Globalizing Integrated Pest Management

A Participatory Research Process

Edited by George W. Norton, E. A. Heinrichs,
Gregory C. Luther, and Michael E. Irwin

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edited by

George W. Norton
Department of Agricultural and Applied Economics,
Virginia Polytechnic Institute and State University,
Blacksburg, Virginia, U.S.A.

E. A. Heinrichs
Office of International Research, Education, and Development
Virginia Polytechnic Institute and State University,
Blacksburg, Virginia, U.S.A.

Gregory C. Luther
The World Vegetable Center
Taiwan

Michael E. Irwin
Entomology Department
University of Illinois
Urbana-Champaign, Illinois, U.S.A.

Blackwell Publishing

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9600 Garsington Road, Oxford OX4 2DQ, UK
Tel.: +44 (0)1865 776868

Blackwell Publishing Asia
550 Swanston Street, Carlton, Victoria 3053, Australia
Tel.: +61 (0)3 8359 1011

This book was produced from camera-ready copy supplied by the authors.

First edition, 2005

ISBN-10: 0-8138-0490-6
ISBN-13: 978-0-8138-0490-3

Library of Congress Cataloging-in-Publication Data available on request

The last digit is the print number: 9 8 7 6 5 4 3 2 1

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Developing IPM Packages in Latin America

Jeffrey Alwang, Stephen C. Weller, Guillermo E. Sánchez,
Luis Calderon, C. Richard Edwards, Sarah Hamilton,
Roger Williams, Mike Ellis, Carmen Suarez, Victor Barrera,
Charles Crissman, and George W. Norton

Introduction

IPM programs have expanded in both central and South America over the past ten years. The South-American program has been focused in the Andean region, especially on potatoes and fruits, and has been led in part by the IPM CRSP, the International Potato Center (CIP), and The International Center for Tropical Agriculture (CIAT) in conjunction with national agricultural research systems (NARS). Central American IPM has focused on non-traditional agricultural export crops, especially fruits and vegetables. The IPM CRSP has centered its regional IPM programs in Ecuador and Guatemala. In this chapter, we turn our attention first to the Ecuador program and then to Guatemala.

South America IPM Program in Ecuador

Ecuador, like much of the Latin-American region, is distinguished by its remarkable physical and ecological diversity. The varied topography of the heavily mountainous country includes coastal plains, highly sloped middle elevation tropical forests, high elevations with steep slopes, and tropical rainforests with Amazon tributaries. Like its topography, Ecuadorian agriculture is characterized by diversity; crops and farming systems vary even within well-defined agro-ecosystems, as do agricultural pests and means of managing pests. As a result of this diversity, Ecuador is particularly suited for the participatory IPM approach, as pest problems are localized and solutions must be tailored to meet local needs.

Ecuador is classified as a lower middle-income country with a PPP GNP of $2,600 in 1999 (World Bank, 2001). The country relies on agriculture for approximately 17% of its GDP, with close to the same percentage derived from oil and natural gas, Ecuador's chief exports. Major crops include banana, flowers, sugar cane, rice, maize, plantain, and potatoes. The latter two crops represent important food staples; potatoes are widely consumed by lower and middle-income groups in the highlands and plantains in the coastal regions. Plantains are increasingly being exported, particularly to Colombia and Central America. Among agricultural exports, bananas reign supreme, accounting for about 85% of the close to $1 billion in agricultural exports in 2001. Plantains are the third most important agricultural export, representing about $18 million in exports in 2001. Plantain production and exports represent a significant source of agricultural growth, particularly in the coastal regions of the country.

Potato production is widespread[1] in the highlands of Ecuador, where more than 44% of the country's nearly 13 million people live. Plantains are grown in areas along the coast and at mixed elevations throughout the tropical regions of the country; FAO estimates that Ecuador has approximately 70,000 hectares of plantains. In coastal areas, plantains represent a major food staple (Figure 5-1).

Ecuador's public agricultural research is principally conducted by the Instituto Nacional Autónomo de Investigaciones Agropecuarias (INIAP), a semi-autonomous agency that was formed to make agricultural research in Ecuador more productive by introducing market-based incentives. INIAP's semi-autonomous structure is suited for project-based support because it is flexible and responsive to client needs. These attributes also make it an appropriate partner for participatory IPM. In the early 1990s, INIAP underwent an administrative reorganization that positioned the institution for participatory IPM work. Its Plant Protection Department adopted an integrated approach to basic and applied research across regions, commodities, and disciplines. The Department had begun training scientists to participate in a country-wide IPM network and had also undertaken a comprehensive assessment of main pests and diseases of vegetables and fruits. As of 1994, the institution was poised to begin intensive work on IPM, but lacked funding and scientific expertise. The IPM CRSP was invited to help fill the void. Although Ecuador was listed as a secondary site in the original IPM CRSP proposal, funding for research in that country began in 1997/98.

[1] Approximately 60,000 hectares of potatoes are grown in Ecuador (FAO).

Figure 5-1. Plantain renovation experiment.

