Crop and Agroecosystem Health Management

Project PE-I

Annual Report 2006

CIAT
Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

Crop and Agroecosystem Health Management

Annual Report 2006
Project PE-1

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Crop and Agroecosystem Health Management (Project PE-1)

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Dedication:

With great admiration and respect, we dedicate this annual report to **Dr**. **César Cardona** for the many years of outstanding service that he gave and for the high quality of research in tropical entomology and the impact he has made to improve agricultural productivity and to protect the environment.

Born in Colombia, Dr. Cardona received his BSc. in Agronomy in 1965 from the National University of Colombia. He joined the Instituto Colombiano Agropecuario (ICA) [1965-1971], where he held a series of positions from research assistant all the way to senior scientist conducting research on insect pests of cotton and fruit crops in Colombia. He continued his education and pursued a Ph. D. in Entomology at the University of California at Riverside. While at UC-Riverside, he received the "Harry S. Smith" Award. This award is conferred to the best graduate student (1971), given by the Department of Entomology. He received his Ph.D. in entomology in 1972 and soon after joined the Colombian National Association of Cotton Growers as Head of the Technical Department Cotton Growers Federation (1971-1978).

Dr. Cardona joined CIAT in 1978 as an entomologist in the Bean Program and worked in that position until 1981. He was responsible for research on control of insects affecting beans in Latin America, particularly focusing on host plant resistance. He then moved and worked at the International Center for Agricultural Research in the Dry Areas (ICARDA) as a legume entomologist for the following 5 years. He returned to CIAT in 1985 as a bean entomologist. In 1997, he added forage entomology to his research responsibility and continued his outstanding and exemplary research until July 2006. Since July 2006, he has served as a consultant to the Forage Entomology program.

All throughout these years he continued his affiliation with the National University of Colombia. He has served as a lecturer and associate professor to the university in several occasions. He is an innate teacher; and under his supervision and mentorship 25 BSc., 5 MSc. and 4 PhD. thesis have been completed. Among his other professional participation we can list his memberships in the Sociedad Colombiana de Entomología (Socolen, Colombia), the Entomological Society of America (U.S.), Florida Entomological Society, and the American Association for the Advancement of Science.

Dr. Cardona's contribution to science has been enormous, making direct impacts on improving the lives of poor farmers. Some of his most outstanding research accomplishments include: 1) pioneering work on host plant resistance to six major insect pests affecting bean production in Latin America and elsewhere; 2) elucidation of the role of arcelin (a novel protein) as the factor conferring resistance to the Mexican bean weevil in beans; and 3) development, testing and

implementation of a highly reliable, mass screening methodology to facilitate breeding for resistance to spittlebugs in *Brachiaria*, thus contributing to the development of *Brachiaria* hybrids with high levels of resistance to several spittlebug species. This led to the characterization of mechanisms of resistance to all six major spittlebug species present in Colombia.

Dr. Cardona has also distinguished himself as a prolific writer, having authored or co-authored more than 123 refereed journal publications (emphasis on host plant resistance and problems related to insecticide abuse), over 7 book chapters, one book on host plant resistance to insects, and many other publications including, pamphlets, brochures, working documents, etc. He has been the recipient of numerous and prestigious awards such as the" National Agricultural Award"1991, given by the Ministry of Agriculture of Colombia and the "Meritorious Service Award" conferred by The Bean, Improvement Cooperative, BIC, in November 1993, in Michigan, USA. As a proof of his excellent research work, he has been awarded the "Hernán Alcaráz Viecco" Annual Award by the Colombian Entomological Society, SOCOLEN in twenty-three occasions! Within CIAT, he has been granted the Outstanding Research publication award in 1993 and in 2004, as well as the Outstanding Senior Staff Achievement award in 1993.

On the personal side, he has been married to Graciela for 40 years and is father of three children and the proud grandfather of two.

