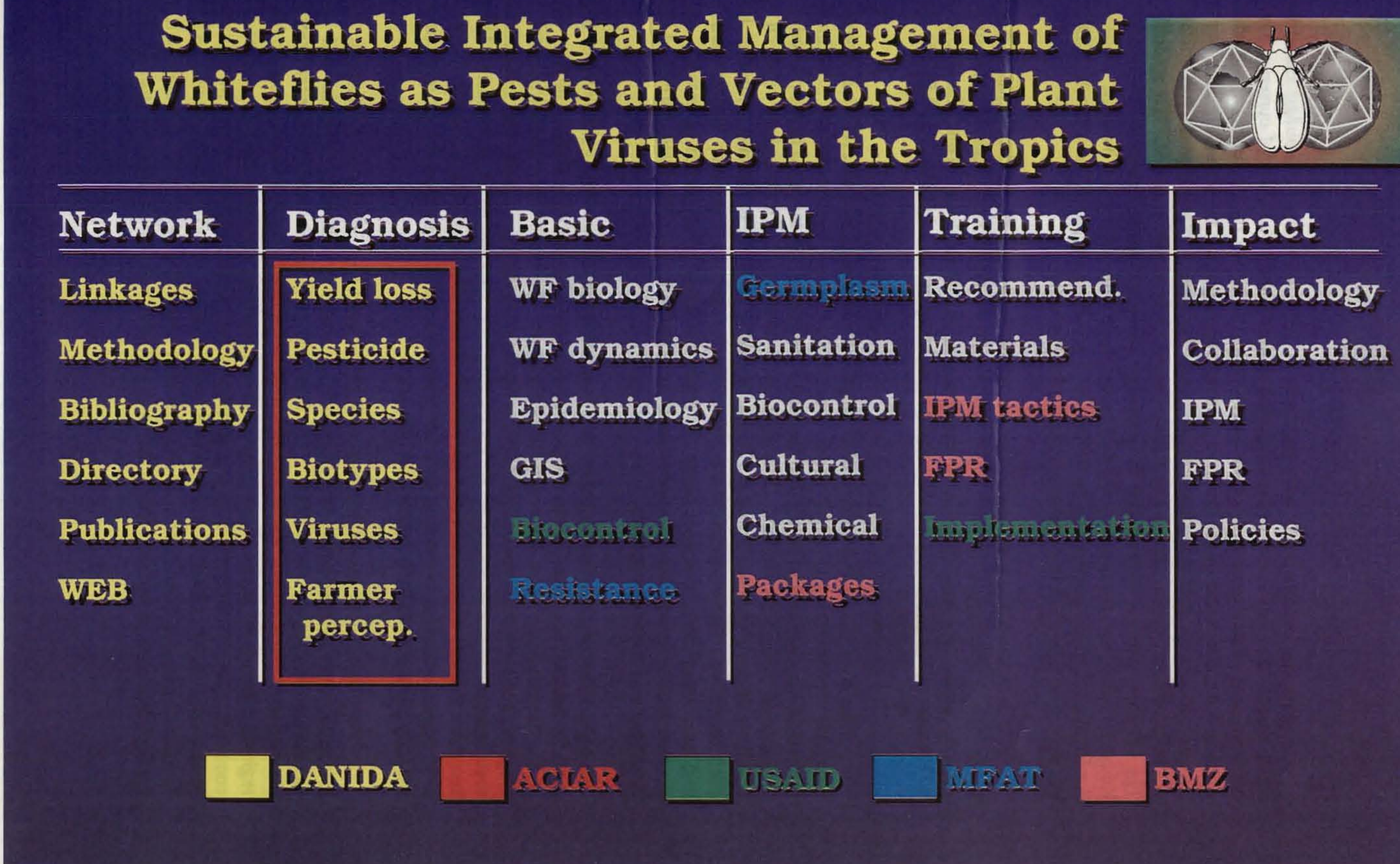
The Coordination Team of the Whitefly IPM Project and the Management Team of the Coordinating Center have been successfully pursuing other linkages with the objective of constructing a constellation of donors to support the global Whitefly IPM Project. The donor groups who have joined the Whitefly IPM Project are outlined below. **Fig. 3** illustrates how these complementary efforts are contributing to the overall work breakdown structure.

The USAID Collaborative Research Grants Program has granted US$63,000 (1998-1999) for studies on biological control of whiteflies pests, by indigenous natural enemies, for major food crops in the Neotropics. The principal objective of this project is to continue exploration of indigenous parasitoids and determine the efficiency of indigenous South American parasitoids against whiteflies pests on cassava. The Whitefly IPM Task Force identified Problem Area 3 as Whiteflies as Pests and Vectors in Cassava. However, in the Danida Phase 1 Project, we prioritized and proposed work on whiteflies as vectors of African Cassava Mosaic Disease (ACMD) in Africa. This USAID-funded project brings the cassava pest component in South America back into the global Project, and builds on the preliminary characterization that CIAT has already done for whitefly pests of cassava in South America.

ACIAR has tentatively approved approximately US$200,000 (1999-2001) to begin a Phase 1-type characterization for whiteflies as pests and vectors in 8 Asian countries. This project would be complementary to the Danida Phase 1 Project, geographically, and make the global Whitefly IPM Project truly pantropical. The funding allocated is equivalent to the funds for the Danida-funded Phase 1 Subprojects in Latin America and Africa. The ACIAR-funded project would also bring AVRDC more actively into the global Whitefly IPM Project, as the coordinator for this subproject

The USAID Office of Foreign Disaster Assistance (OFDA) has granted $150,000 (1999-2000) to IITA for the Emergency Programme to Combat the Cassava Mosaic Disease Pandemic in East Africa. The objective of this disaster assistance is to boost production of cassava in Uganda, Kenya and Tanzania and enhance both short- and longer-term food security, through the implementation of an emergency program to multiply and disseminate mosaic resistant cassava.

Fig. 3. Work breakdown structure: Activities currently receiving direct or indirect support.



When the Danida funds were approved in 1997, we had a 13% budget cut at the onset, due to rounding down of the requested budget and de-valuation of currency. The consequences of this were that certain activities had to be cut out or cut back, including Activity 5.4 (production of ACMV-free cassava planting stock for Uganda). This was of serious concern for humanitarian reasons. Over the past 5 years, Uganda has suffered starvation-related deaths due to the Africa Cassava Mosaic Disease (ACMD) epidemic. The situation remains serious and is spreading into neighboring countries, particularly Kenya. After we approached USAID, specifically the Office of Foreign Disaster Assistance (ODFA), we received an invitation to present a proposal. As a result, ODFA has approved $150,000 in disaster assistance for this work.

It is important to note that in support of the proposal, we sent the Danida-funded video, The White Plague, to the USAID-ODFA office. Our USAID contact wrote back that the video was very helpful in the grant approval process. Thus the $35,000 investment in the video has already assisted in bringing an additional $150,000 to the Whitefly IPM Project.

The New Zealand Ministry of Foreign Affairs and Trade (MFAT) has granted $300,000 (1998-2000) to CIAT (core substitution funds) for the project Sustainable Integrated Management of Whiteflies through Host Plant Resistance, to be carried out in conjunction with New Zealand Crop and Food Research. From previous research at CIAT, a cassava variety (Ecuador 72) that is highly resistant to cassava whiteflies has been identified. The objective of the MFAT-funded project is to study the mechanism and genetics of this resistance, map the genes for whitefly resistance in cassava, and develop molecular markers for subsequent incorporation into improved African, Latin American and Asian germplasm.

The MFAT funding is complementary to a Rockefeller grant currently held by CIAT and IITA for Saturation of the Genetic Map of Cassava with PCR-Based Markers and the Use of the Genetic Map in the Improvement of Cassava. The Rockefeller-funded research is mapping genes for resistance to ACMV in cassava and developing molecular markers for their incorporation into improved African, Latin American and Asian germplasm. These last three projects mentioned (USAID, MFAT, Rockefeller) are supporting the Whitefly IPM Project activities to develop and disseminate cassava germplasm that is resistant to whitefly pests and whitefly-transmitted viruses.

We have also made linkages with REDCAHOR (Collaborative Network for Research and Development of Vegetables in Central America, Panama and the Dominican Republic), an AVRDC-IICA initiative with support from the International Development Bank (IDB). REDCAHOR's main objective is to promote the creation of a regional network for horticultural crops, with emphasis on tomatoes, peppers, onions and cucurbits. The Whitefly IPM Project participated in REDCAHOR's first IPM planning workshop. REDCAHOR representatives undertook a prioritization exercise, which concluded that the most important regional IPM research project is the development of horticultural crop germplasm that is resistant to whitefly-transmitted geminiviruses. As a result of previous work by CIAT, IITA and NARS partners, resistant germplasm has been identified and is being used in breedingprograms for resistance to bean geminiviruses, cassava whiteflies, and African cassava mosaic virus. Regional programs for developing virus-resistant vegetable germplasm have been the weakest.. REDCAHOR will now take on this activity, with their funding. The Whitefly IPM Project will collaborate with information and advising.

At the request of BMZ, CIAT has submitted a Special Project to BMZ (US$900,000, 1999-2001) on Alternative Management Strategies for Whitefly-Transmitted Geminiviruses Affecting Horticultural Crops in Central America, Mexico and the Caribbean. This project would be carried out in conjunction with Biologische Bundesanstalt fur Land -und Fortwirtschaft (BBA). Preliminary results, from the Danida-funded Phase 1 extensive survey work in the region, show that more alternative IPM tactics are already in practice then we believed. However, choice of IPM tactics is random and without any scientific/epidemiological basis. The objective of the BMZ project, if funded, will be to configure and evaluate epidemiologically effective IPM packages of alternative whitefly management tactics in a set of pilot zones, utilizing participatory research/technology transfer methodologies.

Towards the same end, we have made linkages with the CATIE-Nicaragua NORAD-funded Regional Program on Ecologically-Based Participatory Implementation of IPM and Coffee Agroforestry in Nicaragua and Central America. Phase 2 of the NORAD-funded project (1998-2003; tentative approval $US10,112,500) is currently in the planning phase. We propose to link pilot zone work in such a way that the CATIE-Nicaragua team would participate in technology transfer methodology for the Whitefly IPM Project pilot zones, and the Whitefly IPM Project would come into the CATIE pilot zones with the proposed whitefly IPM technologies.

The Whitefly Project continues to be the most complex and most advanced of the SP-IPM Projects. It is the only SP-IPM project that is currently operational. Both the product and the process of Whitefly Task Force Meeting have been used as a model and prototype for other SP-IPM projects, and success of the Whitefly IPM Project is critical to the future success of the entire SP-IPM programme. Even at this incipient stage, it is clear that the financial support from Danida has been essential-as a validation of the worthiness of this Project-to attract further donor support. The preliminary resultsof Phase 1 have provided valuable, objective data to support additional proposals. It is also becoming clear that funding for the two ends of the research continuum (upstream-molecular and downstream-applied), will be much easier to obtain than funding for the laboratory and field studies on pest and disease dynamics which are so necessary to the success of this Project. In addition, it is evident that as Project funding and linkages expand, the Project coordination becomes an increasing challenge. Continued Danida support for overall Project coordination and basic research activities will be of strategic importance to the success of the global Whitefly IPM Project.

II. DANIDA PHASE 1 WHITEFLY PROJECT

A. Project Approval

In March of 1996, Danida invited CIAT to submit a proposal for the start-up phase (Phase 1) of the Whitefly IPM Project. That proposal was submitted in September of 1996 and was approved by Danida in February of 1997.

B. Project Structure

Based on the Whitefly IPM Task Force Meeting and within the framework of an ecoregional problem approach, it was proposed that Phase 1 of theSystemwide Whitefly IPM Project should commence with four subprojects (**Fig. 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 African, and

4) Whiteflies as vectors of viruses in cassava and sweet potato in Africa.

C. Transfer of Funds

The original budget request of US$1,386,327 was rounded down to $1,300,000. Because of a currency devaluation at the time of Project approval, the actual funds received by CIAT in March of 1997 totaled US$1,200,000, a 13% reduction in the funds originally requested. During March and April 1997, the Project and Subproject coordinators revised the Coordination and subproject budgets.

As this has been the first SP-IPM project funded and we are learning to work together in new ways with an unprecedented number of project partners, the logistics involved with starting up the Project have been understandably slow. It was decided by the Administration of the Coordinating Center that Memoranda of Understanding should be signed among the collaborating CGIAR centers. This process took an additional 3 months. Year 1 Project funds were not transferred to IITA and ICIPE until late August 1997.

It was further recommended that the Subproject Coordinating Center sign Memoranda of Understanding with collaborating ARIs and NARS. In cases where established relations and previous MoUs existed, this process was fairly rapid. However, in a number of cases this implied initiating a process to formalize work relationships. For that reason, in several cases, Project funds were not transferred to ARIs and NARS until the first half of 1998. However, we view this as a necessary time investment in organizing and formalizing this tropical whitefly network and facilitating future dispersments of funds.

Thus, while Project documents indicate that Phase 1 began in January of 1997, it is important to understand thatfield work did not begin in any subproject until October or November of 1997. We view that the progress made and reported here in the incredibly short period of time that this Project has been operational is testimony to the commitment of the Subproject field teams and their Coordinators.

D. Project Coordination

The Whitefly IPM Project Coordination Team held its first meeting at CIAT in February of 1997 and has overseen the development of a Methodology Guide, which lays out the standardized procedures and protocols for the projectfield work. At its April 1998 annual meeting, the Inter-Centre IPM Working Group recommended that the Project Coordination Team function as the basic decision-making body for the global Whitefly IPM Project. The current Project Coordination Team consists of the Coordinating Center's Coordinator and Project Manager, and the Coordinator for each of the regional Subprojects. P.K. Anderson is the only member of the Coordination Team being paid by Project funds.

COORDINATION TEAM

Dr. Pamela K. Anderson (CIAT)	Project Coordinator
Dr. Anthony C. Bellotti (CIAT)	Project Manager
Dr. Cesar Cardona (CIAT)	Coordinator: Tropical Highlands
Dr. Francisco Morales (CIAT)	Coordinator: Mexico, Central America and the Caribbean
Dr. S. Sithanantham (ICIPE)	Coordinator: Eastern and southern Africa
Dr. James Legg (IITA)	Coordinator: Cassava and sweet potato in Africa
Dr. Peter Hanson (AVRDC)	Coordinator: Asia/ SE Asia
Dr. Peter Markham (John Innes)	Coordinator:Biotyping Africa, Latin America
Dr. Paul DeBarro	Coordinator:Biotyping Asia
Dr. Richard Markham (IITA)	Secretary, SP-IPM

In addition, it has been recommended that an Advisory Board be established. The Advisory Board would be made up of experts in disciplines relevant to and important for the scientific advancement of the Whitefly IPM Project, and would provide external, neutral reviews of Project activities. Formation of the Advisory Board and the list of proposed advisors will be submitted as part of the Coordination Output for Phase 2 of the Whitefly IPM Project.

Collaborating institutions and scientists remain basically as proposed in the original Phase 1 Project Proposal. An updated list of collaborators is presented in **Appendix A.**

In conclusion, the Project is well under way. As stated in the Project document, the overall objective of the Danida-funded Phase 1 project on Sustainable Management of Whiteflies 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. This progress report is based on the work plan, as laid out in the Phase 1 Project Proposal document (**Appendix B**).

III. OUTPUT 1 - INTERNATIONAL NETWORK FOR WHITEFLIES AND WTVs IN THE TROPICS ESTABLISHED

A. Standardization

One of the obstacles to research progress has been the diversity of methodologies employed to study whiteflies and geminiviruses, to the extent that even similar data sets cannot be compared. For that reason, special emphasis was placed on the standardization of methodologies for activities in Phase 1 of the Whitefly IPM Project. Specifically, the purpose was to present standardized procedures and methodologies for the activities proposed in Outputs 2, 3 and 4 of the Danida-funded Phase 1 Project (**Appendix B**). A document entitled "Standardization of Methods for Whitefly IPM Project Activities" was prepared by the Coordination Team, in consultation with other whitefly and geminivirus experts.

The first draft of the Methodology Guide was completed in April of 1997. It was then pilot tested in Colombia and modified based on producer response. The survey methodology was found to be generally appropriate and manageable. It was possible to sample two sites in the morning and two in the afternoon. This defined the planned rate of sampling for the subsequent full survey. Some problems were noted with specific farmer interview questions, and minor modifications were therefore made to the questionnaire. The survey was also reviewed and modified by a biostatistician to ensure that responses were codifiable and statistically analyzable. In general, the field data and sample collection protocols worked well and no changes were required. The modified version was then pre-tested in the field in Uganda by scientists of the national programs and international centres who would be involved in its eventual implementation. Further minor modifications were again made, to account for differences between cassava and the row crops being surveyed in the other subprojects. The Methodology Guide has been translated into Spanish and French and circulated to project partners, to be utilized by all partners directly involved in Phase 1 Project activities.

We also desired to put forth the working methodology, in detail, for other colleagues. Phase 1 of the Whitefly IPM Project was not able, economically, to include all countries in Latin America, Africa and Asia where whiteflies are problematic as pests and vectors. However, it was reasoned that if national programs are currently dedicating economic resources in their own country and wish to compare their results with those obtained from the Whitefly IPM Project, then the guide would allow them to proceed in a parallel to the formal Project. Interestingly, in January of 1998, Brazilian colleagues submitted a proposal to EMBRAPA to secure additional national funds to study and manage whiteflies in Brazil. The proposal, entitled "Programa Emergencial Visando Medidas de Control da Mosca-Branca *Bemisia argentifolii* no Brasil", included a direct Portuguese translation of the Methodology Guide as the basis for the proposal's work plan.

B. Networking

In Latin America, the whitefly/geminivirus network is relatively advanced due to the existence of the Latin American Whitefly and Geminivirus Network, established in 1993, under the initiative of CATIE. The Whitefly IPM Project scientists have taken an active role in the Network meetings and planning.

In July of 1997, ICIPE took the initiative to organize what will become the African Whitefly and Geminivirus Network. The initial meeting-a satellite meeting of the African Entomology Congress held in Stellenbosch, South Africa-included 32 scientists from 11 African countries, ICIPE, IITA and Wageningen Agricultural University. The goals of the network are: to focus on whitefly problems and on needs/scope for scientific collaboration in Africa; to provide a network for information exchange and access to grey literature; and to act as a link among entomologists, virologists and other specialists in formulating advisory and capacity-building initiatives in the region.

Successful networking will provide a structure for broad dissemination of the products of the Danida-funded Whitefly Project in Latin America and Africa.

C. World Wide Web InterNET Site

The Project Coordinator, in conjunction with the Secretary of the SP-IPM and the Head of CIAT's Communication Unit, is developing a World Wide Web homepage for the Systemwide 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 and link the Whitefly IPM Project homepage and to other WWW whitefly homepages:

Fig. 4 illustrates the mock-up of the SP-IPM Whitefly IPM Project homepage. The homepage has a sidebar, which is a menu featuring 6 major subdivisions in the web site: historical information on the conceptualization of the Whitefly IPM Project **Fig. 5**, I. Whitefly Task Force), the research projects currently contributing directly to the work plan (**Fig. 6**, II. Research Projects), a listing of the formal collaborators in the Project (**Fig. 7**, III. Project Partners), the Standardization of Methodology for Whitefly IPM Project Activities (**Fig. 8**, IV. Methodology Guide), and the documentation subproject (**Fig. 9**, VI. Documentation). We are still in the process of discussing what results should be placed on the WWW site and in what form.

D. Searchable Database for Nonconventional Literature

A tremendous amount of the research has also been conducted on whiteflies and whitefly-transmitted viruses in the tropics, especially in the past decade. In general, 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 languages other than English.

In November 1997, a full-time assistant joined the Project to assist the Project Coordinator with the Documentation Subproject. The CIAT library staff provided 3 months of training in the software, cataloging, coding, abstract and data entry. A keyword list, compatible with the CABI Thesaurus, has been drawn up. Approximately, 450 citations on whiteflies and whitefly-transmitted viruses in Latin America and Africa-which are already housed in the CIAT library, primarily from the nonconventional literature-have been pre-selected and are being processed for introduction into the searchable database. In addition, Project and Subproject Coordinators have been actively collecting additional documentation. Approximately 650 additional citations have been identified for future introduction into the searchable database, which will be housed, and updated, on the Web Site (**Fig. 9**). In recognition that many potential users in the Tropics do not yet have InterNET access, we are discussing the possibility of producing the searchable database as a CD-ROM.

Fig. 4. Homepage for WWWeb site of CGIAR Whitefly IPM Project

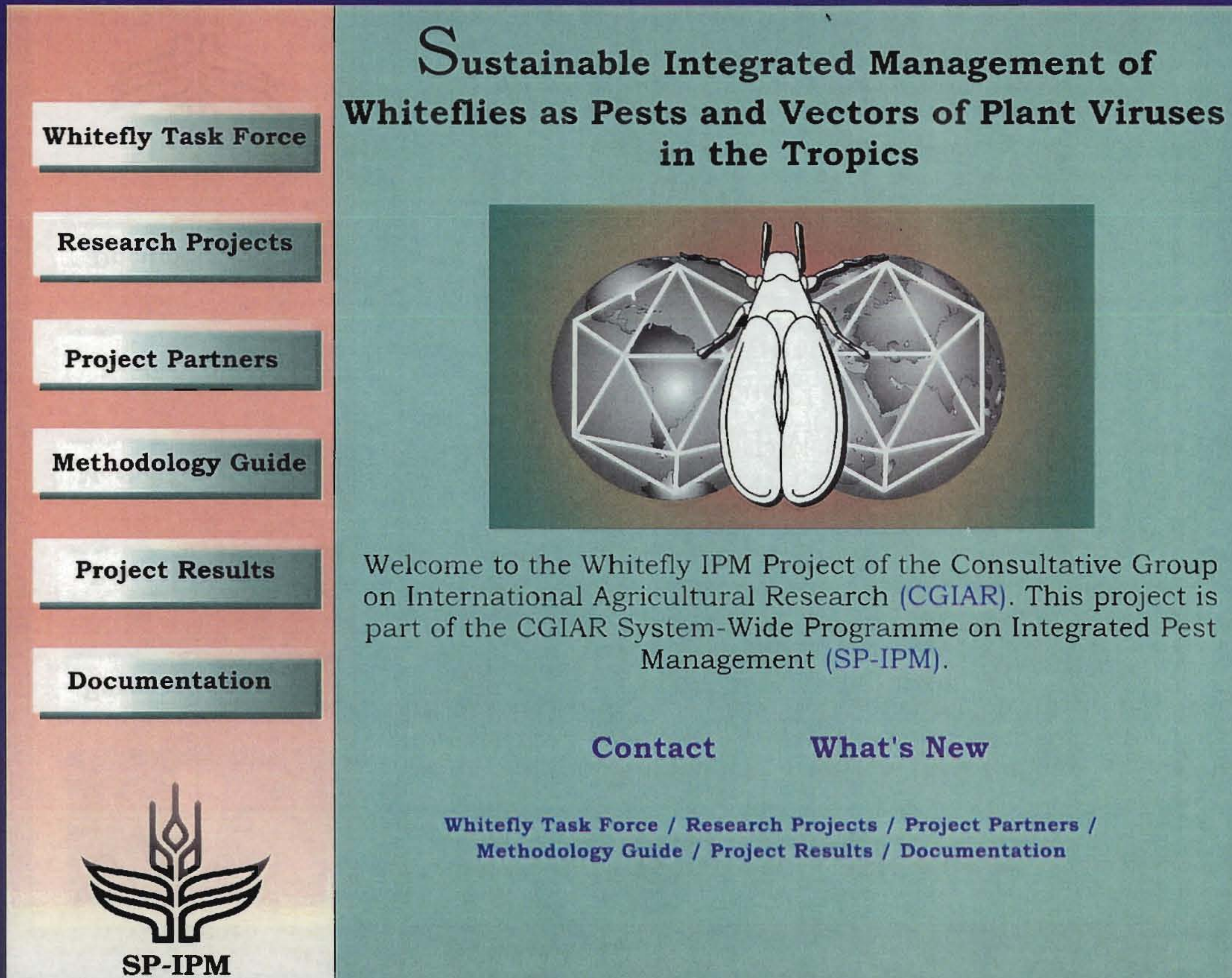


Fig. 5. WWWeb site page for Task Force

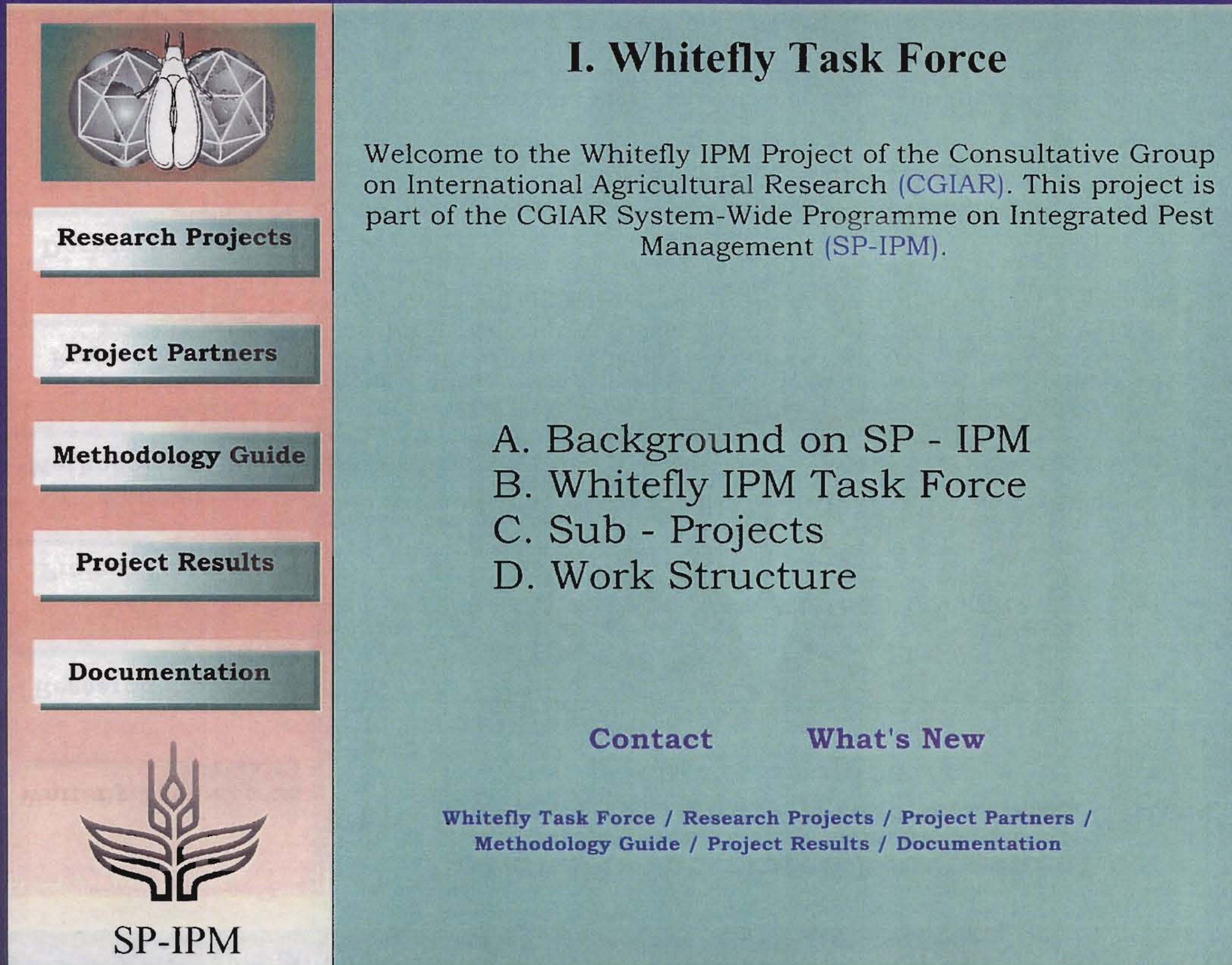
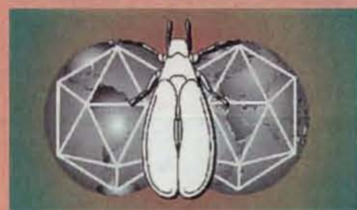


Fig. 6. WWWeb site page for Research Projects

Whitefly Task Force



Project Partners

Methodology Guide

Project Results

Documentation

SP-IPM

II. Research Projects

Welcome to the Whitefly IPM Project of the Consultative Group on International Agricultural Research (CGIAR). This project is part of the CGIAR System-Wide Programme on Integrated Pest Management (SP-IPM).

A. Introduction
B. DANIDA Funded Research
C. BMZ Funded Research
D. USAID Funded Research
E. ACIAR Funded Research
F. NZ MFAT Funded Research

Contact **What's New**

Whitefly Task Force / Research Projects / Project Partners / Methodology Guide / Project Results / Documentation

Fig. 7. WWWeb site page for Project Partners

Fig. 8. WWWeb site page for Methodology Guide

Whitefly Task Force

Research Projects

Project Partners

Project Results

Documentation

SP-IPM

IV. Methodology Guide

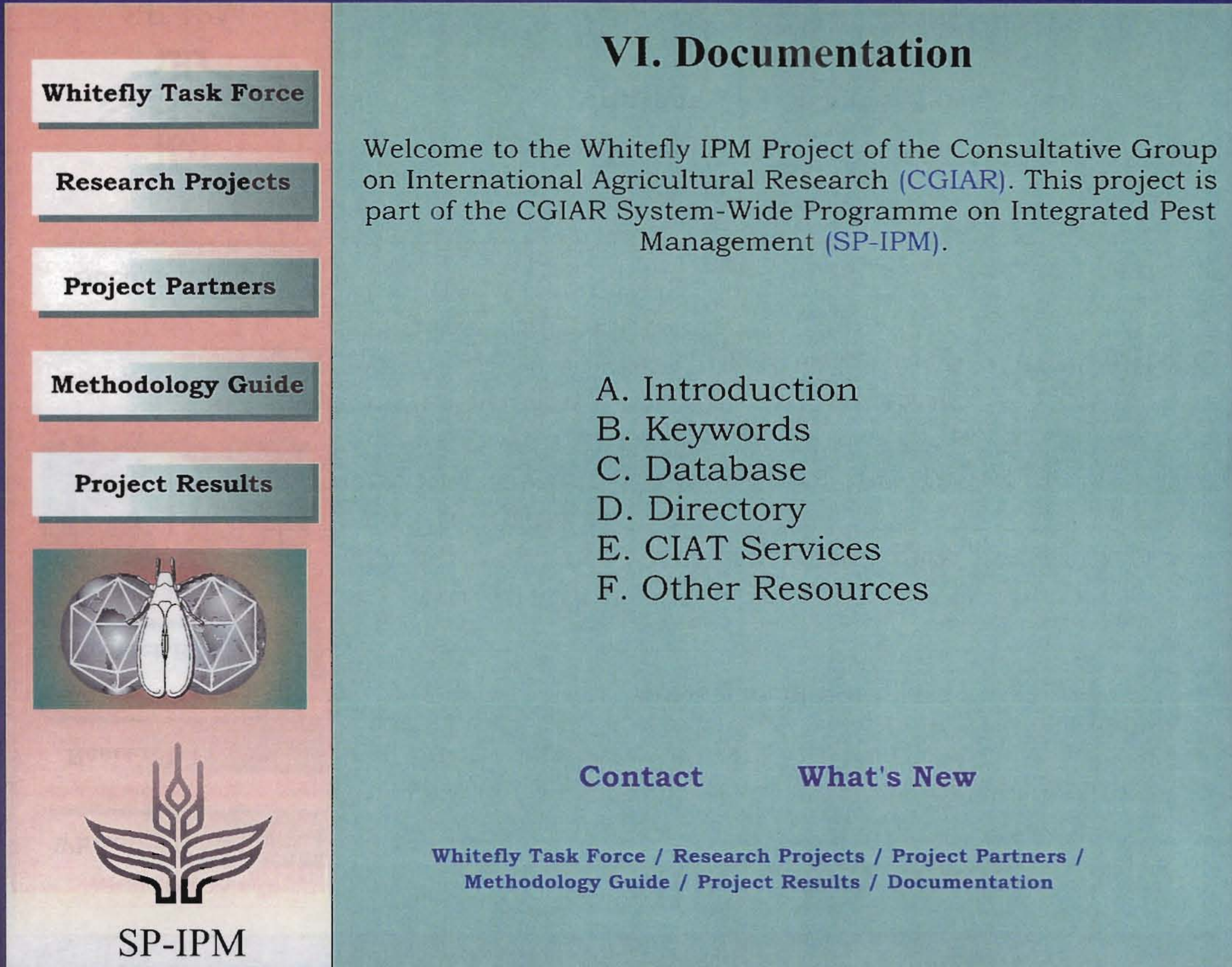
Welcome to the Whitefly IPM Project of the Consultative Group on International Agricultural Research (CGIAR). This project is part of the CGIAR System-Wide Programme on Integrated Pest Management (SP-IPM).