Identifying and Prioritizing IPM Problems and Systems

IPM priorities in Ecuador were determined through a combination of stakeholder meetings, participatory appraisals, an assessment of current information about pests and pest-control measures, crop-pest monitoring, an *ex-ante* analysis of potential impacts of IPM, and analysis of institutional strengths. INIAP and U.S. scientists conducted a series of stakeholder meetings attended by representatives from CIP, PROEXANT (a non-traditional agricultural export assistance firm), CARE, USAID, the Ministry of the Environment, and OIKOS (a local environmental NGO), among other organizations. These meetings, in combination with participatory appraisals, were used to identify serious pest problems in potato, fruit, and plantain cultivation. In the case of potatoes, farmers in one of the main potato-growing regions (Carchi, along the northern border with Colombia) were concerned that pervasive pest problems were inducing over-applications of pesticides and causing reduced yields or storage losses, leading to lower competitiveness of Carchi potatoes and adverse health effects. In plantain regions around El Carmen, growers identified a dearth of pest-related information and were reliant on recommendations from banana exporters. Potatoes and plantain were logical crops for a PIPM focus, due to these problems, the economic importance of the two crops, and a varied institutional base on which to build. This base led the scientists to conclude that IPM in potato and plantain had a high probability of having important economic and institutional impacts.[2]

Highland Potatoes

In potatoes, several institutions had been engaged in basic and applied research and, to a limited extent, technology transfer, both at the Santa Catalina experiment station near Quito and on-site in Carchi. These include the International Potato Center (CIP), INIAP's own National Potato Program (FORTIPAPA), and the Soils CRSP among others. In addition, Eco-Salud, a health-oriented non-governmental organization, had been conducting research on the health and environmental effects of high-input potato production. The research base provided by these entities, their integration into the community, and the possibility for outreach of results[3] created opportunities in potato IPM that did not exist for other crops.

Potatoes are grown in the Carchi region in a mixed farming system where potatoes are primarily rotated with pasture for livestock.[4] Households in the region also produce beans, barley, corn, and a variety of horticultural products. Holding sizes vary, with a mean holding of 2-3 hectares; the typical household produces 0.75-1 hectare of potatoes. Typical holdings are steeply sloped but fertile lands; approximately 33 percent of the land in the area is irrigated. Potato yields are approximately 15,000 kg per hectare, compared to 11,400 nationally (FAO, 2003). The area's economy is heavily dependent on agriculture; about 45 percent of the workforce is comprised of agricultural day laborers, and another 33 percent is described as self-employed (most in agriculture). The largest sources of family incomes are milk and potato sales. Sixty-three percent of the population has received primary education of some type, while 23% have some secondary education. More than 10 percent has had no formal education at all. Farming is a way of life in the area, and men, women, and children share production

[2] The IPM CRSP also worked in Ecuador at middle elevations on pest problems of several Andean Fruits and a mixed coffee-plantain system in a fragile ecosystem.

[3] Ecuador has no formal public agricultural extension service. As a result, INIAP is continually searching for innovative means of extending research results.

[4] Much of the information in this section comes from the IPM CRSP baseline survey for potatoes, conducted in 1999.

duties. Women, in particular, are actively engaged in farm decisions and participate in pesticide use and storage.

The major potato pests identified during the IPM prioritization process were late blight (*Phytophthora infestans*) (see Figure 5-2, page xix), Andean weevil (*Premnotrypes vorax*), and Central American tuber moth (*Tecia solanivora*). The former is a worldwide limiting factor in potato production and, prior to the CRSP, the farmers' primary means of control was intensive field spraying of fungicides, particularly Cymoxanil and Mancozeb. Weevils and tuber moths were also controlled through heavy spraying, with Carbofuran, a highly toxic member of the Carbamate group, being the principal agent. The tuber moth also attacks potatoes in storage. Lack of information on pesticide applications led to widespread mixing of as many as 12 chemical agents into "cocktails." The average farmer made 8 chemical applications in a single growing season with 2-3 insecticides or fungicides in each. In fact, analysis of the base-line data showed that only about 25 percent of farmers applied pesticides in "good" combinations and far less than 50 percent used the appropriate dosage. Women, who in recent years have taken increasing responsibility for management of the farm's affairs, were particularly concerned about the misuse of pesticides, its impacts on farm income and on human health.

The potato IPM strategy

The research base provided by CIP and FORTIPAPA facilitated the CRSP beginning work on pest-management methods at several levels including experiments under greenhouse conditions, trials in farmer fields, and participatory experimentation in farmer field schools. For example, CIP/FORTIPAPA had identified a number of potato clones with horizontal resistance to Late Blight. These clones had not been examined in on-farm conditions nor for farmer acceptance. In fact, farmers in Ecuador are particularly concerned with factors such as coloration, tuber appearance and taste, and consumer acceptance. In the first years of the IPM CRSP, a project that tested these clones in multidisciplinary on-farm pest-management experiments identified three varieties that comprised an integral part of the IPM package for potatoes (Figure 5-3). Late blight damage is controlled in the package through resistance and more limited fungicide applications.

Laboratory experiments sponsored by complementary projects had measured the effectiveness of several low-toxicity products in controlling the Andean potato weevil. The CRSP, building on these findings, immediately

Figure 5-3. IPM CRSP collaborators in Ecuador viewing potato experiment.

began field trials of eight promising products and identified a chitin inhibitor, Triflumuron, as the best means of insect control. During evaluation of these products, their effectiveness in traps, bait plants, and foliar application was tested and the results used to formulate a trap/foliar application strategy that would form the basis of the IPM package for control of the weevil. During subsequent years of the project, foliar application methods were refined as a part of a farmer field school participatory learning experience, and chemical application on the lower leaves of the plant on alternating rows of potatoes was determined to be the best method of control. These recommendations were immediately incorporated into the IPM package.