This is only a small glimpse of the man, the scientist, the mentor, and the colleague. He has many admirable and unique traits that cannot simply be put in words. His impeccable personal and scientific integrity, his selfless willingness to provide help to whomever needs it, his love for science and his dedication to the mission of CIAT are all unprecedented. César's research has unfailingly been characterized by the utmost scientific rigor coupled with intimate and passionate contact with the biological organisms-the insects and plants- that have been the focus of his work. He is the epitome of a "hands on" applied biologist and the best collaborator any scientist could hope for.

1. Project Description and Logframe

Project PE-1: Crop and agroecosystem health management

Research for Development Challenge: Improving Management of Agroecosystems in the Tropics (IMAT), CIAT. The project also contributes to the "Enhancing and Sharing the Benefits of Agrobiodiversity Biodiversity."

Project Manager: Segenet Kelemu

Project Description:

Goal: To enhance crop yields and quality of products, reduce pesticide use and residue, and improve agro-ecosystem health through enhancement of soil health and integrated management of major pests and diseases in the tropics.

Objective: Develop and transfer pest-and-disease knowledge and management systems for sustainable productivity and healthier agro-ecosystems in the tropics.

Target Ecoregion: Humid and sub-humid tropics in eastern and southern Africa, Central America and Andes.

1.1. Narrative Project Description

1.1.1. Rationale:

Most cultivated plant species are susceptible to a wide range of fungal, bacterial, and viral pathogens, and arthropod pests, particularly in tropical climates. These problems are compounded by the lack of resources and technical assistance to poor farmers in developing countries. Under these conditions, crop losses can often be significant or even total, affecting the livelihoods and food security of millions of poor rural and urban communities. In view of this situation, we could expect that the application of improved and intensive crop protection measures would contribute to the sustainability and enhancement of food production in these regions of the world. The development and application of integrated pest and disease management (IPDM) strategies is the basis of the Crop and Agroecosystem Health Management Project activities. Some of these methods include the development of resistant cultivars, including transgenic plants, and a variety of control measures developed for specific plant diseases/pests and agroecosystems. Biotechnology and/or conventional tools perform essential roles in our research activities dealing with crop and agroecosystem health management.

The Project's research activities are organized around four major outputs: 1) Pest and disease complexes described and analyzed, 2) Pest-and-disease management components and IPM strategies developed, 3) NARS' capacity to design and execute IPM research and implementation, and applications of molecular tools for pathogen and pest detection, diagnosis, diversity studies as well as novel disease and pest management strategies strengthened, 4) Global IPM networks (Integrated Whitefly Management Technology) and knowledge systems developed.

Output 1: Pest and disease complexes described and analyzed.

The difficulty of accurately identifying pathogens and pests of tropical crops is often a bottleneck to their control. We, together with various collaborators, have developed several molecular and conventional

diagnostic tools to detect, identify, and characterize pathogens and other pests affecting its mandated crops, that is, beans, cassava, tropical forages, and rice, as well as several high value crops currently grown by small-scale farmers in the tropics.

Extensively characterized pathogen populations at CIAT, with substantial practical implications for their management, include *Xanthomonas axonopodis* pv. *manihotis*, *Colletotrichum gloeosporioides*, *Phaeoisariopsis griseola*, *Pyricularia grisea*, *Sphaceloma manihoticola*, *Colletotrichum lindemuthianum*, species of *Pythium*, *Xanthomonas campestris* pv. g*raminis*, Rice *hoja blanca* virus (RHBV), and begomoviruses and potyviruses that infect important crops found in the tropics. Pests that are well-characterized include species of mealybugs, species of spittlebugs, whiteflies and their parasitoids, biotypes of the whitefly *Bemisia tabaci*, bruchids, and white grubs.

Output 2: Pest-and-disease management components and IPM strategies developed.

