CIP IN 1992 • PROGRAM REPORT

THE INTERNATIONAL POTATO CENTER

CIP IN 1992 PROGRAM REPORT - THE INTERNATIONAL POTATO CENTER

Jamaica

Poland

Swede

United States

Nigeria

Philippines

Indonesia

J

Turkey

Australia

orway

Cuba

Morocco

V uela

Tunisia

Mali

Bolivia

Paraguay

Au

Kenya

Bangladesh

pain

Scotland

Thailand

Braz

Uganda

Vietnan

Guatemala

Egypt

CIP IN 1992

■

PROGRAM REPORT

The International Potato Center (CIP) is a not-for-profit, autonomous scientific institution established in 1971 by agreement with the government of Peru. The Center develops and disseminates knowledge to facilitate use of the potato, sweetpotato, and Andean roots and tubers as basic foods in the developing world. CIP is one of 18 international research and training centers supported by the Consultative Group for International Research (CGIAR). The CGIAR is sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the United Nations Development Programme (UNDP), and the International Bank for Reconstruction and Development (World Bank), and comprises more than 45 countries, international and regional organizations, and private foundations. Specific 1992 donors are listed in *CIP in 1992: Promoting Partnership in Agriculture, CIP's Annual Report.*

This publication, *CIP in 1992: Program Report* covers research conducted by the International Potato Center from January 1, 1992 to December 31, 1992.

Editors: James Bemis, Princess Ferguson, Ilse Zandstra / Bibliographic compilation: Cecilia Ferreya / Text: Ana Maria Perez Garland, Carmen Matallana / Art: Anselmo Morales, Cecilia Lafosse / Layout: Marco Sheen / Photography: Jesus Chang / Photomechanics: Rufino Failoc / Printing: Victor Ayme, Pedro Chavez, Godofredo Lagos, Demetrio Quispe, Hector Rojas / Coordination: Emma Martinez.

Correct Citation:
The International Potato Center. 1993. *CIP in 1992: Program Report.* Lima, Peru. 173 p.
Descriptors: 1. Potatoes 2. Sweetpotatoes 3. Andean root and tubers 4. Andean Ecosystems 5. Andes.
ISSN: 0256-6311.
Printed by the International Potato Center,
P.O. Box 5969, Lima, Peru, November 1993.
Copies Printed: 2,500

Printed on recycled paper.

CONTENTS

OVERVIEW

PROGRAMS

(Each Program Report begins with a detailed contents section)

APPENDIX

Foreword

CIP's Program Report draws from the work of our staff and research partners throughout the world, focusing on developing countries. We have included a special section on these partnerships (page xiv), and each program report lists all collaborative projects and their key contact staff. We expect that you will find useful information from your own or nearby countries and related institutions. ■ To be published every second year, this more detailed technical report complements our Annual Report—"CIP in 1992: Promoting Partnership in Agriculture"—which highlights CIP activities each year. However, the combined publications can only point to CIP's wide-ranging global partnerships. While CIP is foremost a research institution, we work shoulder-to-shoulder with third-party NARS, Universities, and NGOs, who are technically supported by CIP and who have effective contacts in farmer communities and among other users of our technology. We are now setting up additional electronic paths to share such information more quickly and in greater detail, working directly with local researchers and their local scientific community. You can get a glimpse of this growing global community by scanning the list of countries we serve (page xv). ■ We share a responsibility with our partners for effective implementation of improved potato and sweetpotato technology, and our collaborative projects are now introducing and assessing field-proven techniques for production, storage, and processing. ■ Dr. Peter Gregory, CIP's Deputy Director General for Research, begins this report with a summary section that outlines the broader issues that drive our research. He then describes CIP's collaborative, catalytic approach to working with national and regional partners. Our special report reflects this broadening decentralized approach, as well as our impact assessment process. Technical reports from CIP's program areas make up the body of the report. For more specific or localized details, please contact CIP staff at the contact points listed on page xviii.

Hubert Zandstra

Director General

CIP's Strategy

CIP begins by identifying, in close association with its clients, needs for research and technology. If these are addressed elsewhere, the center makes the appropriate information available through its cooperative linkages. If not, comparative advantage and priority of needs are analyzed to determine CIP's approach, involving one or more of the following operational modes:

- encouraging the pursuit of the necessary research in other institutions;
- promoting research collaboration between countries;
- conducting appropriate research in cooperation with national program colleagues;
- initiating specialized research in the center's areas of comparative advantage.

The effective transfer of research results, technology, and capabilities to partner countries is accomplished through training, information dissemination, and collaborative research designed to assist national programs in reaching and maintaining their fullest potential.

Research Director's Overview for 1992

CIP's Role as a Development Catalyst

CIP continues to refine its strategy and objectives through a participatory approach that emphasizes close associations with the NARS and other developing country institutions. These partnerships allow us to systematically develop reliable knowledge bases, identify development opportunities, and respond to specific development bottlenecks. They have been a part of CIP's culture since its inception over 20 years ago. ■ Knowledge gained from these interactions has been the basis for a recent formal priority-setting exercise that involved extensive consultation with ISNAR to help formulate our medium-term plan. We have assessed the potential impact of our research activities by project, program, ecoregion, and commodity (see Collion and Gregory; Priority Setting at CIP, 1993). The 'scores' for each potato and sweetpotato project at CIP have helped us make some difficult decisions about priorities at a time when global donor support for agricultural research appears to be waning. A new project budgeting system also has helped us to translate these priorities into effective, transparent resource allocation. ■ In addition to these ongoing interactions, we also hold timely planning conferences and workshops through which our partners play a major role in helping to assess progress and determine program priorities and key issues to be addressed.

Focus on Practical Impact

The challenge facing us now is to make optimum use of CIP's research products and services in combination with those of our global partners, so as to pay off in actual *practical* impact in the farmers' fields, the villages, and cities of the developing world.

Clearly, we should not divert major resources into "development" work per se. But neither can we ignore the fact that insufficient practical impact will be achieved unless CIP stimulates the development process. The diffusion and adoption of CIP-related technologies and germplasm achieved so far are but an indication of the potential of our impact. Working side-by-side with our partners, we must play an even stronger role in catalyzing the development process. We will be sharing this task with a wider range of partners, including non-government organizations, the private sector, and development-oriented donors, to translate our research, training, and information into relevant products for the ultimate users.

CIP's strategy for the future will also emphasize the collection and review of data to provide a better perspective on the particular concerns of women in farms, households, and markets of client countries. Studies have shown that women represent a large percentage of food producers in the developing world, and are often the neediest.