A. Introduction
B. Survey and Sampling Strategies
C. Preparation
D. In the Field Collection of the Data Set
E. Processing the Field Data
F. Additional Cata and Information
G. At the Coordinating and Collaborating Centers
H. Grey Literature
I. Literature Cited
J. Appendices

Contact **What's New**

Whitefly Task Force / Research Projects / Project Partners / Methodology Guide / Project Results / Documentation

Fig. 9. WWWeb site page for Documentation Project



E. Directory of Professionals

To promote and facilitate communication among colleagues, a directory of professionals actively working on whiteflies and whitefly-transmitted viruses in the tropics is being compiled to accompany the searchable database citations discussed above. For each citation entered into the searchable database, information for the principal contact will be entered into the directory. Because the nonconventional literature includes professionals working in participatory research, technology transfer and extension, this directory will go beyond the standard directories of researchers and reflect a broader array of professionals working in the Tropics on crop protection against whiteflies and whitefly-transmitted viruses.

A standardized profile was provided by the CIAT library staff. At present, 375 professionals have been entered into the directory, based on information provided in publications and workshop lists. Profiles are being emailed to colleagues to verify and update the information.

F. Dissemination of Project Information and Activities

For the most part, project results are too preliminay for widespread dissemination. However, the CGIAR Whitefly IPM Project has generated a great deal of interest among the international scientific community, resulting in numerous requests to make presentations on the experience and preliminary progress as well as presentations on the Project, *per se*.

Anderson, P.K. 1997a. The CGIAR Whitefly IPM Project: A New Forum of Collaboration, presentation at the International Workshop on Geminivirus in the Caribbean, Havana, Cuba, November 28, 1997.

Anderson, P.K. 1997b. The Epidemiology of Geminiviruses, keynote presentation at the VI Latin American Workshop on Whiteflies and Geminiviruses, Santo Domingo, Dominican Republic, August 18, 1997.

Anderson, P.K. 1998a. The CGIAR Whitefly IPM Project: A New Forum of Collaboration, presentation at the REDCAHOR 1st IPM planning meeting, Constanza, Dominican Republic, February 3, 1998.

Anderson, P. K. 1998b. The SP-IPM Project on Sustainable Integrated Management on Whiteflies as Pests and Vectors of Plant Viruses in the Tropics, symposium presentation at International Workshop on *Bemisia* and Geminiviruses, San Juan, Puerto Rico, June 7-12, 1998.

Anderson, P.K. and A.C. Bellotti. 1997. Sustainable Integrated Management of Whiteflies as Pests and Vectors in the Tropics. International Workshop on the Silverleaf Whitefly, *Bemisia argentifolii*. EMBRAPA/CENARGEN. Brasilia, Brazil, November 4-6, 1997.

Bellotti, A.C. 1997. Introduction to the CGIAR System-Wide IPM Program. Third Brisbane Workshop on Soil Invertebrates. University of Queensland, July 15-17, 1997.

Bellotti, A. C. 1998. Host Plant Resistance of Whiteflies in Colombia, symposium presentation at International Workshop on Bemisia and Geminiviruses, San Juan, Puerto Rico, June 7-12, 1998.

Bob, M.A. and Sithanantham, S. 1997. Distribution and determination of species and biotypes among whiteflies in Africa. *In* Proceedings of the Symposium on Whiteflies in Africa. Joint Congress of the Entomological Society of Southern Africa and the African Association of Insect Scientists, Stellenbosch, June 30-July 4, 1997.

Bob, M.A., Sithanantham S. and Nono-Womdim, R. 1997 Whitefly problems in Africa: Known importance and research needs, pp. 859-866. *In* Proceedings of ANPP-4th International Conference on Pests in Agriculture. Montpellier, France, January 7-9, 1997, Vol. 3.: ANPP, Paris.

Bob, M.A., Zebitz, C.P.W., Reineke, A., Sithanantham, S., Osir, E.O. and Monje, J.C. 1998. Studies on genetic variation among and within whitefly (Homoptera: Aleyrodidae) populations using Random Amplified Polymorphic DNA-Polymerase Chain Reaction (RAPD-PCR) (In preparation).

Cardona, C. 1997. First Report on the Occurrence of the B Biotype of*Bemisia tabaci* in Colombia". XXIV Congress of the Colombian Entomological Society, July, 1997.

Cardona, C. 1998a. Chemical Control and Insecticide Resistance of Whiteflies in the Andean Zone: A Progress Report, symposium presentation at International Workshop on Bemisia and Geminiviruses, San Juan, Puerto Rico, June 7-12, 1998.

Cardona, C. 1998b. First Report on the Occurrence of the B Biotype of *Bemisia tabaci*n Colombia. Revista Colombiana de Entomologia (in press).

Legg, J. 1998a. Addressing the cassava production crisis associated with cassava mosaic in Uganda and the wider East African Region. International Institute of Tropical Agriculture (IITA), Kampala, Uganda. 14 pp.

Legg, J. 1998b. Cassava mosaic pandemic threatens food security. AgriForum 3: 1,8.

Legg, J. 1998c. Emergency Programme to Combat the Cassava Mosaic Disease Pandemic in East Africa. International Institute of Tropical Agriculture (IITA), Kampala, Uganda. 9 pp.

Morales, F. J. 1997a. Host Plant Resistance to Whitefly-transmitted Geminiviruses in Latin America, keynote presentation at the International Workshop on Geminivirus in the Caribbean, Havana, Cuba, November 28, 1997.

Morales, F. J. 1997b. Identification of Geminiviruses in Latin America, keynote presentation at the VI Latin American Workshop on Whiteflies and Geminiviruses, Santo Domingo, Dominican Republic, August 18, 1997.

Morales, F. J. 1998a. The Emergence of Whitefly-transmitted Geminiviruses as Important Pathogens of Cultivated Plants in Latin America, symposium presentation at International Workshop on Bemisia and Geminiviruses, San Juan, Puerto Rico, June 7-12, 1998.

Morales, F. J. 1998b. Strategy for Developing Host Plant Resistance to Whitefly-transmitted Geminiviruses: the Case of BGMV-resistant Beans in Latin America, presentation at the REDCAHOR 1st IPM planning meeting, Constanza, Dominican Republic, February 3, 1998.

Polston, J. E., and P. K. Anderson. 1997. The emergence of whitefly-transmitted geminiviruses in tomato in the Western Hemisphere. Plant Disease 81: 1358-1369.

Sithanantham, S. and Bob, M.A. 1997. Known importance, host range and natural enemies of whiteflies in Africa and research towards their sustainable management *In* Proceedings of the Symposium on Whiteflies in Africa. Joint Congress of the Entomological Society of Southern Africa and the African Association of Insect Scientists, Stellenbosch, June 30-July 4, 1997.

Sithanantham, S., Bob, M.A., Anderson, P., Baumgärtner, J., Markham, P., Nono-Womdim, R., Dafalla, G.A. and Osir, E. 1998. Recent initiatives for whitefly-virus problem diagnosis in vegetable-based cropping systems and research networking in Africa (abstract), International Workshop on *Bemisia* and Geminiviral Diseases, San Juan, Puerto Rico, June 7-12, 1998.

IV. OUTPUT 2 - SOCIOECONOMIC AND ENVIRONMENTAL IMPACT ASSESSED

A. Background

The information required for Outputs 2 to 4 is being obtained from literature surveys and diagnostic field surveys. Protocols for the latter are outlined in the Standardized Methodology.

Subproject 1. Activities within Subproject 1 were initiated in April, 1997. Meetings were held at both CIAT and CORPOICA headquarters, in Bogota in order to coordinate Project activities, distribute workload and discuss the standardized methodologies. Corpoica staff were trained in field and lab protocols at CIAT. Corpoica and INIAP (Ecuador) received their funds in October and November, 1997, respectively Field work began in October 1997.

Target areas for field survey work were defined as:

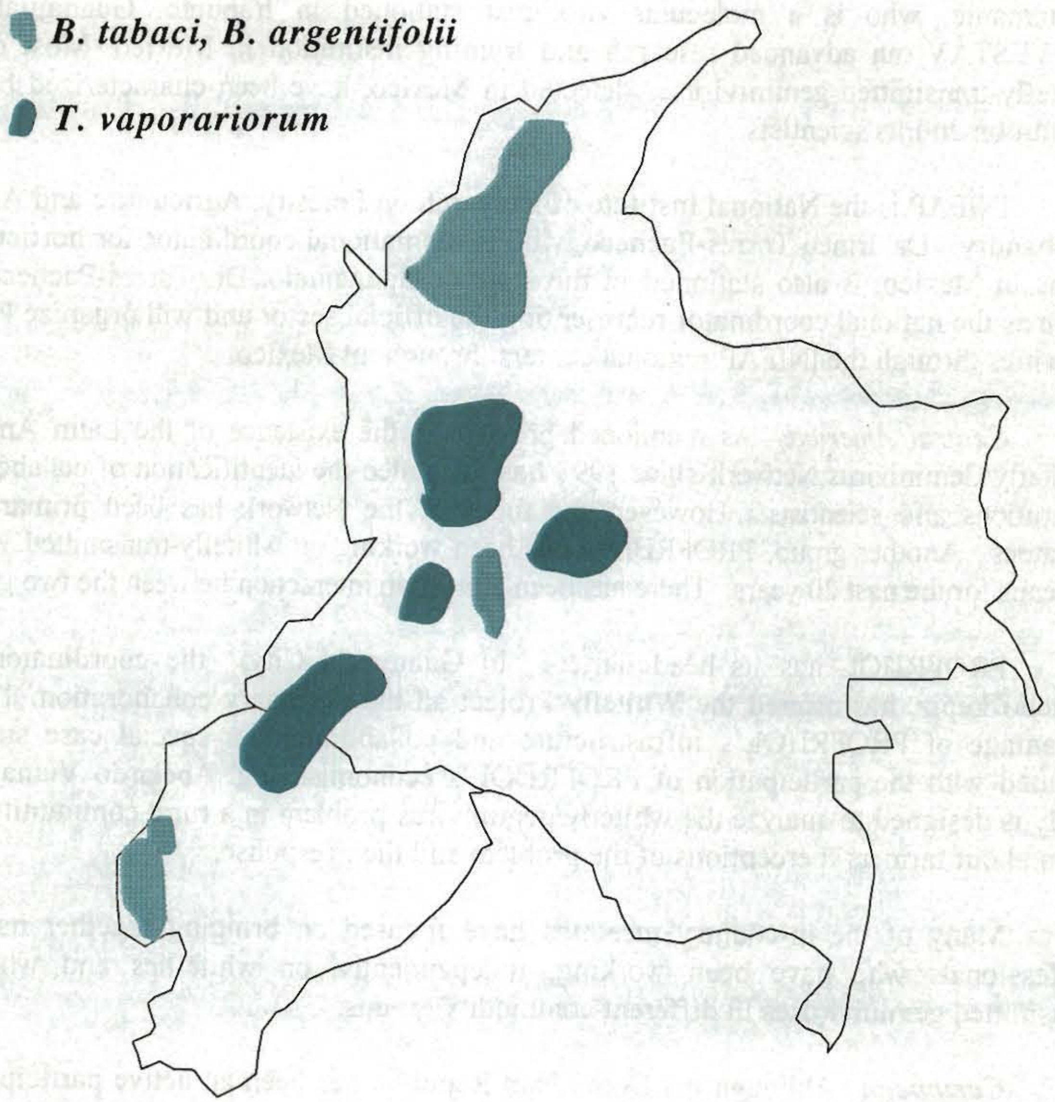
1. northern Ecuador and western Colombia (CIAT),
2. eastern Colombia (Corpoica), and
3. western coastal areas of Ecuador (INIAP) (**Fig. 10**).

To date, the following areas have been visited and sampled:
Northern Ecuador: Provinces of Ibarra and Carchi
Western Colombia: States of Nariño, Cauca, Cauca Valley, Antioquia, Córdoba, Sucre, Atlántico and Magdalena.
Eastern Colombia: States of Tolima, Huila and Cundinamarca.
Western Ecuador: Provinces of Guayas and Manabí

A total of 112 sites have been visited in Colombia and Ecuador. As a result: 98 surveys are being statistically analyzed; 29 insecticide resistance tests have been conducted, and; 120 adult and pupal whitefly samples, 35 parasitoid samples, 28 predator samples, 13 entomopathogen samples and 11 virus samples have been delivered to CIAT for identification.

Subproject 2. Because of the production crisis that whitefly-transmitted geminiviruses have caused in Mexico, Central America and the Caribbean over the past decade, the number of professionals involved in whitefly work in this region is high. Because many colleagues are isolated and contact among professionals working in different commodity groups is limited, the coordination in this region is particularly challenging. There has also been a tremendous amount of information generated, much of which is in local collections or filing cabinets. One of the major efforts in this subproject is to gather, analyze and integrate the data that have already been generated over the past decade.

Fig. 10. Subproject 1, target field areas in Colombia and Ecuador.



To initiate coordination activities, a series of trips were planned to attend four joint meetings in Mexico (Mexican Phytopathological Society, the American Phytopathological Society-Caribbean Division, the VI International IPM Congress and the V Latin American Workshop on Whiteflies and Geminiviruses). Regional scientific meetings have been utilized as much as possible for keeping in touch with regional collaborators. And in late 1997 and early 1998, a coordinating trip was made to visit key whitefly/geminivirus research institutions and national program scientists in selected target regions. All countries in the subproject have been visited with the exception of Belize (due to visa difficulties).

Mexico. The project identified a national coordinator, Dr. Rafael Rivera-Bustamante, who is a molecular virologist stationed in Irapuato, Guanajuato, at CINVESTAV, an advanced research and training institution in México. Most of the whitefly-transmitted geminiviruses detected in México, have been characterized by this institution and its scientists.

INIFAP is the National Institute of Research on Forestry, Agriculture and Animal Husbandry; Dr. Irineo Torres-Pacheco, who is the national coordinator for horticultural crops in México, is also stationed in the state of Guanajuato. Dr. Torres-Pacheco will serve as the national coordinator representing the official sector and will organize Project activities through the INIFAP regional centers throughout Mexico.

Central America. As mentioned previously, the existence of the Latin America Whitefly/Geminivirus Network since 1993 has facilitated the identification of collaborating institutions and scientists. However, the focus of the Network has been primarily on tomatoes. Another group, PROFRIJOL, has been working on whitefly-transmitted viruses in beans for the past 20 years. There has been almost no interaction between the two groups.

PROFRIJOL has its headquarters in Guatemala City; the coordinator, Dr. Rogelio Lepiz, has offered the Whitefly Project all the necessary collaboration. Taking advantage of PROFRIJOL's infrastructure and collaboration, a special case study is planned with the participation of PROFRIJOL's economist, Ing. Abelardo Viana. This study is designed to analyze the whitefly/geminivirus problem in a rural community, and learn about farmers' perceptions of the problem and their response.

Many of the in-country meetings have focused on bringing together national professionals who have been working, independently, on whiteflies and whitefly-transmitted geminiviruses in different commodity groups.

Caribbean. Although the Dominican Republic has been an active participant in the regional whitefly networks and activities, both Cuba and Haiti have been relatively isolated. We have given particular attention to bringing them into the subproject activities.

Subproject 3. A planning and methodology workshop for subproject partners was held at ICIPE in Nairobi during April 1997, with project participants from ICIPE, AVRDC and the NARS partners from Sudan, Kenya, Tanzania and Malawi. The objectives of the workshop were to discuss methodologies and develop detailed workplans. Areas to be surveyed in Sudan (**Fig. 12**), Kenya (**Fig. 13**), Tanzania (**Fig. 14**) and Malawi (**Fig. 15**) were defined.

Subproject 4. Subproject 4 also involves a large number of partners, including NARS in Ghana, Benin, Nigeria, Cameroon, Uganda, Kenya, Tanzania, Malawi and Madagascar, three CG centres (IITA, CIP and CIAT), and two Europe-based research institutes (NRI and BBA). The coordination mechanism developed by IITA for the Project was centred around its regional cassava plant protection project in West Africa, the "Ecologically Sustainable Cassava Plant Protection Project" (ESCaPP), based in Cotonou, Benin and its Eastern and Southern Africa Regional Centre (ESARC), based in Kampala, Uganda. Since most activities within Phase 1 were concentrated within the participating countries in Africa, the division of the coordination effort between West and East Africa-based branches of IITA facilitated the effective management of subproject activities.

Fig. 11. Subproject 2, natural geographic areas in Mexico.

Fig. 12. Subproject 3, target field areas in Sudan.

Fig. 13. Subproject 3, target field areas in Kenya.

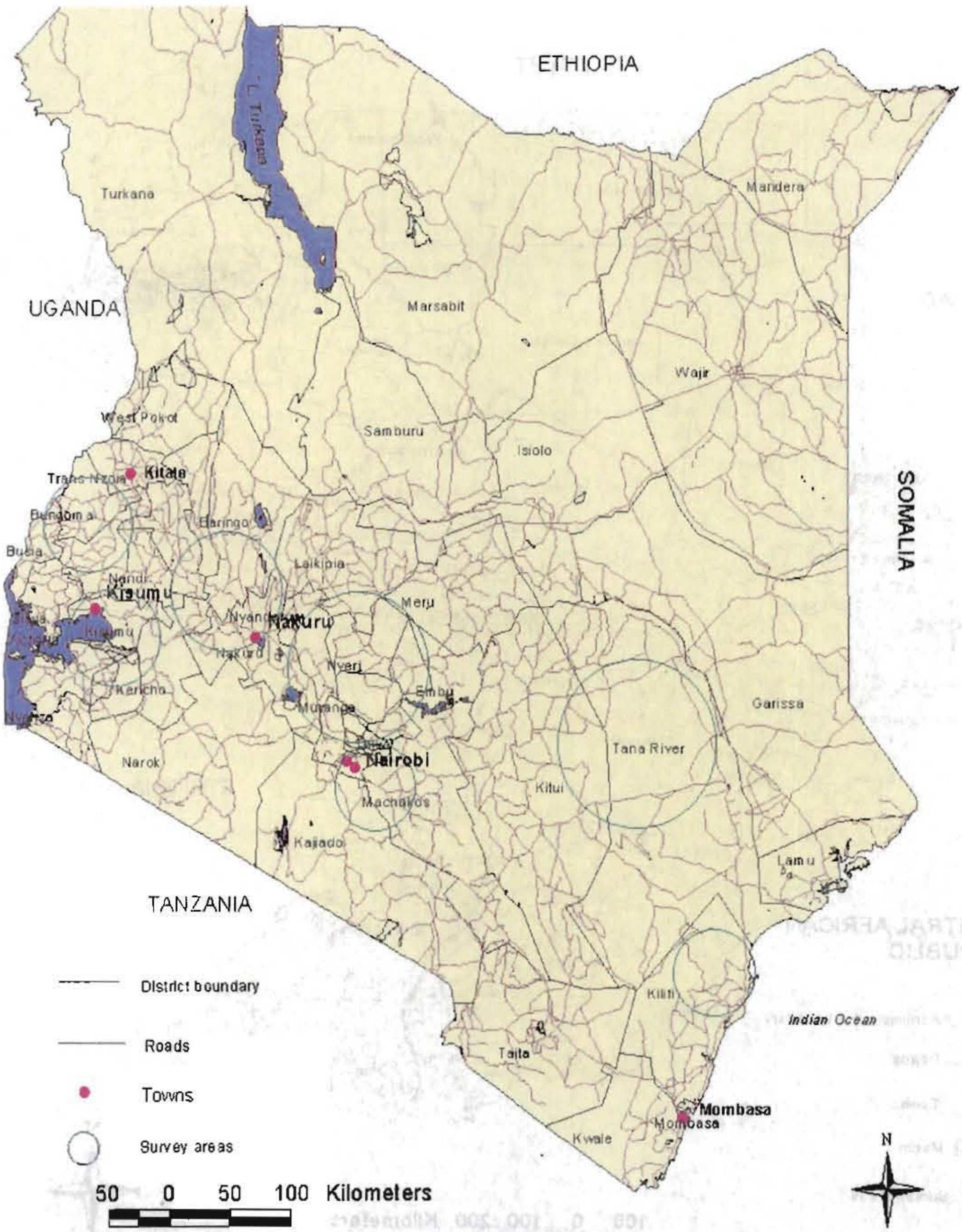


Fig. 14. Subproject 3, target field areas in Tanzania.

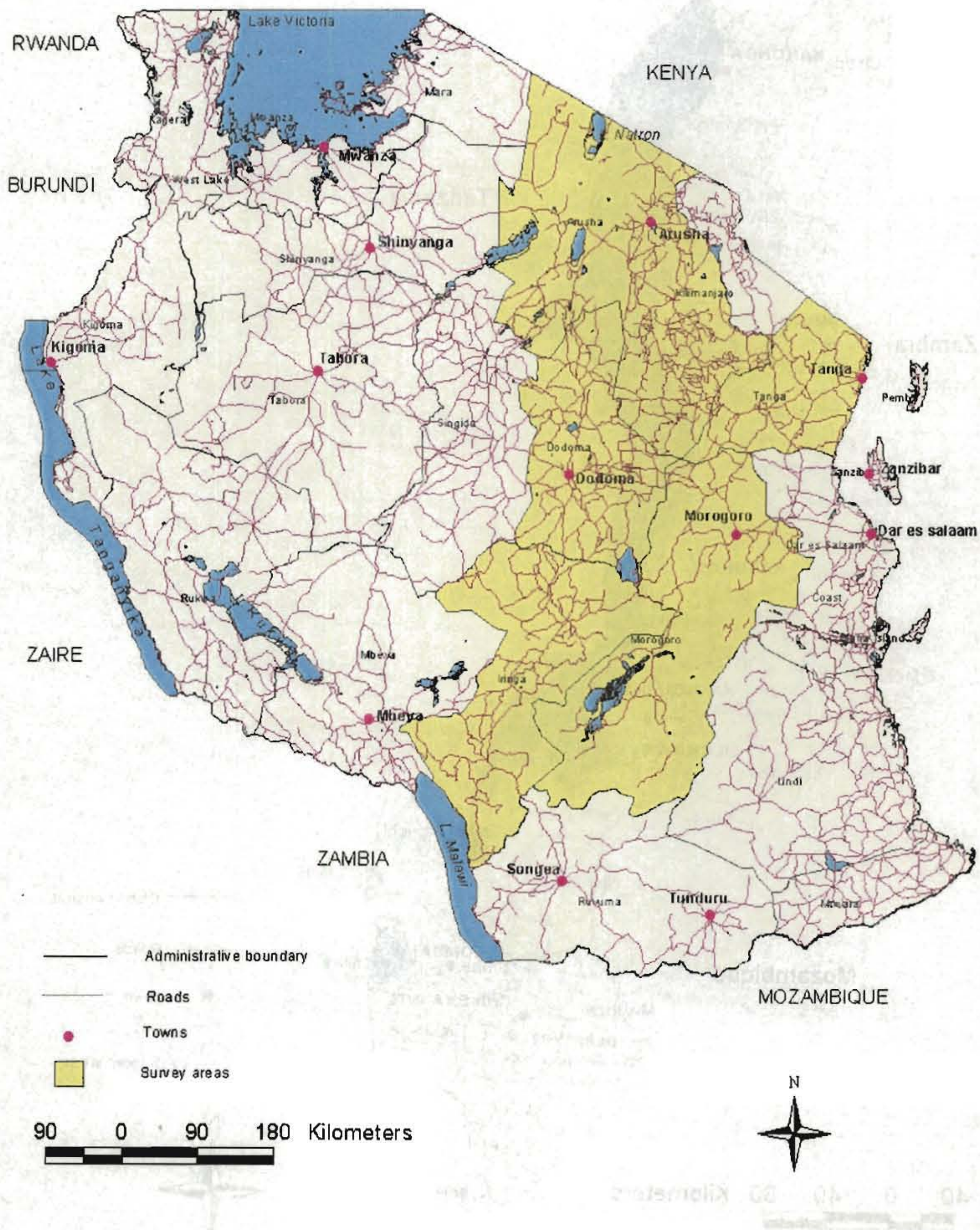
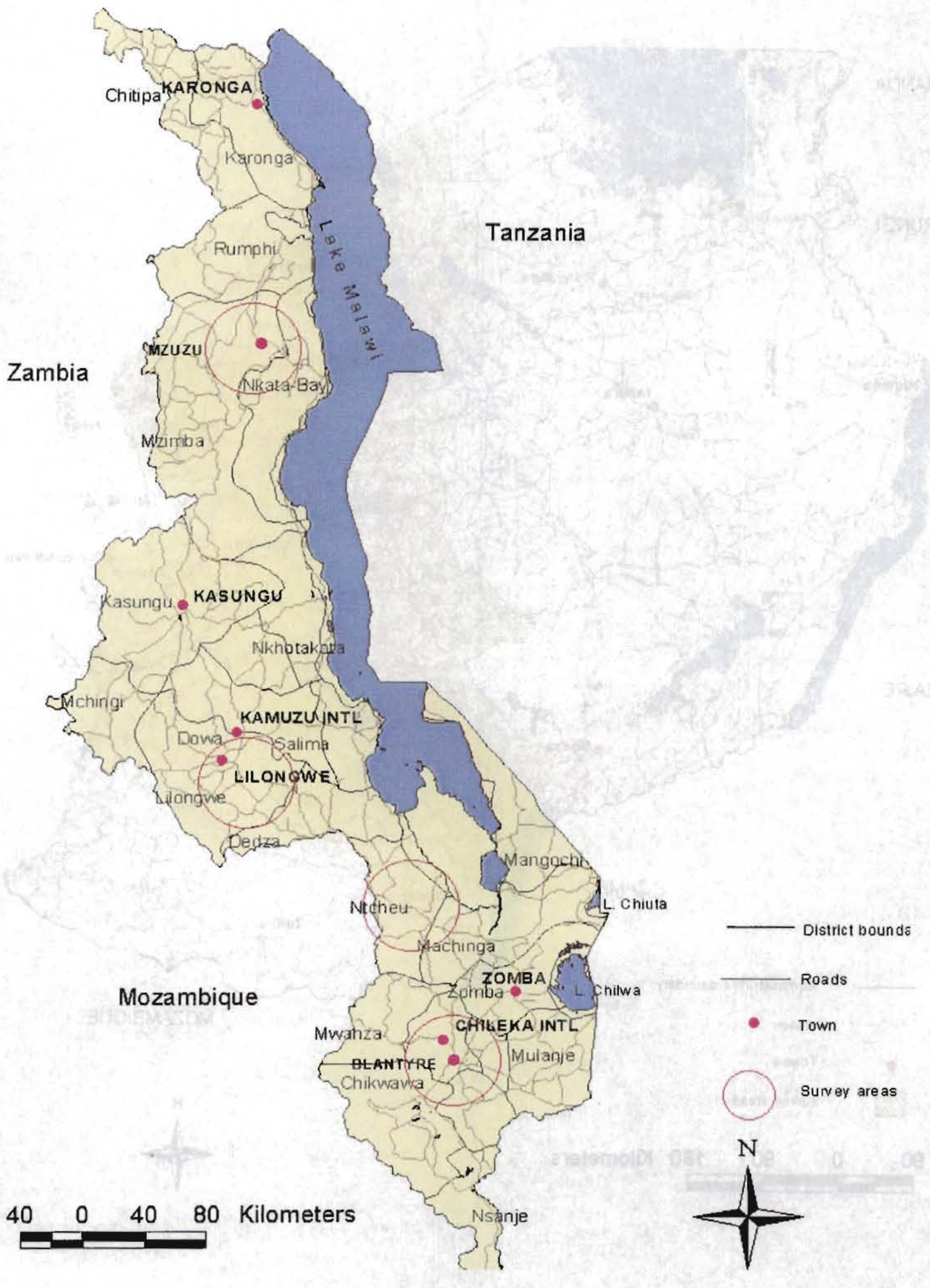


Fig. 15. Subproject 3, target field areas in Malawi.



A meeting was held in Uganda in August of 1997 with IITA, CIP and Uganda NARS in order to review the Whitefly IPM Project structure, objectives and the standardized methodology. A brief overview of the history of the Project's development, its structure, aims and proposed methods was given to a group of sweet potato and cassava scientists from the Uganda National Agricultural Research Organization (NARO), IITA and CIP. This was followed by a practical training session in which the diagnostic survey methods were explained. This session focused on sampling methods, how to conduct field assessments of cassava and sweet potato virus diseases, identification and collection of whitefly nymphs, adults and natural enemies, and interview technique for the questionnaires. By the end of the session participants had sufficient background to proceed to the pre-testing of the protocol.

Overall coordination and effective implementation of the subproject were hindered, however, by the fact that it was not possible to bring together all key stakeholders/ participants at the outset. This would have provided an opportunity for participants to have been familiarized with the rationale, objectives and proposed methodologies of the program, and to have participated in the development of the implementation plan. Such a meeting would also have provided an opportunity for training in some of the more specialized aspects of the proposed diagnostic survey protocol. The principal reason why such a meeting was not possible was the limitation of funds available. The importance of this constraint should be borne in mind when considering the development of proposals for the implementation phase of the Project.

Funds for the implementation of subproject 4 arrived at IITA in late August 1997 and were received at coordination centres in Benin and Uganda in September 1997. Given that it was originally anticipated that field-based activities should start from the first quarter of the year, this represented a significant delay; as a consequence the implementation plan had to be significantly modified. Many of the activities planned for 1997 were delayed to 1998.

The samples collected, to date, are outlined in **Table 1.**

Table 1. Countries, target areas and data sets-completed diagnostic surveys, Subproject 4.

Country	Target Area	No. data sets
Uganda	North	Cassava – 20
		Sweet Potato – 20
	East	Cassava – 20
		Sweet Potato – 20
	South/Central	Cassava – 20
		Sweet Potato – 20
	West	Cassava – 20
		Sweet Potato – 20
Ghana	Coastal savannah	10
	Rainforest	25
	Transition forest	25
	Guinea savannah	20
Benin	Transition forest	28
	Wet savannah	19
	Dry savannah	13
Nigeria	Rainforest	25
	Transition forest	25
	Wet savannah	20
	Dry savannah	10
Cameroon	Southwest	26
	Northwest	16
	Center south	28

B. Identify Whitefly- and Whitefly-Transmitted Virus-Affected Zones in Each Target Area

Subproject 1. A preliminary analysis of the data shows that the greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood) is the predominant species causing mechanical damage to several important crops in the highlands of the Andes, from northern Ecuador to Antioquia and Cundinamarca in Colombia. Populations of *T. vaporariorum* are higher at altitudes ranging from 1000 to 2200 m. Low populations of *B. tabaci* were detected in mid-altitude areas (900-1000 m) along the Andes.

Subproject 2. Figs. 16-18 show the results of a preliminary study of the main agricultural regions affected by whitefly-transmitted viruses in Mexico, Central America and the Caribbean Region, respectively.

Fig. 16. Distribution of whitefly-transmitted geminivirus-affected areas in Mexico.

Fig. 17. Distribution of whitefly-transmitted geminivirus-affected areas in Central America.