Resistance (conventional breeding): Managing diseases and pests through host resistance is economically attractive and practical. To develop cultivars resistant to diseases and insect pests, a common strategy, known as 'gene pyramiding', is to incorporate as many resistance genes into a single plant genotype as possible, in the hope that it will be statistically unlikely for a pathogenic race or insect pest to evolve that can overcome all the resistance genes simultaneously. However, combining several resistance genes simultaneously in one background becomes difficult without using markers for each gene. In this context, the use of marker-assisted selection to contain pest damage becomes essential.

Transgenic crops as components of IPDM strategies: Genomic approaches are increasing our understanding of the genetic basis of plant disease and pest resistance by enabling us to better understand resistance genes themselves, other genes, and the pathways they regulate. While fully recognizing the controversy on transgenic organisms, we value the potential role they can play in arthropod pest, disease, and virus management strategies across several crops. The role of transgenic organisms in IPDM will increase in the future and has already been shown as a way of drastically decreasing pesticide use.

Transgenic crops developed at CIAT include *Stylosanthes guianensis* containing a rice-basic chitinase gene for resistance to the fungal pathogen *Rhizoctonia solani*; rice, for resistance to Rice *hoja blanca* virus (RHBV), containing the RHBV nucleocapsid protein (*N*) gene. As the possibilities of combining genes from various sources expand, the need for biosafety regulations and risk assessment increases. Our studies on the effect of transgenic (Bt) varieties on non-target soil organisms showed that no statistical differences were detected in abundance and diversity of soil organisms in conventional versus genetically modified cotton [Bollgard ® Bt Cry 1A ©] during the 2003-05 period in the Cauca Valley, Colombia.

Bio-pesticides:

The concerns on excessive pesticide use and the threat to human health and the environment, coupled with increasing regulatory and market pressures, along with pest and pathogen resistance to synthetic chemicals, have led to a reappraisal of approaches to pest and disease control strategies that include the development of safer "biological pesticides." This excessive use of pesticides threatens to weaken the competitiveness of many Latin American countries' agriculture by: 1) threatening to disqualify export products especially in those countries that have stringent food safety regulations, 2) increasing production cost, 3) degrading the general ecosystem, making their soils less productive over time, 4) contaminating water supplies, 5) causing health problems among agricultural workers and thus affecting the labor force. In this context, we believe

natural plant and microbial compounds will play a major role in pest and disease control in both developed and developing countries.

Biological control is an important component of integrated pest and pathogen management. Endophytic microbes, fungi, bacteria, nematodes, viruses, plant-derived compounds are all identified and characterized for use as biocontrol agents against a wide range of pathogens and pests attacking various crops. Biopesticides developed and currently made commercially available in collaborative projects with the private sector include: 1) Biocanii, based on a strain of the fungus *Verticillium lecanii* for the control of whiteflies and thrips on flowers, beans, avocado, cotton, onion, citrus, asparagus, papaya, tomatoes and other horticultural crops; 2) Biorhizium**,** based on two strains of the fungus *Metarhizium anisopliae* for the control of various insects such as spittlebugs in pastures; 3) Biovirus**,** based on a baculovirus and used for the control of cassava hornworm, 4) Ecoswing®,.a biofungicide formulated from extracts of the plant swinglia (*Swinglia glutinosa*).

Plant-derived compounds: We have identified plant-derived compounds that are effective in controlling diseases and pests. These include: 1) fique (*Furcraea cabuya*), 2) swinglia (*Swinglia glutinosa*), 3) *Clitoria ternatea*.

Legumes have been used as cover crops and as sources of green manure. The use of cover crops (e.g. Canavalaia ensiformis, Crotalaria rahamiana, Crotalaria juncea, C. ochroleuca, Desmodium intortum, D. unicanatum, Lablab purpureus, Tagetes patula, Mucuna pruriens) has been associated with a decrease in incidence of soil-borne pathogens and pests in several cropping systems.

Output 3: NARS' capacity to design and execute IPM research and implementation, and applications of molecular tools for pathogen and pest detection, diagnosis, diversity studies as well as novel disease and pest management strategies strengthened.