We are now stimulating the diffusion and adoption of several "ripe" technologies, such as integrated pest management, seed technology (including TPS), and sweetpotato processing for animal feed. The following section highlights some of these field-proven technologies, and describes how we plan to catalyze their diffusion and adoption.

Program Highlights

Genetic Improvement

One of the biggest contributions that CIP can make on a global scale is to preserve biodiversity and facilitate distribution of pathogen-tested germplasm for use by the breeding programs of developing countries. We continue to maintain the largest potato and sweetpotato collections in the world, and pathogen-tested materials from our collections are routinely distributed globally.

For example, 61 new outstanding potato clones with high levels of resistance to late blight, the most important disease worldwide, were added to CIP's international late blight trials. These clones show desirable horizontal resistance, combined with R-gene-based vertical resistance. These trials now include a total of 306 clones, and they have been distributed to more than 40 countries. These clones also have other characteristics required by partner countries, including early maturity and high-yield potential. Similarly, new parental lines have been identified that have durable horizontal resistance, with the added advantage of being R-gene-free. Such materials, free of vertical resistance, can be used more easily in developing new varieties with long-term resistance to late blight. These are being pathogen-tested and should be available for distribution in 1994. Segregating populations, true seed families, and tuber families that use the new progenitors will be available in 1993.

In 1992, 128 new sweetpotato clones that had been selected for desirable traits were cleaned of viruses and other pathogens for international distribution and evaluation. A total of 217 sweetpotato accessions were distributed as stem cuttings or storage roots to researchers in **Peru.** Twenty-two countries screened 642 accessions as in vitro plants, and 135 accessions of wild *Ipomoaea* species were distributed to breeders in 7 developing countries.

We are continuing with the characterization, disease cleanup, and international distribution of genetic materials from our major germplasm collections. But we also have new cultivars of potato and sweetpotato at the end of the research pipeline, which can immediately help in feeding the poor and hungry of the developing world. For example, 22 new potato varieties have been selected from breeding materials that were distributed to **Rwanda, Burundi, Madagascar, Uganda, Cameroon,** and **Ethiopia.** These potatoes have valuable characteristics, including resistance to late blight and to viruses, heat tolerance, high yields, good agronomic characteristics, and wide adaptation. Widespread use of these materials in these African countries can make a major difference to satisfying nutritional requirements, while decreasing the environmental and financial costs associated with control of late blight and other pests.

Six new sweetpotato varieties have just been selected and released in **Peru** as a result of our collaboration with the Universidad Nacional Jorge Basadre Grohmann de Tacna. These new varieties are early maturing, high yielding, and high in dry-matter content. They are tolerant to salinity, drought, and boron and are moderately resistant to root-knot nematode. Clearly, these varieties have the potential to rapidly provide food to the world's poor and hungry, even in areas where growing conditions are marginal and financial resources are scarce.

These examples represent only a small portion of CIP's total output of advanced genetic materials. Many others have been distributed and selected, and more are in the pipeline. Taken as a whole, the diversity of these materials is so rich that, theoretically, they could be used for genetic improvements to overcome almost every biotic and abiotic constraint to potato and sweetpotato production in the developing world. This gives us the potential to help partners lower financial and environmental production costs and to increase yields and net profit. At the same time, we benefit low-income farmers and consumers.

Improved Seed Production: Top Priority

But to achieve real impact by converting this potential into a real difference for our partners, clean seeds of these varieties must be produced and made available on a massive scale. Many countries are not yet equipped for this task; hence, our broadened base of assistance to partner countries to develop this capacity through collaborative research, training, and information. For example in **Uganda**, CIP-assisted seed programs produced 20 tons of prebasic seed and 100 tons of basic seed, using rapid multiplication and clonal multiplication of nuclear stock. This improved distribution is being translated into improved yields, including yields of traditional varieties. High-quality seed has increased yields by 51 to 139% in farmers' fields.

Cameroon provides another example of yield payoffs from our catalytic work. CIP has assisted the national program in developing improved virus cleanup and distribution facilities for potato and this is playing an important role in production of their three newly released late blight resistant varieties. Such improvements are the result of intensive efforts of CIP scientists working on site. However, it is not feasible to assist all of our partner countries in the same manner. Thus we will be relying increasingly on our concept of catalyzing others in the development process.

TPS Technology

Our approach to energizing the diffusion and adoption of research products is illustrated by recent developments in TPS technology. One of the major challenges in TPS work is to be sure that there is an adequate supply of planting materials to promote effective use of this valuable, innovative technology in each country that is committed to it. We have already launched the development process, and in some countries national program efforts are being reinforced by work within the private sector. Such is the case in India and Egypt, where private companies are collaborating in large-scale TPS production and use. As this process continues to spread the adoption of TPS technologies, we are establishing stronger communication links with public and private sector institutions, CIP-related networks, and public institutions involved in the development process. New research results are being exchanged, using advanced data bases and telecommunications. It is vital that such breakthroughs are rapidly and efficiently communicated to our widening array of partners in the developing world.

Again using TPS as an example, interdisciplinary integration has paid off in a breakthrough that will promote widespread use of new TPS materials. We have known for years that this technology can reduce the cost of planting materials by 50 to 90%, along with other advantages, but seedling vigor has been a major limiting factor in the utilization of the new TPS hybrids. Our research has now shown that seed size and seed maturity are associated with TPS seedling vigor and precise conditions have been formulated at CIP for seed harvesting, drying, and storage to ensure optimum performance.

Integrated Pest Management

Our research on control of potato tuber moth, the most serious insect pest of tropical developing countries, has "ripened," so that we can focus on the diffusion and adoption of the technologies that we and our partners have developed. The use of *granulosis baculovirus* for biological control of this pest is being promoted at the village level in **Tunisia, Egypt, Peru,** and **Bolivia.** As a component of an integrated pest management system, this technique is reducing damage to potato tubers, and increasing economical yield and income of farmers, while reducing the use of costly and toxic pesticides.

In the Andes, we are reporting another "ripe" technology for control of Andean potato weevil using the parasitic fungus *Beauveria brogniartii* and other complementary measures. Demonstration trials at Chinchero, **Peru,** have shown that this technology can reduce the weevil damage by 50% and more.

For both the potato tuber moth and the Andean potato weevil control measures, technology is being diffused by integration of training and information that are appropriate for the specific conditions in each country. As in the case of seed program development discussed above, CIP has had intensive inputs in these activities to date and is now emphasizing ways of catalyzing technology transfer through greater involvement of other, more development-oriented institutions.