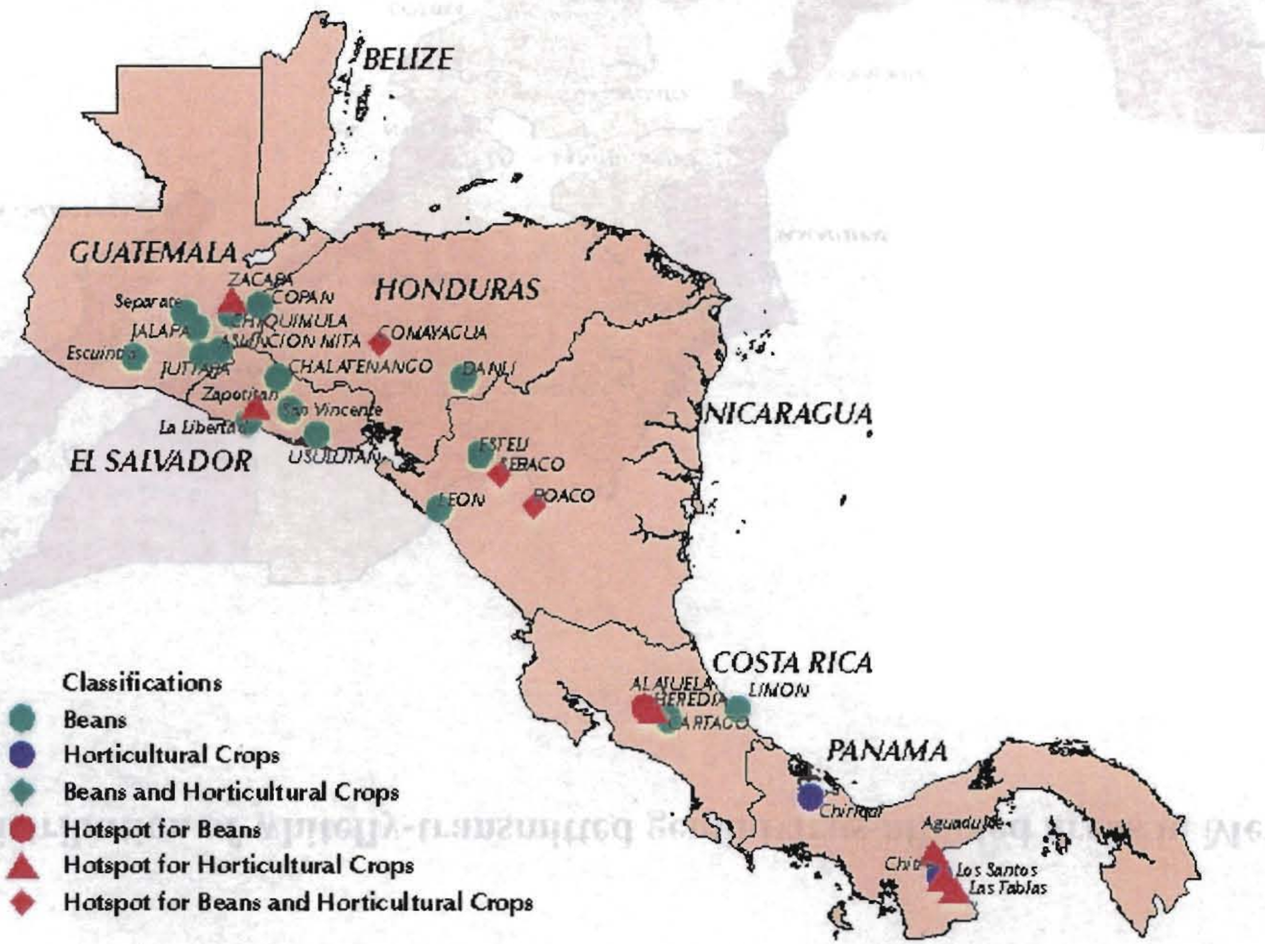
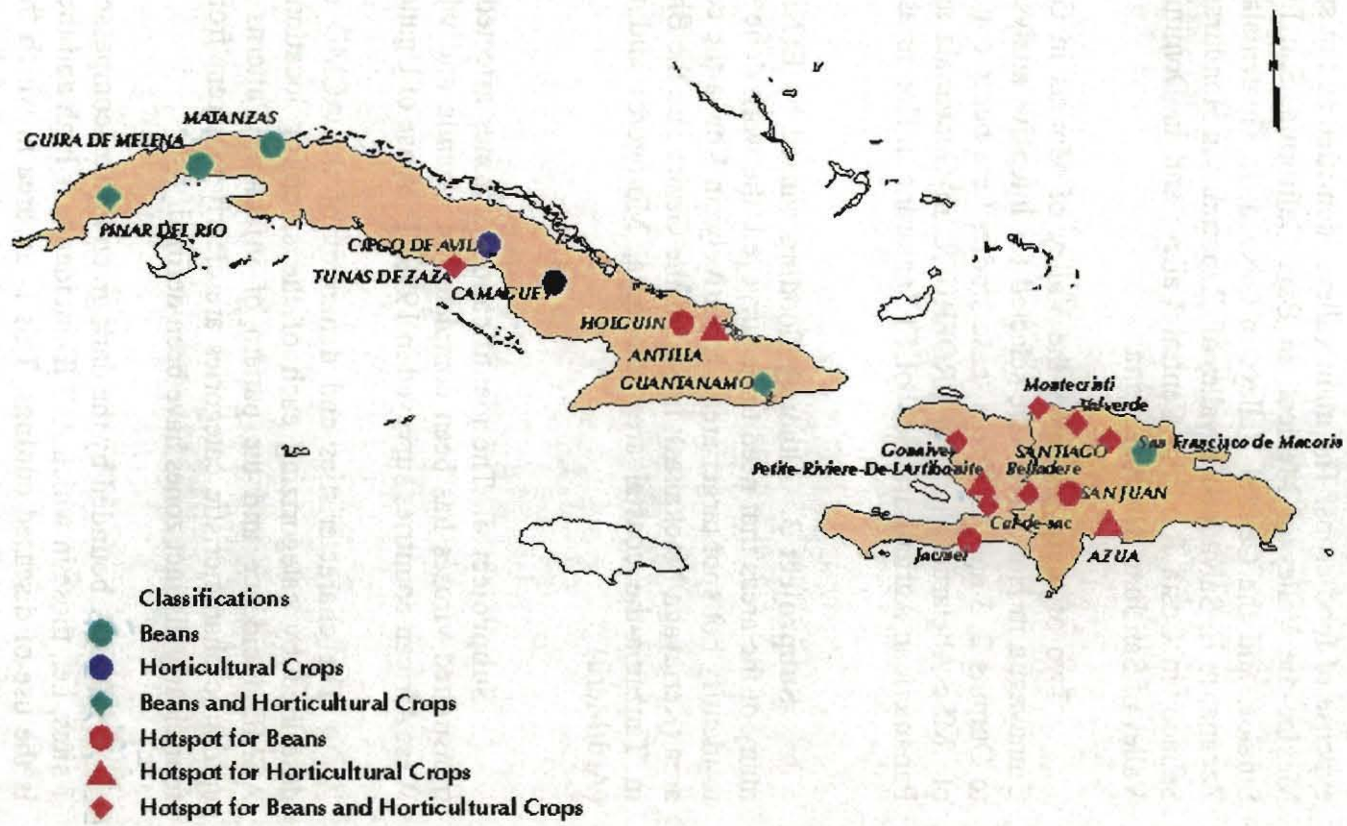


Fig. 18. Distribution of whitefly-transmitted geminivirus-affected areas in the Caribbean.



Further analyses (**Figs.19-21**) show that whitefly/geminivirus-affected zones are located between sea level and 1000 m (3300ft), and most of the "hot spots" are either coastal areas or mid-altitude valleys (200-1000 m). These valleys are relatively warm (ca. 26°C, mean annual temperature) and dry, particularly during the summer months. Most of these valleys used to be planted to traditional food crops such as beans, but the 1980s brought about the expansion of the non-traditional horticultural crops for export, at the expense of food crops. The main valleys identified as hot spots in the target area are: in Mexico-the Valley of Mexicali in Baja California, San Luis in Sonora, El Fuerte in Sinaloa, and the Central Valleys of Oaxaca; in Guatemala-the valleys of Monjas and Zacapa; in El Salvador-the valley of Zapotitán; in Honduras-Comayagua; in Nicaragua-Sébaco; in Costa Rica-the Central Valley; and in Dominican Republic-Azua and the Valley of San Juan de la Maguana.

Two of these hot spots-the Valley of Monjas in Guatemala and the Valley of Comayagua in Honduras-were selected for intensive analysis of all the activities related to Outputs 2, 3 and 4. These "case studies" are being conducted with the collaboration of MSc Abelardo Viana of PROFRIJOL in Guatemala and Dr. Allan Hruska of the Panamerican Agricultural School, El Zamorano in Honduras.

Subproject 3. Although flooding caused by El Nino has prevented access to many of the areas that need to be surveyed, the work done so far has made it is possible to identify hot spot target areas, tentatively: in Kenya-the coastal district and the central area (Keriayaga/Mackakas); in Sudan-the Gezira and the Blue Nile production areas; and in Tanzania-the coastal area (Dodoma, Morogoro) and the northern highlands area (Aru/Meru).

Subproject 4. The identification of zones affected by whiteflies and whitefly-transmitted viruses has been completed in Uganda and will be completed for the four West African countries surveyed in 1998. The case of Uganda is presented here.

The characteristics and dynamics of the ACMD epidemic in Uganda can be described by categorizing each of the sampling locations according to the level of ACMD incidence and the pattern of infection. Patterns in the distribution of these epidemic characteristic categories are clearly apparent from the map in **Fig. 22,** where four clearly distinct zones have been defined.

Zone 1, bounded by the dark green line, encompasses virtually all of the Category 1 sites; i.e., those in which ACMD incidence is high and the principal source of infection is the use of diseased cuttings. This is an area in which the ACMD epidemic has been present for a number of years. Given the high level of disease, it is also an area in which the crisis in the availability of clean planting material is most acute.

Fig. 19. Elevation and distribution of whitefly-transmitted geminivirus-affected areas in Mexico.

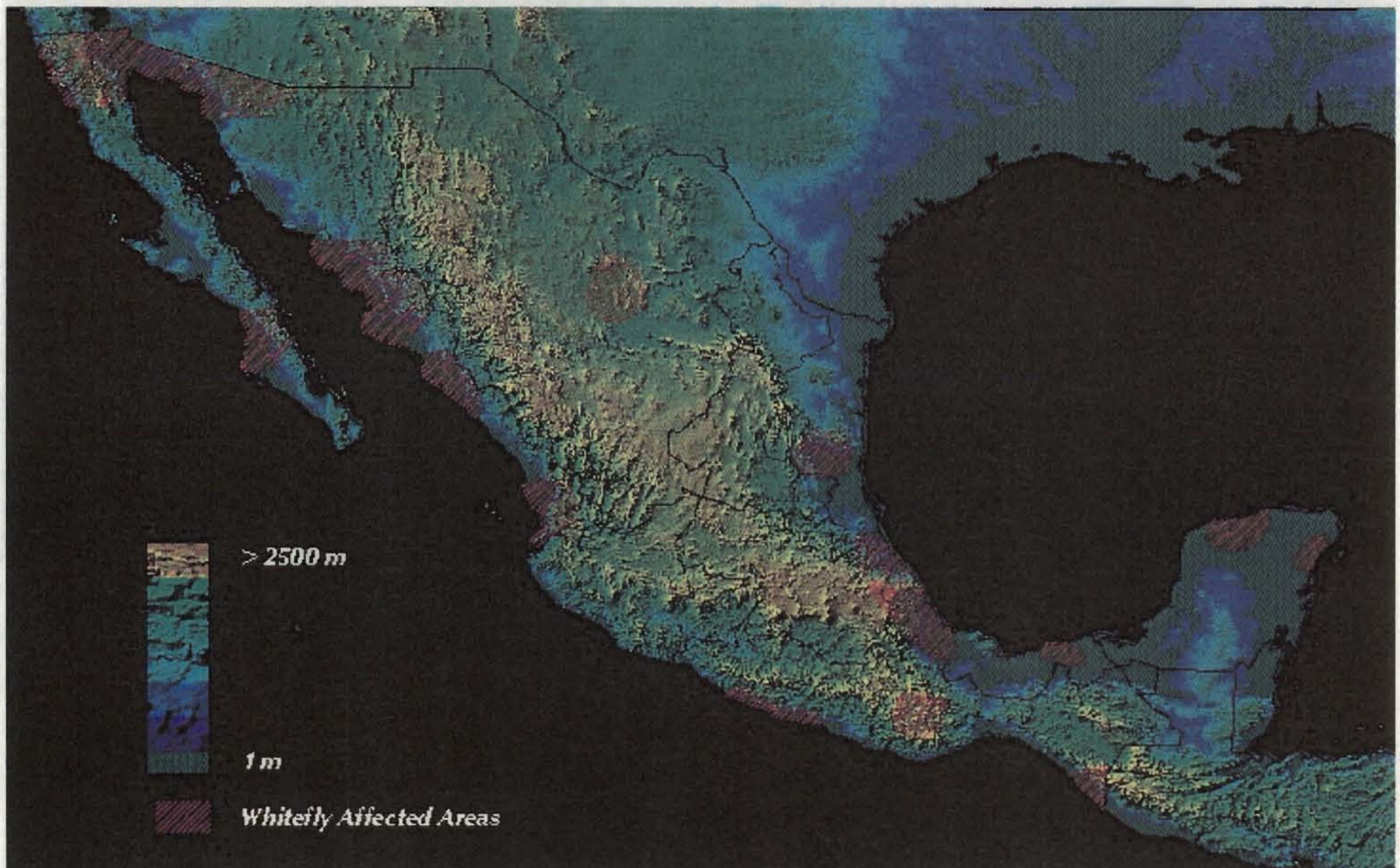
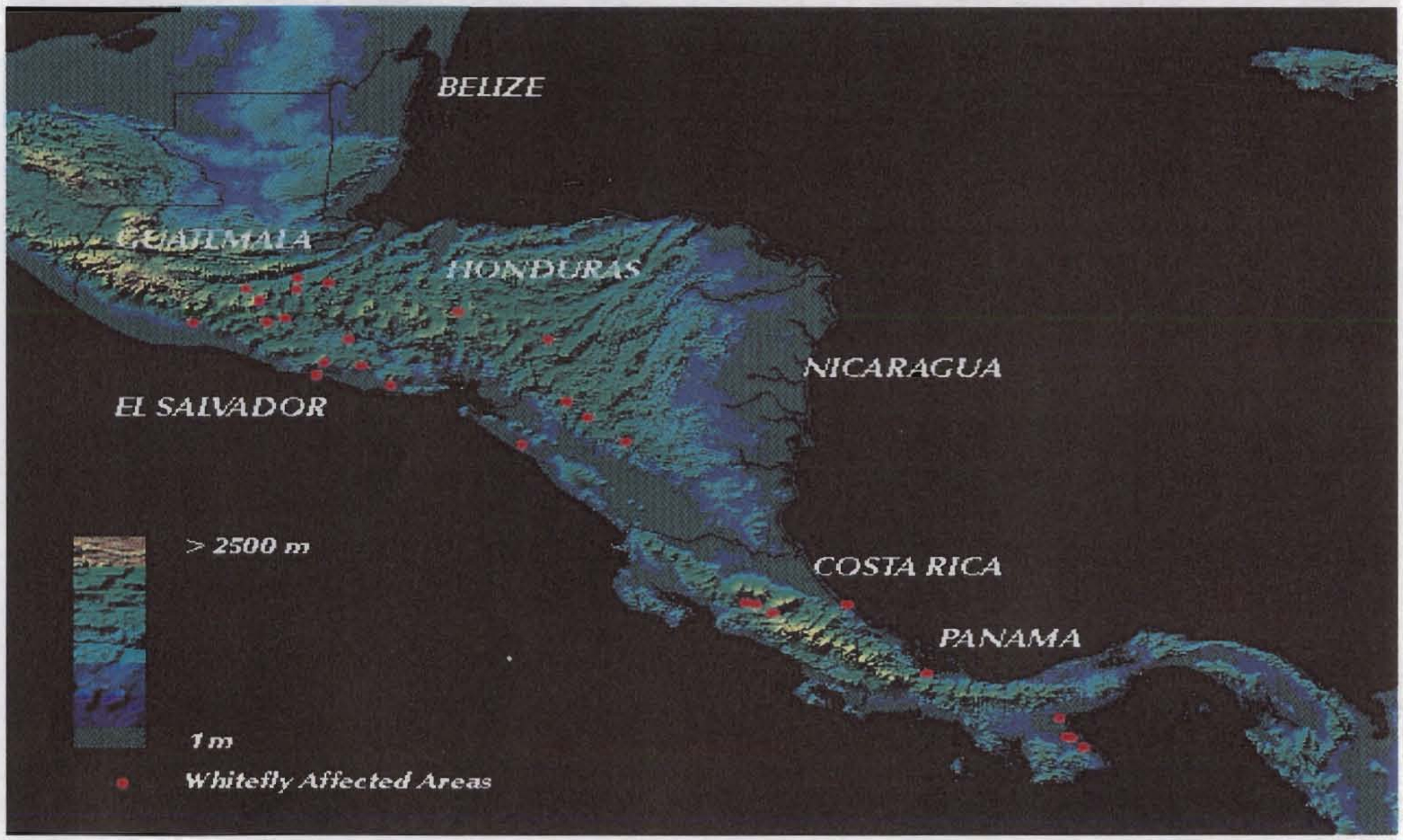


Fig. 20. **Elevation and distribution of whitefly-transmitted geminivirus-affected areas in Central America.**



Fig, 21. Elevation and distribution of whitefly-transmitted geminivirus-affected areas in the Caribbean.

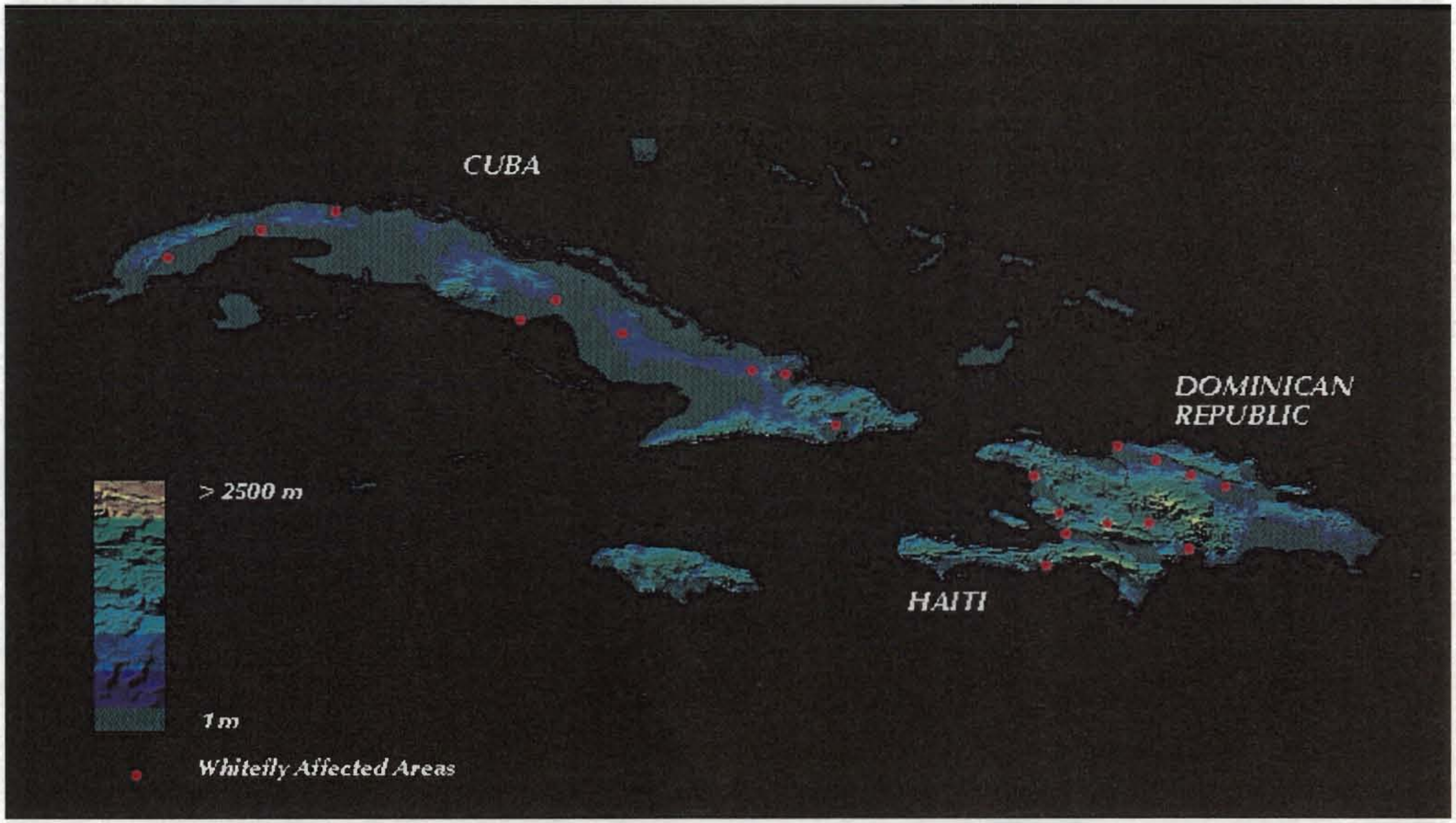
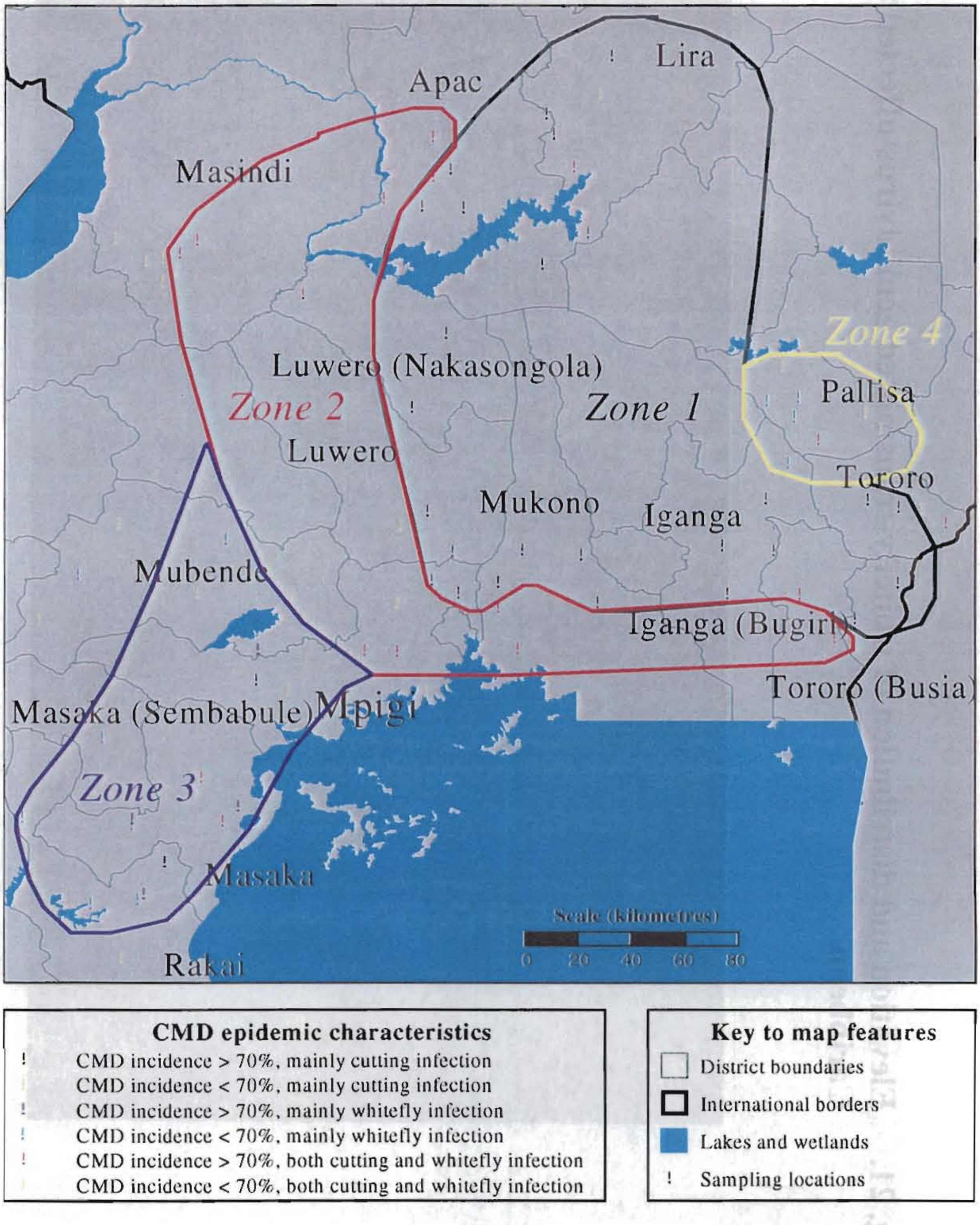


Fig. 22. Epidemic characteristics of ACMD in 12 districts of Uganda, November/ December, 1997.



Zone 2, bounded by the red line, encompasses most of the Category 5 sites, those in which incidence is high and there is a mixture of cutting and whitefly-infected plants. This zone bounds Zone 1 on the western and southern sides and can be considered as a more recent area of epidemic expansion. Sites in the south and southwestern parts of this area have been affected by the epidemic in the last one to two years, and its impact is therefore just now being felt. As is apparent from the Fig., there are areas within this zone where the level of incidence is less than 70%, and scarcity of planting material is not such an acute problem as in Zone 1. In the absence of measures to tackle the situation, the pattern of disease in Zone 2 is likely to change to that of Zone 1 within the next one to two years with a concomitant negative effect upon planting material supply. Areas most likely to be affected in this way include southern Iganga, southern Mukono and western Mpigi.

Zone 3, bounded by the blue line, encompasses most of the Category 3 sites, or those with high ACMD incidence and a high proportion of plants with current season, whitefly-borne infection. This represents the area of current epidemic expansion. The zone bounds Zone 2 to the southwest and extends down along the shoreline of Lake Victoria towards the Tanzania border. ACMD incidence has increased at many of the locations within this area in the last year (1997). Over the next one to two years the pattern of the epidemic is anticipated to progress to that characteristic of Zone 2, and further expansion is expected southwards into Tanzania. At present the incidence of ACMD is less, however, than in either Zones 1 or 2, and selection of ACMD-free stems should allow farmers to obtain sufficient planting material for next season's crop. This zone is likely to be the one with the greatest planting material demands in two to three year's time.

Zone 4, bounded by the yellow line, encompasses sites from a mixture of categories, although significantly, seven of the eight are from low incidence categories. The key characteristic of this zone is that it is largely restricted to Pallisa District, the only district where recently introduced ACMD-resistant varieties were found at the majority of sampling locations (**Table 2**). The zone therefore represents the potential impact of the introduction and disseminationof ACMD-resistant materials. This is put into context by historical information indicating that the pattern of disease in Pallisa prior to the introduction of the new materials was as that in Zone 1. Similar changes in the pattern of disease incidence and infection characteristics have been reported for the districts of Soroti and Kumi, immediately to the north of Pallisa. A key target in the implementation of future ACMD control programmes should therefore be to recreate this Zone 1 to Zone 4 shift.

Table 2. Number of farmers growing improved, ACMD resistant and local cassava varieties.

District	Improved varieties	Local varieties	District	Improved varieties	Local varieties
Apac	0	6	Mpigi	0	7
Iganga	1	6	Mubende	0	7
Lira	0	7	Mukono	0	6
Luwero	1	6	Pallisa	6	1
Masaka	0	6	Rakai	0	7
Masindi	0	7	Tororo	1	5
			TOTAL	9	72

C. Estimate Disease Incidence and Yield Losses due to Whiteflies and Whitefly-Transmitted Viruses in Affected Zones

Subproject 1. A trial to assess yield losses due to *T. vaporariorum* on snap beans was conducted. Data indicate that losses due to mechanical damage by this species can be as high as 50%. This study will be repeated in late 1998.

The impact of biotypes A and B of *B. tabaci* is being assessed on 20 crop host plants. Preliminary results indicate that dry beans are less affected by both A and B biotypes than other crops. Cucurbit and solanaceous host plants yield significantly less when attacked by the B biotype. Biotype B causes more damage than biotype A on squash, cabbage, cucumber and soybean. Snap beans are also affected and suffer significant reductions in biomass as a result of damage by biotype B. On the contrary dry beans are not as severely affected as other host plants.

Subproject 2. Yield losses associated with transmission of viruses by whiteflies vary according to the cultivated plant species, planting season and environmental conditions, which directly affect the dynamics of *B. tabaci* populations and their behavior. The hot spots shown in **Figs. 16, 17 and 18** are characterized by the presence of high whitefly populations, particularly during the summer months, causing up to 100% yield losses. In other agricultural areas where *B. tabaci* affects crops-both as a pest (direct feeding damage) or as a vector of viruses-yield losses vary according to the crop, year and planting season. These data are being assembled in order to be analyzed by country and by planting season; but it is already evident from the surveys conducted so far, that the planting date is one of the cultural control practices most frequently adopted throughout the study area to combat whitefly-transmitted geminiviruses. It is also clear that producers cannot anticipate the extent of whitefly damage or geminivirus incidence in any of the countries visited due to the extreme climatic changes that often occur in the tropics. Additionally, the phenomenon of "El Niño" has caused major changes in planting dates and whitefly population dynamics since 1997.

Subproject 3. On-farm surveys on tomatoes showed that the percent fields with tomato yellow leaf curl virus (TYLCV) in the four countries Kenya, Malawi, Sudan and Tanzania was 38, 57, 97 and 97%, respectively, with maximum disease incidence levels per farm being 83, 40, 80 and 100%, in that order (**Table 3**). On beans, there was an abundant whitefly population, but no disease problem was seen.

Table 3. Field incidence of TYLC in partner countries.

	Tanzania	Malawi	Kenya	Sudan
Totals	**29**	**7**	**16**	**35**
None[1]	1(1)	3(3)	10(3)	1(1)
0.1-25%	23	3	4	10
26-50%	0	1	1	3
51-75%	3	0	0	3
76-99%	2	0	1	0
100%	0	0	0	17
Maximum %	80	40	83	100
% field infested	97%	57%	38%	97%

1 Figures in parentheses show no data in field records

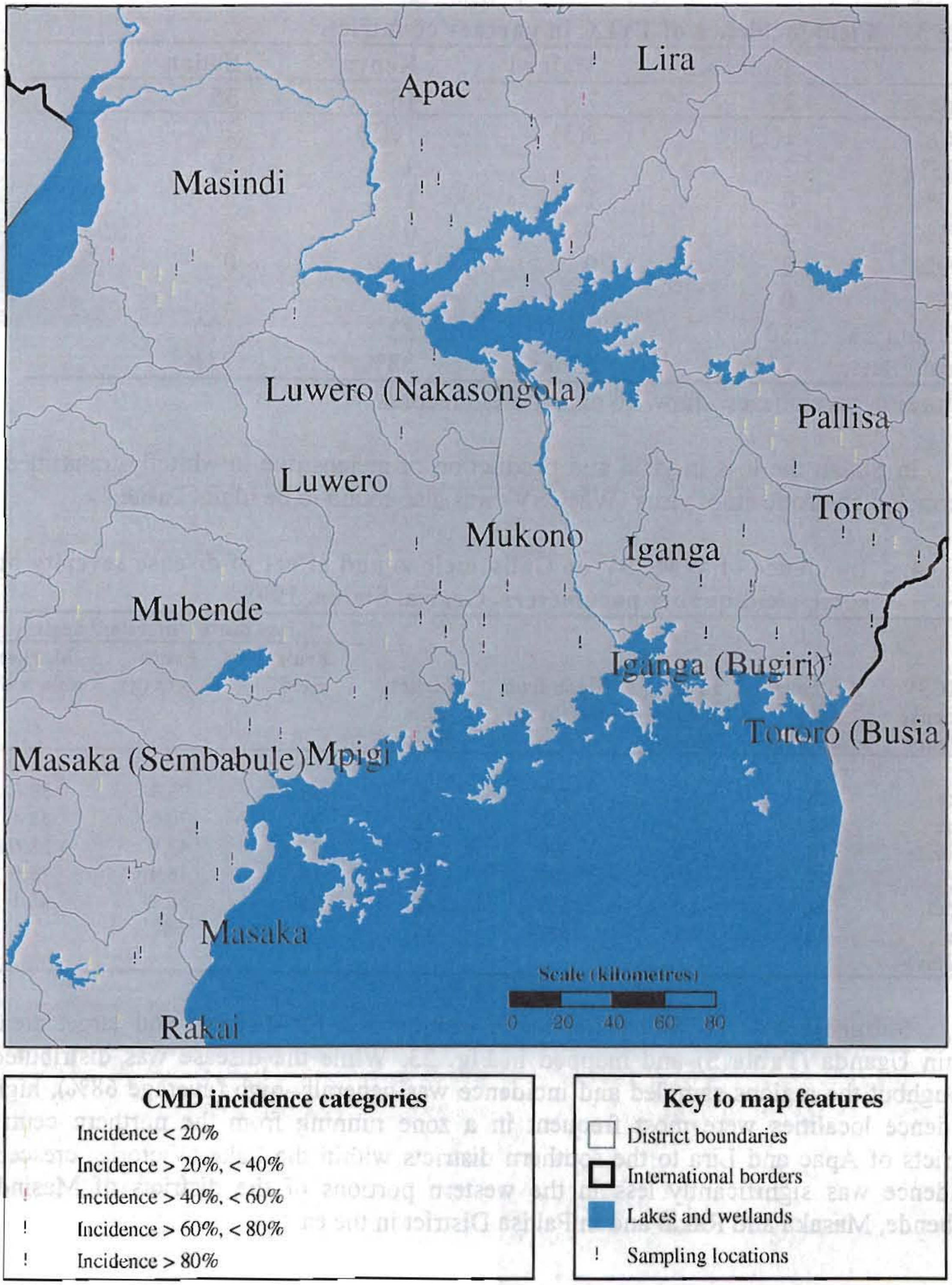
In Sudan the loss in yield and production of melons due to whitefly-transmitted watermelon chlorotic stunt virus (WMCSV) was also found to be high (**Table 4**).

Table 4. Incidence of WMCSV on Galia melons and effect of disease severity on some yield/quality parameters, Gezira, Sudan, 1998.

					%loss due to infection/ healthy		
WMCSV Incidence category	**% Plants with symptoms**	**Fruits yield/ plant**	**Mean fruit weight (g)**	**Market-able fruits**	**Fruit yield**	**Fruit weight (g)**	**Market-able fruits**
Very severe	16	1.3	178	8	38.1	73.9	89.6
Severe	21	1.6	200	32	23.8	70.6	58.4
Moderate	18	1.6	390	55	23.8	42.8	28.6
Mild	27	1.8	570	65	14.3	16.4	15.6
Overall	82	1.6	335	40	25.0	50.9	48.1
None (Healthy)	18	2.1	682	77	2.1	682	77

Subproject 4. *ACMD incidence* is summarized for districts and target areas within Uganda (**Table 5**) and mapped in **Fig. 23**. While the disease was distributed throughout the regions sampled and incidence was generally high (average 68%), high-incidence localities were most frequent in a zone running from the northern central districts of Apac and Lira to the southern districts within the Lake (Victoria) crescent. Incidence was significantly less in the western portions of the districts of Masindi, Mubende, Masaka and Rakai and in Pallisa District in the east.

Fig. 23. ACMD incidence in 12 districts of Uganda, November-December, 1997.