In the case of the Central-American tuber moth, farmers immediately identified damage caused by the pest during storage of tubers as its most serious impact. As a result of this damage, farmers relied on heavy applications of pesticides in storage areas, areas often involving storage of other foods and household implements. The CRSP began working in collaboration with French researchers and staff at the Catholic University of Quito to study the effectiveness of biological control methods, particularly Bacolovirus. Because of the existing research base, CRSP researchers were able to begin their investigations in farmer storage facilities. Researchers discovered that more virulent strains of Bacolovirus were needed for effective control, but existing strains, in combination with low-level applications of Carbaryl, were deemed to be an effective temporary means of controlling the pest. As a part of this participatory trial, researchers were closely engaged in observing potato storage techniques; observation of the techniques permitted researchers to propose and test more effective means of tuber storage including simple low-technology storage silos. These silos also form part of the recommended IPM package (Figure 5-4).

Socioeconomics in potato production

Socioeconomic concerns were completely integrated into the potato research, starting with identification of stakeholders, interactions with producers and experts to understand key problems, and evaluation of solutions to pest problems. This integration enabled the researchers to move quickly toward socially acceptable solutions and facilitated efforts at out-

Figure 5-4. Seed potato storage in Ecuador.

reach and evaluation of IPM program impacts. In particular, the baseline survey, whose analysis was well underway at the start of the second year of the project, helped tailor subsequent technical and socioeconomic research. Concerns expressed by producers about taste, coloring, and other potato properties helped guide the selection of resistant clones. The key concern was market acceptance of the product — an economic problem. Problems with chemical and potato storage led researchers to investigate alternative storage systems. Information about surplus labor on small-scale potato farms allowed researchers to investigate labor-intensive practices such as scouting, trapping, and use of labor-intensive methods to remove leaf-miners from fields.

Gender analysis comprised a major portion of the socioeconomic work and provided important insights into the research. During the process of creating the baseline, women identified health problems as their primary concern relative to pesticide use on potatoes; subsequent research was designed to minimize adverse health impacts. The baseline survey examined decision-making within the family and showed that women and men jointly make many decisions about production systems and field operations and that women make important decisions related to pesticide storage and its proximity to other household activities. As a result of these findings, female producers were brought into the farmer field schools and played a key role in sensitizing the men about adverse health effects of improper pesticide use. Women's groups were also formed as a means of educating and empowering women to influence important health-related and other household decisions.

Research and outreach were informed by economic analysis. All the technical activities collected information on costs of alternative practices; these costs, combined with information about impacts on yields, helped identify economically optimal pest-control methods. The farmer field schools used this information to identify alternative IPM packages, and the schools themselves collected further information on costs of different practices during field trials. One result of combining experiment-field-based economic information with that information gained through field schools was the knowledge that costs and yields based on a small experimental plot could not just be expanded to produce yield estimates for larger fields. In fact, experiment-field-based data generally tend to understate costs and overstate yields when projected to full field estimates.

By the end of the second year of the project, field-school participants in Carchi knew that the net benefits from an IPM package involving a late blight-resistant variety (INIAP-FRIPAPA99), traps and limited leaf spraying for Andean weevil, monitoring and limited spraying for the tuber moth, and other low-input controls, were associated with a $643 per hectare net benefit when compared to local practices. Other field-school experiences showed similar magnitudes of benefits. An impact analysis of a single program (late blight resistance) in the Northern Region showed a net present value of research of almost $34 million.

IPM for Plantain

Two main plantain production systems exist in Ecuador: monoculture plantain predominating in coastal areas and mixed cacao-coffee-plantain systems at low and intermediate elevations. The former system typically involves medium to large holdings averaging 40-70 hectares, depending on location, while the latter is exercised on smaller holdings, varying anywhere from 5-25 hectares in size. The IPM CRSP decided to focus on monoculture plantain for several reasons. First, pest problems appeared to be most limiting in the monoculture system. Second, the information base for integrated control of plantain pests was minimal, and researchers decided to address the plantain problems first before tackling them in a mixed system. Third, INIAP made an institutional decision to invest in plantain research and, because of limited human and financial resources, was unable to support too-diversified a research program.

The institutional base for plantain research was entirely different from that of potato, and IPM CRSP research on plantain began with a narrow information base. Unlike potato research, few domestic organizations were involved in plantain, the International Banana Research Center did not have an active program in plantain in Ecuador, and the Pichilingue Agricultural Experiment Station, where plantain research is centered, had limited human resources. The IPM CRSP has helped address each of these problems.

Common wisdom held that because of the botanical similarity[5] between plantain and banana, plantain pest problems were likely to be similar in nature to those of bananas, and control techniques practiced by banana producers would also be applicable to plantains. As multi-national corporations are key players in banana production and export, banana research is largely conducted by private firms; pest-control methods in bananas are based on export company recommendations. These recommendations, as adopted by plantain producers, became the base of comparison for IPM CRSP plantain research.

[5] Both belong to the Musaceae family.