Postharvest Management and Marketing

Several CIP-related postharvest technologies are being promoted for wider use. In India, for example, low-cost rustic stores are being used to spread potato availability over a longer period and are helping the farmers to obtain better prices. Storage of potatoes for 2 months has helped boost farmer returns by 50%. This technology is being disseminated in India and several other Asian countries via our training and information sciences activities. A similar approach is being used in the transfer of an important postharvest technology for sweetpotato. Techniques for using grated sweetpotato to substitute for up to 30% of wheat flour in bread making have been transferred from **Peru** to **Cameroon** and **Burundi.**

The private sector is becoming an increasingly important partner in our processing work. In **Colombia,** for example, an agreement has been signed for the private sector to support a major research project on breeding for processing potato varieties. This was the result of CIP-supported market research on semi-industrial and industrial processed potato products.

Evolution of the CIP Model

Clearly, CIP and its developing country partners are providing a steady stream of technologies and new genetic materials that have the potential to fight hunger and poverty in the years to come. We are taking steps to translate these research products into practical impact through catalyzing their diffusion and adoption. Our CIP teams based in Asia, Africa, and Latin America are achieving this through a combination of training and information sharing that complement our collaborative research.

But, in the longer term, these activities will not be sufficient to maximize our long-term effectiveness. The only way that really sustainable development can be achieved is through empowering our partners to become increasingly independent. We must focus much more strongly on helping them to produce their own new techniques, technologies, and materials and to adapt them for national and regional use.

How do we achieve this? One key element is to stimulate systematic information flow between CIP, our national partners and networks, the NGO's, and the private sector. Timely sharing of new technological breakthroughs and the availability of new germplasm will have to be complemented by stronger national capacities to use the advances. We will need to complement our traditional training of national program staff with stronger efforts to link them with the university-based scientists in their own countries. One way of bringing this about is through fostering new, impact-driven collaborations. We will be looking for opportunities to provide contracts from our core funding for the work and we will assist in obtaining external sources of funding. We will emphasize participation of the networks in regionalizing these initiatives.

CIP's role will change as these national and regional partnerships become self-sustaining. Our partners will be doing even more of the research and diffusion. CIP will be called upon to provide specific inputs, and the nature of these inputs will vary enormously between countries and regions because of the strong differences in the problems they face and the disparities in their institutional and scientific development. One of our chief involvements in the future will be to help our partners keep abreast of rapidly emerging technologies and to enable them to incorporate these into their ongoing country and regional research activities. Information gathering and sharing by all participating parties will be of prime importance. CIP plans to have services in place to serve as a broker of information and to respond to requests where it is most needed.

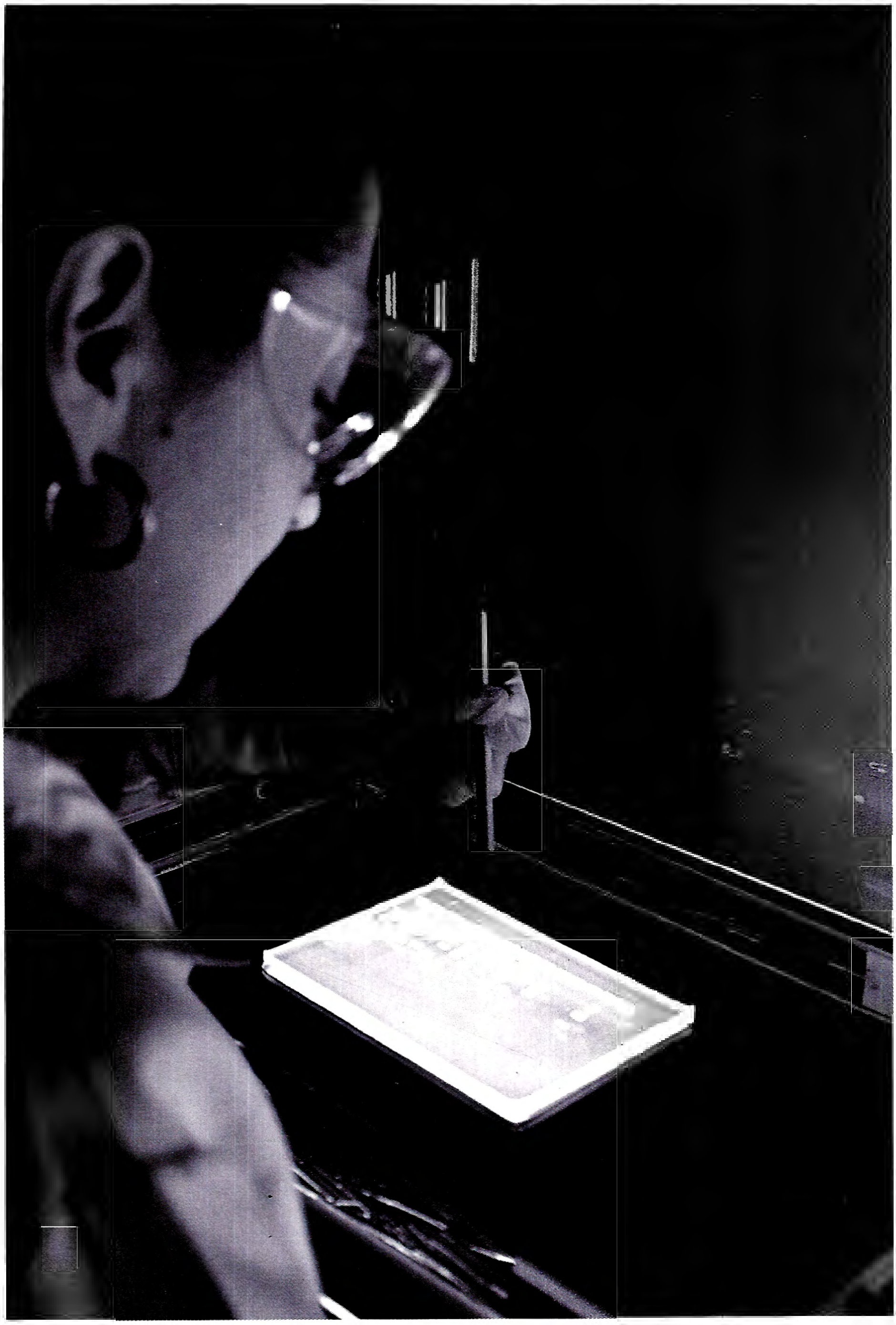
Our training and information work is integrated within and across programs and is widely dispersed globally, see Page xv. In 1992, we helped train 822 scientists and technicians from developing countries, including research-oriented degree programs, individual training, and short-term courses. The publications listed on pages A1-12 represent only a portion of the media that are prepared and delivered. New electronic paths and data bases are now being created to relay information to and from our partners.