Whitefly abundance. Whiteflies were present on both cassava and sweet potato at all locations sampled in Uganda although patterns of abundance varied between target areas and districts (three within each target area). Mean numbers of whitefly adults recorded in each district for cassava and sweet potato are given together with disease incidence information in **Tables 5** and **6**, and whitefly abundance is mapped for cassava and sweet potato in **Figs. 24** and **25**.

SPVD incidence. Sweet potato viruses recorded during the survey included: sweet potato chlorotic stunt virus (SPCSV), sweet potato feathery mottle virus (SPFMV) and sweet potato mild mottle virus (SPMMV). SPCSV and SPMMV are transmitted by *B. tabaci* and SPFMV by aphid species. While all three viruses produce either very mild or no symptoms at all in the majority of sweet potato cultivars in Uganda, SPCSV and SPFMV combine to produce moderate-to-severe chlorotic mosaic-like symptoms commonly referred to as sweet potato virus disease (SPVD). SPVD incidence of was recorded during the survey in Uganda and is summarized for districts and target areas within Uganda (**Table 6**) and mapped in **Fig. 26**.

ACMD was present in all cassava fields sampled in Uganda SPVD, in contrast, occurred in only 60 of the 80 sweet potato fields sampled, reflecting its generally lower incidence. No SPVD at all was recorded for more than a quarter of all fields sampled, and the overall average incidence was a little over 5%. While regional variations were less obvious than for ACMD in cassava, SPVD incidence was generally greater in southern areas around the shoreline of Lake Victoria, and the highest incidence was recorded in Mpigi District (29%). There was a clear positive association between SPVD incidence and whitefly abundance, as is apparent from comparison of **Figs. 25** and **26**. Patterns of spread of SPVD and the population dynamics of the *B. tabaci* on sweet potato remain poorly characterized, but ongoing experiments within the Project (and discussed subsequently under Output 5) aim to develop understanding in these areas.

Table 5. ACMD and whitefly data, cassava, Uganda, November/December 1997.

District	Target area	Healthy (%)	Whitefly infection	Cutting infection	Total infection	Severity means	Whitefly means
Masindi	1	55	11 (19)[1]	34	45	3.0	0.7
Apac	1	7	22 (140)	71	93	3.0	1.4
Lira	1	8	11 (89)	81	92	3.0	1.4
Iganga	2	16	20 (80)	64	84	2.8	1.6
Tororo	2	15	16 (73)	69	85	3.6	0.9
Pallisa	2	64	21 (28)	15	36	3.0	3.0
Mukono	3	23	13 (47)	64	77	3.0	3.7
Mpigi	3	22	17 (59)	61	78	2.8	4.6
Luwero	3	17	12 (56)	71	83	2.6	3.0
Mubende	4	69	24 (29)	7	31	2.7	3.4
Masaka	4	33	50 (91)	17	67	3.0	13.1
Rakai	4	53	44 (60)	3	47	2.7	11.1
AVERAGE		32	22 (65)	46	68	2.9	3.9

1 Figures in parentheses transformed to allow for multiple infection

Fig. 24. Cassava whitefly abundance in 12 districts of Uganda, November-December, 1997.

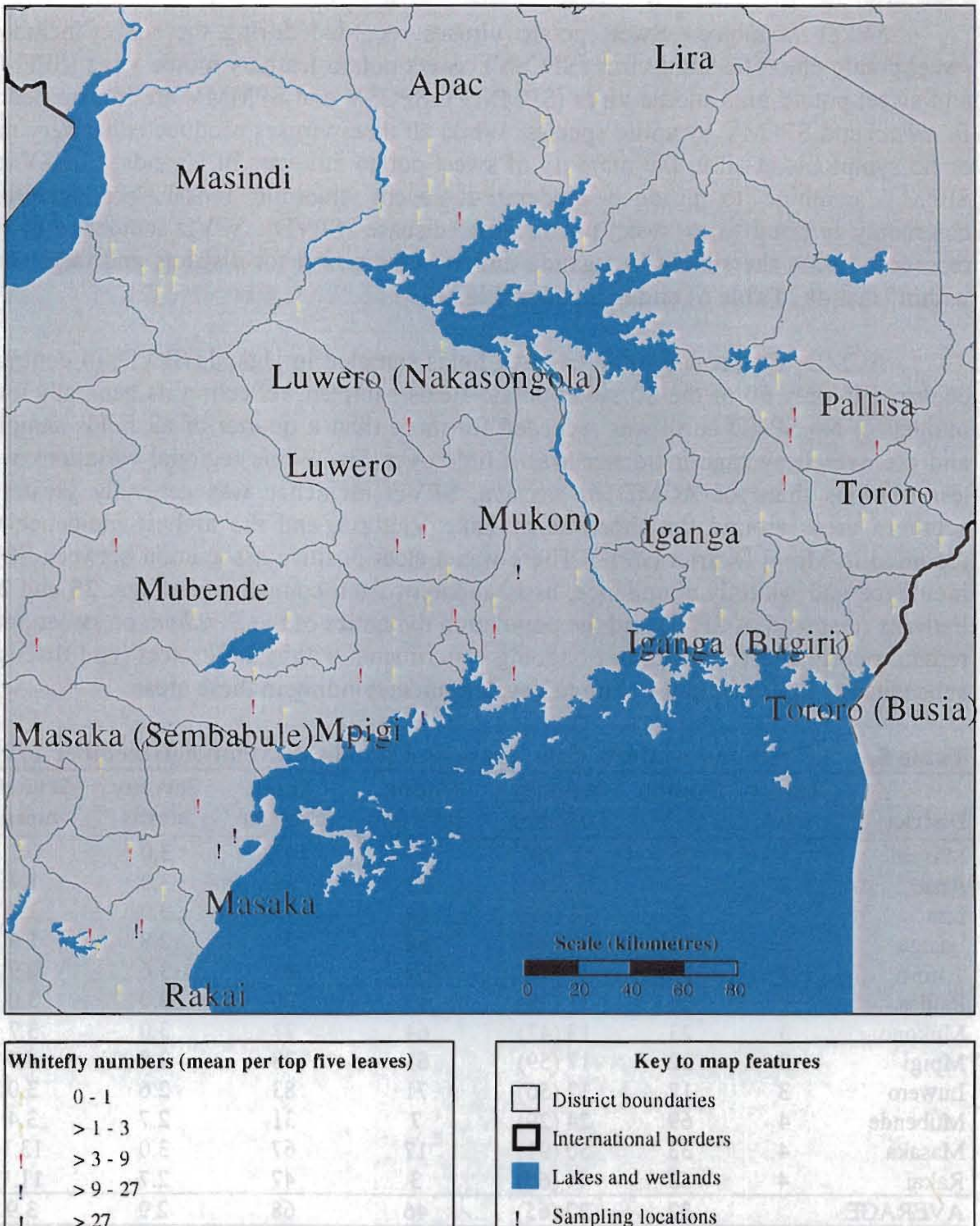


Fig. 25. Sweet potato whitefly abundance in 12 districts of Uganda, November-December, 1997.

Fig. 26. SPVD incidence in 12 districts of Uganda, November-December, 1997.

For both cassava and sweet potato, whiteflies were more abundant in the southern and southwestern Target Areas 3 and 4, than in Target Areas 1 and 2 to the north and east. While assessing the significance of these differences is not easy based on records collected on a single occasion, this general geographical trend in abundance does seem to reflect the current situation. Other recent studies on whiteflies on sweet potato have indicated their greater abundance in the southern and central zones characterized by less seasonal rainfall (i.e. more evenly distributed) than the northern and eastern zones. However, previous information of geographical patterns of abundance of whiteflies on cassava have been very variable; it appears that a complex of factors influence these populations, including the physical environment, host plant condition (including whether the plant is ACMD-diseased or not) and natural enemies. The epidemic of severe ACMD, which has recently expanded its range to cover much of Uganda, seems to have been associated with increases in *B. tabaci* numbers. There is also preliminary evidence for the occurrence of biotypes of *B. tabaci* on cassava in Uganda. The relationship between the ACMD epidemic and changes in abundance of *B. tabaci* is currently the subject of ongoing research in Uganda.

Table 6. SPVD incidence and whitefly data, sweet potato, Uganda, November/ December 1997.

District	Target area	SPVD incidence	Whitefly means
Masindi	1	3	0.9
Apac	1	9	1.9
Lira	1	3	1.4
Iganga	2	16	11.2
Tororo	2	15	1.5
Pallisa	2	6	3.4
Mukono	3	10	14.8
Mpigi	3	29	14.7
Luwero	3	7	7.8
Mubende	4	9	3.8
Masaka	4	14	3.2
Rakai	4	8	2.0
AVERAGE		11	5.5

ACMD symptom severity. There was limited contrast in the severity of ACMD symptoms across the locations sampled, and local variation in symptom expression from plant to plant and between varieties was generally more important than gross patterns of geographic variation. However, there are some important features apparent from the map presented in **Fig. 27**. Locations where symptoms were unusually severe are concentrated in the southwestern and southeastern districts. These areas correspond to the areas where the ACMD epidemic is currently expanding as is apparent through comparison with the epidemic characteristics map (**Fig. 22**). A feature of the severe ACMD associated with the epidemic is that newly infected plants (initially ACMD-free) appear to express more severe symptoms than plants infected from the cutting. This phenomenon and the possible roles of ACMV and the Uganda Variant (UV) in the etiology of severeACMD, are currently being investigated in Uganda. The only district where a significant proportion of sampled sites had mild symptoms was Pallisa. This again is a likely consequence of the dominance there of new ACMD-resistant materials. These varieties (the IITA-derived TMS 30572 and TMS 30337, locally released under the names Migyera and Nase 2, respectively), in addition to being resistant to infection, are also tolerant of the effects of infection. Symptom expression is less pronounced and often restricted in its distribution within the plant.

Estimation of yield and financial losses attributable to ACMD Recent experimental trials conducted in Uganda have measured average yield losses attributable to ACMD in the most widely grown local cultivar (Ebwanateraka) at 56%. Making a more modest assumption of 40% yield loss, a conservative value for fresh rootsof US$150 per ton, and using the 1996 FAO production estimate for Uganda of 2,650,000 tons, annual losses based on the survey incidence Fig. of 68% would be more than 990,000 tons, which is equivalent to more than US$148 million. Also assumed in this calculation are the overall countrywide validity of the average incidence figure and the even distribution of ACMD across areas of high and low intensity of cassava cultivation.

Estimation of yield and financial losses attributable to SPVD In a manner similar to the calculation of yield losses attributable to ACMD, losses to sweet potato production in Uganda can be estimated based on a series of assumptions. Yield losses due to SPVD are highly variable, depending on the cultivar; however, a conservative average approximation would be 40%. If average incidence is 5.5%, the crop loss would therefore be 2.2%. FAO data for 1996 indicates national sweet potato production to be 2,250,000 tons. The total annual crop loss calculated from these figures is 50,614 tons, which at a fresh tuber price of US$100 per ton would be equivalent to more than US$5 million.

Fig. 27. ACMD symptom severity in 12 districts of Uganda, November-December, 1997.

D. Determine Whitefly-Related Crop Protection Costs and Crop Production Costs in Affected Zones

Subproject 1. The survey data are currently being analyzed.

Subproject 2. The data collected so far and personal observations suggestthat crop protection costs and the development of pesticide resistance in whitefly populations are important factors leading to the displacement of whitefly/geminivirus-susceptible crops. Currently, the new insecticide imidacloprid is the chemical of choice to control whiteflies, but its high cost (approximately US$200 ha) prevents its use by small scale farmers and, in the case of large-scale producers, significantly increases the cost of producing vegetables. The high cost of modern and more stable pesticides to control whiteflies may be a favorable factor in the adoption ofnonchemical whitefly control practices. One of the objectives of this activity is to estimate the feasibility and cost of alternative control practices such as physical whitefly barriers (microtunnels, screenhouses), biological control agents, legal measures, etc. and to anticipate potential problems for their adoption. The information that has been collected is currently being organized and analyzed.

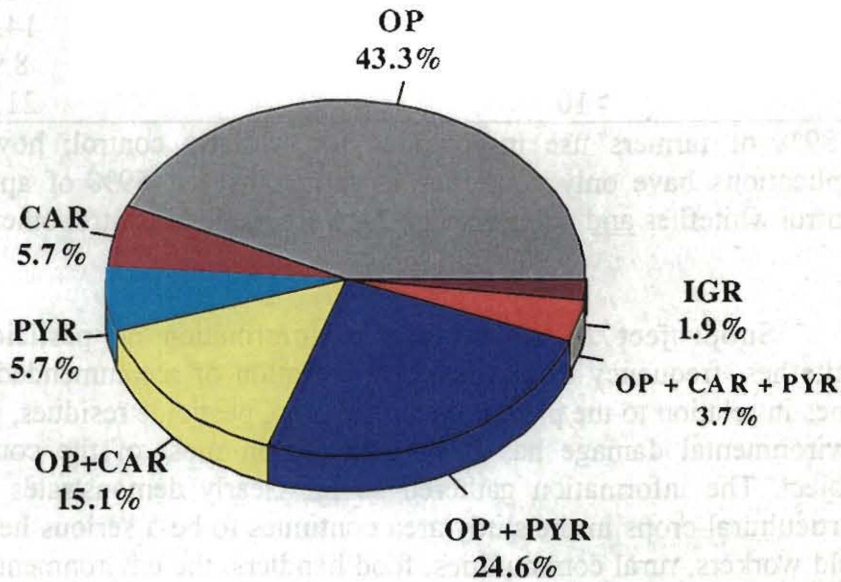
Subproject 3. The average cost to control whitefly/TYLC per hectare of tomato in one season were US$201 in Kenya, US$223 in Malawi, US$149 in Sudan and US$200 in Tanzania.

Subproject 4. Because most cassava and sweet potato production is for home consumption rather than for sale, it was difficult to assess costs incurred in controlling ACMD and SPVD; most costs are not directly financial. The most widely practiced control practices were selection of disease-free planting material and roguing, both of which have a time-related opportunity cost rather than a direct financial one. Interviewers in the diagnostic survey attempted to assess control costs by asking farmers how much money they had spent directly on control (which did apply where farmers had purchased pesticides or disease-resistant planting material) and how many days had been allocated to control activities. Using a standard Fig. for the cost of a day's work, this procedure allowed some rough cost estimates to be developed, but these were widely variable. It was therefore concluded that more focused follow-up studies would be required to obtain more robust information on this aspect of the impact of WFs and WTVs on cassava and sweet potato producers.

E. Survey for Pesticide Use Against Whiteflies and Whitefly-Transmitted Viruses in Affected Zones

Subproject 1. Preliminary analysis of 83 data sets show that 80% of the farmers surveyed know whiteflies as pests and that 41% regard them as key pests on several different crops. In Colombia and Ecuador, 89% use insecticides to control whiteflies. Up to 43% of the applications are made with organophosphate insecticides (OPs) alone; however, OPs are also used in mixtures with carbamates and pyrethroids (**Fig. 28**).

Fig. 28. Insecticide use for whitefly control in the Andean zone.



Most insecticides used are highly toxic (30% category I, 44% category II). The frequency of insecticidal applications on tomatoes and snap beans can be as high as three times a week. The number of applications per season varies with regions, but it is interesting to note that 30% of the farmers surveyed make 10 or more applications per cropping season (**Table 7**). Most farmers (69%) use very low, ineffective dosages (0.2 cc/l) or extremely high (4.8 cc/l) dosages. Up to 80% of them take their own decisions on timing of applications. More than half (52%) spray on a calendar basis, regardless of infestation levels; only 30% of those surveyed receive some kind of technical assistance. Many (41%) are influenced by pesticide salesmen. Less than 10% take precautions (use of masks, gloves) when using highly toxic insecticides. Up to 35% of farmers claim that crops have been abandoned as a result of WF attack or WF-induced problems.

Table 7. **Patterns of insecticide use for whitefly control in selected area of the Andean zone.**

No. of insecticide applications per cropping season[1]	% farmers
1-3	34.0
4-6	21.4
7-9	14.3
10	8.9
>10	21.4

1 89% of farmers use insecticides for whitefly control; however, just 9% of the applications have only whiteflies as target insects; 59% of applications are made to control whiteflies and other insects; 21% are made to control other insects.

Subproject 2. A great deal of information on pesticides applied to control whiteflies, frequency of applications, violation of recommended doses and application times in relation to the phenology of the crop, pesticide residues, pesticide resistance and environmental damage has been collected in most of the countries selected in this project. The information gathered so far clearly demonstrates that the production of horticultural crops in the study area continues to be a serious health hazard for farmers, field workers, rural communities, food handlers, the environment and, most importantly, consumers in urban areas. Photographic evidence of this continuing problem has also been obtained.

Subproject 3. All tomato farmers seem to use some chemical pesticides to control the whitefly/disease problems. One farmer in Kenya also used ash in addition to chemicals to manage the whitefly disease problems on his tomato farm. Farmers in Sudan, Kenya and Tanzania made an average of 10, 9 and 7 applications of pesticides per season, respectively, against whitefly/disease problems, while in Malawi an average of 6 applications were made (**Fig. 29**). The majority of farmers apply insecticides on a calendar basis and as a prevention measure rather than based on threshold levels or when they observe whitefly or disease damage. Recommendations for control methods were received by the farmer from other producers, technicians, sales persons, family members and neighbors, among others, in varying frequencies in the four countries (**Fig. 30**).

Subproject 4. At the outset of the Project, it was known that there was minimal if any usage of pesticides in cassava and sweet potato production systems in sub-Saharan Africa, and therefore agreed that it would be inappropriate to incorporate routine questions and protocols for insecticide use and the assay of insecticide resistance into the surveys of Subproject 4. It was suggested, however, that populations of*B. tabaci* from cassava and sweet potato in Africa might serve as good pesticide-sensitive controls for comparison with populations from the Americas.

Fig. 29. Frequency of insecticide application by farmers against whiteflies in one season.

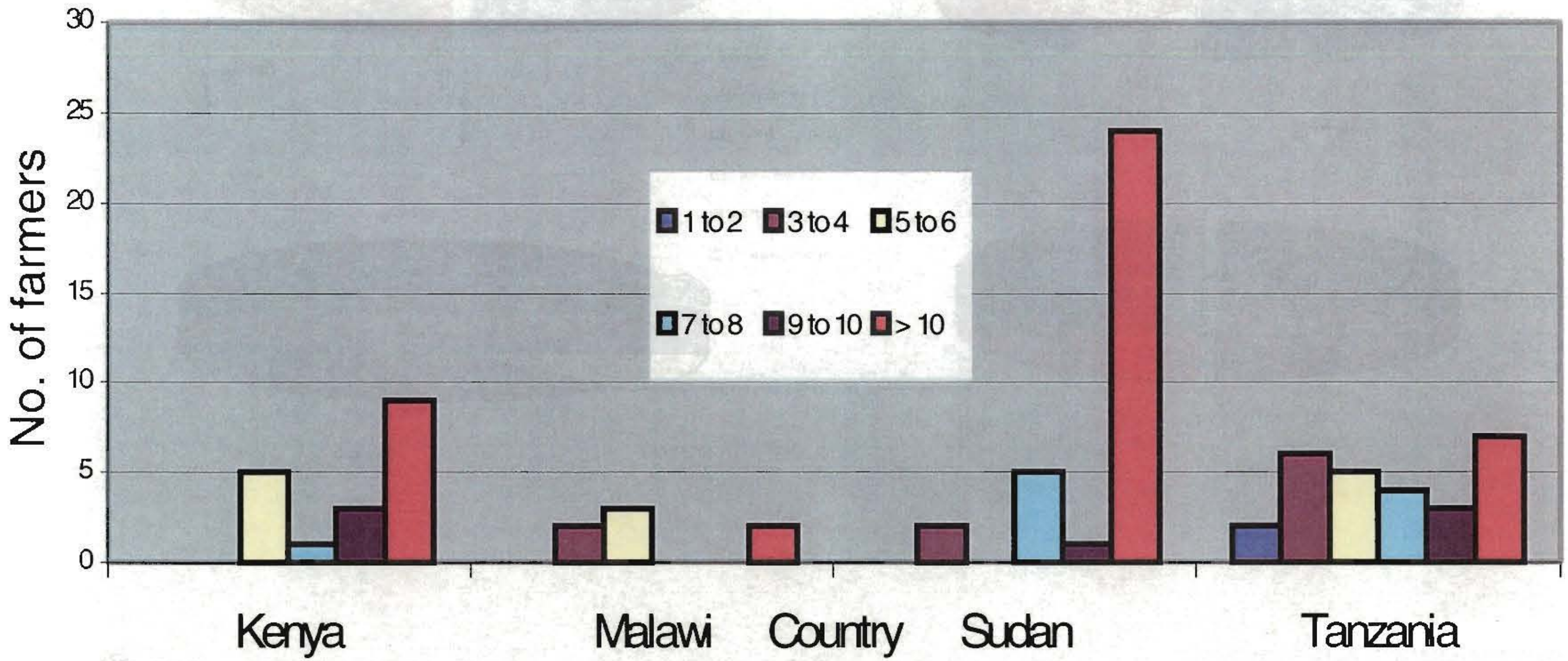
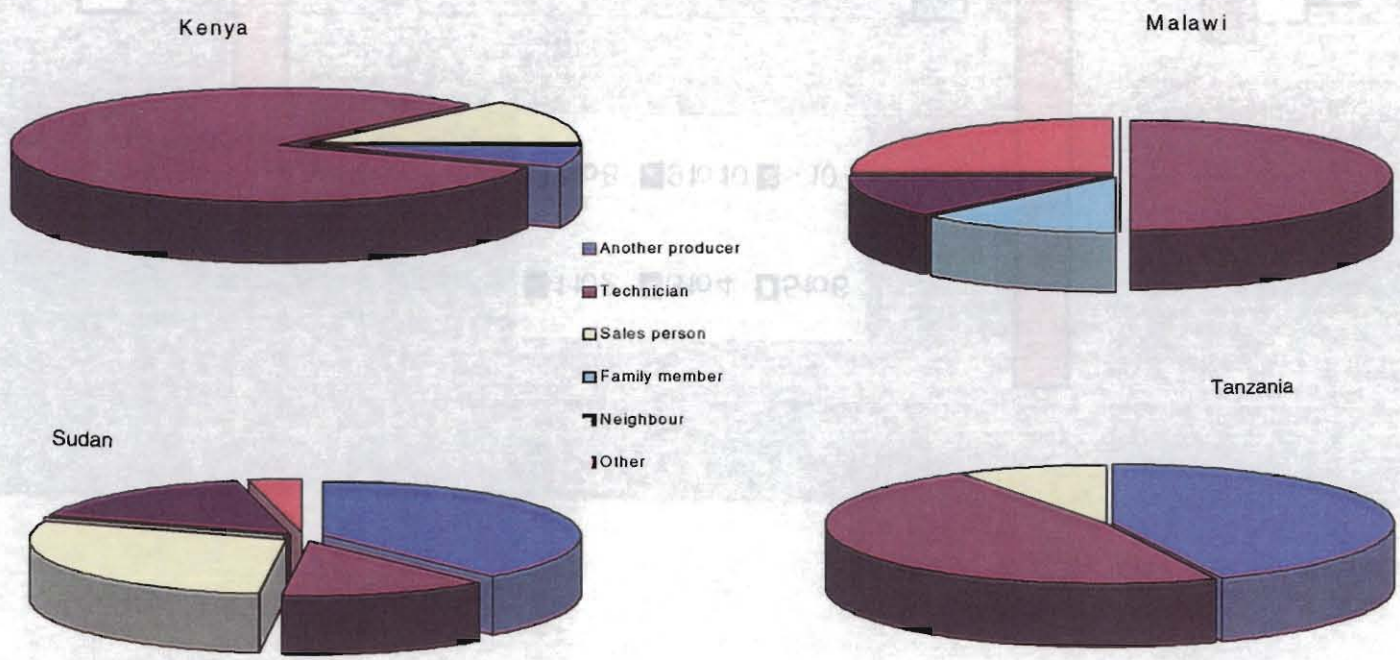


Fig. 30. Who recommended the whitefly management practices that the farmers use.



F. Determine Insecticide Resistance Levels in Target Areas

Subproject 1. Baseline data for insecticide resistance levels in *T. vaporariorum* (**Table 8**) and *B. tabaci* (**Table 9**) were obtained using mass rearings maintained at CIAT for several years. For each species the LC_{50} values were calculated for an organophosphate (methamidophos), a carbamate (methomyl) and a pyrethroid (cypermethrin). With the baseline data, dosages for percentage mortalities ranging from 5 to 95% were used to calculate mortalities at diagnostic concentrations (**Table 10**). The diagnostic concentrations were then used to monitor insecticide resistance levels in the field using the vial technique.

To date, the analyses of 29 tests suggest that resistance of *T. vaporariorum* to organophosphates is widespread in the Andean regions of Ecuador and Colombia (**Fig.s 31 and 32**). Low levels of resistance of *T. vaporariorum* to cypermethrin occur in specific areas of the Andean zone. No significant resistance to methomyl was detected. Biotype B of *B. tabaci* present on the Atlantic Coast of Colombia showed high levels of resistance to carbamates (methomyl) (**Fig. 33**) and to OPs (methamidophos) (**Fig. 34**), with less resistance to pyrethroids (cypermethrin). Intensive survey of insecticide resistance levels should continue.

Table 8. Toxicological responses of laboratory strains of *T. vaporariorum* to three insecticides, using insecticide coated glass vials.

Insecticide	n	Slope ± SEM	LC_{50} (95% FL)[1]
Methomyl	457	2.2 ± 0.5	0.25 (0.15 -2.6)
Methamidophos	600	2.0 ± 0.5	5.3 (2.5 – 7.6)
Cypermethrin	480	1.2 ± 0.2	37.0 (22.0 - 55.7)

1 µg/vial

Table 9. Toxicological responses of laboratory strains of *B. tabaci* to three insecticides, using insecticide coated glass vials.

Insecticide	n	Slope ± SEM	LC_{50} (95% FL)[1]
Methomyl	500	1.7 ± 0.2	1.7 (1.1 – 2.3)
Methamidophos	517	1.9 ± 0.5	1.4 (0.9- 1.6)
Cypermethrin	502	1.1 + 0.1	14.4 (5.8 – 27.2)

1 µg/vial

Table 10. Response (% mortality) of *T. vaporariorum* and *B. tabaci* adults to three insecticides (diagnostic dosages were tested using insecticide coated glass vials).

Whitefly species	methomyl (2.5 µg/vial)	methamidophos (32 µg/vial)	cypermethrin (500 µg/vial)
T. vaporariorum	97	99	88
B. tabaci	99	100	98

Fig. 31. Responses of *T. vaporariorum* populations to methamidophos in northern Ecuador-southern Colombia.

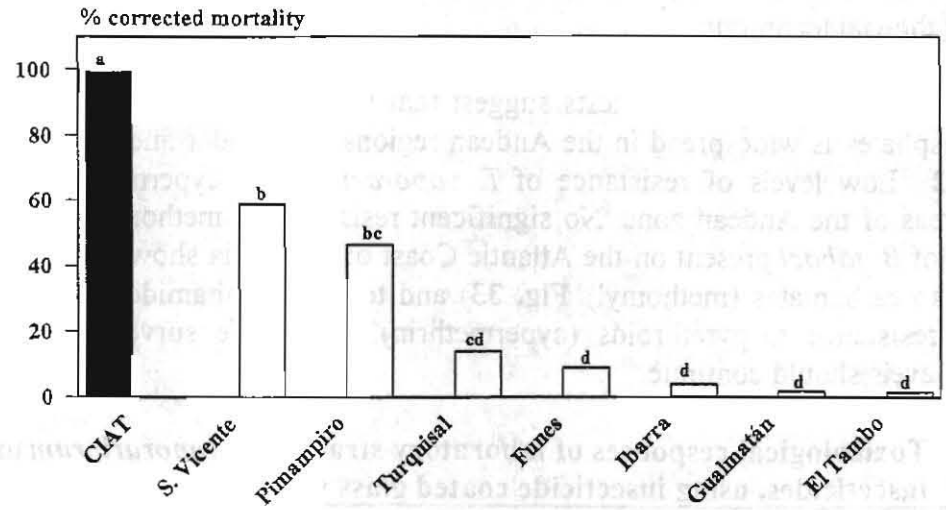


Fig. 32. Responses of *T. vaporariorum* populations to methamidophos in western-central Colombia.

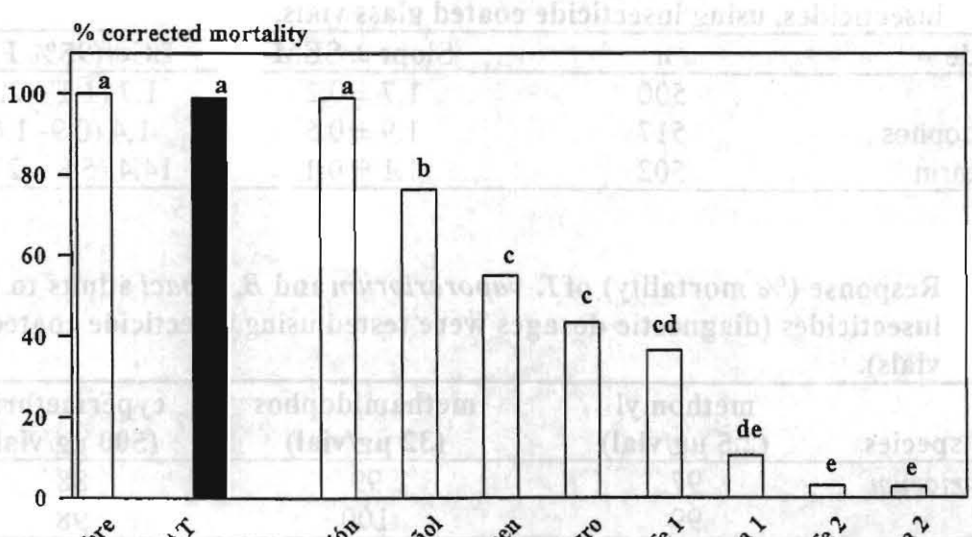


Fig. 33. Responses of *B. tabaci*, biotype B, populations to methomyl on the Atlantic Coast of Colombia.

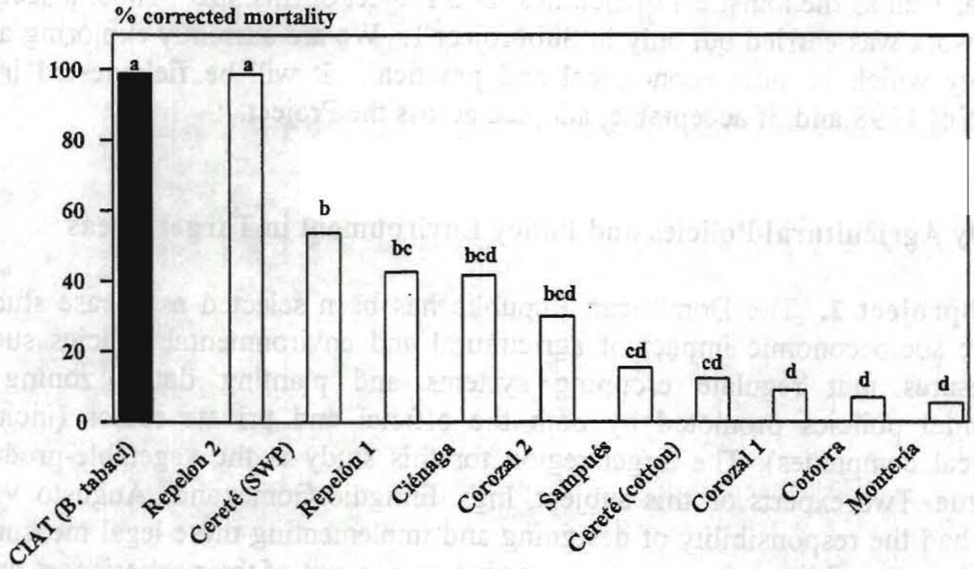
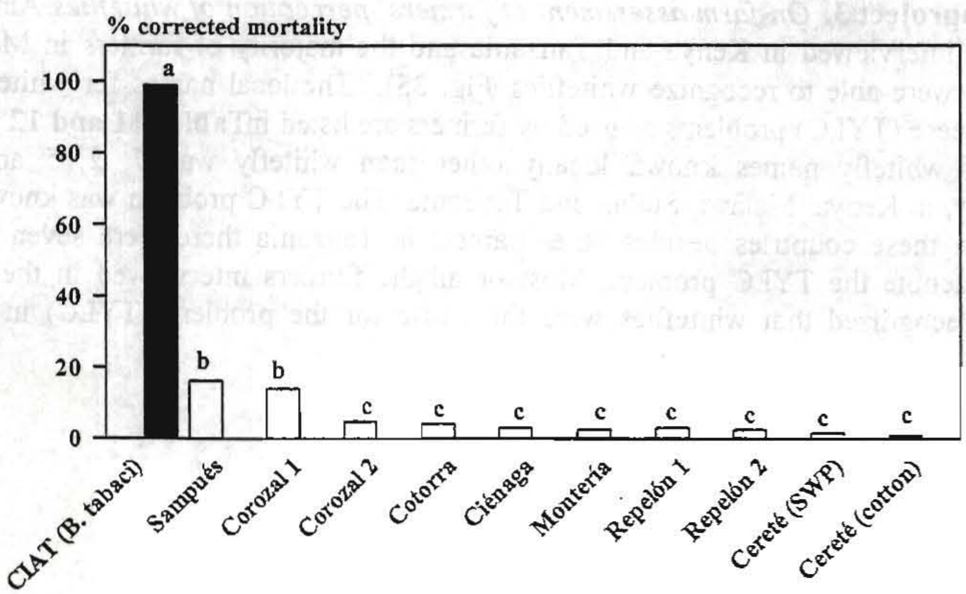


Fig. 34. Responses of *B. tabaci*, biotype B, populations to methamidophos on the Atlantic Coast of Colombia.