The major plantain pests and diseases were identified through participatory appraisals conducted in the El Carmen region of Ecuador and subsequent pest-monitoring exercises sponsored by the CRSP. These problems are: Black Sigatoka (*Mycosphaerella fijiensis*), black weevils (*Cosmopolites sordidus*), and parasitic nematodes (*Helicotylenchus* and *Meloidogyne*). Black Sigatoka is a fungal disease, and is recognized as a severe problem that, due to poor management practices, had become endemic to the region. Banana export companies' control strategies for Black Sigatoka include regular heavy spraying of a fungicide (including varying amounts of Benomil, Tilt, and Calixin) mixed with agricultural oil combined with weekly sanitary leaf pruning. Black weevils (also known as the banana root borer) were also recognized by producers as a limiting pest, and subsequent research indicated that as much as 30 percent of the yield loss in plantain was caused by this pest. The weevil causes most damage during its larval stage when it feeds on the plant's corms. Local recommendations for black weevil control included aggressive spraying with highly toxic insecticides such as Furadan (Carbofuran) and Lorsban (Clorpiriphos). Nematodes were not recognized by local farmers as a pest problem, and were only identified by the CRSP as such after the project's second year.

Integrated management of plantain involved more than management of its pests. The monoculture producing region is comprised of an abundance of plantations that had suffered for 20 or more years of poor management. Poor management was manifest in improperly spaced and cleaned trees, overgrowth of weeds, and resultant low yields. Improvement of production systems required decisions about complete renovation or rehabilitation of these poorly managed plantations. Renovation involves removal of the entire plantation stock and replanting, while rehabilitation involves selective removal and replanting. IPM CRSP researchers decided early in their plantain work to investigate the relative benefits of renovation versus rehabilitation; this decision required integration of economic analysis into the research from its very start. The monoculture plantain production system is also characterized by a high degree of involvement of women in farm decisions, and the CRSP decided to invest resources in understanding how decisions were made. This information will help inform design of an outreach program in plantain.

The research program

Plantain research combined laboratory experiments, experiment station plots, and participatory on-farm experiments. The former two were conducted at INIAP's Pichilingue Experiment Station, located outside Quevedo in the Coastal region of the country. The participatory on-farm experiments, focusing on creation of a plantain IPM package and evaluation of renovation versus rehabilitation of existing plantations, were conducted in El Carmen.[6] In addition to testing IPM packages and evaluating rehabilitation versus renovation management systems, on-farm experiments investigated alternative means of trapping black weevils and the impacts of IPM practices on black weevil populations. Laboratory experiments focused on testing and generating local strains of entomopathogenic fungi (*Beauveria bassiana*) to control black weevil. Surveys were also undertaken to determine the incidence and economic importance of nematodes in plantain. These surveys were taken throughout the "Plantain Belt," which encompasses some 45,000 hectares of monoculture plantain.

The on-farm experiments formed the core of the plantain research, and were designed to identify and test an IPM package, including recommendations about rehabilitation versus renovation, within 3 years of project inception. Plantain reproduction time, the rate of return from one generation to the next, varies depending on cultural practices, and the rate of return is a major determinant of economic viability of alternative management systems. Additional variables considered in the on-farm experiments were: disease index, youngest infected leaf, area under the disease progress curve (AUDPC), number of black weevils and nematodes present,[7] plantain yields, and costs of the treatments. Four treatments were evaluated (Table 5-1) for the rehabilitation trial; treatments were distributed in a randomized complete block design with four repetitions.

The large number of variables evaluated during the trials and the evolutionary nature of the research helped solidify our knowledge of the plantain insect/disease complex (see Figure 5-5, page xx). For instance, levels of infection with Black Sigatoka were relatively high on all treatments and fungicide applications originally appeared to be effective, when using the disease index variable, at controlling the disease (45-day intervals were no different than 30-day intervals). However, analysis of AUDPC values showed that except in years with extremely high rainfall and favorable

[6] Formally, the participatory on-farm experiments were conducted at the "Santa Marianita" farm, owned by the Carranza family. It is located in San Augustin Parish, Manabi Province, 250 meters above sea level. The average temperature is 24°C. with 2900 millimeters of annual rain.

[7] For nematodes, the severity of diseased roots was measured using a locally developed scale.

Table 5-1. Description of on-farm participatory experiments, monoculture plantain

Treatment	Description
Export Company	Weekly sanitary leaf pruning (removal of entire leaf where any necrosand is found); fungicide application with Benomil (280g/ha), Tilt (4l/ha) and Calixin (.6l/ha)—2 successive sprays monthly; trapping of Black Weevils; weed control with Glyphosate; 3-4 daughter plants per reproduction unit
IPM with fungicide	Leaf surgery (removal of only the necrosand area) every 15 days and management of pruned leaves on the ground to avoid dispersal of inoculums; 45-day interval for same fungicide application as under Export Company recommendations; monthly trapping of Black Weevils using V-traps with newly harvested pseudostems used as bait; manual weed control combined with natural cover (*Geophila macropoda*); fertilizer following soil analysis; selection and ordering of productive units to cover empty areas (rehabilitation trial); no more than 3 daughter plants.
IPM without fungicide	Same as above, without fungicide applications
Farmer's practice	Light weeding twice yearly; annual cleaning of plants (removal of dead leaves).

disease conditions, differences across treatments were not statistically significant. The full analysis, including evaluation of costs and values of plantain production, showed that fungicide applications were less successful without complementary management practices and that, with good IPM practices, fungicides were not economically recommended except in years of extremely heavy disease incidence.