More Selective "In-House" Research

CIP will become even more selective in the research conducted "in-house". Our research should be complementary to that of our partners, so that there is minimum overlap. The global funding situation is such that we must make full use of our own and our partners' comparative advantages to achieve maximum efficiency in resource use. CIP will continue to have a comparative advantage to pursue upstream topics of global importance. New topics are constantly emerging and CIP must be on the alert to deal with them. A very recent example is in late blight research, including the rapid international spread of the A2 strain of the late blight. (see page 44). CIP is joining forces with several institutions in **Mexico**, the **USA**, the **UK**, and **Holland** to launch an international research effort to eliminate this new version of an old threat to worldwide potato production.

Emerging Technologies

Molecular biology at CIP is complementary to some of the conventional approaches that we are pursuing, and in recent years there have been explosive advances in this area. These advances are being made by a range of public and private institutions in industrialized and in



Among the emerging technologies is development of molecular probes for the NASH test which includes cloning of viral genomes and screening of selected sequence fragments. This virus detection techniques helps CIP ensure that the germplasm it distributes to partner countries is free of diseases.

developing countries. CIP will increasingly emphasize networking among our partners to facilitate timely sharing of vital information and to promote impact-driven training and research activities.

Major payoffs can be expected in widespread use of molecular techniques such as RFLP and RAPD to speed up selection of potato and sweetpotato in national and regional breeding programs. Consequently, we can expect a major improvement in our partners' abilities to tap the enormous biodiversity contained in the germplasm collections at CIP and elsewhere. Ten years from now, gene-mapping and the ability to isolate and transfer specific genes promise a major revolution in potato and sweetpotato improvement. CIP will play a key role, through its networking approach, in ensuring that this scientific revolution has the maximum impact in the developing world, where it is needed most.

Rio Earth Summit

Perhaps one of CIP's biggest future challenges, and that of the CGIAR, is to address the issues highlighted in the Rio Earth Summit and tackle the relationships between agricultural productivity, environment, and population. This must be done without destroying our comparative advantage to tackle commodity/constraint problems that continue to be our top priority. We are making good headway. We have initiated an Andean ecoregional initiative, a program that will help conserve the vast genetic diversity of the Andean highlands while seeking a reversal of land and water resources degradation in this threatened environment. The goal is to promote sustainable agriculture in this area stretching from **Venezuela** to **Argentina**. Due to the complexity of these efforts, a research consortium has been established to provide broad collaboration among national and international institutions, combining many areas of comparative advantage. The initiative will heighten collaboration among CGIAR centers and will produce results of practical applicability to the Andean zone and to similar ecologies in Africa and in Asia. Here, again, we will have more than the opportunity to develop and diffuse information, technologies, and germplasm per se.

An entirely new approach is being born and it may be of tremendous value to our partners who are also taking a holistic view of the struggle for global survival that lies ahead for all of us. Certainly, our combined resources will be needed.

CIP Partnerships: Priority No. 1

CIP partnerships help us share potato and sweetpotato technologies and germplasm directly with farmers and colleagues on a global basis. This special section acknowledges the contributions of these partners in the field, as well as in reporting our program findings. CIP's decentralized activities depend heavily on close cooperation among partner countries and scientists listed in the Research Project and Contract's section of each Program. Trials under their local conditions are the ultimate test of appropriateness and effectiveness of our research. (See following Special Report on Program 1 Impact Studies). Through partnerships in networks (pg. xx), in national programs, and with institutional and individual collaborators, we work side-by-side in research, training, evaluation, and information activities.

Agroecological Considerations

Increasingly, we are evaluating the potential and setting priorities for this combined work on the basis of a classification system for agroecologies for potato and sweetpotato (see foldout map). This classification is based on climatic and geographical criteria, taking into account TAC agroecologies and other criteria related to root and tuber crops. Recently we have emphasized the Andean ecosystem.

The geographical distribution of potato production is better understood than that for sweetpotato production. Potatoes are grown in wider range of altitudes, latitudes and climatic conditions than any other food crop (see foldout map and figure). Among CIP partner countries, the most important agroecologies with relation to potato production countries are the Subtropical Lowlands with cool-season production, the Temperate zones; the tropical and subtropical Highlands; and the Arid and Mediterranean lowland climates. Subtropical winter-season, lowland production is found mainly in Asia, extending from Pakistan through India and Bangladesh into China. Production in the Temperate zones also is concentrated primarily in Asia, although there is an important share in Latin America. Highland, and Arid and Mediterranean production are dispersed throughout Africa, Latin America, and Asia.