Determination of insecticide resistance is important input data for evaluating the urgency of insecticide rotation/management, and providing arguments for the move towards non-pesticide alternatives. This is one area where it has been especially difficult to compare data sets due to the diversity of methodologies that have been employed to test for insecticide resistance. Standardization is critical. However, in proposing the standardized use of the vial bioassay, we seriously underestimated the costs in time and materials, as well as the logistical difficulties for a Project of this size. Thus, insecticide resistance work was carried out only in Subproject 1. We are currently exploring a new methodology which is more economical and practical. It will be field tested in the second half of 1998 and, if acceptable, adopted across the Project.

G. Identify Agricultural Policies and Policy Environment in Target Areas

Subproject 2. The Dominican Republic has been selected as a case study to analyze the socioeconomic impact of agricultural and environmental policies such as legal measures that regulate cropping systems and planting dates, zoning and environmental policies promoted by both the official and private sector (including agrochemical companies). The target region for this study is the vegetable-producing area of Azua. Two experts on this subject, Ings. Emigdio Gomezand Augusto Villar, who have had the responsibility of designing and implementing these legal measures in the Dominican Republic, are currently producing an account of their experiences and the socioeconomic impact of these legal policies in that country.

H. Farmers' Perceptions of the Whitefly Problem

Subprojects 1 and 2. Producer interviews are currently undergoing statistical analysis.

Subproject 3. *On-farm assessment of farmers' perception of whiteflies.* Almost all farmers interviewed in Kenya and Tanzania and the majority of farmers in Malawi and Sudan were able to recognize whiteflies (**Fig. 35**). The local names for whiteflies and the disease (TYLC) problems as used by farmers are listed in **Tables 11 and 12**. The number of whitefly names known locally other than whitefly was 7, 2, 5 and 9, respectively, in Kenya, Malawi, Sudan and Tanzania. The TYLC problem was known as leaf curl in these countries besides other names; in Tanzania there were seven other names to denote the TYLC problem. Most or all the farmers interviewed in the four countries recognized that whiteflies were the cause for the problem (TYLC) in their crops.

Table 11. Farmers' local names for whiteflies in partner countries.

Kenya	Malawi	Sudan	Tanzania
Whitefly	Aphids	Dubbana	Insects
Mbuu	Msambe	Dubbana beida	Wadudu
Rwagi		Zubaba	Kipepeo
Ebichuni		Zubaba beida	Sughru
Okogatua		Asala	Tukorokotwa
Kudni			Sunhuu
Oulolo			Wadudu weupe
Gathuri			Inzi weupe
			Mbuu

Table 12. Farmers' local names for tomato yellow leaf curl in partner countries.

Kenya	Malawi	Sudan	Tanzania
Mite damage	Blight	Karmata	Rasta
	Natural phenomenon	Karmasha	Masai
	Malformation	Kurmut	Dume
	Red mite spider damage		Poor bean yield
			Ukoma (Leprosy)
			Bondia (Boxer)
			Ngumi (Boxer)

The proportion of farmers recognizing whitefly, TYLC or both as a problem on their crop varied among the countries (**Fig. 36**). Some of the farmers in Kenya were not able to recognize tomato yellow leaf curl (mainly in Nyanza and Western Provinces), and some who were able to recognize the disease associated the symptoms with moisture deficiency, spider mites and aphids. The majority of farmers in Malawi, Sudan and Tanzania were able to recognize the disease. However, some farmers in Malawi associated TYLC with aphids, and the majority of them did not have any name for the disease. Farmers believed that whiteflies caused problems in their tomato fields **Fig. 37**).

The majority of farmers seem to believe that they have whitefly/virus problem every year (**Fig. 38**). Interestingly, all farmers in Malawi mentioned that in 1997 the whitefly/disease problems were especially severe. The majority of farmers in Kenya said that the problem was more severe in 1996/97 season. In the Sudan the problem was severe in 1997 while in Tanzania the problem was worse in 1996 and 1997 (**Fig. 39**).

Fig. 35. Proportion of farmers who can recognize whiteflies.

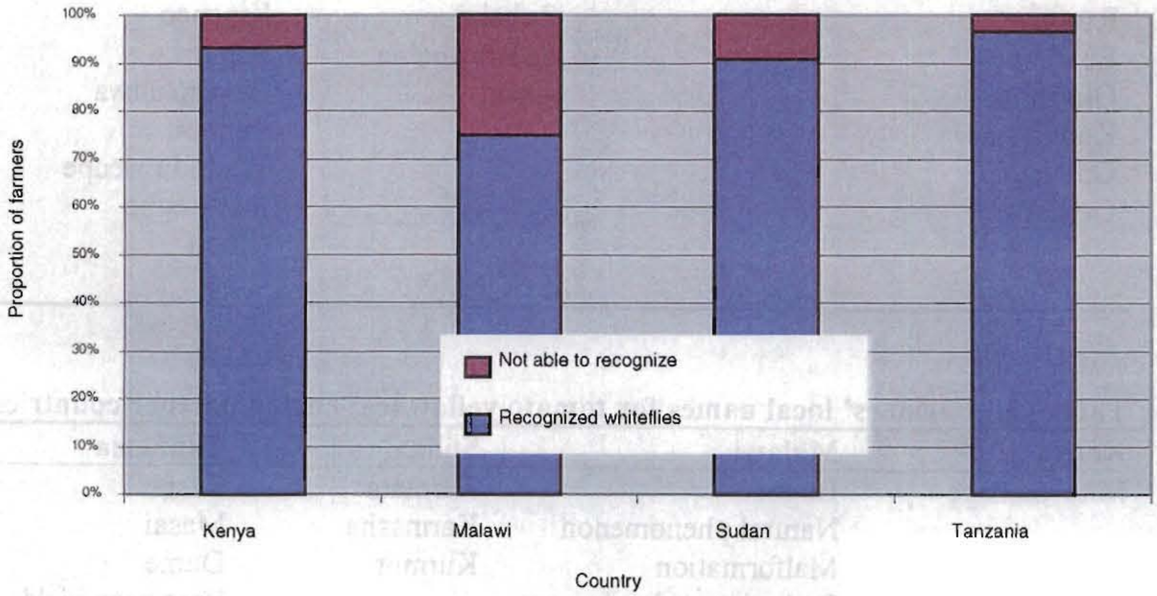


Fig. 36. Proportion of farmers perceiving that whiteflies cause problems in their crops.

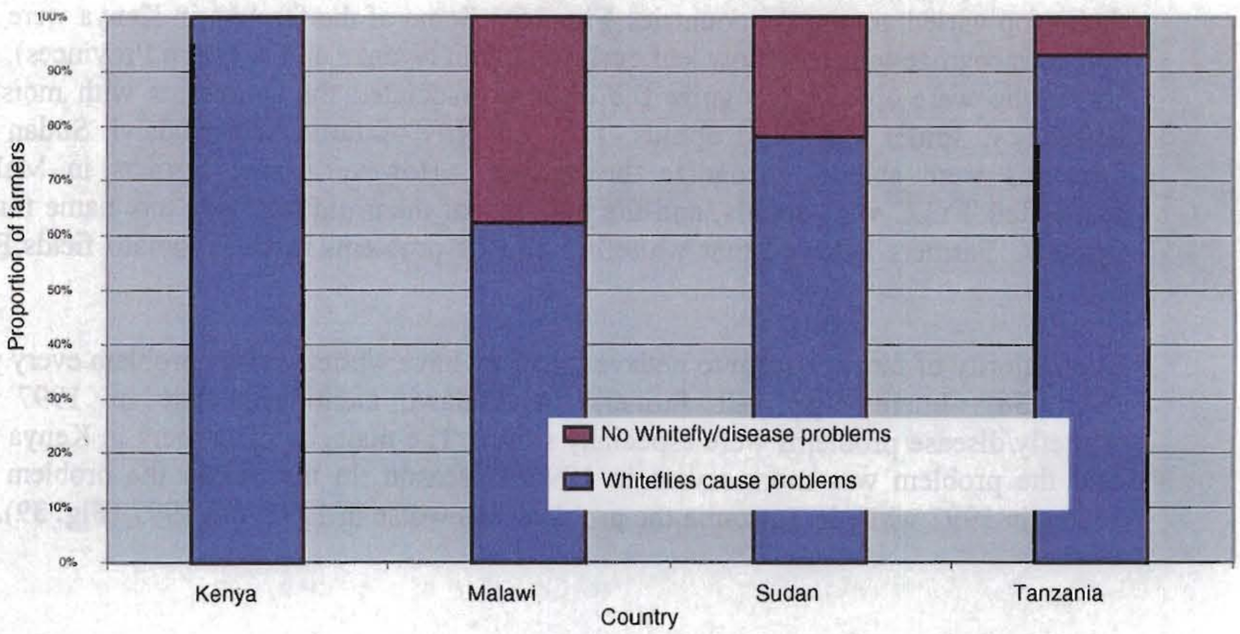


Fig. 37. Farmers' perceptions of whitefly/disease problems on tomato.

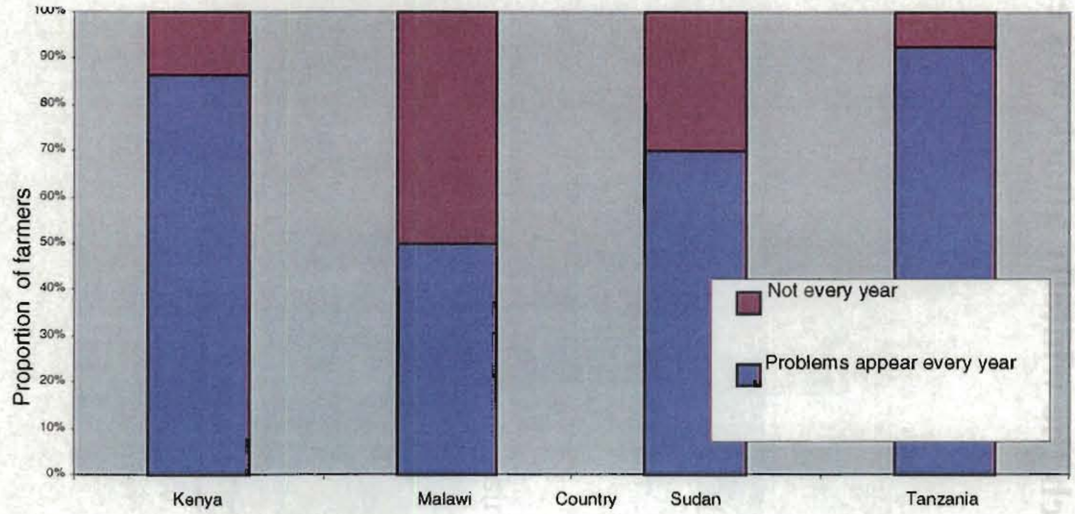


Fig. 38. Proportion of farmers perceiving that whitefly/disease problems appear every year.

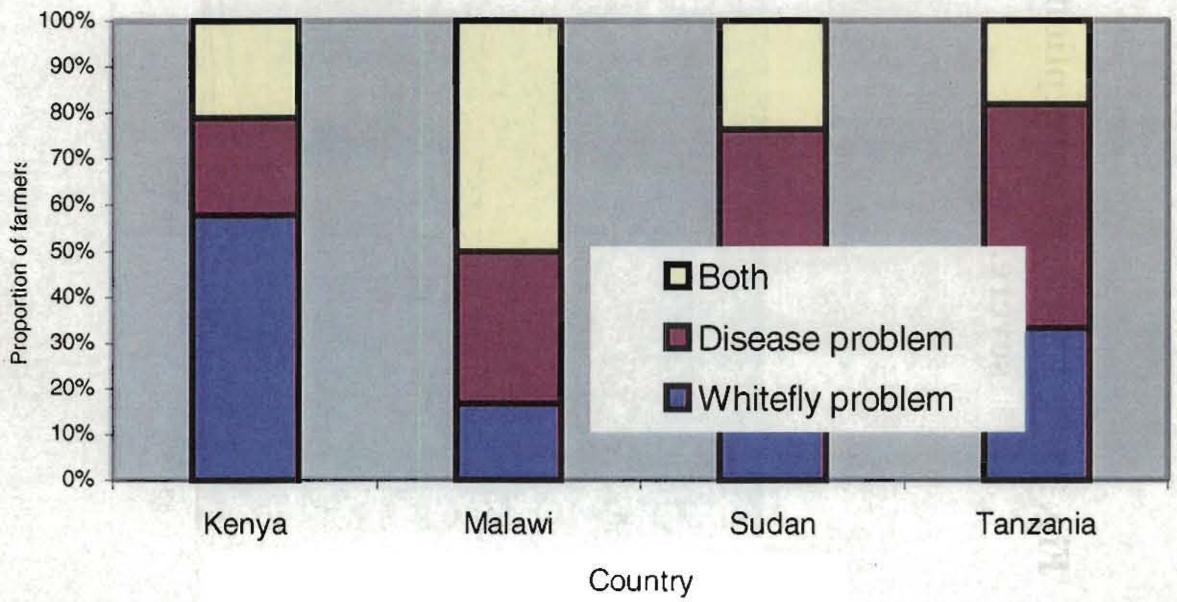
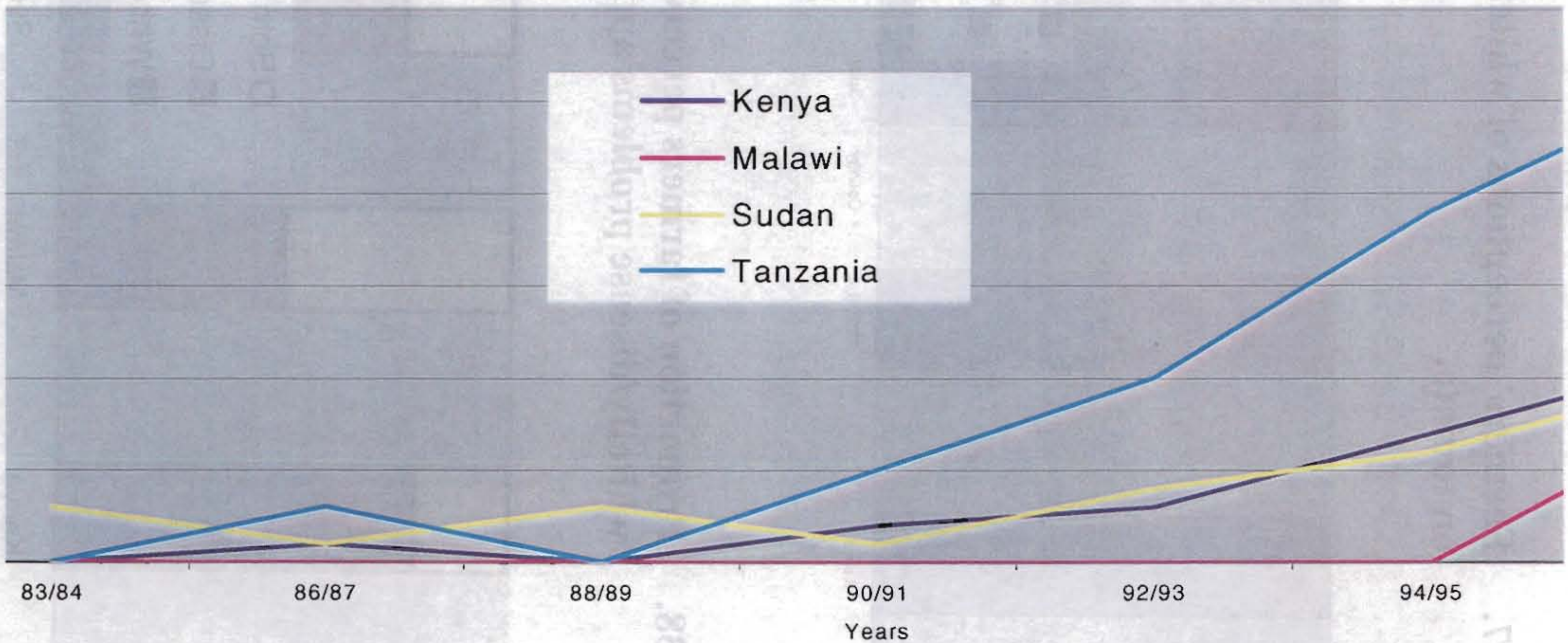


Fig. 39. Farmers' perceptions of years in which the whitefly attack was especially severe.



On-farm assessment of cropping and management practices Most of the tomato production in Kenya, Malawi, Sudan and Tanzania was by farmers using their own lands. The majority of farmers were men. Tomato was regarded the most profitable among the vegetable/legume crops produced by these subsistence farmers. Most farmers practice crop rotation. The crops grown include beans, maize, tomato, sweet pepper, onions, cassava, cucumber, sweet potato, groundnuts, sunflower, kale and cabbage. The common tomato varieties grown are Moneymaker, Cal-j, Strain B, Red Khakhi, Margalobe, Pearson and Roma.

Assessment of economic importance of whitefly problem In Malawi the main pests and diseases recorded on tomatoes according to importance were late blight, red spider mites, TYLC and whiteflies. In Kenya the main pests and diseases appear to be late blight, whiteflies, bollworms, wilt, TYLC and red spider mites. In Sudan the main pests and diseases were whiteflies, TYLC and bollworms. In Tanzania the main pest and disease constraints appear to be: late blight, TYLC, whiteflies and red spider mites, respectively (**Table 13**). Whiteflies ranked 2, 6, 1 and 3 among biotic constraints in Kenya, Malawi, Sudan and Tanzania, respectively. The respective ranking for TYLC was 5, 5, 2 and 2.

Table 13. Perceived relative importance of whitefly/TYLC as biological constraints to crop production in partner countries (no.of farmers perceiving as important).

Kenya		Malawi		Sudan		Tanzania	
Blight	14	Blight	7	Whiteflies	30	Blight	17
Whiteflies	11	Mites	6	TYLC	22	TYLC	16
Bollworms	7	Wilt	3	Bollworm	11	Whiteflies	11
Wilt	5	Cutworms	3	Fruitworms	5	Mites	5
TYLC	4	TYLC	2			Wilt	5
Mites	4	Whiteflies	1			Fruitworms	3
Aphids	3	Leaf eaters	1			Leaf eaters	1
Cutworms	2					Aphids	1
Nematodes	2					Nematodes	1
Endrot	2						
Blackrot	2						
Thrips	1						
Rats	1						

Average perceived yield losses in tomatoes were up to 40% in Malawi, 50% in Kenya, 75% in Tanzania and 100% in Sudan (**Fig. 40**). Some farmers in Malawi, Kenya and Sudan reported abandoning their tomato crops due to whitefly/disease problems. In Tanzania such cases of farmers abandoning their crops in the 1994 season was experienced due to similar problems (**Fig. 41**).

Fig. 40. Perceived crop loss due to the whitefly/disease problem.

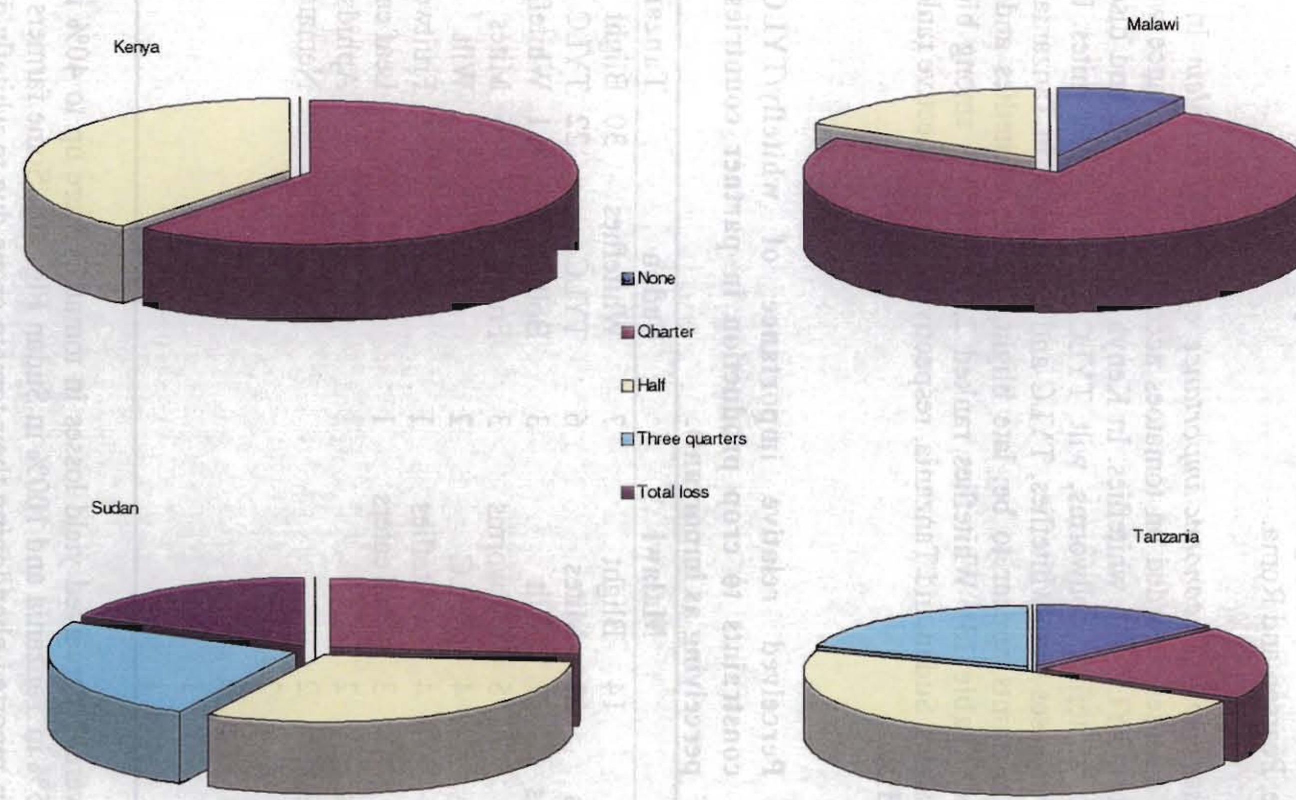


Fig. 41. Proportion of farmers who have ever abandoned their tomato crop because of whitefly/disease problems.

The majority of farmers also seem to believe that there is direct relationship between the climate and the whitefly disease incidence (**Fig. 42**). Farmers believe that there is more whitefly/TYLC incidence in dry and hot seasons (**Figs. 43, 44**). In Malawi the majority of farmers around Lilongwe believed that they have more whitefly/disease problems when the weather is hot and the rains are more frequent.

Subproject 4. *Farmer awareness and assessment of whitefly/disease problems.* A relatively small proportion of both cassava and sweet potato farmers (22%) were able to recognize whiteflies, and names given to them were almost entirely nonspecific (i.e. translated as insect, etc.). Names given for whiteflies were similar for both cassava and sweet potato and none of them included the word white. In contrast, the diseases ACMD and SPVD were both more widely recognized (100 and 48%, respectively) and had specific names in most of the locations where they were recognized. Both diseases were commonly referred to with words describing the mottling or deformation of the leaves induced by the disease, and a number of names were common for both cassava and sweet potato. Virtually all cassava farmers recognized ACMD as a production constraint, whereas for SPVD only 35% considered it to be a problem. While ACMD was considered to be the most important biotic constraint to cassava production by virtually all (94%) cassava producers interviewed, for sweet potato, constraints reported in addition to SPVD by a substantial number of farmers were weevils and sweet potato butterfly (**Fig. 45**).

Fig. 42. Proportion of farmers believing in relationship between climate and the whitefly/disease problem.

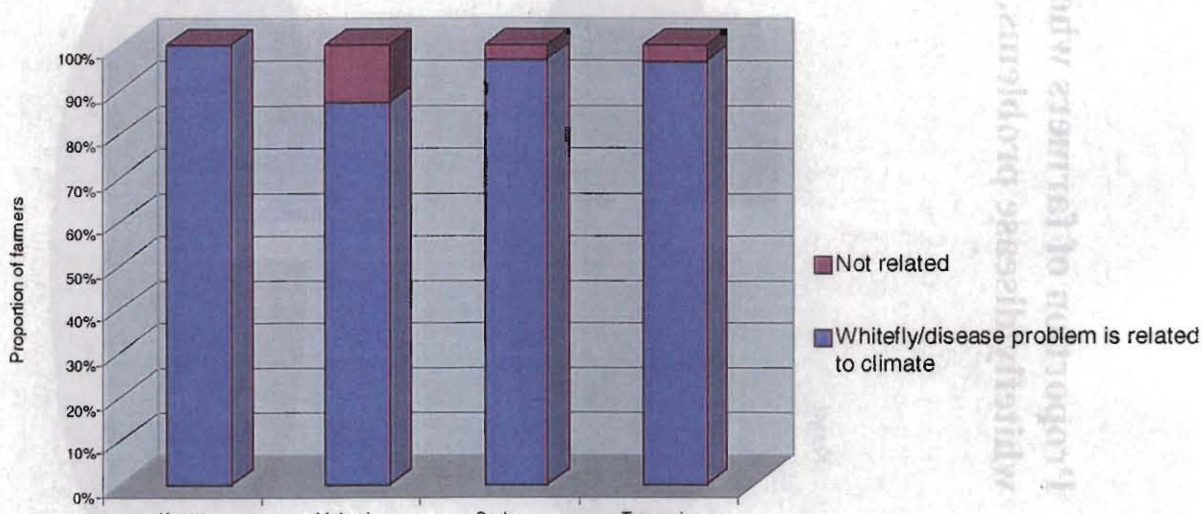


Fig. 43. Farmers' perceptions of the relationship between the whitefly/disease problem and extent of rains.

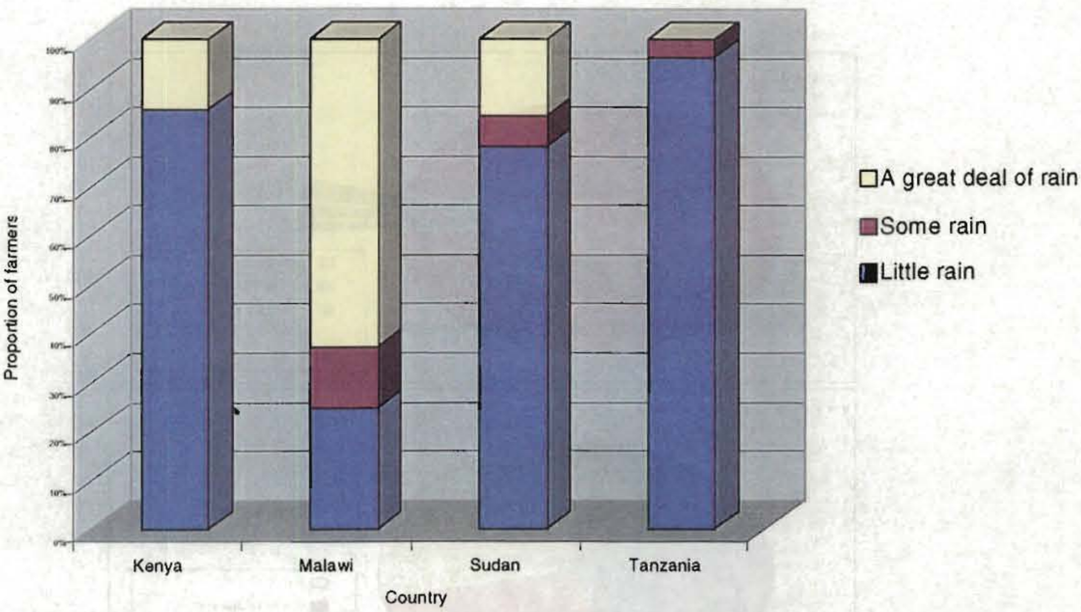


Fig. 44. Farmers' perceptions of cold moderate or hot seasons as favoring severe whitefly/disease problems.

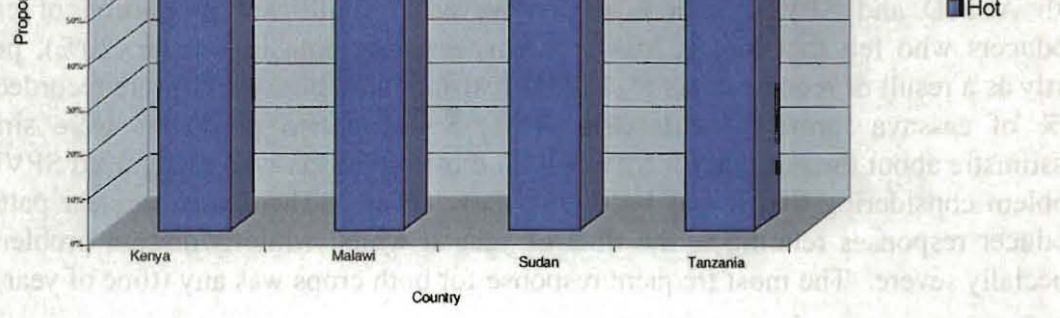
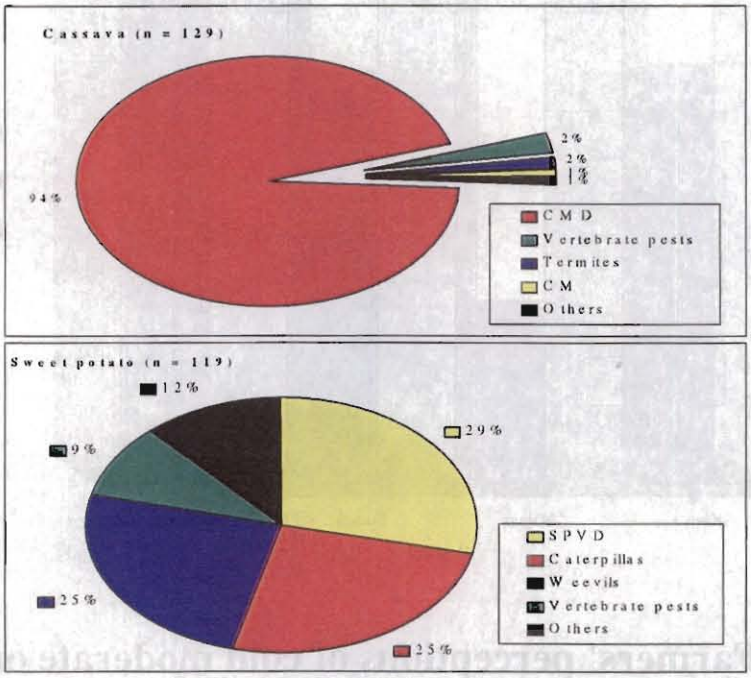


Fig. 45. Major pests and diseases of cassava and sweet potato as perceived by farmers interviewed.



These two groups of insect pests are widely considered to be the most damaging in Uganda and more economically important than SPVD. The greater importance attached to SPVD in this survey is again likely to be at least partly due to bias. Virus diseases were reported as affecting crops every year by 81% of the cassava producers and 35 % of the sweet potato producers. Most cassava farmers (74%) considered that the ACMD problem was becoming more severe. This picture is confirmed by the information provided by farmers on the years in which the effects of ACMD were most severe (**Fig. 46**). Although a measure of bias in responses towards more recent years can be anticipated, there is nevertheless a clear pattern of deterioration in the situation for both ACMD and SPVD. There was, however, a significant proportion of cassava producers who felt that the ACMD problem was becoming less acute (20%), perhaps partly as a result of recent access to ACMD-resistant varieties, which were recorded from 11% of cassava farmers' fields (**Fig. 47**). Sweet potato producers were similarly pessimistic about the outlook for SPVD, with most producers who recognized SPVD as a problem considering that it was becoming more severe. There was no clear pattern in producer responses relating to the time of year at which whitefly/disease problems are especially severe. The most frequent response for both crops was any (time of year) (**Fig.

48). This is unsurprising given the virtually year-round planting of both cassava and sweet potato and the nature of the virus diseases that are widely propagated through the use of diseased planting material. For ACMD the manner of expansion of the epidemic of severe disease is well illustrated by the map in **Fig. 49**, in which the first year of severe disease has been plotted for each of the locations from which farmers reported its occurrence. This compares closely with the epidemic map plotted from field data, and the general north-south progression of the epidemic is clearly defined. The figure does also suggest, however, that the origin of the epidemic was not in the far north of Uganda, but rather in the area surrounding Lake Kyoga, in central Uganda. Another interesting aspect of this map is the apparently early impact of ACMD on Mubende District in Target Area 4, with the majority of farmers reporting most severe ACMD problems in 1992. Like Pallisa District in the east, this district now has a generally low incidence of ACMD (**Fig. 23**) although unlike Pallisa, this is not the consequence of a massive program for the introduction of improved ACMD-resistant varieties. None of the 20 fields sampled in the western Target Area 4 included any of these improved varieties. The reasons behind the decline in ACMD in Mubende District are an important topic of future study.