The purpose of this output is to strengthen our national partners' capacity to diagnose and detect pests and diseases; develop and execute IPDM strategies that would contribute to the reduction of losses caused by pests and diseases through effective targeting, dissemination and adoption of integrated pest management strategies that are acceptable to smallholder farmers in eastern, central and southern Africa and Latin America. Useful practical experiences have been gained, successes achieved and lessons learnt during the promotion of technologies at target sites. We will help to develop plant diagnostic networks to combat invasive pests, promote regional collaboration, and strengthen local diagnostic and outreach capabilities.

Through strong partnerships with national programs, universities, farmer groups, and the private sector we develop and evaluate diagnostic tools, disease and pest management methods including resistant materials, cultural methods and biopesticides. Capacity building and training of students, farmers and professionals at various levels is a major activity of the project staff.

Output 4: Global IPM networks (Integrated Whitefly Management Technology) and knowledge systems developed.

One of our main research areas is the management of whiteflies as pests and vectors of plant viruses attacking a broad range of crops throughout the tropics. Whiteflies are phloem feeders that cause direct damage in some of their hosts by removing large quantities of sap. In addition, species of whiteflies, such as *Bemisia tabaci* and *Trialeurodes vaporariorum,* are vectors of plant viruses of significant economic

importance. These whitefly species cause significant and often total direct or indirect (as vectors) damage to a wide range of food and industrial crops throughout the tropics. For example, African cassava mosaic disease is caused by different but related viruses transmitted by *B. tabaci*. Similarly, *Bemisia*-transmitted viruses affect many traditional (e.g. common bean) and non-traditional (e.g. tomato, peppers, cucurbits) crops in the tropics. The pest problem that is associated with many horticultural crops is often dealt with multiple applications of pesticides. These and other similar scenarios have major consequences to food security, human and agroecosystem health, and farm income.

In the1990s, new inter-center initiatives including the System-wide Program on Integrated Pest Management (SP-IPM) were created by the CGIAR. Due to the importance of whiteflies and the viruses they transmit, the Tropical Whitefly IPM Project (TWFP) was the first inter-center project within SP-IPM. The Project was developed in three phases to be carried out over a 10-year period, and launched in 1997 with CIAT as the convening Center. Five IARCs (CIAT, IITA, AVRDC, ICIPE, CIP), 12 advanced research institutes, and 31National Agricultural Research and Extension Systems in Latin America, Caribbean, Africa and Asia are included. This extensive partnership was made possible through the financial support of six major donors: Danish International Development Agency (DANIDA), Australian Center for International Agricultural Research (ACIAR), United States Agency for International Development (USAID), Ministry of Foreign Affairs and Trade (MFAT, now New Zealand Aid), U.S. Department of Agriculture-Agricultural Research Service (USDA-ARS), Department for International Development (DFID, UK)

1.1.2. CGIAR System Priorities:

The Crop and Agroecosystem Health Management Project contributes essentially to all the 5 CGIAR Research Priorities (2005-2015). Specific activities conducted by the Project to contribute to the CGIAR priorities are:

- Developing molecular and conventional methods for screening of germplasm for resistance to diseases and pests- (Priority 1)
- Characterization of germplasm and identification of sources of resistance to diseases and pests- (Priority 1)
- Developing phytosanitory methods and protocols for the safe movement of germplasm-(Priority 1)
- Identification, characterization and conservation of beneficial microorganisms associated with plant germplasm (eg. endophytic bacteria and fungi), and predators of harmful pets-(Priority 1)
- Enhancing yields of crops through pest and disease resistance- (Priority 2)
- Reduction of pesticide use in various crops including high value crops, thus reduction of pesticide residue and improving food safety- (Priority 2)
- Monitoring pathogens and pests that develop resistance to pesticides- (Priority 2)
- Screening high value crops for resistance to key pathogens and pests- (Priority 3)
- Management of diseases and pests in fruits and vegetables- (Priority 3)
- Developing methods to prevent post harvest losses- (Priority 3)
- Improving water quality through pesticide use reduction- (Priority 4)
- Enhancing soil health through improved and integrated disease and pest management strategies- (Priority 4)
- Development and implementation of integrated disease and pest management strategies for sustainable management of agroecosystems- (Priority 5)
- Development of phytosanitary protocols and certification systems to facilitate international trades- (Priority 5)