Experience during the first two years of the on-farm trials helped identify nematodes as a significant source of damage to plantain plants, but black weevils were shown to be the most damaging plantain pest. Measures to control black weevil damage became a critical focus of IPM CRSP researchers because trapping methods were not yielding promising results. In fact, black weevil infestation levels did not respond to any of the on-farm treatments using a variety of traps and baits. As a result of these findings, activities were initiated to investigate alternative biological controls for black weevils, to understand black weevil behavior under natural conditions, and to develop alternative trapping systems, including use of synthetic attractants. Experimental observation of black weevil behavior at different times of day, seasons, and points in the life cycle helped researchers design and evaluate improved trapping systems. Experiments with different attractants led to improved trapping methods, and an alternative trapping system is now being evaluated in on-farm trials.

Socioeconomics in plantain production

Little was known at the start of the plantain activities of conditions in producing households, decision-making within the households, or the degree of knowledge about plantain pests and pesticides. In contrast to the potato-growing region, few studies of social conditions in plantain-producing regions had been conducted. In addition to the relative absence of this information, CRSP researchers were interested in investigating alternative methods of dissemination of IPM technologies. Farmer field schools had been the principal source of dissemination and capacity building in potato-producing areas, but plantain researchers were skeptical of direct application of the field school methodology in the plantain region. Field schools have been shown by others to be a relatively expensive means of reaching participants (Quizon, Feder, and Mugai)[8]. Field schools also would be a less appropriate means of eliciting participation of neighboring farmers because of landscape differences between potato- and plantain-producing regions and because production units are so large in monoculture plantain regions. IPM CRSP researchers decided to consolidate the baseline survey of socio-economic conditions in plantain regions with an exercise that gathers information about how knowledge is transmitted among plantain producers. This process helped lower costs of information gathering and ensure

[8] In fact, in the potato region, more than $50,000 has been spent using IPM CRSP funds in field schools with a total of 302 participants. Although the money was also used to promote field days with roughly 1700 person-day participants and field-school participants are encouraged to share their experiences with neighbors, this represents an expensive means of transmitting knowledge. The $50,000 figure understates the true cost because FAO and INIAP also provided counterpart funds for the field schools.

that technology dissemination measures were optimally designed with respect to cost, message content, and audience.

Economic evaluation of IPM in plantain began with partial budget analysis that was built directly into the research. This analysis helped establish the economic viability of alternative treatments and the importance of evaluating the "rate of return" of plantain daughters under the different treatments. Budget information, along with an assessment of likely adoption rates from interviews with field staff, is being used to produce an assessment of impacts of the research program. Plantain producers are frequent employers of hired labor, and IPM measures are expected to have strong off-farm impacts through labor market linkages. The assessment of economic impacts of IPM in plantain thus had to consider these off-farm impacts. Analysts were also interested in impacts of such research on the poor and lower-income groups. The impact assessment was tailored to examine the distribution of benefits and costs of IPM research among producers, consumers, and suppliers of labor.

Interdisciplinary Analysis and Institutional Linkages

The PIPM approach in Ecuador benefited from strong linkages to INIAP, the public agricultural research institution, but linkages with other institutions helped strengthen the overall program. Linkages with institutions such as CIP, Eco-salud, PROMSA (World Bank-supported agricultural technology and training project), and others deepened the financial resource pool and broadened and deepened the pool of expertise in support of project objectives. These linkages were especially important in facilitating and promoting interdisciplinary analysis. INIAP staff is almost universally trained in the biological sciences, and interactions with other institutions, whose expertise was often socio-economic in nature, helped build capacity for and appreciation of multidisciplinary analysis. Entry of the project into national policy dialogue together with the heavy emphasis on documenting impacts also helped create a bridge between the biological science and policy analysis.

The project also benefited from different degrees of institutional support at the start. As noted, the institutional base in potato-producing areas was substantial from the inception of the project. This base helped researchers quickly enter into validation and outreach activities. Plantain researchers had to build the institutional base, and were able to learn from the potato areas the importance of the institutions. Thus, INIBAP[9] was consulted early in the project and became intimately involved with scientists, local banana and plantain societies were used to promote and guide the on-farm experimental work, and private technical assistance providers have been engaged in the on-farm activities and in designing the outreach program. These institutions have helped build the technical base, have given the project legitimacy among producer groups, and have generally enhanced the project's impacts.

Central America IPM Program

The Central American IPM program has focused on non-traditional vegetable and fruit export (NTAE) crops that are important for the U.S. market. Fruit and vegetable exports from Guatemala have increased to more than $360 million (Sullivan et al., 1999). It is imperative that these exports be grown according to accepted practices to meet sanitary and phyto-sanitary standards of the importing country and ensure a safe food source. Production should also be economically viable with minimum adverse impacts on the environment and the health of producers. The overriding challenge faced by the NTAE sector in Central America is to produce crops that are accepted in the international marketplace. The main threats to this challenge have been high dependence on chemicals, lack of sustainable bio-rational practices, lack of institutionalized phyto-sanitary post-harvest standards, and lack of pre-inspection protocols for product pre-clearance and certification (Julian et al., 2000b).

The IPM CRSP has designed research and education programs focused on scientifically integrated crop management (ICM) production systems for NTAEs. The program is research-focused and interdisciplinary, relying on development of 'total system' management strategies to achieve greater sustainability and increased competitiveness in NTAEs. The research focuses on: (1) reduction of agricultural crop losses due to insect, disease, weed, and other pests while relying less on pesticides and chemicals; 2) production of high quality crops that are less susceptible to post-harvest degradation; (3) production and post-harvest practices to allow producers to meet established phyto-sanitary standards and regulatory compliances in export markets; (4) reduced damage to regional ecosystems; and (5) enhanced overall socio-economic conditions of producing families.