Partnerships in Training, Research, and Information

Country/Partner	Training[1]	Research Projects[2]	Germplasm[3]	Information[4]	Library[5]
REGION I: Latin America & The Caribbean					
Argentina	3	4	SP/P	187	33
Bahamas				4	
Barbados				10	
Belize				8	
Bolivia	24	7	P	163	50
Brazil	1+*	2	P	224	
Chile	4	8	SP/P	103	24
Colombia	22	9	SP/P	221	26
Costa Rica			P	96	7
Cuba	3		SP/P	99	30
Dominican Republic	1	4	P	47	3
Ecuador	32+*	9	P	113	25
El Salvador				19	2
Granada				4	
Guatemala	1	1	P	66	2
Guadeloupe	*			3	
Guyana				4	
Haiti		1	P	11	
Honduras			P	33	5
Jamaica			SP/P	24	5
Mexico	12+*	1	P	160	15
Monserrat		1		1	3
Nicaragua	1	1	P	45	4
Panama			SP/P	107	15
Paraguay		1	P	37	2
Peru	71		SP/P	925	273
Puerto Rico				4	
St. Kitts				1	
St. Christopher-Nevis					5
St. Lucia				4	
St. Vincent				3	
Suriname			P	4	
Trinidad & Tobago				21	
Uruguay	1+*	2	P	68	17
Venezuela	3	4	SP/P	138	17
Virgin Islands				3	
REGION II: Sub-Saharan Africa					
Angola				3	
Benin				5	
Bostwana			P	11	
Burkina Faso				5	
Burundi	55	6	SP/P	29	7
Cameroon	1	2	SP/P	87	13
Cape Verde				19	
Comoras				2	
Congo				8	1
Ivory Coast	1			15	
Djibouti				1	
Ethiopia	1+*	1	P	56	9
Gabon				4	
Gambia				16	
Ghana		1	P	35	2
Guinée				7	
Ghinée-Bissau				5	
Guinée-Equatoriale				5	
Kenya	5	7	SP/P	121	6
Lesotho			SP/P	10	
Liberia				7	
Madagascar	1		P	34	4
Malawi			P	25	
Mali	1	1	P	12	
Mauritius	*		P	18	5
Mozambique			P	15	1
Niger				8	
Nigeria	25	1	P	153	15
Reunion	*		SP	3	
Rwanda	4	2	SP/P	43	13
Sao Tomé / Principe				1	
Senegal				27	7
Seychelles				3	
Sierra Leone				7	
Somalia				2	
Sudan			P	23	2
Swaziland			P	14	1
Tanzania	28	1	P	44	4
Tchad				3	
Togo	2			13	
Uganda	93	3	P	30	5
Zaire	1		P	29	1
Zambia			P	43	4
Zimbabwe			P	20	3
REGION III: Middle East & North Africa					
Algeria				20	10
Cyprus				7	
Egypt	12	5	SP/P	27	11
Iraq			P	12	
Jordan				11	
Kuwait				2	
Lebanon				6	1
Libya				5	
Morocco		1	P	86	12
Mauritania				4	
Oman				2	
Pakistan				113	9
Saudi Arabia			P	19	2
Sudan			P		
Syria				15	
Tunisia		5	P	124	12
Turkey		1	P	53	3
United Arab Emirates				3	
Yemen Arab Rep.				15	
Yemen Democratic		1		1	
REGION IV: South & West Asia					
Bangladesh	1+*	4	SP/P	75	6
Bhutan			P	27	
India	4+*	11	SP/P	245	18
Iran				26	2
Nepal	4+*		P	44	1
Sri Lanka	3+*		SP/P	72	6
REGION V: East Asia, South East Asia & The Pacific					
Brunei				2	1
Cambodia				1	
China	147	8	P	88	41
Cook Islands				3	
Fiji				18	1
Guam				1	
Indonesia	39+*	5	SP/P	100	2
Kiribati				1	
Korea, Democratic				19	
Laos				6	
Malaysia	1+*		P	21	1
Myanmar				13	
New Caledonia				9	
Papua New Guinea	2			31	
Philippines	46+*	9	SP/P	300	26
French Polynesia				1	
Singapore				3	
Solomon Islands				6	
South Korea	1		P	32	3
Taiwan	*			20	
Thailand	6	1	P	79	1
Tonga				8	
Vanuatu				6	
Vietnam	5	1	SP/P	44	5
Western Samoa				11	
OTHER COUNTRIES					
Australia	*			85	1
Austria				17	
Belgium		1	P	22	
Bulgaria			P	1	
Canada			SP/P	111	2
Czechoslovakia	2			10	20
Germany	1	1		112	6
Denmark				12	
Spain				44	
Finland				13	2
France	*	1	SP/P	75	3
Greece			P	7	
Hong Kong				1	
Hungary				8	
Iceland				2	
Ireland				10	1
Israel		1	SP/P	23	
Italy	2	3	SP/P	66	6
Japan	2	1	P	86	
Mongolia				1	
Namibia				2	
Netherlands			P	116	9
New Zealand				15	1
Norway				14	
Poland		1	P	11	2
Portugal				15	1
Romania			P	5	
Russia			P	10	3
South Africa	*			16	2
Sweden				22	
Switzerland	1			41	2
United Kingdom	*	4	SP	168	20
USA	2+*	10	SP/P	784	15
Yugoslavia				3	

[1] Persons from these countries participated in group or individual training. The * designates additional participants when exact numbers are not available.

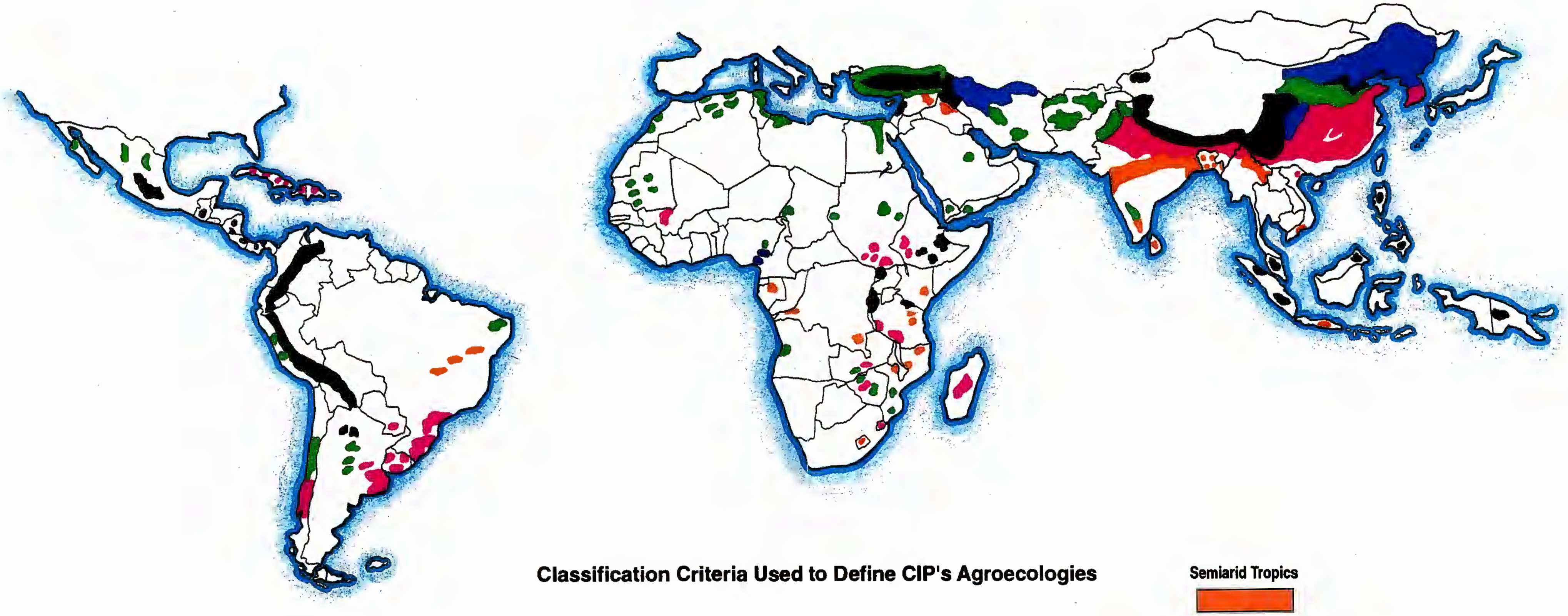
[2] All projects: collaborative, contract, or special project are grouped into this column.