1.1.3. Impact Pathways:

The project contributes to improved crop productivity and improved livelihoods through development of efficient and accurate tools for disease and pest diagnosis (output 1), and cost-effective disease and arthropod pest management strategies (output 2). We screen for host plant resistance and identify important sources of resistance to a wide range of pests and pathogens. These sources of resistance are used in the breeding programs to incorporate the resistance genes with a number of other genes of agronomic importance. We develop other components of integrated pest and disease management strategies including biopesticides and cultural practices. The capacity of our national partners to diagnose and detect pathogens and pests and to implement effective disease and pest management strategies is enhanced through our activities in output 3. We communicate our results through publications in international and regional journals, books and manuals, articles presented in conferences and workshops, websites, and in English, Spanish and other major local languages. Other communication outlets are newspaper articles and other journals intended for the general public. Global networks on sustainable management of key pests, such as whiteflies, which attack staple crops, high value crops and industrial crops are established (output 4). The outputs of the Project benefit NARS scientists, farmers, and consumers by increasing crop yields, crop quality, agro-ecosystem health and stabilizing production systems. The judicious use of pesticides results in clean harvests with little or no pesticide residues, leading to increased income and market access through healthier products, and cleaner environment.

1.1.4. International Public Goods:

The project works on diseases and pests of rice, beans, cassava, tropical forages and tropical fruits. In addition to the research activities involving CIAT's commodity crops, the Project scientists are also involved in projects that expand their expertise to other agricultural and industrial crops. These include maize, cotton, onions, asparagus, other vegetables, potatoes, cut flowers and oil palm.

The Project has played a major role in the formation and development of the CGIAR Systemwide Program in IPM (SP-IPM). CIAT is the Convening Center for the major ongoing project in the SP-IPM, The Tropical Whitefly IPM Project. A draft SP-IPM proposal on "Soil Biota, Fertility and Plant Health" is available. The Project staff as well as the TSBF Institute of CIAT have played major roles in this proposal.

The Instituto Agronómico de Colombia (ICA) invited the Project and its scientists to apply for, and acquire accreditation to evaluate the quality and effectiveness of biological pesticides. The CIAT laboratories and scientists would become registered with ICA to perform quality control analysis of biopesticide products of commercial producers seeking ICA registration. Furthermore, the Project is invited to participate in major activities of ICA involving phytosanitary issues. The citrus virus certification work that the Project has conducted in collaboration with ICA and CORPOICA is now considered as a model for expansion to other crops, diseases and regions.

The science dealing with the identification, naming and classification of organisms, is a vital component in a pest management program. An inaccurate identification of a pest organism can result in an acute loss of time and resources and delay the most appropriate response to pest attack. The Project provides a service for the identification of arthropod pests and pathogens collected from various crops, but especially from CIAT's mandated crops, and related activities. The Project maintains a working collection, now totaling over 20,000 specimens, of arthropod pests and their natural enemies for cassava, beans, rice, tropical pastures and tropical fruits, as well as those collected from related agroecosystems. A database containing information on individual specimens accompanies this collection and this is made available to collaborating institutions, museums, universities and national research and extension programs. The project also maintains large collections of fungal and bacterial pathogens, and beneficial microorganisms including nitrogen fixers, plant growth promoters, biocontrol agents. In addition, a collection of entomopathogenic

fungi, bacteria and nematodes is also maintained. These potential biological control agents have been isolated from crop pests through field surveys, or have been received from other research institutions (e.g. CENICAFE) in collaborative exchange projects.