Fig. 46. Years of severest ACMD and SPVD reported by farmers.

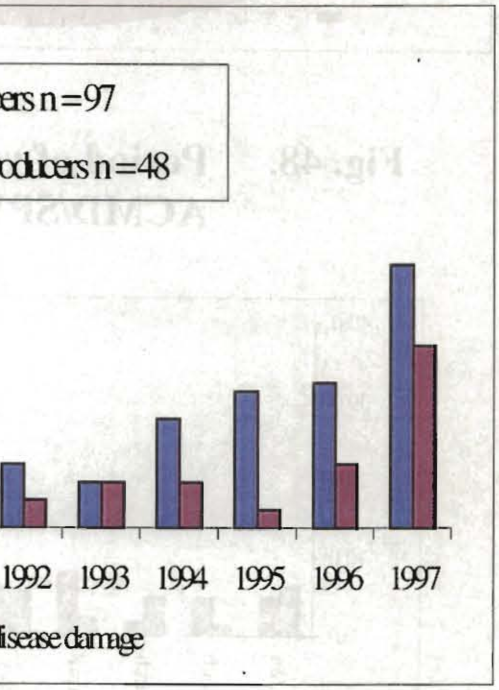
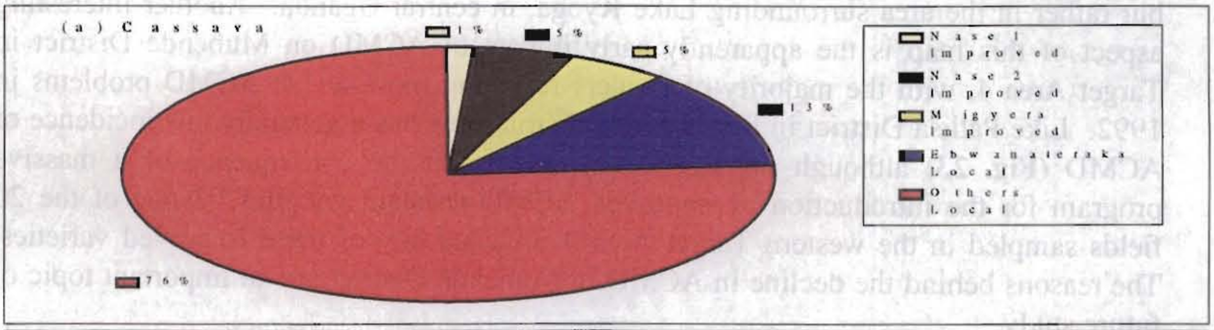


Fig. 47. Local and improved (a) cassava and (b) sweet potato cultivars recorded in field data collection, Whitefly IPM Survey.



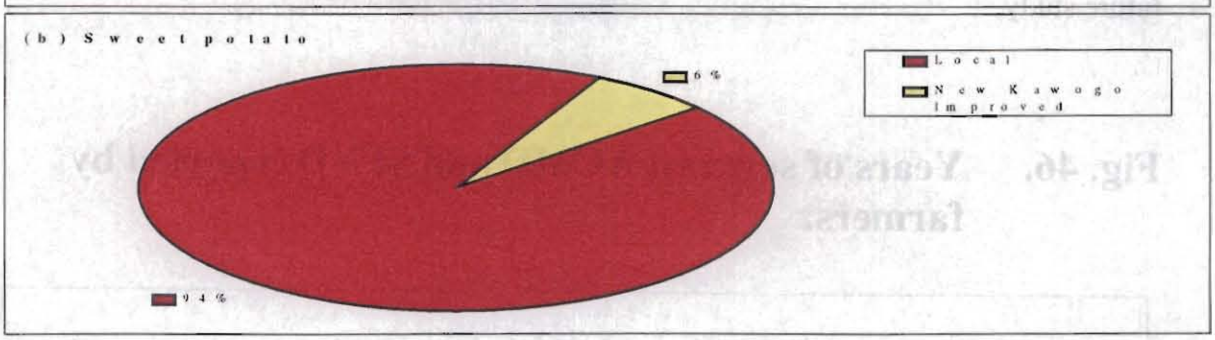


Fig. 48. Period of year with worst whitefly and ACMD/SPVD problem.

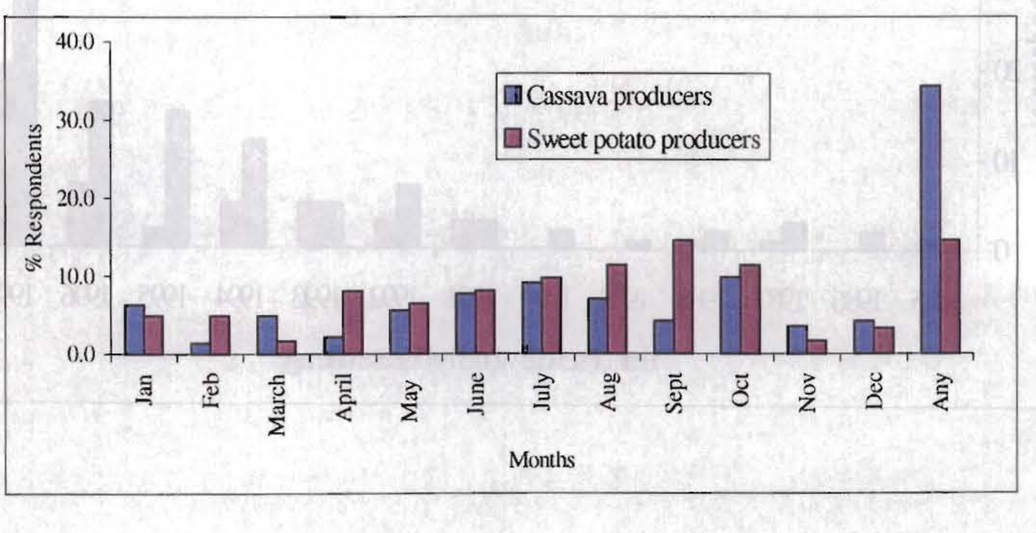
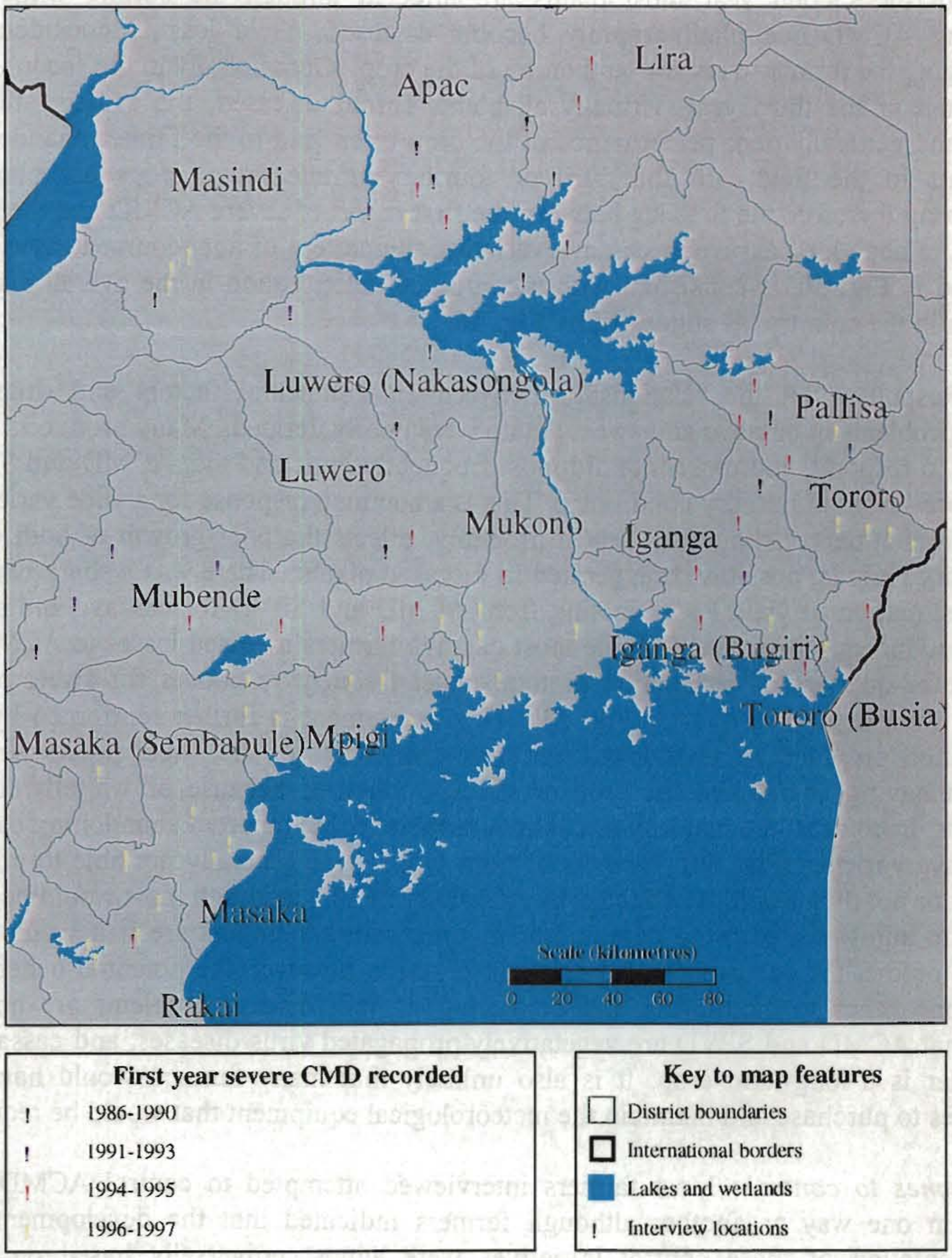


Fig. 49. First occurrence of severe ACMD reported by farmers, November-December, 1997.



A common response among farmers to the ACMD problem has been to abandon production of the crop altogether. The frequencies of farmers either abandoning cassava/sweet potato or cassava/sweet potato cultivars over time is plotted in**Fig. 50**. For any given location affected by the epidemic of severe ACMD disease, a clear sequence of events seems to occur over a period of two to four years. In the first year a large proportion of cassava plants are infected by whiteflies, although yield loss is not great. In the second year most plants are infected through the cutting while the remaining ACMD-free plants rapidly become diseased. Yield loss is considerable, encouraging the farmer to review cultivation of the crop. Occasionally in the second, but more often in the third year, virtually all plants sprout diseased; the evident stunted growth and generally poor performance of the crop often lead to the farmer abandoning the plants in the field. In the third or fourth year alternative crops are planted. Considering therefore the time lag between the first report of severe ACMD and the final decision to abandon cassava or cassava varieties, the pattern of abandonment over time, presented in **Fig. 50**, is consistent with a continued deterioration in the overall disease situation in the country, as suggested by **Fig. 46**.

Responses on the relationship between environmental factors and whitefly/ disease problems in cassava and sweet potato were poorly defined. Many producers were not able to respond, and those that did most frequently indicated that ACMD and SPVD were more severe in hot, dry conditions. This is a common response for a wide variety of biotic production constraints and most probably reflects the poor growth of both crops during dry periods, possibly exaggerated in diseased plants. There was a sharp contrast in the estimation of yield losses arising from ACMD and SPVD for cassava and sweet potato producers, respectively. While most cassava farmers assessed losses to ACMD as either three-quarters of production or total, most frequent responses for sweet potato farmers were none or a quarter (**Fig. 51**). This assessment is further reinforced by the information provided on abandoned varieties. Only 10% of the sweet potato farmers reported having abandoned the crop or specific varieties because of whitefly/disease problems. In contrast the majority of cassava farmers (69%) reported abandoning cassava or cassava varieties (**Fig. 50**). Farmers of both crops were generally not able to predict whether or not they would be affected by ACMD or SPVD, although most would be both willing to adjust the planting date and/or monitor rainfall/temperature if it would help them to predict the occurrence of disease. In practice, however, the potential benefits of such approaches to monitoring and predicting whitefly/disease problems are limited, given that ACMD and SPVD are vegetatively propagated virus diseases, and cassava in particular is a long-term crop. It is also unlikely that many farmers would have the resources to purchase and maintain the meteorological equipment that would be required.

Approaches to control. Most farmers interviewed attempted to control ACMD and SPVD in one way or another although farmers indicated that the development and implementation of these control initiatives were almost universally based on local knowledge. Only a small proportion of producers interviewed reported having received information on control practices through normal extension/research channels. In contrast, most farmers suggested that the control practices they used were their own **Fig. 52**).

Fig. 50. Abandonment of cassava and sweet potato crops by farmers due to whitefly/disease.

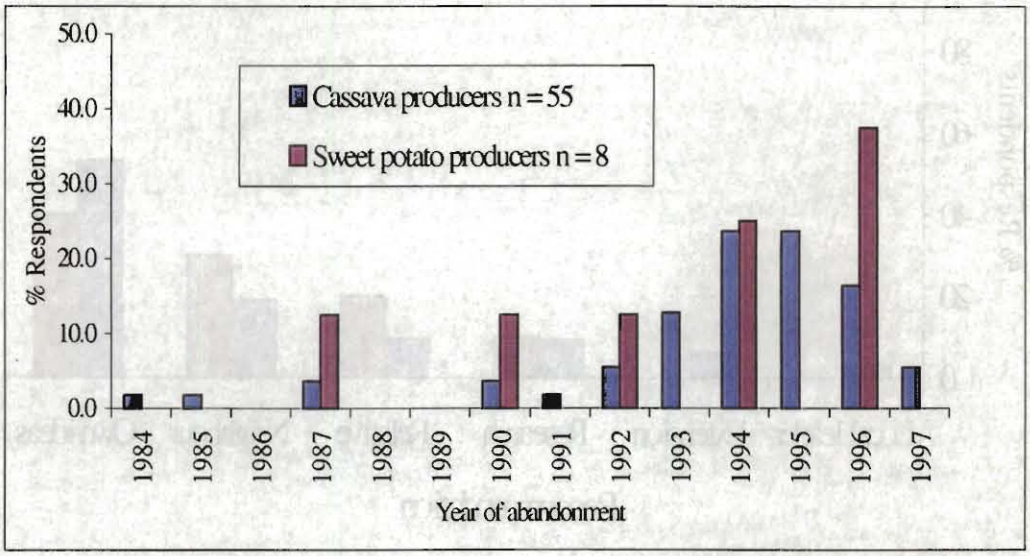


Fig. 51. Producer estimates of yield loss due to ACMD and SPVD.

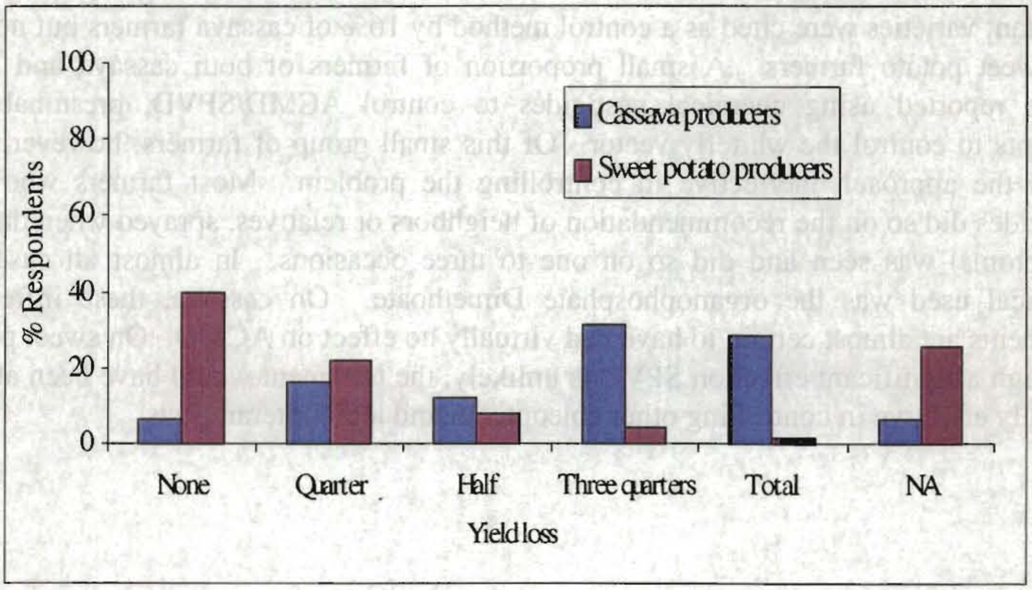
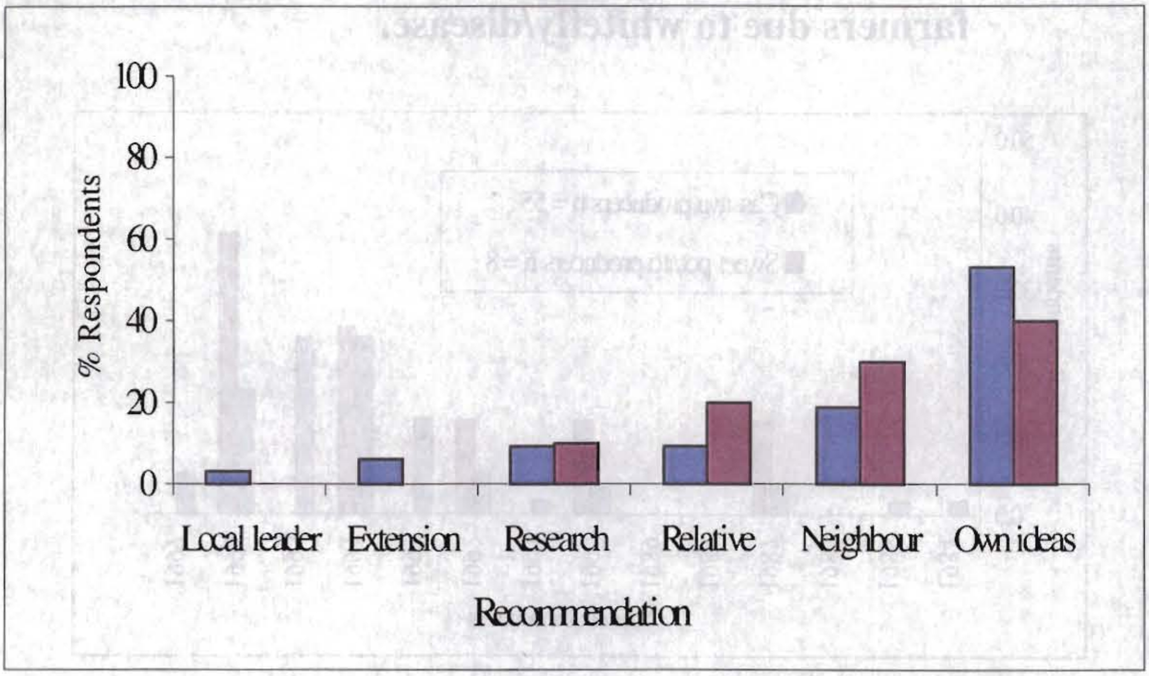
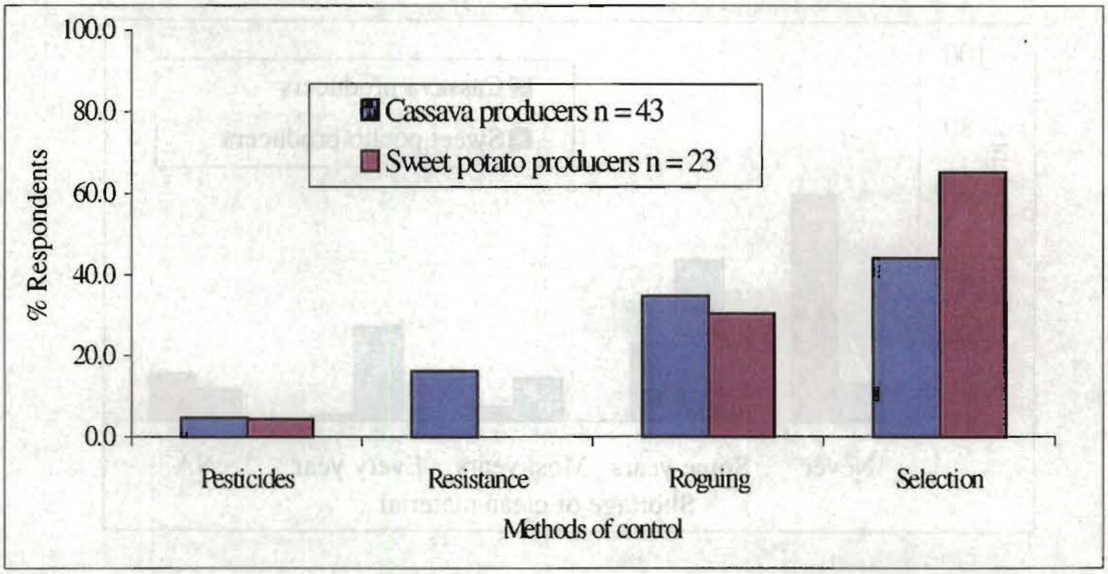


Fig. 52. Source of information for control methods used.



Selection of disease-free planting material was the most widely used disease control practice for both cassava and sweet potato, followed by roguing (**Fig. 53**). Resistant varieties were cited as a control method by 16% of cassava farmers but none of the sweet potato farmers. A small proportion of farmers of both cassava and sweet potato reported using chemical pesticides to control ACMD/SPVD, presumably in attempts to control the whitefly vector. Of this small group of farmers, however, most found the approach ineffective in controlling the problem. Most farmers who used pesticides did so on the recommendation of neighbors or relatives, sprayed when damage (symptoms) was seen and did so on one to three occasions. In almost all cases the chemical used was the organophosphate Dimethoate. On cassava, these infrequent treatments are almost certain to have had virtually no effect on ACMD. On sweet potato, although a significant effect on SPVD is unlikely, the treatment would have been at least partially effective in controlling other coleopteran and lepidopteran pests.

Fig. 53. Frequency of farmers using different control methods for ACMD and SPVD.



Selection of planting material was an important practice for the control of both ACMD and SPVD although regular shortages of healthy planting material (**Fig. 54**) made the application of the method difficult for many of the cassava farmers. Most farmers reported the approach to be only partially effective in controlling the diseases (**Fig. 55**), with many indicating that even clean materials became rapidly infected following sprouting. Perceptions on the effectiveness of roguing were similar to those for selection of clean planting material except that more cassava respondents considered roguing to be ineffective in controlling ACMD (**Fig. 56**). Many of the farmers who recognized differences in the response of different varieties to virus disease thought that varieties with less disease had some kind of resistance to infection although a similarly large proportion had no idea as to why such differences should occur (**Fig. 57**). Data collected from the field assessments indicated that a relatively small proportion of farmers of both cassava and sweet potato were growing improved virus-resistant varieties (**Fig. 47**) although farmers that had planted these materials found their performance better than local materials. All cassava farmers growing resistant varieties indicated them to be superior to local materials, and most of these considered the performance of resistant varieties to be highly superior. In contrast, assessments of the benefits of disease-resistant sweet potato varieties were more mixed, and some farmers reported no difference in performance between improved and local varieties. Understandably, when queried about the reasons for the better performance of improved over local materials, most farmers referred to improvements in yield rather than better resistance to disease.

Fig. 54. Shortage of clean planting material in farmers' cassava and sweet potato fields.

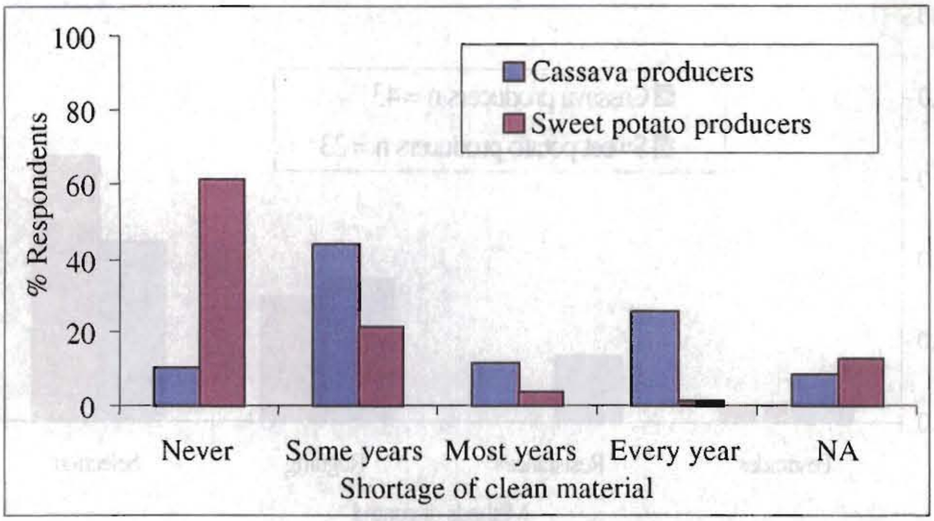


Fig. 55. Farmers' perceptions of the effectiveness of selecting for clean material in cassava and sweet potato fields.

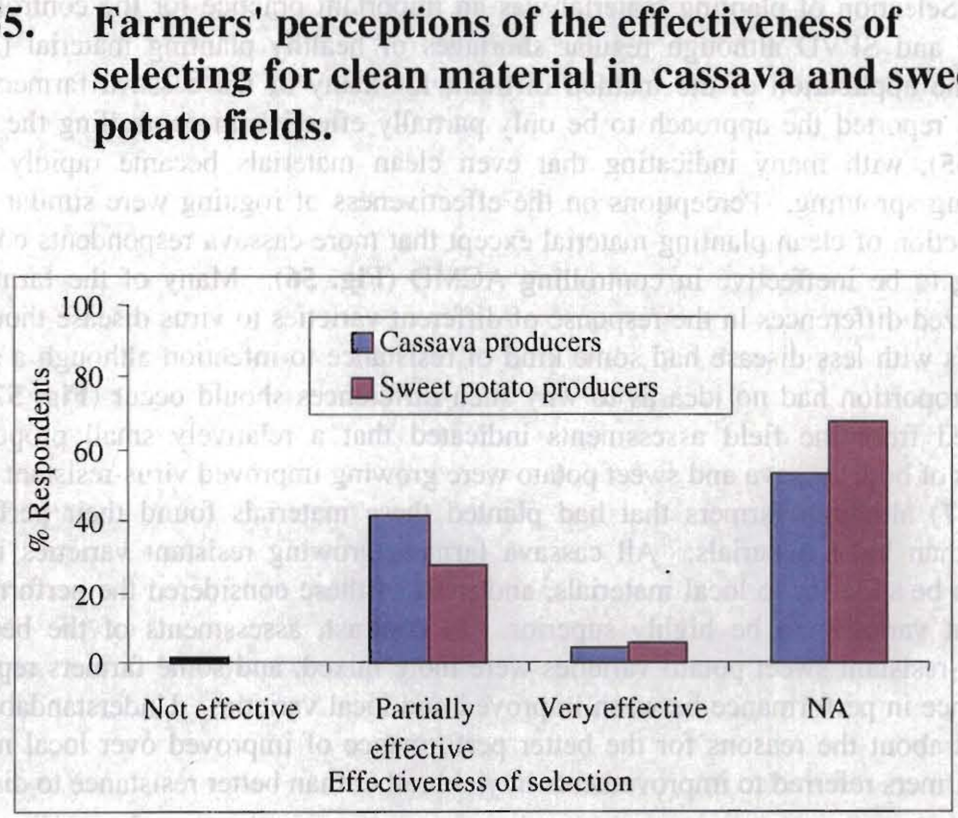


Fig. 56. Farmers' perceptions of the effectiveness of roguing for cassava and sweet potato.

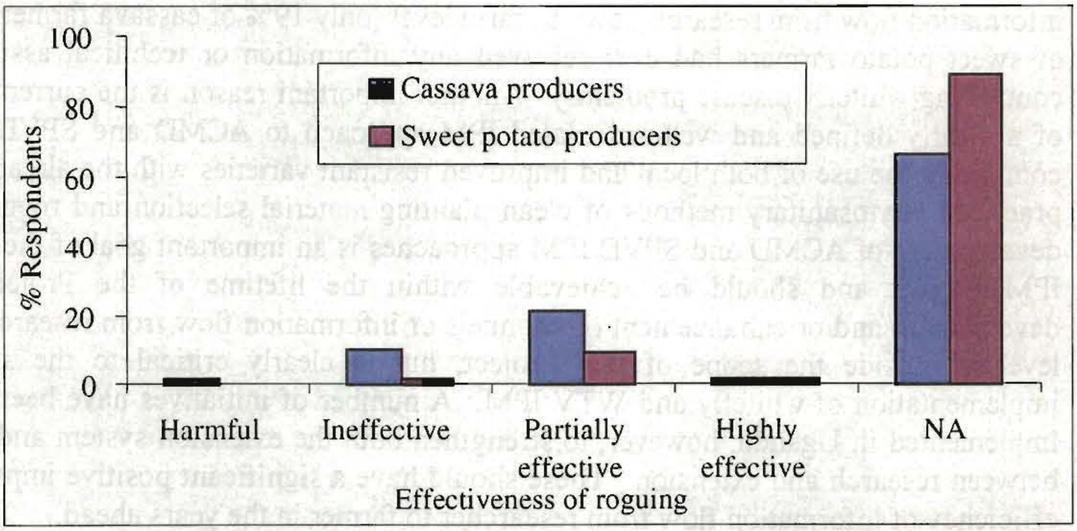
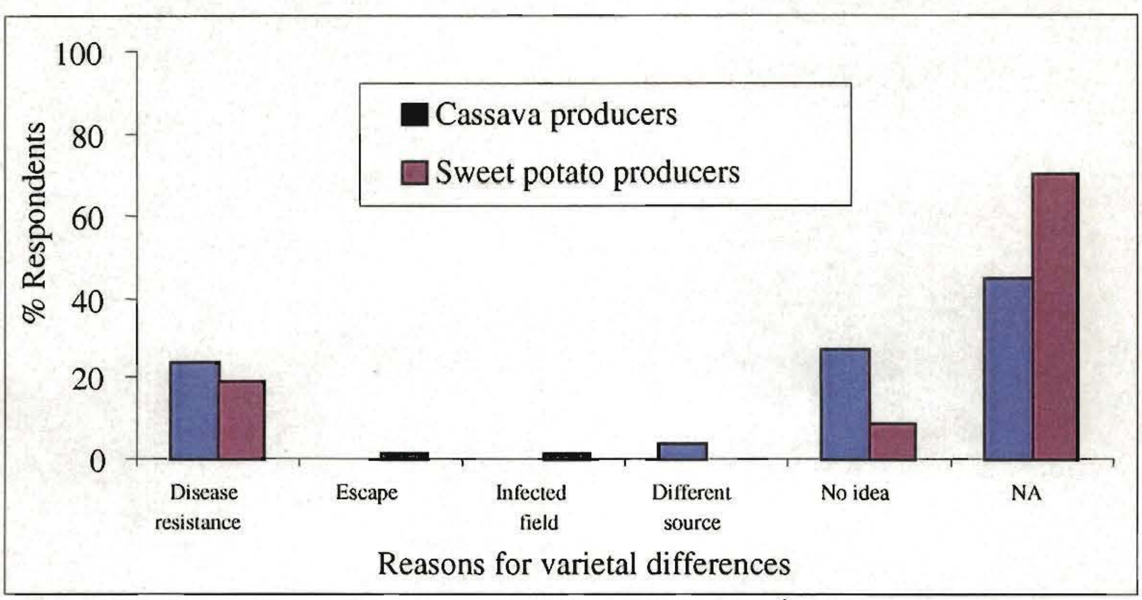


Fig. 57. Farmers' reasons for varietal differences in cassava and sweet potato fields.



The clear picture emerging from the responses of farmers on approaches to control is that while most farmers are implementing some sort of measures to tackle the problem posed by the whitefly-borne virus diseases ACMD and SPVD, this implementation is generally *ad hoc* and based on a partial understanding of the problems. This could be attributable in large part to weaknesses in channels of information flow from research down to farm level (only 19% of cassava farmers and 7% of sweet potato farmers had ever received any information or technical assistance in controlling whitefly/disease problems). Another important reason is the current absence of a clearly defined and well-articulated IPM approach to ACMD and SPVD control, combining the use of both local and improved resistant varieties with the already widely practiced phytosanitary methods of clean planting material selection and roguing. The development of ACMD and SPVD IPM approaches is an important goal of the Whitefly IPM Project and should be achievable within the lifetime of the Project. The development and/or enhancement of channels of information flow from research to farm level is outside the scope of this Project, but is clearly critical to the successful implementation of whitefly and WTV IPM. A number of initiatives have been recently implemented in Uganda, however, to strengthen both the extension system and linkages between research and extension. These should have a significant positive impact on the efficiency of information flow from researcher to farmer in the years ahead.

V. OUTPUT 3 - EPIDEMIOLOGICAL CHARACTERIZATION INITIATED

A. Identify Whitefly Species and Biotypes

1. Whitefly species

Project staff at CIAT and ICIPE, who are responsible for whitefly identification, received a training course at the International Institute of Entomology (UK) as well as on-site training.