[3] Includes all types of germplasm provided; tubers, tuberlets, botanical seed, in vitro. SP = sweetpotato, P = potato.

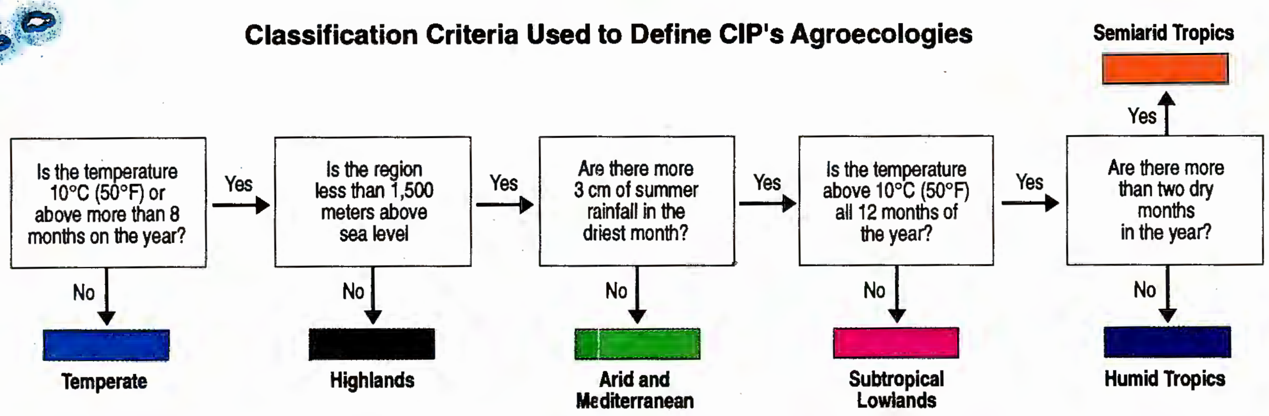
[4] Persons receiving CIP's principal publications.

[5] Specialized searches and user-profile generated periodic information updates to users.

Potato Production Zones by Agroecologies in CIP's Partner Countries



Classification Criteria Used to Define CIP's Agroecologies



Shares (%) of Potato and Sweetpotato Production in Developing Countries by Agroecology and by Continental Region

POTATO

Contribution by Continental Region

Contribution by Agroecology

Continental Region						Continental Region				
Total	Latin America	North Africa and West Asia	Asia	Sub-Saharan Africa		Sub-Saharan Africa	Asia	North Africa and West Asia	Latin America	**Total**
100	73.9	0.0	0.0	26.1	**Semiarid Tropics**	5.3	0.0	0.0	2.9	0.7
100	6.1	0.0	90.7	3.2	**Humid Tropics**	0.9	1.3	0.0	0.3	0.9
100	3.0	0.0	97.0	0.0	**Subtropical Lowlands**	0.0	58.6	0.0	6.8	38.7
100	15.5	54.7	29.6	0.2	**Arid and Mediterranean**	0.7	6.7	52.0	13.2	14.6
100	55.6	15.6	12.5	16.3	**Highlands**	93.1	3.7	19.2	61.5	19.0
100	10.0	1 7.0	73.0	0.0	**Temperate**	0.0	29.7	28.8	15.3	26.1
						100	100	100	100	100
Total Contribution of Region						Total				

SWEETPOTATO

Contribution by Continental Region

Contribution by Agroecology

Continental Region							Continental Region						
Total	Latin America	North Africa and West Asia	Asia	China	Sub-Saharan Africa		Sub-Saharan Africa	China	Asia	North Africa and West Asia	Latin America	**Total**	**Total (Except China)**
100	6.6	0.0	27.3	0.0	56.1	**Semiarid Tropics**	59.5	0.0	19.3	0.0	46.4	5.13	6.6
100	0.9	0.0	88.5	0.0	10.6	**Humid Tropics**	8.6	0.0	47.6	0.0	1.9	3.9	28.0
100	0.8	0.0	2.4	96.8	0.0	**Subtropical Lowlands**	0.0	69.2	20.6	0.0 2	5.6	61.5	14.0
100	7.0	1.0	0.1	91.8	0.1	**Arid and Mediterranean**	0.2	6.1	0.1	100	21.9	5.7	3.4
100	3.7	0.0	22.1	0.0	74.2	**Highlands**	31.7	0.0	6.3	0.0	4.2	2.1	14.8
100	0.0	0.0	2.0	98.0	0.0	**Temperate**	0.0	24.7	6.1	0.0	0.0	21.7	3.2
100	1.8	0.1	7.2	86.1	4.8		100	100	100	100	100	100	100
Total Contribution of Region							Total						

CIP's Global Contact Points

In 1992, CIP reorganized and consolidated its regional offices to provide more efficient management and fuller integration of the Center's global activities. The following list indicates CIP's principal contact points worldwide, by region. A more detailed list, including current staff contacts, can be obtained from the office of the Associate Director for International Cooperation.

Latin America and the Caribbean

Regional Office/Headquarters

Peru
International Potato Center
Apartado 5969
Lima 100, Peru
Phone: (51-14) 35-4354/36-6920
Fax: (51-14) 35-1570
Telex: 25672 PE
Cable: CIPAPA, Lima
E-mail: 157:CGI801
ohidalgo@cipa.pe

Liaison Office

Chile
Fidel Oteiza 1956 - Piso 12
Casilla 16487
Santiago 9, Chile
Phone: (56-2) 225-2118
Fax: (56-2) 225-8773
Telex: 242207 INIA CL

Research Stations

Colombia
Rionegro
c/o CIP-ICA (La Selva)
Apartado Aereo 128
742 Rionegro, Antioquia
Colombia
Phone: (57-4) 537-0161/537-0079
E-mail: cipcol@sigma.eafit.edu.co

Ecuador
Santa Catalina
Phone: (593-2) 69-0990
Fax: (593-2) 56-2286
E-mail: Internet: quito@CIP.org.ec;
sta-cata@cip.ec
Quito
Apartado 17-16-129-CEQ
Quito, Ecuador
Phone: (593-2) 55-4721/55-4726