The project uniquely works on endophytic fungi and bacteria, multiple resistances to spittlebugs, microbial and plant-derived biopesticides. Several biopesticides have been commercially made available through collaborative projects with the private sector. The project staff in Africa provide capacity building in molecular tools for disease diagnosis and pathogen characterization, marker assisted selection methods to improve the efficiency of breeding for disease resistance, participatory evaluation and implementation of disease and pest management methods, as well as supervision of graduate student thesis.

The research outputs of the PE-1 Project are in line with the mandate of the CGIAR of producing international public goods (IPGs). The IPGs of the research outputs of this Project are summarized as follows:

1. Mechanisms:

a) Understanding mechanisms of resistance to fungal, bacterial and viral pathogens leading to the development of screening methods
b) Understanding mechanisms of resistance to arthropod pests thus, leading to development of methods for resistance screening.
c) Understanding mechanisms of how pathogens and pests evolve and overcome host resistance
d) Understanding mechanisms of how pathogens and pests evolve and develop resistance to pesticides

2. Methods:

a) Techniques and methodologies for mass rearing of arthropod pests for resistance screening and biopesticide testing
b) Standardized protocols for risk evaluations of genetically modified organisms (GMOs) on non-target soil organisms.
c) Genetic transformation methods for pathogenic and non-pathogenic fungi and bacteria.
d) Methods for long-term storage of microbes.
e) Methods for artificial inoculation/infestation and for resistance measurement for a number of pathogens and pests.
f) An improved greenhouse inoculation method to detect quantitative differences for genetic studies and breeding, and evaluation, eg. sheath blight resistance (*Rhizoctonia solani*) in rice
g) Methods for screening potential biopesticides
h) Protocols for the safe movement of germplasm within and across regions

3. Products:

a) Genotypes with resistance to pests and diseases identified among the collection of beans, cassava, rice, tropical forages and tropical fruits
b) High yielding disease and pest resistant breeding lines
c) Microbial-derived biopesticides
d) Plant-derived biopesticides
e) Improved biocontrol agents
f) Microbial and arthropod pest databases.

1.1. 5. Partners:

- **Bolivia-** PROIMPA: Management of whitefly.
- **Brazil**- EMBRAPA- CNPMF, - CNPGC, IAC – Development of host plant resistance to spittlebugs
- **Canada**- Agriculture & Agri-Food- *Pythium* species identification
- **China-** Yunnan Academy of Agricultural Sciences – Development of runner bean project
- **Colombia-** CORPOICA, ICA, Universidad Nacional de Colombia-Palmira and Bogotá, Life Systems Technology (LST) S.A, Universidad del Valle, Universidad de Caldas, Universidad Católica, Universidad de la Amazonía, Universidad de los Andes, Profrutales Ltda, BIOTROPICAL, Palmar del Oriente: provide samples, validation of control and management practices); Corporación BIOTEC, FEDEPLATANO: farmers groups, and many more; graduate and undergraduate thesis of students, development of disease and pest diagnosis tools, evaluation of pest and disease management methods, quarantine pests and diseases, certification programs; - Biotropical: development, evaluation and formulation of biopesticides.
- **Denmark -** The Royal Veterinanry and Agricultural University: induced resistance and training
- **Ecuador-** Instituto Nacional Autónomo de Investigaciones Agropecuarias (INIAP), Escuela Politécnica del Ejército (ESPE): pest and pathogen resistance to pesticides, research on soil arthropods. Manrecur: management of whitefly.
- **France**- IRD: insect physiology and biochemistry.
- **Germany-** Institut für Pflanzenkrankheiten und Pflanzenschutz, Fachbereich Gartenbau, Universität Hannover, Agrar- undErnährungswissenschaftliche Fakultät, Universität Kiel, Federal Biological Research Centre for Agriculture and Forestry (BBA): soil arthropod pests, entomopathogens.
- **Honduras**- PROMIPPAC: biopesticides
- **Kenya**- International Centre of Insect Physiology and Ecology (ICIPE): insect physiology.
- **Nicaragua**- MAGFOR: capacity strengthening in disease and pest diagnosis, disease and pest management.
- **Nigeria**-IITA: System –wide program on IPM, management of whiteflies.
- **Peru**-CIP: management of whiteflies.
- **Rwanda**- Institut des Sciences Agronomiques du Rwanda (ISAR): integrated disease and management and soil fertility management for enhancing soil health
- **Taiwán**- AVRDC: management of whiteflies in tropical crops.
- **Tanzania**- Agricultural Research Institute, African Highlands Ecoregional Program, Adventist Development and Relief Agency, Ministry of Agric.-Armyworm project, Farm Africa, Farm Africa, World Vision, farmers groups, and others: Evaluation of disease and pest management methods.
- **Uganda**- National Agricultural Research Organization (NARO), African Highlands Ecoregional Program, Makerere University, Uganda National Agricultural Advisory services, farmers groups, and others: Evaluation of disease and pest management methods, thesis students.
- **United Kingdom**- Commonwealth Agricultural Bureaux International (CABI), Horticulture Research International (HRI), Natural Resources Institute: management of whiteflies. Scottish Crop Research Institute: Isolation and conservation techniques.
- **United States**-University of Kentucky, Cornell University, Iowa State University, Kansas State University, University of Georgia, University of Florida, University of California-Davis, Michigan State University, Texas A& M, United States Department of Agriculture (USDA): insect taxonomy, analysis of alkaloids from endophytes, diagnosis and detection tools.
- **Venezuela**- Instituto Nacional de Investigación Agrícola (INIA): pesticide use and resistance of pathogens and pests to agrochemicals.

1.2. Project Log-frame (2006-2008)

Project: Crop and Agroecosystem Health Management
Project Manager: Segenet Kelemu

	Outputs	Intended User	Outcome	Impact
Output 1	Pest and pathogen complexes in key crops described and analyzed.	NARIs, universities, NGOs, IARCs	• Molecular and conventional tools for disease and pest diagnosis, detection and characterization developed, evaluated and disseminated to researchers.	• Improved crop productivity from more efficient and accurate tools for disease and pest diagnosis, and cost-effective disease and insect pest management strategies. • Improved livelihoods of small farmers through higher yields of crops obtained by better disease and insect pest management
Output 1 Targets 2006	Invasive pest species, white grub, burrower bugs and their natural enemies taxonomically identified and characterized	NARIs, universities, NGOs, IARCs	• Pest characterization tools developed and adopted by researchers.	
Output 1 Targets 2007	Molecular tools for detection, diagnosis and diversity studies of key pathogens and pests of CIAT commodities made available	NARIs researchers in LAC, Asia and Africa, IARCs	• Disease and pest characterization tools developed and adopted by researchers.	
Output 1 Targets 2008	Two plant- growth promoting bacteria and one biological control agent characterized.	NARIs researchers in LAC, Asia and Africa	• New options for disease and pest management and plant health enhancement developed and tested by researchers.	
Output 2	Pest-and-disease management components and strategies developed for key crops.	Researchers in LAC, Asia and Africa	• Integrated disease and pest management strategies developed and adopted by farmers.	• Increased and stable income of small farmers through increased crop yields and enhanced quality of products
Output 2 Targets 2006	Bean, cassava, rice and tropical forage lines resistant to major diseases and pests and molecular markers associated with some of these resistance genes identified	Researchers in LAC, Asia and Africa	• Tools that contribute to efficient breeding strategies developed	

PE-1 project Log Frame (Continued)