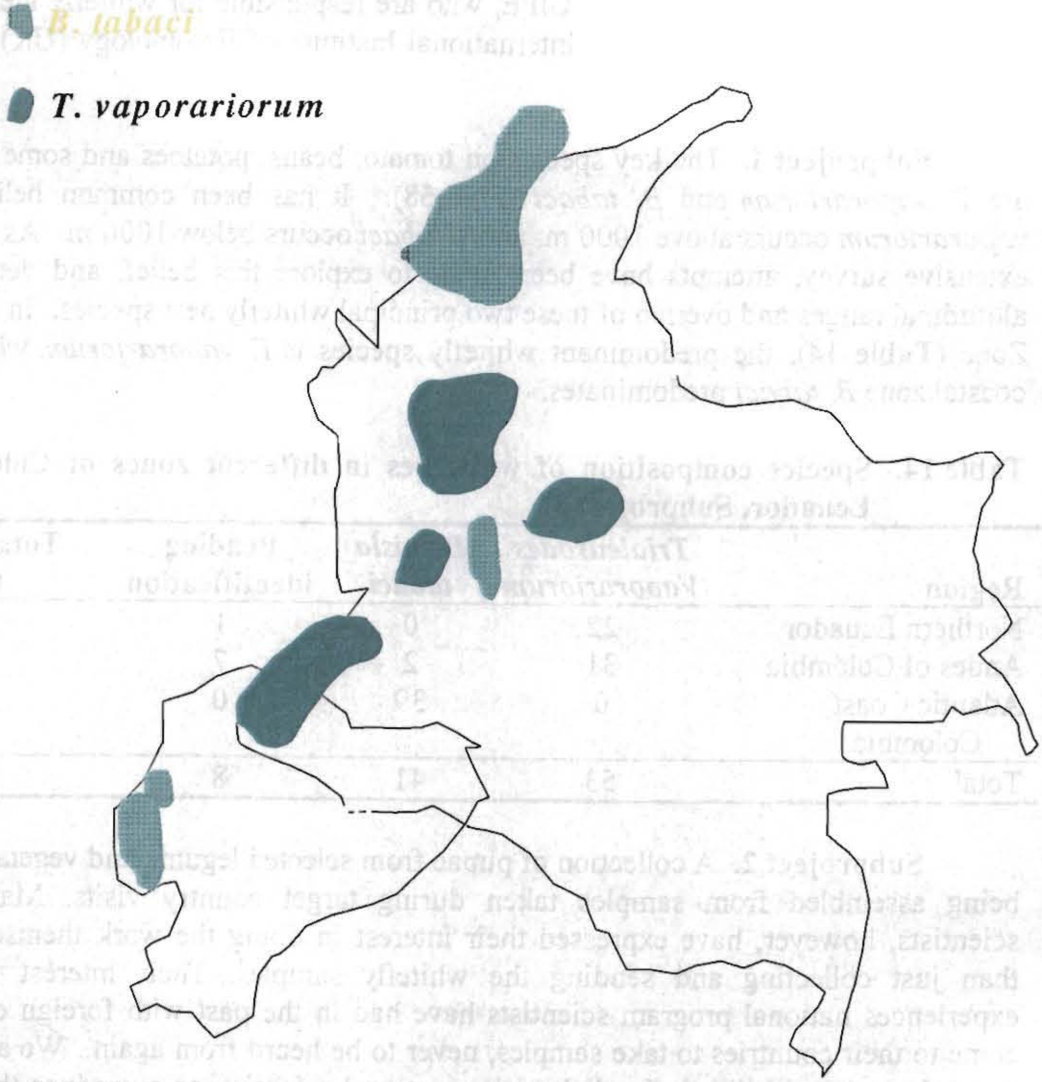
Subproject 1. The key species on tomato, beans, potatoes and some vegetables are *T. vaporariorum* and *B. tabaci* (**Fig. 58**). It has been common belief that *T. vaporariorum* occurs above 1000 m, and *B. tabaci* occurs below 1000 m. As part of the extensive survey, attempts have been made to explore this belief, and determine the altitudinal ranges and overlap of these two principal whitefly pest species. In the Andean Zone (**Table 14**), the predominant whitefly species is *T. vaporariorum*, while in the coastal zone *B. tabaci* predominates.

Table 14. Species composition of whiteflies in different zones of Colombia and Ecuador, Subproject 1.

Region	*Trialeurodes Vaporariorum*	*Bemisia tabaci*	Pending identification	Total samples taken
Northern Ecuador	22	0	1	23
Andes of Colombia	31	2	7	40
Atlantic Coast, Colombia	0	39	0	39
Total	53	41	8	102

Subproject 2. A collection of pupae from selected legume and vegetable crops is being assembled from samples taken during target country visits. Many national scientists, however, have expressed their interest in doing the work themselves, rather than just collecting and sending the whitefly samples. Their interest stems from experiences national program scientists have had in the past with foreign experts, who come to their countries to take samples, never to be heard from again. We are assessing the technical capabilities of collaborating national scientists to reproduce the molecular whitefly identification methods currently used at CIAT, to train a group of scientists representing key countries in the study area. So far, five scientists from Central America and the Caribbean have been at CIAT in molecular techniques for the identification of *B. tabaci* biotypes (Table 20).

Fig. 58. Predominant whitefly species found in most affected areas of the Andean zone.



Subproject 3. Table 15 indicates the numbers of whitefly samples assembled from surveys up to January, 1998 from the four partner countries:

Table 15. Whitefly collections assembled and processed, Subproject 3.

Country	No. of collections	Remarks
Kenya	56 collections	Processing and identification completed
Malawi	9 collections	Processing and identification completed
Sudan	20 collections	Collections being processed
Tanzania	50 collections	Processing and identification completed
TOTAL	356 collections	Identification completed for 300 and remainder being processed

Preliminary identification of the samples (collected from vegetable crops/weeds) identified at ICIPE indicated the occurrence of the following whitefly species listed in **Table 16.**

Table 16. Whitefly species encountered in vegetable-based systems, Subproject 3.

Whitefly species	Comments
Bemisia tabaci (Gennadius):	Most common species
Bemisia afer (Priesner &Hosney):	Common species on cassava in Malawi and Tanzania
Bemisia hirta	Identification to be confirmed
Aleyrodes proletella Linnaeus	Collected form velvet beans in Malawi
Trialeurodes vaporariorum (Westwood)	Common on beans and some other weeds
Trialeurodes ricini (Misra)	Common species

Other whitefly species from nontarget crops were also collected and identified. These include *Aleurothrixus floccosus* (Maskell) on citrus and *Siphoninus phyllyreae* (Haliday) on a tree species.

Subproject 4. Progress in the dispatch and analysis of samples collected in the surveys so far completed is summarized in **Table 17**. Identifications and characterizations differ in the degree of complexity and thereby specialist expertise needed, and this is reflected in the current state of progress. Most straightforward are the identifications of whitefly species and predator genera, and these are the only areas where results have been obtained. More complex are the biotype and virus characterizations. This work is currently ongoing, and first results are expected during the second half of 1998.

Table 17. Summary of progress in dispatch and identification/characterization of samples collected from Uganda, Ghana, Benin, Nigeria and Cameroon.

Country	Item	No. of samples	Date of dispatch	Sent to	Status
Uganda	Cassava cuttings	80	12/97	JIC	Planted out, being characterized
	ACMD leaf samples	207	2/98	JIC	Characterization initiated
	Whitefly adults				
	Cassava (S potato)	81 (75)	12/97	JIC	Biotype characterization initiated
	Whitefly nymphs	81 (75)	12/97	JIC	Biotype characterization initiated
	Cassava (S potato)	81 (75)	12/97	ICIPE	Species identification. Preliminary results
	Predators	21	12/97	ICIPE	Preliminary results
	Parasitoids	62	12/97	ICIPE	Processing initiated
Ghana	Cassava cuttings	> 80	2/98	JIC	Spoiled in transit
	ACMD leaf samples	?	2/98	JIC	Characterization initiated
	Whitefly adults	84		JIC	Biotype characterization initiated
	Whitefly nymphs	76		JIC	Biotype characterization initiated
		65		ICIPE	Processing initiated
	Predators	45		ICIPE	Processing initiated
	Parasitoids	18		ICIPE	Processing initiated
Benin	Cassava cuttings	> 60	1/98	JIC	Planted out, being characterized
	ACMD leaf samples	?	1/98	JIC	Characterization initiated
	Whitefly adults	120		JIC	Biotype characterization initiated
	Whitefly nymphs	60		JIC	Biotype characterization initiated
		60		ICIPE	Processing initiated
	Predators	0			
	Parasitoids	24		ICIPE	Processing initiated
Nigeria	Cassava cuttings	> 80	12/97	JIC	Planted out, being characterized
	ACMD leaf samples	?	12/97	JIC	Characterization initiated
	Whitefly adults	80	12/97	JIC	Biotype characterization initiated
	Whitefly nymphs	80	12/97	JIC	Biotype characterization initiated
		80	12/97	ICIPE	Species identification. Preliminary results
	Predators	> 40	12/97	ICIPE	Preliminary results
	Parasitoids	0			
Cameroon	Cassava cuttings	> 70			Dispatch to JIC delayed
	ACMD leaf samples	> 70	2/98	JIC	Characterization initiated
	Whitefly adults	140		JIC	Biotype characterization initiated
	Whitefly nymphs	69		JIC	Biotype characterization initiated
		69		ICIPE	Processing initiated
	Predators	0			
	Parasitoids	6		ICIPE	Processing initiated

Preliminary results for the whitefly species identification done by ICIPE are summarized in **Table 18**. Sample identifications will be confirmed in the second half of 1998 by the Natural History Museum, UK. Results to date are much as expected with virtually all samples containing *B. tabaci.* The only unusual occurrence was a sample containing *T. vaporariorum*, recorded from the transition forest zone of Nigeria. The occurrence of late stage nymphs of this species on cassava does suggest that cassava can be a reproductive host for this species although follow-up experiments would be required to confirm this. *Bemisia afer*, another whitefly species commonly found on cassava, was not recorded from any of the samples collected. Individuals collected subsequent to the survey from Uganda have nevertheless been sent to ICIPE, specifically for use in the clarification of identities of unusual *B. tabaci* specimens.

Table 18. Completed whitefly species identifications (ICIPE).

Location	Samples received	Individuals examined	Identifications
Uganda	Cassava 80 vials	81	*B. tabaci* – 80; *B. tabaci* ? – 1
	S potato 80 vials	88	*B. tabaci* – 84; *B. tabaci* ? – 4
Nigeria	80 vials	38	*B. tabaci* – 37 *T. vaporariorum* – 1

2. Whitefly biotypes

For regional surveys to function without quarantine problems, it was essential to develop methods that utilize dead insects. Methods to extract DNA were analyzed using pupae stored in 70-95% alcohol. This method works for single pupa or adult insects but is somewhat time consuming, and it is difficult to extract from more that 32 individuals in a day. The DNA isolated by this method is very stable even when stored for several years.

Four different oligonucleotide primers have been selected to the B biotype of*B. tabaci.* These primers were used to develop baseline data not only for*B. tabaci* but also other whitefly species. The results of PCR product analysis (primer H9) of four species of whiteflies compared with biotype B of*Bemisia tabaci.* These primers are appropriate for distinguishing species but are not specific enough to distinguish biotypes within the whitefly *B. tuberculata*, *A. socialis*, *T. vaporariorum*, or *T. variabilis*. The primers do distinguish between the "A" and "B" biotypes of *Bemisia tabaci*.

A more detailed analysis of variation is being done that allows a comparison of evolutionary relatedness. This involves cDNA cloning and sequencing of a region that is commonly used in studies of biodiversity. In the first experiments, a region of the 16S ribosomal RNA gene was selected. Using specific oligonucleotide primers, a representative of *B. tabaci, B. tuberculata, T. variabilis, A. socialis* and *T. vaporariorum* were amplified by PRC, cloned into bacterial plasmids and sequenced. There is polymorphism between species, but there is little variation in the between isolates of the "B" biotype of *B. tabaci*.

The mitochondrial gene for the subunit I of cytochrome oxidase (COI) is being assessed for it usefulness in whitefly phylogenic and population analysis. Previous studies have identified two regions within the gene that had been identified as the most variable between species. One study used one of those regions to look at variation within whiteflies and found that there were more decision-making bases in the COI gene than in the 16S region. It was decided to use the COI gene for whitefly phylogenic and population analysis. A set of primers have been utilized and we are able to amplify portions of COI in all whitefly species test to date. The preliminary analysis of the results indicate that there is more variation in COI gene than the 16S gene, and this has been adopted as the standard method for the studies of evolutionary relatedness within species.

The detailed information from sequencing the COI gene is needed for studies with species. One method that is being tested to increase the number of samples that can be processed is direct sequencing of PCR clones. Preliminary tests were successful for about 70% of the PCR products. This method will continue to be optimized and will greatly increase the quantity of samples that can be analyzed at the level of sequence determination.

Subproject 1. The key species on tomato, beans, potatoes and some vegetables are *T. vaporariorum* and *B. tabaci* - Biotype B. In general the A biotype of *B. tabaci* seems to be less important **(Fig. 59)**. The number of samples processed and the species composition thereof is shown in **Table 19**. The presence of Biotype B was confirmed in a wide area of the Atlantic Coast of Colombia, and in the States ofTolima and Cauca. This was achieved by means of esterase banding patterns in polyacrylamide gel electrophoresis (PAGE), RAPD-PCR analysis, reproductive differences on selected hosts, induction of silver leaf symptoms in *Cucurbita* spp. and field recognition of symptoms induced by this insect on tomato, *Brassica* spp., poinsettia and lettuce. Further characterization of species and bioptype composition will continue.

Fig. 59. Preliminary results on distribution of *B. tabaci* biotypes A and B in Colombia.

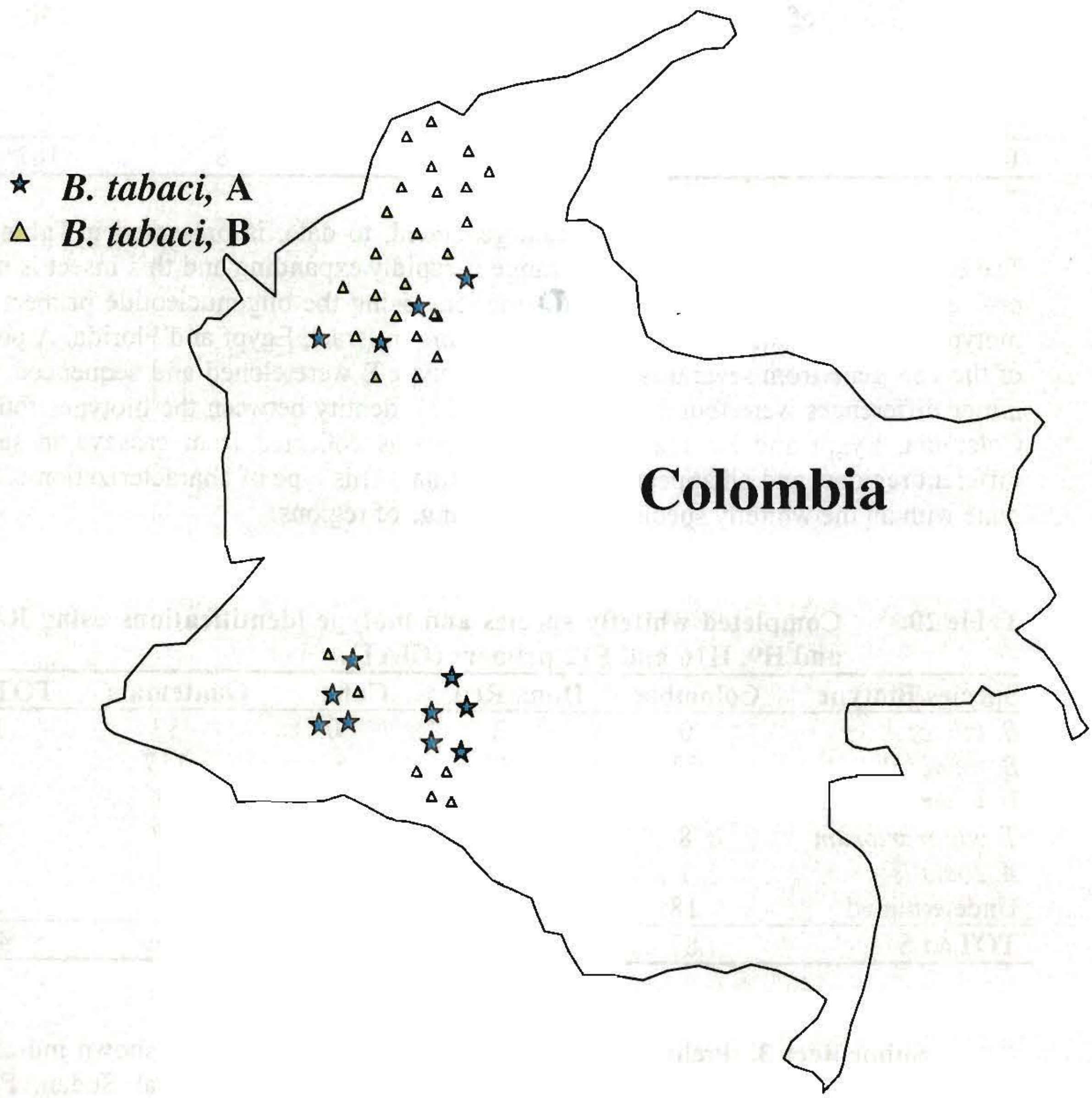


Table 19. **Species and biotype identifications of whiteflies in different zones of Colombia and Ecuador, Subproject 1.**

Region	*Trialeurodes vaporariorum*	*Bemisia Tabaci* A	*Bemisia tabaci* B	Pending identification	Total samples taken
Northern Ecuador	22	0	0	1	23
Andes of Colombia	31	2	0	7	40
Atlantic Coast, Colombia	0	4	35	0	39
Total	53	6	35	8	102

Subproject 2. The biotype data generated, to date, is presented in **Table 20.** The *B. tabaci* biotype B geographical range is rapidly expanding and this insect is now a problem in most countries of tropical America. Using the oligonucleotide primers, this biotype looks very similar to the biotype B found in Israel, Egypt and Florida. A portion of the 16S gene from several isolates of the biotype B were cloned and sequenced. Only minor differences were found. There is 98-100% identity between the biotypes found in Colombia, Eygpt and Florida. *B. tuberculata* was collected from cassava in several different regions, and all appear to be quite similar. This type of characterization is being done with all the whitefly species and over a range of regions.

Table 20. **Completed whitefly species and biotype identifications using RAPDs and H9, H16 and F12 primers (CIAT).**

Species/Biotype	Colombia	Dom. Rep.	Cuba	Guatemala	TOTALS
B. tabaci A	0	2	0	13	15
B. tabaci B	32	89	54	117	
B. tuberculata	28	9	0	0	37
T. vaporariorum	8	0	0	63	71
A. socialis	1	0	0	0	1
Undetermined	18	6	0	3	27
TOTALS	87	106	54	196	443

Subproject 3. Preliminary field observations in Sudan have shown indications of occurrence of silverleaf symptoms in squash in Gezira, Central Sudan. Further observations are being made there, and efforts to characterize the Sudan whitefly collections by molecular techniques are being pursued.

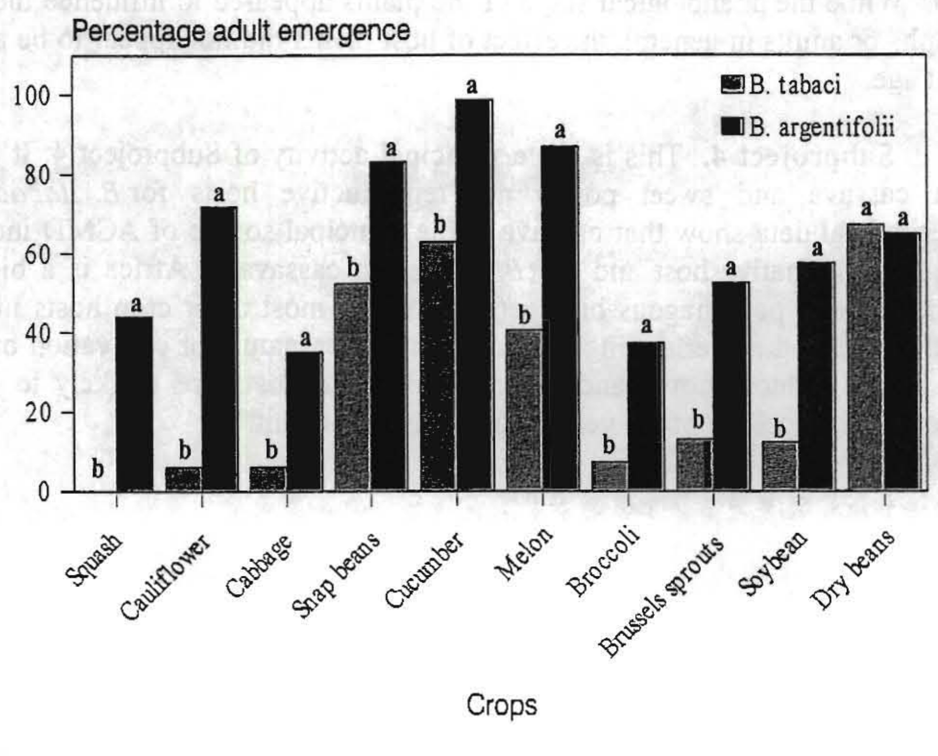
Subproject 4. Table 17 indicates the samples that have been sent, to date, for biotyping.

B. Identify Whitefly Crop Reproductive Hosts

Subproject 1. The following crop plants have been identified as reproductive hosts of *T. vaporariorum* in the Andean region of Colombia and Ecuador: beans, tomatoes, potatoes, snap beans and *Cucurbita* spp. *B. tabaci* biotype A has been recorded breeding on soybean, tomato and eggplant. *B. argentifolii* has been found reproducing on cabbage, egg plant, lima beans, tomato, squash, pepper, *Brassica* spp., melon, dry beans, cotton and watermelon. This activity will continue. Identification of some wild hosts is pending.

A greenhouse-laboratory study on the comparative biology of biotypes A and B of *B. tabaci* on 20 cultivated host plants was initiated. Results obtained so far (10 host plants) can be summarized as follows: (a) There were no significant differences between biotypes in terms of total oviposition per plant. Ovipositional behavior did not differ either; (b) Biotype B bred faster on cabbage and cauliflower than biotype A; and (c) Percent emergence of biotype B was significantly higher on 9 out of 10 host plants studied **(Fig. 60)**.

Fig. 60. Percent emergence of two whiteflies species on different host plants.



Subproject 2. A list of all the hosts of the whitefly *B. tabaci* is being prepared for all of the countries selected for this subproject. This information will be analyzed by locality, country and region in order to study patterns of whitefly behavior in wild and cultivated plant species, and in relation to different cropping systems. Particular attention is being given in this subproject to the current replacement of legume and horticultural crops, such as beans and tomatoes, for other crops such as tobacco in relation to the role of the latter as reproductive hosts of *B. tabaci*. Dramatic changes in the dynamics of whitefly populations were observed this year in northwestern Dominican Republic as a result of changes in cropping systems.

Subproject 3. Surveys in the four partner countries (**Table 21**) have shown that tomato is seldom the reproductive host for the whiteflies. While adults are not uncommon on the crop in farmers' fields, the developmental stages are very rarely encountered. This suggests that the local whitefly populations reproduce on some other host plants and the adults visit the tomato crop mainly for feeding. Some of the hosts listed in **Table 21** are apparently new host records.

During 1997 cage experiments were conducted at ICIPE, using pot-grown plants of four hosts: common bean (*Phaseolus vulgaris*), *Dolichos lablab*, cowpea (*Vigna unguiculata*) and okra (*Abelmoschus esculentus*). Observations showed that adult numbers per plant were significantly greater on common bean, followed by *Dolichos*, which supported more adults than the other two hosts. The overall ranking for number of eggs laid per plant was bean>*Dolichos*>cowpea>okra. However, the pupa: egg ratio (indirect index of survival) was greatest on cowpea, followed by bean, *Dolichos* and okra. While the phenological stage of the plants appeared to influence the adults, eggs, nymphs or adults in general, the effect of host plants did not appear to be affected by the plant age.

Subproject 4. This is not a principal activity of Subproject 4. It is known that both cassava and sweet potato are reproductive hosts for *B. tabaci*. Published experimental data show that cassava is the principal source of ACMD inoculum, rather than any alternative host and that *B. tabaci* on cassava in Africa is a biotype distinct from the more polyphagous biotype(s) found on most other crop hosts including sweet potato. Due to the overlapping and often unbroken nature of cultivation of both cassava and sweet potato, known and potential alternate hosts are unlikely to be significant factors in the ecology of the vector and viruses transmitted.

Table 21. **List of whitefly reproductive host plants identified from surveys in partner countries, Subproject 3.**

Plant host	Whitefly species	Country [1]
Achyranthes asprea	*Trialeurodes ricini*	Tanzania
	Trialeurodes	Kenya
Ageratum conyzoides	*vaporariorum*	Tanzania
Aspilia mosssamlacensis	*B. tabaci*	Kenya
Asystasia schimperi	*B. tabaci*	Kenya
Bean	*B. tabaci*	Kenya
	B. afer	Kenya,Malawi,Tanzania
	B. tabaci	Malawi
	T. ricini	Kenya,Malawi, Tanzania
Bidens pilosa	*T. vaporariorum*	Kenya
Cassava	*B. tabaci*	Kenya,Malawi,Tanzania
	B. afer	Kenya,Malawi,Tanzania
Comelina benghalensis	*B. tabaci*	Kenya
	B . tabaci	Kenya
Crotolaria sp.	*B. afer*	Kenya
Datura stramonium	*B. tabaci*	Kenya
Emilia descifolia	*B. tabaci*	Kenya
Euphorbia heterophyla	*B. tabaci*	Kenya
Cotton	*B. tabaci*	Kenya
	Bemisia?	Tanzania
	Bemisia hirta?	Kenya,Malawi,Tanzania
	B. tabaci	Kenya
Galinsoga parviflora	*T. ricini*	Tanzania
	T. vaporariorum	Kenya, Tanzania
Green leaf desmodium	*B. tabaci*	Tanzania
Lantana camara	*T. ricini*	Tanzania
Lionotis molissima	*B. tabaci*	Tanzania
	B. tabaci	Kenya
Mito (local name)	*B. tabaci*	Kenya
Morning glory	*T. ricini*	Kenya
Nicandra physaloides	*B. tabaci*	Kenya
Silver leaf desmodium	*B. tabaci*	Kenya
Sweet potato	*B. tabaci*	Tanzania
Tithonia diversifolia	*B. tabaci*	Kenya
	B. tabaci	Kenya
	B. tabaci	Kenya
Tomato	*T. ricini*	Kenya
	T. vaporariorum	Kenya
	B. tabaci	Kenya
Unidentified	*T, ricini*	Kenya
	T. vaporariorum	Kenya
Velvet beans	*B. tabaci*	Kenya
	T. vaporariorum	Malawi
Wild cassava	*Aleyrodes proletella*	Malawi
	B. tabaci	Tanzania
	B. tabaci	

1 Samples from Sudan not included.

C. Identify Whitefly-Transmitted Viruses in Affected Zones

Subproject 1. Focus of Subproject 1 is on whiteflies as pests. Thus virus identification is not a planned activity.

Subproject 2. Literature survey indicates that there are at least 17 geminiviruses infecting vegetables in the Americas and that this represents a significant emergence of tomato geminiviruses in the last two decades (**Figs. 61 and 62**). The main objective of this activity in the field, at this initial project stage, is to confirm the presence of viruses transmitted by whiteflies in affected legume and horticultural crops in the target region. The subproject is using monoclonal antibodies developed by CIAT, which recognize all bi-component whitefly-transmitted geminiviruses. In the case of the mono-component whitefly-transmitted TYLCV, which is not detected by the broad-spectrum monoclonal antibody in use, three different set of TYLCV primers, developed to detect Old and New World strains of this geminivirus, are being used.

Preliminary results from surveys and assays conducted so far indicate that over 90% of the bean samples collected were infected by geminiviruses, but that there is already unexpected variability in the bean golden mosaic virus (BGMV) isolates collected in Central America and the Caribbean. We are already aware of the differences that exist between the geminiviruses that infect beans in northern Mexico and the geminiviruses isolated from beans in southern Mexico, the latter being similar to the Central American isolates of BGMV. The geminiviruses infecting beans in northern Mexico are strains of squash leaf curl virus, which probably emerged in horticultural crops in southern United States (California).

The detection rate for geminiviruses in horticultural crops is lower than in the case of beans. In tomatoes, approximately 75% of the samples collected are infected by geminiviruses; in peppers, only 35% of the samples react positively with the broad-spectrum geminivirus monoclonal antibody. The majority of cucurbit samples collected show clear symptoms of whitefly damage as a direct pest. Geminiviruses, however, are now being detected in other crops, such as tobacco and soybean, currently planted throughout the target area.

Subproject 3. The samples assembled for identification of WTVs on tomato are furnished in **Table 22**.

Fig. 61. **Known distribution of tomato geminiviruses in the Americas in the early 1970s.**

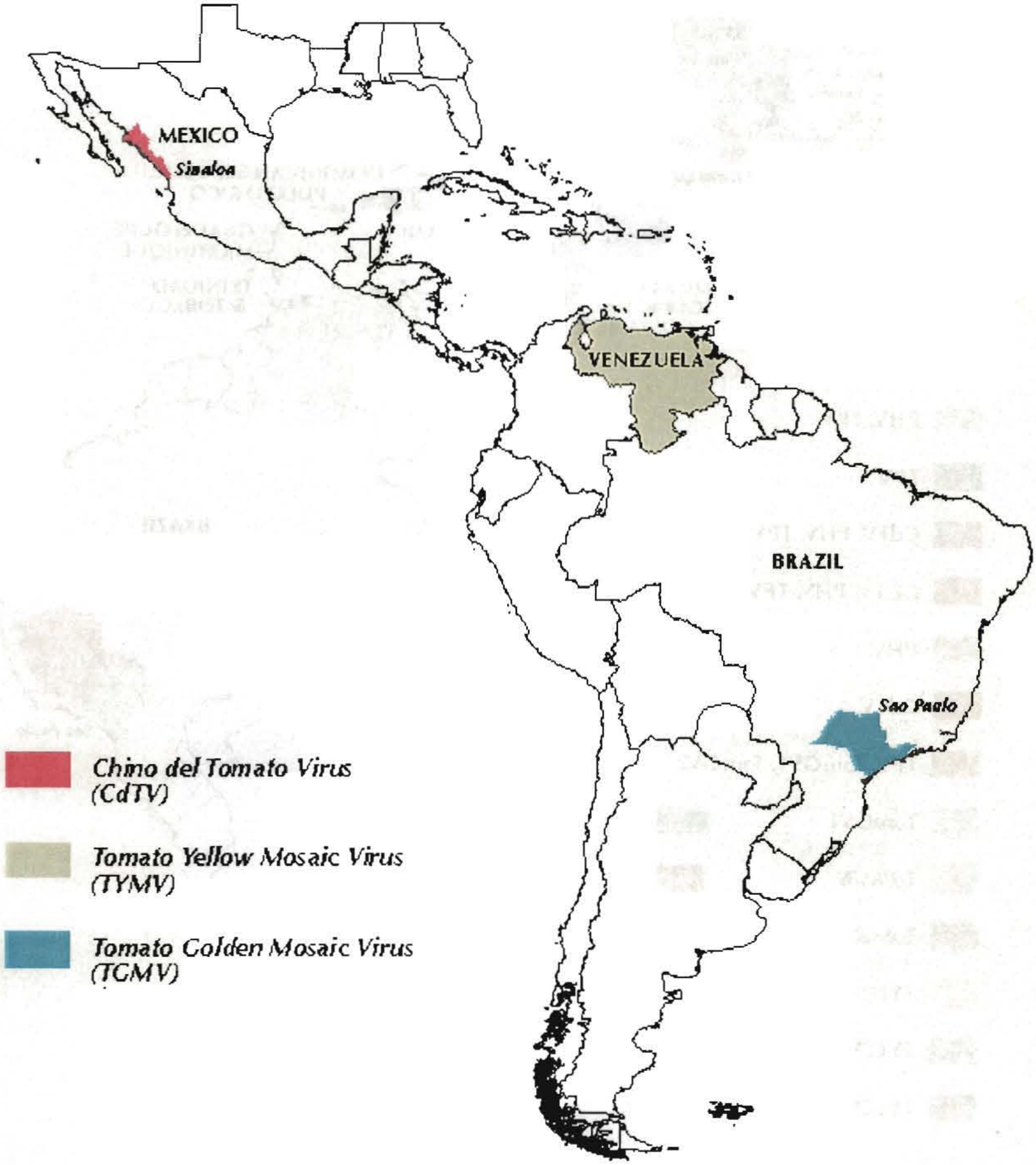


Fig. 62. Known distribution of tomato geminiviruses in the Americas in the mid-1990s.