Special Projects

Peru
SEINPA (CIP-INIA)
(same as CIP Headquarters)

Ecuador
FORTIPAPA (CIP-INIAP)
(same phone/fax as Santa Catalina RS)
E-mail: fpapa@cip.ec

Bolivia
PROINPA (CIP-IBTA)
Man Cesped 0293
Casilla Postal 4285
Cochabamba, Bolivia
Phone: (591-42) 49-506/49-013
Fax: (591-42) 45-708
E-mail: CGI272
Internet: proinpa@papa.bo;
devaux@papa.bo

Networks

PRACIPA
(same as PROINPA)
PRECODEPA
Apartado 322
Volcan Chiriquí, Panama
PROCIPA
(same as CIP Headquarters)

Sub-Saharan Africa

Regional Office

Kenya
P. O. Box 25171
Nairobi, Kenya
Phone: (254-2) 63-2054/63-2206/63-2151
Fax: (254-2) 63-1499
Telex: 22040
Cable: CIPAPA, Nairobi
E-Mail: CGI265

Liaison Office

Cameroon
P. O. Box 279
Bamenda, Cameroon
Telex: 58442 (NWDA)

Special Projects

Burundi
B.P. 75
Bujumbura, Burundi
Phone: (257-44) 2103 (Gisozi)
Fax: (257-22) 4074 (Bujumbura)
Telex: 5030 BDI (via Hotel Source du Nil)
5092 (via FAO FOODAG BDI)
E-mail: CGI422

Uganda
c/o USAID
P.O. Box 7007
Kampala, Uganda
Fax: (256-41) 23-3417/3308

Network

PRAPACE
B.P. 2847
Kigali, Rwanda
Phone/Fax: TRANSINTRA 250-73374; 72519
Telex: 22510 TRAKIG Rwanda

Middle East & North Africa

Regional Office

Tunisia
11 rue des Orangers
2080 Ariana
Tunis, Tunisia
Phone: (216-1) 71-6047
Field phone: (216-1) 53-9092
Fax: (216-1) 71-8431
Telex: 14965 CIP TN
E-mail: CGI019

Liaison Office

Egypt
P. O. Box 17
Kafr El Zayat, Egypt
Phone: (20-40) 58-6720
Fax: (20-40) 33-0320
c/o Greenhouse Hotel
Telex: 23605 PBTNA UN

South and West Asia

Regional Office

India
IARI Campus
New Delhi 110012, India
Phone: (91-11) 574-8055/573-1481
Telex: 3173140 FI IN
3173168 EIC IN
Cable: CIPAPA, New Delhi
E-mail: CGI046

East and Southeast Asia & the Pacific

Regional Office

Indonesia
c/o CRIFC
Jalan, Merdeka 147
Bogor 16111, Indonesia
Phone: (62-251) 31-6264
Fax: (62-251) 31-6264
E-mail: CGI193
CG1196
Lembang Annex
Fax: (62-22) 28-6025
E-mail: CGI120

Liaison Offices

Philippines
c/o IRRI
P. O. Box 933
Manila, Philippines
Phone: (63-94) 50235/50015-19,
ext. 248
Fax: (63-2) 5224240
(63-94) 50235 (Los Banos)
Telex: 40890 RICE PM
40860 PARRS PM
E-mail: CGI401 or IRRI

China
c/o The Chinese Academy of Agricultural
Sciences
Bai Shi Qiao Rd. No. 30
West Suburbs of Beijing
Beijing, People's Republic of China
Phone: (86-1) 831-6536
Fax: (86-1) 831-5329
Telex: 22233
222720 CAAS CN
Cable: AGRIACA
E-mail CGI030

Networks

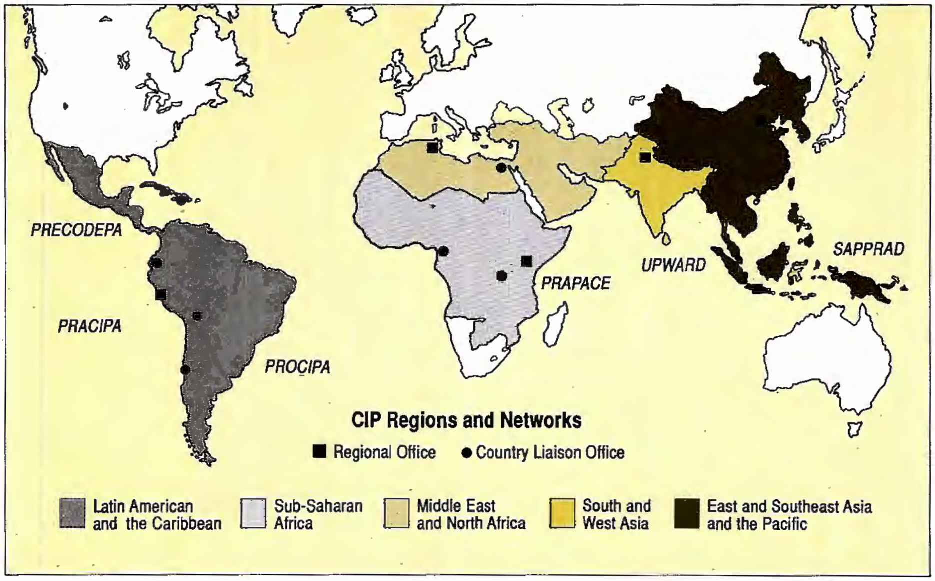
SAPPRAD
(same as Philippines Liason Office)
UPWARD
(same as Philippines Liason Office)

CIP Networks

CIP's Networks and their Partner Countries

PRACIPA	PRAPAC	PRECODEPA	PROCIPA	SAPPRAD
Programa Andino Cooperativo de Investigación en Papa	*Programme Régional d'Amélioration de la Culture de Pomme de Terre en Afrique Centrale*	*Programa Regional Cooperativo de Papa*	*Programa Cooperativo de Investigaciones en Papa*	*Southeast Asian Program for Potato Research and Development*
Bolivia, Colombia, Ecuador, Peru, Venezuela	Burundi, Rwanda, Uganda, Zaire	Costa Rica, Cuba, Dominican Republic El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama	Argentina, Brazil, Chile, Uruguay, Paraguay	Indonesia, Papua New Guinea Philippines, Sri Lanka, Thailand, Malaysia

CIP Regions and Networks



The CGIAR: A Global Agricultural Research System

CIP is a member of the Consultative Group on International Agricultural Research (CGIAR), an association of public and private sector donors that supports a worldwide network of agricultural research centers. Together, the 18 CGIAR centers have more than 1,800 scientists representing 60 nationalities stationed in 40 developing countries, where they work closely with national partners to promote sustainable agricultural advances. Their research involves crops that provide 75% of food energy and a similar share of protein requirements in the developing countries.