Output 2 Targets 2007	At least 2 *Brachiaria* genotypes with spittlebug resistance, a whitefly resistant cassava variety, and 50 blast and sheath blight resistant rice lines developed.	Researchers in LAC, Asia and Africa; CIAT scientists; farmers	• Selected genotypes of *Brachiaria,* cassava and rice tested for resistance to insects and pathogens in different regions.	
Output 2 Targets 2008	Three biological pesticides, and angular leaf spot and *Pythium* resistant bean varieties made available	Researchers in LAC, Asia and Africa; farmers	• Disease /pest resistant crops developed and adopted; biopesticides formulated and adopted.	
Output 3	Strengthened capacity of NARS to design and execute IPM R&D, to apply molecular tools for pathogen and pest detection, diagnosis, diversity studies and to device novel disease and pest management strategies	NARIs in LAC, Asia and Africa; farmers	• Improved capacity of NARS partners to disseminate to farmers disease and pest management strategies	• More income to farmers by using; environmentally-friendly disease and pest management strategies.
Output 3 Targets 2006	Use biopesticides and other pest management practices on common bean crop transferred to farmers in Malawi, Kenya, Tanzania and Uganda	NARIs in Africa; farmers	• Improved disease and pest management strategies adopted	
Output 3 Targets 2007	Management strategies for soil-borne pests (white grubs and burrowers bugs) evaluated with farmers	NARIs and farmers in LAC, Africa	• Soil pest management methods adopted by farmers.	
Output 3 Targets 2008	Combination of whitefly resistant cassava varieties and biological control agents made available to farmers	NARIs, NGOs and farmers	• Improved cassava varieties together with improved disease and pest management practices adopted.	

PE-1 project Log Frame (Continued)

Output 4	Global IPM networks (Integrated Whitefly Management Technology) and knowledge systems developed.	NARIs, Universities, NGOs, IARCs, farmers	• Sustainable food and cash crop production systems with reduced environmental impact and production costs adopted.	• Improved livelihoods, rural and urban health standards, and increased farm/household income
Output4 Targets 2006	Guidelines and technical information on whitefly management distributed in Asia, Africa and Latin America	NARIs, Universities, NGOs, IARCs, farmers	• Information on improved whitefly management strategies disseminated	
Output 4 Targets 2007	Farmer participatory research conducted in selected pilot sites of sub-Saharan Africa, S.E. Asia and Latin America.	NARIs, Universities, NGOs, IARCs, farmers	• Methods in lower pesticide use resulting in lower production costs and environmental contamination adopted.	
Output 4 Targets 2008	Impact assessment and Policy guidelines implemented for the benefit of farmers.	Government Institutions, NARs, NGOs, farmers	• Food production and income-generating strategies for small-scale farmers facilitated by official decrees	

1.3. CGIAR Output template 2006

PE-1
Crop and Agroecosystem Health Management

	Output Targets 2006	Proof of Achievements
OUPUT 1 Pest and pathogen complexes in key crops described and analyzed.	Invasive pest species, white grub, burrower bugs and their natural enemies taxonomically identified and characterized	Achieved. Annual Reports 2005, 2006, other publications (see publication list)
OUTPUT 2 Pest-and-disease management components and strategies developed for key crops.	Bean, cassava, rice and tropical forage lines resistant to major diseases and pests and molecular markers associated with some of these resistance genes identified	90% achieved. Annual Reports 2005,2006, other publications (see publication list)
OUTPUT 3 Strengthened capacity of NARS to design and execute IPM R&D, to apply molecular tools for pathogen and pest detection, diagnosis, diversity studies and to device novel disease and pest management strategies	Use biopesticides and other pest management practices on common bean crop transferred to farmers in Malawi, Kenya ,Tanzania and Uganda	75% achieved: Annual Reports 2005, other communiques
OUTPUT 4 Global IPM networks (Integrated Whitefly Management Technology) and knowledge systems developed.	Guidelines and technical information on whitefly management distributed in Asia, Africa and Latin America	Achieved A book and technical manuals in English and Spanish developed; other publications (see publication list)