[9] The banana research CGIAR institution in Montpelier, France.

Program Establishment

The initial step in establishing the IPM CRSP program in Central America was to hold participatory appraisals with stakeholders in production, research, and marketing in order to identify the most important issues facing the NTAE sector. The PAs, held in Chilasco/Baja, Verapaz, and Chimaltenango in the Guatemalan highlands, lasted two weeks and were followed by a research planning workshop to identify research activities. These activities revolved around targeted crops, pests, production programs, post-harvest handling, and marketing. Stakeholder meetings were held in 1994 among representatives of the national agricultural research institution (ICTA), the University of Del Valle (UVG), CARE-Guatemala, AGEXPRONT (comprised of more than 300 producers and marketing groups), ALTERTEC (which works on biological control and organic methods), AGRILAB (which serves the non-traditional crop sector with disease management and soils testing), the PanAmerican Agricultural School at Zamorano, Honduras, FLASCO (a resource institution on socioeconomic analysis), and the following U.S. institutions: Purdue University, Ohio State University, Virginia Tech, and the University of Georgia.

Following the PAs, a market assessment helped to identify windows of opportunity in U.S. markets, non-economic barriers to export trade expansion, needed policy revisions related to chemical registration and labeling, and market linkages from growers to retail buyers in the United States. IPM activities were prioritized around specific crops: broccoli, snowpeas, and brambles. Other crops including tomatoes, melons, papaya, mango, and starfruit were identified as important future IPM research targets. Crop-pest monitoring and baseline surveys helped measure the importance of pest, production, and handling problems.

The approach then shifted to connecting IPM research with a long list of major collaborators through establishment of a site committee. The research was designed to implement replicable and sustainable approaches to ICM focused on development of 'total system' management strategies. Crop-based research was conducted on farms, at research centers, in the greenhouse, and in laboratories. Socioeconomic research emphasized gender issues and farmer health. Strategic planning was used to identify mechanisms for transferring results to stakeholders. These mechanisms included training meetings, seminars, pilot production programs, and publications.

Results

Research found that the NTAE sector in Guatemala continues to enjoy a regional advantage in the production of horticultural crops targeted for sale in North America and Europe. Guatemala derives its economic advantage from an abundance of small-farm family labor, diversified microclimates for producing high quality counter-seasonal crops, and access to low-cost transportation infrastructure. Research suggested that future expansion of economically sustainable production in Guatemala would depend upon the industry's capacity to address increasingly important non-economic constraints to interregional trade, particularly more demanding food safety standards in the United States. The main non-economic constraints related to phyto-sanitary compliance and contamination from unapproved chemicals. A few examples illustrate some of the dimensions of these constraints.

Snowpea IPM

Snowpea programs illustrate how an initial interest in IPM can ripple through the entire NTAE sector, helping to achieve economic and environmental goals across multiple cropping systems. Guatemalan snowpea production has continually been harmed by insect and disease infestations leading to excessive reliance on chemical control measures. Leafminer (*Liriomyza huidobrensis*) became a major insect pest whose importance was magnified in 1995 when the USDA placed a Plant Protection Quarantine (PPQ) at U.S. ports-of-entry on all Guatemalan snowpea shipments due to fear that the species on Guatemalan snowpeas was an exotic pest in the United States (Sullivan et al., 1999). Research protocols were established to address the snowpea leafminer quarantine problem in March 1996. IPM CRSP research documented that the Guatemalan leafminer was not a species exotic to the United States, and consequently not a threat to U.S. producers. As a result, the quarantine was lifted (Sullivan et al., 1999). The process illustrates the need for proactive approaches to IPM.

The IPM CRSP recommended several testable strategies to reduce chemical residues on snowpeas and enhance product quality. The approach included non-chemical research regimes integrated into a holistic system. The main insect pests monitored were leafminers and thrips (*Frankliniella* spp.). Disease monitoring included Ascochyta (*Ascochyta pisi*), Fusarium wilt (*Fusarium oxysporum* f.sp. *pisi*), and powdery mildew (*Oidium* spp.).

In snowpeas and most other NTAE vegetables, the main pest-control strategy relied on the application of chemical pesticides using a 7- to 10-day calendar schedule. Few farmers in Guatemala were acquainted with IPM strategies, and most relied heavily on agrochemical distributors for pest-management information. IPM tactics included pest scouting for insects, pathogens, and weeds. Leafminer sampling occurred once a week to determine adult insect pressure, thresholds, and the need for pesticide applications. Sticky traps were used to reduce adult insect leafminer pressures and to determine adult insect thresholds. Row hilling was used to reduce adult leafminer reproductive capacities. Environmental Protection Agency (EPA)-approved pesticides were applied to the IPM plots. EPA-approved fungicides were applied sparingly, depending on environmental conditions. Grower-managed control plots followed traditional calendar pesticide application schedules at 7- to 10-day intervals regardless of insect pressure or growing conditions. Factors evaluated were snowpea export-quality yield, and leafminer larval populations 35, 65, and 90 days after planting.