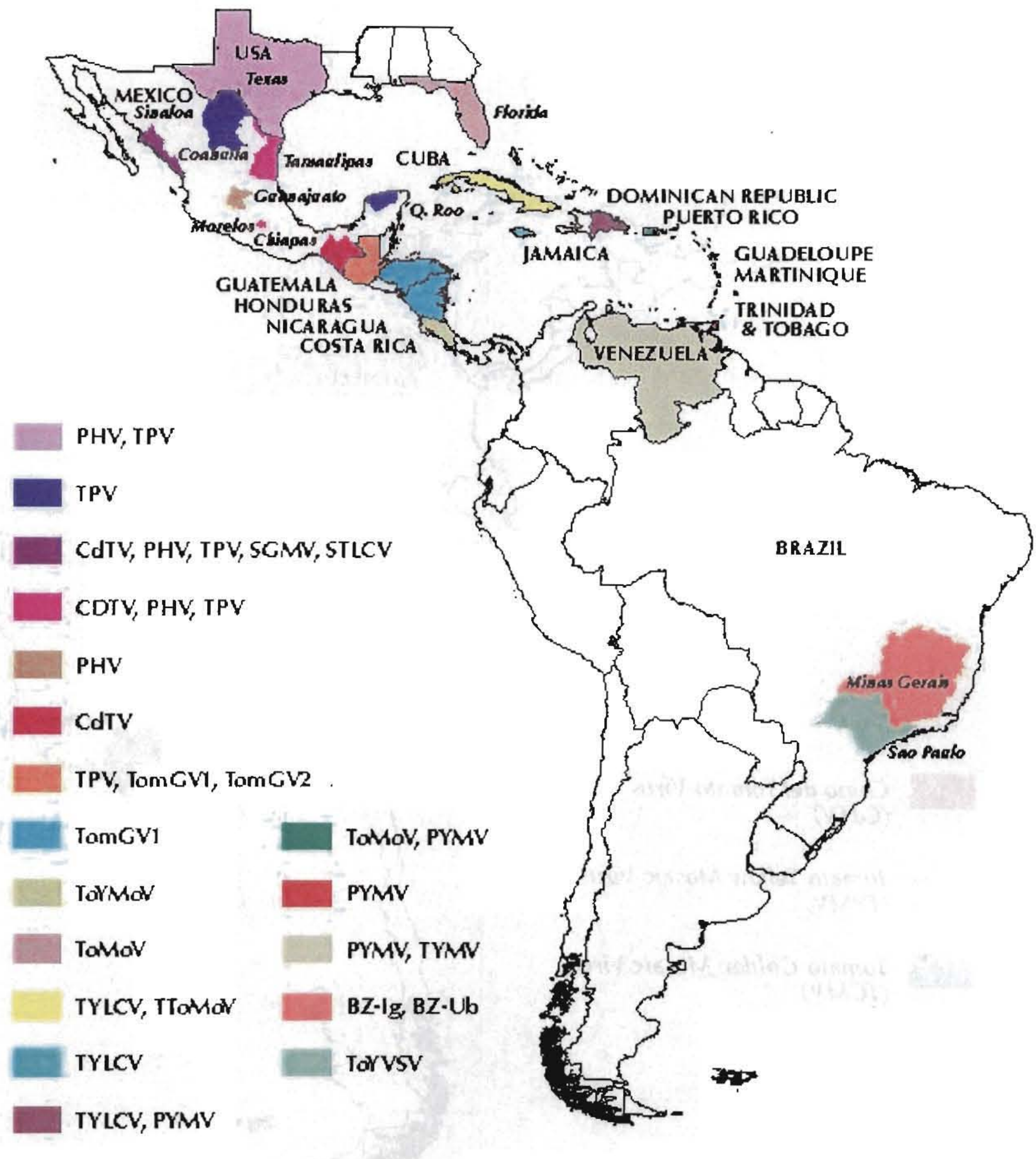


Table 22. Whitefly-transmitted virus samples assembled from the surveys, Subproject 3.

Country	Sites	Samples [1]
Kenya	Central Province	2
	Eastern Province	3
	Western Province	8
	Nyanza Province	5
Malawi	Blantyre Division	1
	Ntcheu Division	4
	Bvumbwe Division	2
Sudan	Gezira area	10
	Rahad area	4
	Managil area	5
	Botana area	4
Tanzania	Arusha region	10
	Kilimanjaro region	9
	Irringa region	7
	Mbeya region	5

1 Indications obtained from test of 28 samples by JIC, U.K. for presence of TYLCV (Israeli strain) are furnished in **Table 23**.

Table 23. Results of preliminary testing for TYLCV (Israeli strain) in tomatoes.

Country	Province	Samples tested	Samples positive to Israeli strain of TYLCV	Remarks on signals
	Central	2	2	Strong
Kenya	Eastern	3	3	Weak
	Nyanza	3	0	-
	Western	3	0	-
	Blantyre Division	1	0	-
Malawi	Ntcheu Division	4	2	Very weak
	Bvumbwe Division	2	0	-
	Arusha	9	6	Strong/Weak
Tanzania	Kilimanjaro region	1	1	Strong

As indicated by the John Innes Centre (JIC), a weak hybridization signal or a strong signal it might be due to a difference in the percent nucleic acid homology, suggesting different strains of geminivirus. However, it is impossible at this stage to tell whether or not the difference in signal strength is to do with a sampling problem because of virus titre in the particular bits of tissue sampled or low virus titre due to an early stage of infection.

In the Kenya (June 1997) survey, out of 14 fields/plots of tomato surveyed, the incidence of plants with distinct symptoms of WTVs ranged from 0-100%, with about half the number of fields showing 15-50% incidence. The whitefly adults were found to occur on the tomato crop in most fields observed and were generally highly abundant (**Table 24**).

Table 24. Incidence of whitefly-transmitted viruses and whiteflies intomatoes and other crops, Kenya, June, 1997.

Region	Site/crop	WF[1]	WTVs[2]
Thika	Site 1 (Tomato)	+ + +	-
	Site 2 (Tomato)	-	-
Machakos	1 – Tomato-Money Maker: Field 1	+ +	15%
	2 – Tomato-Money Maker: Field 2	+ + +	30%
	3 – Tomato-Cal-j field 1	+ + +	>10%
Lake Naivasha	1st Site (tomato)	+ +	5%
	2nd Site (tomato)	+ + +	30%
	3rd Site (tomato)	+ +	40%
	4th Site (tomato)	+ + +	40%
Kibwezi	Plot 1 (tomato)	+ +	50%
	Plot 2 (tomato)	+ +	10%
	Plot 3 (tomato)	+	50%
	Plot 4 (tomato)	+	-
	Plot 5 (tomato)	+ + +	100%
Kibwezi	Sweet pepper 1	+ +	-
	Sweet pepper 2	+ + +	90% (?)[3]
	Watermelon	+ + +	5% (?)[3]
	Okra	+ +	-

1 Insect populations + = Low; + + = High; + + + = Very high
2 Percentages of plants showing symptoms over total plant population
3 Awaiting laboratory diagnosis

Subproject 4. *Cassava mosaic geminiviruses-background.*Up until 1994, it was considered that there were two cassava mosaic geminivirus species in Africa, namely: African cassava mosaic virus (ACMV) and East African cassava mosaic virus (EACMV). ACMV was reported to occur throughout central andwest Africa, while EACMV was said to be largely restricted to the coastal hinterland of East Africa, but also in Zimbabwe, Malawi and the Indian Ocean islands. More recent diagnostics and characterisation work have revealed a much more complex picture. Surveys in East and Southern Africa using ELISA-based diagnostics indicated that EACMV has a much wider distribution than previously realised. This species was identified from western

Kenya, western Tanzania and northeastern Zambia, in all cases co-occurring with ACMV. More recent PCR diagnostics have confirmed some of these findings, in addition to demonstrating mixed infection of ACMV and EACMV. In Uganda, concern arising from the expansion of an epidemic of severe ACMD led to intensified efforts to characterise the virus associated with this phenomenon. In 1997 a variant form, termed the Uganda Variant (UV), which appeared to be a recombinant hybrid of ACMV and EACMV, was shown to be associated with the epidemic. Furthermore, it was shown that UV gave rise to more severe symptoms in cassava than did ACMV, and that UV+ACMV mixtures gave even more severe symptoms. These recent findings highlight the inadequacy of current understanding and are, in part, the rationale behind this subproject's effort to characterise a wide range of isolates from across Africa.

ELISA and PCR-based diagnostics, Uganda Two fresh cassava leaf samples were collected from each sampling location and tested with an ELISA protocol using two detecting monoclonal antibodies (SCR 23 and SCR 33) to distinguish between ACMV and EACMV. The technique is unsuitable for separating ACMV and UV as both give the same response to Mabs; their coat proteins are virtually identical. In addition, it does not allow the detection of mixtures. The purpose of the test in this instance, therefore, was to confirm presence of virus and identify any possible occurrences of EACMV-only infections (never previously demonstrated in Uganda). All samples, regardless of symptom characteristics, gave positive reactions although samples with more severe symptoms in general gave stronger reactions than those with mild symptoms. All samples gave positive reactions with SCR 33 (ACMV/UV specific). This is an inconclusive result as such reactions could occur for single ACMV, single UV or mixed ACMV/UV infections. DNA was therefore extracted from all samples for subsequent PCR analysis. Samples collected from Target Area 1 were tested with PCR. Two primer pairs were used: AR1/F1 with AR1/R0; and CT/AL1/F with CT/AL1/R. The first pair is specific for ACMV and gives rise to a 1024 nucleotide product. The second pair gives a 538 nucleotide product with EACMV or UV. Eighteen samples were tested from 10 sampling locations, all from Apac and Lira Districts in Target Area 1. Seventeen of the samples gave 538nt products with CT/AL1/F&R and no product with ARI/F1&R0. One sample, from Lira District, gave no product with CT/AL1/F&R and a 1024nt product with AL1/F&R0. Given evidence from ELISA suggesting the absence of EACMV, these results suggest that most CMD diseased plants in Target Area 1 contain UV alone, with a small proportion containing ACMV. Unusually, no apparent mixed infections were recorded. Completion of the PCR analysis should provide a more comprehensive picture of the pattern of UV/ACMV distribution in Uganda. This work will be completed by mid-1998.

Molecular characterization. Leaf and stem samples have been received at John Innes Centre from all five surveyed countries, with the exception of stem samples from Ghana and Cameroon. Stems have been planted out in the glasshouse and characterization procedures have been initiated. First results will be available during the second half of 1998.

Sweet potato viruses. Uganda sweet potato leaf samples were collected in the diagnostic survey from plants showing typical symptoms of sweet potato virus disease (SPVD) and sweet potato chlorotic stunt virus (SPCSV). Two pairs of leaf samples were picked per field with each pair being two old diseased leaves from one plant. Most of the samples collected from Target Area 1 and parts of Target Area 2 (Pallisa and Tororo) had symptoms characteristic of SPCSV infection, whereas most collections from Target Areas 3 and 4 had SPVD symptoms.

Table 25. Summary of ELISA techniques used in Uganda.

Virus group	Technique	Antibodies	Species/serotype detection	No. samples
Cassava mosaic geminiviruses	TAS ELISA	MAb SCR 23 MAb SCR 33	EACMV/ACMV	160
Sweet potato feathery mottle virus	DAS ELISA NCM ELISA	Polyclonal Polyclonal	SPFMV Single species/serotype	74 80
Sweet potato chlorotic stunt virus	TAS ELISA	MAb A MAb F	Uganda/Kenya serotypes	154
Sweet potato mild mottle virus	NCM ELISA	Polyclonal	Single species/serotype	154

A summary of the ELISA results for sweet potato, by district, is presented in **Table 26**. Not all samples collected were positive for the viruses tested, possibly due to low virus concentrations or to symptoms of nonviral origin. Symptoms of both SPVD and SPCSV can be difficult to recognize under certain circumstances, which is likely to have led to the collection of some uninfected samples, particularly in locations where the viruses occur less frequently, as was the case in Target Areas 1 and 2. Of the 154 samples, 100 reacted positively with SPCSV monoclonal antibodies, 72 with SPFMV. SPMMV, which like SPFMV is typically symptomless in Ugandan sweet potato cultivars, was detected in 9 samples from the central (2) and western (7) target areas only.

There were large differences in the frequencies of detection of the various virus species in samples between districts and target areas (**Table 26**). SPFMV and SPCSV were most frequently detected in Target Area 4 (west) and Mpigi District in Target Area 3 (central). All samples collected from Target Area 4 and 37 out of 38 from Target Area 3 were infected with one or more virus species, compared with 18 from 36 for Target Area 1and 20 from 40 for Target Area 2. It is possible that the purpling symptoms (suspected to be SPCSV infections) especially in Apac, and Tororo Districts were caused by factors other than viruses (e.g., nutrient disorders, senescence, insect damage or other environmental stresses). Overall, 54 samples had both SPFMV and SPCSV and five contained all three virus species.

Table 26. Viruses identified by serology in diseased sweet potato leaves from 12 districts in Uganda.

District	Target Area	No. of samples	SPMMV	SPFMV	SPCSV (Ky)	SPCSV (Ug)	SPVD[1]
Masindi	1	14	0	6	5	0	4
Lira	1	14	0	5	1	4	3
Apac	1	12	0	1	1	3	1
Iganga	2	10	0	6	5	0	2
Pallisa	2	12	0	4	6	2	4
Tororo	2	14	0	3	3	0	1
Mukono	3	14	0	9	4	7	6
Mpigi	3	12	2	10	2	8	9
Luwero	3	12	0	7	0	11	6
Mubende	4	14	3	6	2	11	6
Masaka	4	14	2	6	3	10	5
Rakai	4	12	2	7	0	12	7
Total		154	9	72	32	68	54

Ky = Kenyan isolate, Ug = Ugandan isolate.

[1] = Both SPFMV and SPCSV detected in the same sample

The distribution of the two serotypes of SPCSV is presented in **Fig. 63**. The Ugandan serotype that reacts only to MAb A (1-2G8) was detected in 68 out of the 100 SPCSV positive samples. The Kenyan serotype that reacts both to MAbs A and F (1-6D12) was detected in 32 of the SPCSV-positive samples. The Ugandan serotype occurred in all districts except for Tororo although it occurred much more frequently in the south and west (Target Areas 3 and 4) than in the north and east (Target Areas 1 and 2). The Kenyan serotype was more evenly distributed across target areas; in contrast to the Uganda serotype it occurred more frequently in Target Areas 1 and 2 with the highest incidence recorded in Pallisa District. SPFMV occurred most frequently in the central Districts of Mpigi and Mukono (**Table 26** and **Fig. 64**) although there was less variation in its geographical distribution than for either of the serotypes of SPCSV.

It is anticipated that a PCR-based diagnostic technique, to be developed by BBA, will be used to validate and add to the ELISA-based diagnostics already done. For this purpose, dried leaf samples were collected from each sample location, and small portions of fresh samples have been preserved in the freezer for subsequent PCR-based analyses.

Fig. 63. Distribution of sweet potato chlorotic stunt virus serotypes in 12 districts of Uganda, November-December, 1997.

Fig. 64. Occurrence of sweet potato feathery mottle virus and sweet potato chlorotic stunt virus as detected by ELISA, 12 districts of Uganda, November-December, 1997.

Sweet potato viruses
No virus detected
SPFMV alone
SPCSV alone
Both SPFMV & SPCSV

Key to map features
District boundaries
International borders
Lakes and wetlands
Sampling locations

D. Identify Whitefly Natural Enemies

Subprojects 1 and 2. The most prevalent (not necessarily the most efficient) natural enemy *of T. vaporariorum* recorded so far is the nymphal parasitoid *Amitus fuscipennis*. *Encarsia* spp. were also registered. The predators *Delphastus pussillus* and *Chrysopa* spp. and the entomopathogenic fungus *Verticillium lecanii* were found in Cundinamarca. Preliminary identification of natural enemies of *B. tabaci* is in progress at CIAT. For all subprojects, verification of parasitoid species identifications will be done by Dr. Andrew Polaszek (British Museum), Dr. Gregg Evans (Florida Arthropod Collection) and Dr. Mike Rose (Texas A&M).

Subproject 3 and 4. Tables 27-28 indicate the samples being processed from Subproject 3.

Table 27. Whitefly parasitoid samples assembled from the surveys, subproject 3.

Country	No. of collections	Remarks
Kenya	10	Preliminary identification completed
Malawi	0	
Sudan	5	Preliminary identification completed
Tanzania	0	
Subproject 4	89	Preliminary identification completed

Preliminary identification of these samples collected form vegetablecrops/weeds were identified as *Encarsia formosa, Encarsia transvena* (the most common species), *Eretmocerus mundus, Eretmocerus* sp. and several Eulophid parasitoids.

Table 28. Whitefly predator samples assembled from the surveys, Subproject 3.

Country	No. of collections	Remarks
Kenya	8	Preliminary identification completed
Malawi	4	Preliminary identification completed
Sudan	0	
Tanzania	4	Preliminary identification completed
Subproject 4	104	Preliminary identification completed

Preliminary examination/identification has shown several species of ladybird beetles and predatory bugs were common in vegetable-based cropping systems. Collections from Subproject 4 (cassava/sweet potato systems) showed predominance of phytoseiids and ladybird beetles.

Subproject 4. Samples of whitefly natural enemies collected and dispatched to institutions responsible for identification have been summarized in **Table 17**. Progress in the processing and identification in each of the principal groups is described below:

Samples collected from each of the five surveyed countries were sent to ICIPE. Numbers of predators collected have been low. This is due to three principal reasons, namely, the small amount of time available during the survey to collect samples, the relatively low populations of whiteflies found on cassava and sweet potato, and the difficulty in observing arthropods actually feeding on whitefly immature or adult stages.

Samples of parasitoids were also sent to ICIPE. Collection within the framework of the diagnostic survey again posed problems although these were less significant than those associated with predators. In Uganda, 121 individual parasitoids were reared through to the adult stage and preserved from 61 sampling locations. The distribution of the parasitoids was highly irregular, however, with some sites yielding relatively large numbers (max. 17) while many yielded none. Adult parasitoids failed to emerge from many of the mummies collected, and losses at this stage exceeded 80% although the level of loss was highly dependent upon the manner of collection, with excessive humidity resulting from putting too much leaf material in collecting dishes being a major cause of loss. These shortcomings will be rectified in surveys to be implemented in 1998.

While samples are currently being processed at ICIPE, preliminary examination of material in Uganda prior to dispatch indicates that at least three species of whitefly parasitoid occur on cassava and sweet potato in the country, with*Encarsia transvena* probably the most widespread and numerous. Additionally, a species of*Encarsia* not previously observed on*B. tabaci*, was recorded from three locations and on both cassava and sweet potato.

ICIPE was unable to act as a clearing center forentomopathogen specimens from Subproject 4 for reasons of quarantine. In Uganda collection of entomopathogen specimens proved difficult as a consequence of the heavy ElNiño-associated rainfall received throughout the surveying period. Identification in the field was also problematic, with the distinction between active parasites and secondary saprophytes causing difficulty. As a consequence this part of the survey was less successfully implemented than others. This pattern was repeated in the other countries surveyed in West Africa. In addition, no confirmed processing/identification channels were available at the time surveys were completed, with the exception of Benin, where support is being provided by scientists actively working on the use of entomopathogens for the control of other pest constraints. In consequence, it has not been possible to process entomopathogen samples collected in surveyed countries other than Benin. Shortcomings in the standardized methodology, in this respect, are being rectified prior to the execution of further country surveys.

VI. OUTPUT 4 - AGRONOMIC CHARACTERIZATION INITIATED

Characterization of the cropping systems, cropping patterns, cropping intensity, crop varieties, agronomic practices, agroecology and agrometerology of the target areas is in progress for all subprojects. The detailed nature of this type of data does not lend itself for inclusion in a progress report.

VII. OUTPUT 5 - PRELIMINARY STUDIES FOR PHASE 2

A. Develop GIS

In Phase 1, the development of a geographical information system (GIS) was planned (and budgeted) only as an activity for Subproject 2. To meet this objective, Subproject 2 hired a GIS specialist.

Establishing a GIS for purposes of subsequent application to whitefly IPM studies involves accessing or creating digitized base maps, agrometerological maps, crop use maps and a series of data maps (e.g., whitefly reproductive host plants; disease incidence and yield loss; distribution of viruses, whitefly species, biotypes and natural enemies; pesticide use; etc.). Development of a GIS in Phase 1 will allow descriptive analysis and lay the basis for more sophisticated regional analytical work in Phase 2 of the Danida project.

Digitized base maps, with municipal-level boundaries, have been created for Mexico, Central America and the Caribbean countries in Subproject 2. Agroclimatic maps (rainfall, temperature) for the region have also been accessed. Crop-use maps for beans have been accessed for the entire region. However, there is a general lack of information on the geographic distribution of horticultural crops in the region. We have started to incorporate the data generated for Mexico by the National Institute of Statistics, Geography and Information (INEGI) for the following crops: beans, tomatoes, peppers, broccoli, squash, melon, cucumber, watermelon, soybean and tobacco. We are exploring the availability of similar data sets from other countries in the region.

A biological database for the distribution of geminiviruses, whitefly species and biotypes, natural enemies and yield/economic losses is being set up. The GIS interface for the base maps and biological data has already been established.

B. Conduct Critical Area Analysis

Once the GIS is developed and the biological databases imported, it will be possible to use overlay methodologies to conduct a critical area analysis. Critical area analysis involves creating classifications for each map, assigning numerical values to the various classifications, combining values and creating a product map that integrates information from the individual maps. This analysis should indicate and prioritize critical areas, or hot spots, where intensive characterization and basic studies, including epidemiological field studies, should be carried out in Phase 2 of the Danida Project.

C. Conduct Preliminary Quantitative Analysis of Key WTV Pathosystems

In 1998 development of a mathematical simulation model, for within-field spread of whitefly-transmitted geminiviruses, advanced. This model will be verified using the tomato geminivirus pathosystems. Results of the verification will be presented in late 1998.

D. Produce ACM-free Planting Stock for Uganda

This activity was removed from Subproject 4 following the 13% reduction in the proposed Project budget prior to its final approval. However, in order to address the real needs for ACMD-resistant cassava planting material in Uganda and the wider East African region, a concept note has been developed and submitted to the OFDA of USAID. The US$150,000 granted will facilitate a two-year program focusing on the multiplication and dissemination of ACMD resistant varieties in regions especially vulnerable to the effects of the severe ACMD epidemic. Threatened regions identified include the southwestern region of Uganda, Western and Nyanza Provinces in western Kenya, and the Uganda and Kenya border areas of north-western Tanzania. **The diagnostic survey of the Danida Phase 1 Whitefly IPM Project has been instrumental in the identification of these vulnerable regions.**

E. Improve ACMD-resistant Varieties

As for activity 5.4, this component was removed following the budget reduction. Subproject 4, being coordinated as it is by IITA, does however have direct access to the major germplasm development program of the Institute. IITA-ESARC is also the base for the germplasm enhancement program for the mid-altitude ecologies of Eastern and Southern Africa, which is the largest single program of its kind in Africa. In addition to making direct use of IITA cassava varieties within initiatives proposed for the second phase of the Whitefly IPM Project, as described above, Subproject 4 will also develop improved IPM approaches to ACMD control, combining the use of new cassava materials, as they become available, with phytosanitary measures.

F. Epidemiological Monitoring for ACMD

Cassava. Studies to investigate the effect of varietal mixtures on patterns of ACMD epidemiology are being initiated in Uganda as part of the NRI cassava component of Subproject 4. Efforts will also be made to examine the responses of a range of local cassava cultivars to infection with different cassava mosaic geminivirus species. The rationale behind this work is that patterns of ACMD epidemiology appear to vary significantly from one location to another; in some areas, such as Mubende District in western Uganda, relatively low levels of incidence of ACMD have been sustained in spite of the proximity of the ACMD epidemic zone (**Fig. 22**). A range of factors may be behind this phenomenon, but is it thought that two of the most important are moderate levels of ACMD resistance in some of the local cultivars and the mixed planting of more resistant with more susceptible materials. Multiplication and distribution of improved ACMD resistant varieties is expensive and time consuming, and resistant materials commonly have inferior quality characteristics to local materials. The managed use of local cassava cultivars may therefore represent an important potential component in an overall IPM approach to the control of ACMD.

Sweet potato. Virtually nothing is known about whiteflies on sweet potato in spite of the fact that they have been recognized for many years as a vector of viruses affecting the crop. Similarly, understanding of the characteristics of the epidemiology of sweet potato viruses vectored by whiteflies is limited. NRI is therefore collaborating with NARO, CIP and IITA in implementing a research program to characterize the epidemiology of SPCSV/SPVD and the population dynamics of the whitefly vector of SPCSV on sweet potato in Uganda.

On-farm epidemiology trials. A series of experimental trials were planted in farmers' fields in locations with contrasting patterns of SPVD incidence. Three trials each were planted at Kanoni (southern Mpigi), Namulonge (northern Mpigi) and Soroti in late November using two varieties that are relatively susceptible to SPVD. All plants were initially disease free at the outset. Records are being taken monthly on SPVD incidence and whitefly numbers. Monthly surveys of SPVD incidence and whitefly populations on sweet potato fields in farmers' fields are similarly being monitored in six districts using the same method as was used in the survey.

By January the fields in Soroti and Namulonge were still disease free but some plants in Kanoni had developed SPCSV symptoms (**Table 29**). Whitefly abundance in the trials varied considerably, being greatest at Kanoni, intermediate at Namulonge and lowest in Soroti. There was also variation in whitefly populations within the three trials in a single district. Disease incidence ranged from 1 to 4% although the trials are still at an early stage. Whitefly abundance in farmers' fields surveyed ranged from 4.8 in Soroti to 20.2 in Iganga. Disease incidence was highest at Kanoni and lowest in Soroti.

In February, whitefly abundance was generally greater than in January at all six locations, with little variation. SPVD, in contrast, was more variable, with virtually no disease recorded from the eastern locations of Soroti and Busia, but 4-11% incidence recorded from other locations, generally increasing to the west. The Soroti and Namulonge trials (except for one) still had no disease in February, and little change in incidence was recorded at Kanoni. Whitefly abundance within the trials increased by a similar order of magnitude to that in the farmers' fields surveyed.

These results correspond well with data collected during the diagnostic survey. The greater incidence of SPVD in the south-central and southwestern region is clearly apparent, although the trials are far from complete, initial results suggest that SPVD spread is also substantially greater in this region than in the east and northeast. A more complete set of results and thorough analysis will be presented in the second progress report.

Table 29. Number of whiteflies and SPVD incidence in farmers' fields and field trials.

			Farmers' field data			
	Iganga	**Busia**	**Masaka**	**Soroti**	**Namulonge**	**Kanoni**
January						
Whitefly	20.2	11.8	8.8	4.8	13.1	11.0
SPVD	1.8	0.3	1.3	0	2.0	5.1
February						
Whitefly	17.8	19.7	32.4	15.5	20.6	22.9
SPVD	3.4	0.6	9.4	0	5.4	11.2
			Field trials			
		January			**February**	
	Soroti	**Namulonge**	**Kanoni**	**Soroti**	**Namulonge**	**Kanoni**
Whitefly						
Tanzania						
Field 1	5.2	4.8	9.6	3.5	12.8	13.8
Field 2	[1]	12.6	22.0	18.6	25.4	16.8
Field 3	0.8	8.8	33.2	6.3	16.6	15.0
Tororo 3						
Field 1	1.8	4.4	5.8	10.5	16.3	9.0
Field 2	[1]	11.6	16.6	8.6	20.2	14.8
Field 3	0.6	9.8	24.0	4.8	12	14.2
SPVD[2]						
Tanzania						
Field 1	0	0	2	0	2	4
Field 2	[1]	0	4	0	0	6
Field 3	0	0	2	0	0	4
Tororo 3						
Field 1	0	0	1	0	1	3
Field 2	[1]	0	3	0	0	3
Field 3	0	0	2	0	0	4

1 Field destroyed by cattle

2 Number of infected plants out of 100

APPENDIX A: PARTICIPATING INSTITUTIONS AND PRINCIPAL CONTACT PERSONS

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APPENDIX B: WORKPLAN FOR DANIDA PHASE 1 WHITEFLY PROJECT: NETWORK FORMATION, DIAGNOSIS AND ANALYSIS FOR IPM OF WHITEFLIES IN THE TROPICS

The objective 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.

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

Activity 1.1 Develop an electronic conference for communication between IARC, NARS and ARI collaborators

Efficient communications among collaborators in 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.

The Project will assist those collaborators who do not have email capacity in getting on-line.

Activity 1.2 Create a Project homepage on the InterNET WWW

The Project Coordinator, in conjunction with the System-wide IPM Initiative 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:

Activity 1.3 Standardize methodologies that will be used for each of the activities undertaken for 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 also be consulted. A document with clear instructions on proposed methodologies, protocols and surveys will be produced. At the onset of the Project, before actual fieldwork 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.

Activity 1.4 Publish a bibliography of the grey literature on whiteflies and WTVs

A tremendous amount of the research has also been conducted on whiteflies and whitefly-transmitted viruses 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 whitefly-transmitted viruses in the tropics will be developed and made available to the WF/WTV community, to complement the existing bibliographies.

Activity 1.5 Publish 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 Disseminate Project research results through the CG System electronic and printed media

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 coauthor 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 a mosaic 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 Identify whitefly 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 Estimate disease incidence and yield losses due to whiteflies 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 Determine whitefly-related crops 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 for pesticide use against whiteflies and WTVs in affected areas

Information on the pesticides used against whiteflies ad WTVs (how much, which pesticides, 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 Determine 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 Identify 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 pesticides are subsidized.

Output 3 - Epidemiological characterization initiated

Activity 3.1 Identify whitefly crop reproductive hosts

Bemisia tabaci (Gennadius) has been considered to be an extremely polyphagous species characterized by its 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 exist which indicate that we should not assume that *Bemisia tabaci* populations are homogeneous and reproduce freely among all available cultivated hosts.

In Phase 1, 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 Identify whitefly species and biotypes

It is clear that crop plants may 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 principal whitefly-infested 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 Identify whitefly-transmitted viruses in epidemic areas

Although many WTVs have been identified as the causal agents for regional epidemics, there are many zones in which we still do not understand which WTVs are responsible for the epidemics that are being 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 Identify efficient whitefly 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 providing efficient levels of control 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 effective in controlling whiteflies in the field.

Output 4 - Agronomic characterization initiated

Activity 4.1 Characterize 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 Characterize crop varieties and agronomic practices

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

Activity 4.3 Characterize 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 already existent 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 2 conducted

Activity 5.1 Develop GIS

A Geographical Information System (GIS) offers the opportunity to integrate and analyze multiple data sets. A GIS will be established by creating a base map, and a series of data maps (e.g. whitefly reproductive host plants, target crops of interest, disease incidence and yield loss, pesticide use hot spots, agro-meteorological data, etc.). Development of a GIS in Phase 1 will also allow more sophisticated regional analyses in Phase 2 of the Project.

Activity 5.2 Conduct critical area analysis

Once a Geographical Information System is developed, it will be possible to use overlay methodologies to conduct a critical area analysis. Critical area analysis involves creating classifications for each map, assigning numerical values to the various classifications, combining the values and creating a product map that integrates information from the individual maps. This analysis will indicate and prioritize critical areas, or hot spots, where intensive characterization and diagnosis, as well as epidemiological field studies, should be carried out in Phase 2 of the Project.

Activity 5.3 Conduct 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; Anderson, 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 1, will provide an objective basis for defining Phase 2 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 1, rather than waiting until Phase 2 when most of the IPM development and implementation activities will take place.

Activity 5.4 Produce ACMV-free planting stock for Uganda

Before new ACMD-resistant varieties are deployed, it is first essential to establish virus-free stocks of planting material. Cassava is a vegetative crop with a long growing season, which limits the rate of propagation. As a result, there has been a shortage of ACMD-free planting stems, and produces in Uganda would bring in susceptible varieties from areas not yet affected by the ACMD epidemics. The new cuttings were planted either adjacent to or mixed with heavily infected stands. Rapid infection of the new plantings occurred and within 10 months all fields were again severely affected. It is necessary to multiply and distribute virus-free planting material in ACMD-epidemic areas of Uganda.

Activity 5.5 Improve ACMD-resistant varieties

In the severe ACMD epidemic conditions prevalent over much of Uganda, IITA ACMD-resistant varieties, such as 30572, have been shown to provide good yields whereas local varieties produced virtually nothing. Although the IITA variety 30572 is an excellent source of ACMD resistance, it is high in cyanide and is not suitable for local consumption in Northern Uganda, where cassava is eaten with minimal processing. The NARO breeding program is releasing 2 new ACMD-resistant varieties, with IITA parentage. Still, there remains a need to support on-going breeding programs to develop locally adapted cassava varieties with a high level of ACMD resistance.

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 CIAT and IITA would allow breeding to follow a novel strategy of combining 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 know to reproduce on cassava in the Americas (Costa & Russell, 1976). If a new biotype of *Bemisia* is moving onto cassava in the Americas, then beginning to introduce ACMV resistance into American cassava varieties would be a visionary endeavor. This project can link with efforts to breed for ACMD in the absence of disease pressure.

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 ACMD 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 two years, when combined with molecular characterization of whiteflies and virus isolates, should provide 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 cassava mosaic disease into plots of disease-free cassava in different countries and agro-ecologies. It will be coordinated by ESCARC and ESCaPP and conducted and conducted in Ghana, Benin, Nigeria, Cameroon, Uganda, Kenya and Tanzania. A standard set of cassava varieties will be planted in the main cassava-producing agro-ecologies in each country, and rates of spread of cassava mosaic 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. This information should help decide on intervention measures to protect countries that neighbor Uganda, and that are currently threatened by the spreading ACMD epidemic.

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Activity 5.6 Epidemiological monitoring for CMD

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