ICM plots required only 3.7 pesticide applications, while traditional chemical-control plots required an average 10.4 pesticide applications (Sullivan et al., 2000). Insect populations and diseases were similar in ICM plots and control plots. In nine out of nine comparisons, ICM plots required fewer insecticide sprays; and in seven out of nine comparisons, the ICM plots had higher yields. These results translated into an average 61% reduction in pesticide use, and a 6% increase in average total yield. Product quality was found to be higher in the IPM plots, as measured by marketable yields at the shipping-point grading facilities. Product rejections at the shipping point averaged 6% less from the IPM plots. These results indicate that production and export of high quality crops are possible using IPM strategies.

Another example of leafminer control research in snowpeas investigated the potential of faba bean as a trap crop for leafminer (Sullivan et al., 2000). Trap crops are used to attract insect pests away from the primary income crop, thereby lowering insect pressure and reducing the need for chemical applications. Plots were managed using good agricultural practices without use of pesticides.

Results from greenhouse and field experiments showed that faba beans can be an effective trap crop for leafminers and can protect snowpeas from infestation. In preference studies in the greenhouse where leafminer females could choose between faba beans and snowpeas for egg laying, there was a significantly higher number ($P < 0.01$) of eggs laid on faba beans (5.41/gFW) than on snowpeas (0.12/gFW), and the number of emerging pupae from faba beans (2.14/g FW) was also greater than from snowpeas (0.25/gFW). Similar results were observed in field studies where the numbers of emerging larvae were higher in monoculture snowpeas than in snowpeas surrounded by faba beans. These results supported a hypothesis that faba beans are a preferred host for leafminer oviposition and can serve as a season-long trap crop. Currently over 30 percent of Guatemalan snowpea growers are using the faba bean trap crop in their ICM management programs in snowpeas (Sullivan et al., 2000). Other snowpea cultural and pest management experiments included intercropping, scouting, trap cropping, mobile trapping, minimum threshold pesticide applications, optimum crop cultural practices, and cultivar selection (Weller et al., 2002).

Tomato IPM

Another example of effective IPM research is in tomato. IPM research involved testing five approaches to reduce incidence of the whitefly-geminivirus complex and then validating these results in farmer fields. The tactics were: (1) seedbeds covered by a foamy cloth (anti-aphid covering), (2) tomato seedlings grown in newspaper transplant plugs, (3) use of sorghum barriers planted 45 days before tomato transplanting, (4) use of plastic sticky traps, and (5) rotational use of insecticides (rotating chemical groups) and sampling of whitefly populations. These treatments were compared to grower practices that included: (1) purchased tomato seedlings, (2) no sorghum barriers, (3) no sticky traps, and (4) programmed use of insecticides (without rotating chemical groups) and without sampling populations. Results showed that IPM production costs were $700/ha lower, profits were $1,700/ha greater, and pesticide sprays were reduced from more than 23 in grower plots to 13 in IPM plots (Weller et al., 2002).

Impact and Effect of IPM Research on Farmer and Industry Attitudes

The ICM strategy developed on the CRSP is applicable to multi-crop systems and is a critical element for achieving potential long-term sustainability in the NTAE production sectors of Central America. Programs must be transferred to the growers as a first step in the institutionalization of IPM. The transfer of IPM technology occurs mainly through field visits to research and validation plots. For example, between January 2000 and May 2001, there were 32 different extension activities, involving more than 1,000 participants (farmers and technicians from export companies, chemical companies, private and public organizations). These activities involved field days in which growers and technicians were taken to IPM tomato fields in eastern Guatemala and snowpea locations in the central highlands. These field days continue to the present.

Technology transfer is the first step in the broad-based sustainable NTAE production. The second step is to implement industry-wide uniform production and post-harvest handling programs consistent with U.S. Good Agricultural Practices and Food Safety guidelines for pre-inspection certification. For example, with Guatemalan snowpeas shipments to the United States, there have been a large number of port-of-entry detentions in the past. Pre-inspection protocols developed by IPM CRSP are designed to ensure the phyto-sanitary quality of snowpeas. Efforts to institutionalize a formal pre-inspection program were undertaken by AGEXPRONT, with regulation and certification of snowpeas now conducted by the Program for the Integrated Protection of Agriculture and the Environment (PIPAA), a joint AGEXPRONT–MAGA organization (Sandoval et al., 2001a,b).

The snowpea pre-inspection program (SPP) is based on ICM principles. The pre-inspection protocol includes integration of non-chemical approaches to pest management, including pest scouting and monitoring, cultural practices, physical control, and the build-up of natural controls (predators and parasitoids). To allow for adequate traceability and field certification, record keeping constitutes an important element, where pest scouting, management, fertilization, and other practices are recorded. Participating growers are visited twice a month by trained inspectors who evaluate adherence to pre-inspection guidelines. To ensure the sanitary conditions of the export pods, two snowpea samples are taken from each field, one pre-harvest (leaf samples) and one at harvest. Supervisors test samples for clorothalonil and metamidophos residues. At harvest, field supervisors issue a field certificate of clearance, which allows the product to enter packing-plant facilities. A field code is assigned to identify all product originating from specific fields. At the packing plant, plant inspectors randomly sample product, with the purpose of establishing sanitary and phyto-sanitary tolerance levels in exports. Once the product has complied with all requirements at the field and packing-plant level, a phyto-sanitary certificate, approved by the plant protection and quarantine office of the Ministry of Agriculture, is issued.

For NTAE crops more broadly, the FDA's Hazard Analysis and Critical Control Point (HACCP) and the APHIS Certified Pre-inspection Program (CPP) represent science-based risk-management approaches to safe food production. These programs are the centerpiece of successful NTAE expansion initiatives. HACCP programs are site-specific plans where producers identify 'critical control points' in food production and marketing systems, and then put appropriate monitoring and control measures in place. The GOG and the Ministry of Agriculture and USDA/FAS are now working to establish regional NTAE crop distribution centers to serve as gathering points for produce that will be properly handled and shipped to commercial outlets. These centers can further serve to help organize farmers, provide assistance in use of accepted IPM production practices, be training centers for farmer schools and workshops, and have research demonstration areas showing the latest production technology. All these activities will help focus farmers' attention to the necessity of following accepted and research-proven pest-management tactics to achieve the economic and environmental objectives and to ensure sustainability of the Central American farm community. The first center (FRUTAGRU – Associacion de Fruiticultores Agrupados) opened in November of 2002 in San Cristobal, Totonicapan, and has been successful.

Socio-economic Impacts of IPM Research and Implementation

Another important aspect of IPM programs in Central America involves evaluation of socioeconomic impacts of IPM and NTAE crop-production strategies on small-farm households in Guatemala. The objectives of this research have been to assess economic and social benefits of IPM for all members of farm families and to measure economic and social impacts of and constraints to IPM adoption by gender. Research has involved socio-economic impact assessment surveys and has examined constraints to IPM adoption and the effects of IPM adoption on the well-being of women and children in farm families. It has contributed to identifying organizational constraints to adoption and effective practice of IPM.

Results have demonstrated that most farmers are willing to adopt some, but not all, of the recommended IPM practices, and that adoption of the most difficult practices will require sustained producer contact with trained IPM technicians. In addition, incentives for producers to seek out new knowledge required to practice IPM appears to be related to availability of organizations' input supply and credit supply channels from government, coops, exporters, and banks.

Household surveys during 1998-2001 found that farmers had: (1) a high level of self and family involvement in NTAE labor, (2) a continuing need for production credit, (3) a high-level adoption of technology-based IPM but low-level adoption of scouting and other labor- and information-intensive practices, and (4) received better prices if they sold nontraditional export crops through production cooperatives or had contracts with exporters than if they marketed independently. Research uncovered a disarticulation between organizations' informational bases and producer perceptions of credit and input supply channels. This information can help in organizational recruitment and communication and can provide useful knowledge of diffusion mechanisms for IPM stakeholders throughout the research, extension, and marketing chains in order to gain broader acceptance of these IPM production strategies.

Conclusions

IPM strategies, when properly implemented and precisely managed, significantly reduce the use of pesticides to control crop-pest problems, and provide more economically sustainable and ecologically balanced production systems. Adoption of IPM by farmers can have a significant and positive effect on the socio-economic status of the farm family.

IPM research in Central America has been instrumental in establishing and institutionalizing pest-management programs, and CPP and HACCP protocols. The snowpea pre-inspection program is the first fully integrated program to be approved by the government of Guatemala and certified by APHIS. These programs and protocols will assure greater access to U.S. markets and safer food supplies for U.S. consumers while ensuring more sustainable trade. Similar pre-inspection protocols are now being developed for other NTAE crops. Regional supply consolidation and distribution centers are being established. These centers will be the focal point of all pre-inspection activities. Such programs may lead all Central American countries to establish proactive NTAE policies. Proactive policies require a 'total systems approach,' including a market-driven production and post-harvest handling strategy.

IPM programs in Ecuador have demonstrated the potential to significantly reduce pest problems and pesticide use, and to raise farm incomes for plantain and potato growers. The absence of cost-effective technology-transfer mechanisms remains a concern, however, in a country devoid of a functional public extension system. Farmer field schools have proven effective in potatoes, but relatively expensive, and perhaps non-sustainable in their current form. Efforts are underway to redesign these schools and to combine them with other approaches to reach a larger number of growers, both on the coast and in the highlands.

Acknowledgments

The authors thank the many collaborators who supported the research effort. In Ecuador, INIAP Director Dr. Gustavo Enriquez provided strong institutional support and intellectual input into the project. Greg Forbes of CIP provided excellent collaboration in plant pathology, and Aziz Lagnaoui the same in entomology. Wills Flowers at Florida A&M contributed in entomology, and Colette Harris and Sally Hamilton at Virginia Tech in gender analysis. Several researchers in Ecuador made important contributions, including Ings. Patricio Gallegos, José Ochoa, Danilo Vera, Raul Quijije, Jovanny Suquillo, Fernando Echeverría, Jorge Revelo, P. Rodriguez, Carmen Triviño, Pedro Oyarzun, Hector Andrade, Flor Maria Cardenas, and Dr. Gustavo Bernal.

Many people helped coordinate and conduct field work in the highlands and Coastal Regions. Of special mention are Luis Escudero and Ivanna Carranza. In Central America, special note goes to Glenn Sullivan of Purdue for his long-standing excellent site leadership. Rich Edwards, R. Martyn, and Jim Julian at Purdue, Ron Carroll at Georgia, and Linda Asturias deserve special note. At ICTA: D. Dardon, H. Carranza, M. Morales, O. Sierra, D. Danilo, and M. Marquez were key collaborators. Dale Krisvold, J. M. Rivera, J. C. Melgar at FHIA in Honduras, M. Mercedes Doyle, E. Barrientos, M. Bustamante, and A. Hruska at Zamorano, Honduras, and L. Caniz – APHIS-IS/Guatemala were special contributors.

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