The other 17 centers are:

CIAT
International Center for Tropical
Agriculture
Cali, Colombia

CIFOR
Center for International Forestry Research
Bogor, Indonesia

CIMMYT
International Maize and Wheat
Improvement Center
Mexico City, Mexico

IBPGR
International Board for Plant Genetic
Resources
Rome, Italy

ICARDA
International Center for Agricultural
Research in the Dry Areas
Aleppo, Syria

ICLARM
International Center for Living Aquatic
Resources Management
Manila, the Philippines

ICRAF
International Centre for Research in
Agroforestry
Nairobi, Kenya

ICRISAT
International Crops Research Institute for
the Semi-Arid Tropics
Hyderabad, India

IFPRI
International Food Policy Research
Institute
Washington DC, USA

IIMI
International Irrigation Management
Institute
Colombo, Sri Lanka

IITA
International Institute of Tropical
Agriculture
Ibadan, Nigeria

ILCA
International Livestock Centre for Africa
Addis Ababa, Ethiopia

ILRAD
International Laboratory for Research on
Animal Diseases
Nairobi, Kenya

INIBAP
International Network for the
Improvement of Banana and Plantain
Montferrier-sur-Lez, France

IRRI
International Rice Research Institute
Manila, the Philippines

ISNAR
International Service for National
Agricultural Research
The Hague, The Netherlands

WARDA
West Africa Rice Development
Association
Bouake, Ivory Coast

Special Report: Measures of Impact and Sustainability

Making Research Count in Farmers' Fields

Measured in terms of better nutrition, equity, and environment, impact is not usually achieved as the result of a single research breakthrough. More often, such impact comes from the meshing together of various elements of research, training, and information sciences to solve a specific problem in a given country or region. Our new organizational structure has greatly facilitated this type of integration within the new Programs, as well as between them. These reports taken directly from Program 1 show the practical impact of our work with partners in the developing world. Impact-related work consists of three major components: case studies, development of data bases to analyze germplasm diffusion, and studies on sustainability. ■ For the first time in 1992, we have documented this impact in studies that have two main purposes. They demonstrate to our donors the value of investing in global potato and sweetpotato research; and they also are a useful management tool which can be used to demonstrate which of our approaches are the most effective.

CIP's Approach to Impact Assessment

CIP uses a case study approach to document the ultimate impact of successful CIP-related varietal improvement, integrated pest management, and seed technologies. Complementary research is now being initiated to build data bases on CIP-related genetic material and all varieties released by national programs in several major potato producing countries.

This emphasis on case studies stems from a need to document the potentially large benefits of agricultural research, and to obtain practical field-level guidelines for priority setting. In any portfolio of agricultural research projects, some will lead to technologies that will be adopted by farmers; but many will not be successful in generating practical results in the short or medium term. For example, about 170 improved potato varieties were officially released in the United States and Canada between 1932 and 1979. Only about 20 of those varieties have ever accounted for more than one percent of area planted in any year from their release date to 1989.

Compared to other investment projects, agricultural research is a relatively low-cost activity. Almost any biological technology that is rapidly accepted by a sizable number of farmers generates sufficient returns to cover not only its own costs, but also to pay for the costs of many research projects that do not ultimately generate practical results used by farmers. For example, in North America, one of the first releases from the USDA, Katahdin, generated the annual equivalent of tens of millions of dollars in benefits to potato producers and consumers. The magnitude of these benefits is probably substantially greater than the total cost of the national breeding program during the decades of the 1940s, 1950s, and 1960s.

In the cases discussed here, no effort is made to assign credit to individual national programs, mentor institutes, and donor agencies. Success is a joint product of many institutional actors. For example, in the early 1970s, CIP pathogen-tested and distributed Achirana INTA to many national programs. This variety was bred and released by the **Argentine** national program in 1971, and subsequently has been reported on 200,000 hectares in **North China** and is being produced by farmers in countries ranging from **Bhutan** to **Madagascar**. Without the work of INTA potato breeders, there would not have been a success story to record.

In the case studies shown in Table 1, seed, varietal, and IPM technologies are equally represented. These case studies are based on documented historical information (i.e., the timing of benefits in Table 1 is ex-post). A minority of the studies focus on technologies that are still in the pipeline, or that are being used where transfer is just beginning. For these technologies, benefits are projected based on the best available information. Because of the uncertainty of agricultural research and extension, ex-post empirical facts are substantially more informative than ex-ante projections.

Economic Returns in Rwanda and Burundi

In 1992, several hundred potato farmers on small holdings were surveyed in **Rwanda** and **Burundi** to determine their use of improved potato varieties released by the national programs: PNAP in **Rwanda** and ISABU in **Burundi**. The findings show a strong demand by farmers for the officially released varieties. Both their extensive coverage and rapid speed of diffusion indicate the widespread popularity of these public-sector varieties.

Fifteen years ago nearly all potatoes grown in the East African Highlands were of European origin. These were highly susceptible to late blight and bacterial wilt, the two major biotic constraints to potato production in the region.

During the 1970s, several varieties with late blight tolerance developed and/or tested in Mexico were introduced into Rwanda. Since 1979, Le Programme National pour l'Amélioration de la Pomme de Terre (PNAP) in Rwanda has introduced advanced genetic materials from CIP-Lima; and since 1982, new varieties characterized by high yield, late blight resistance, and some level of tolerance to bacterial wilt, have begun to be

Table 1. Impact case studies

Technology		Benefits		Country
General	Specific	Source	Timing	
Varietal	Late blight resistance	Increased yields	Ex-post	Burundi, Rwanda, Uganda, Zaire
Varietal	Late blight resistance	Increased yields	Largely ex-post	Peru
Varietal	Resistance to biotic and abiotic stresses	Increased yields	Ex-post	China
Integrated pest management	Potato tuber moth	Better prices	Ex-post	Tunisia
Integrated pest management	Sweetpotato weevil	Better prices	Largely ex-ante	Dominican Republic
Integrated pest management	Andean potato weevil	Better prices	Largely ex-ante	Peru
Seed	True potato seed	Reduced costs	Largely ex-ante	Egypt, India, Indonesia, Nicaragua
Seed	Rapid multiplication	Increased yields	Ex-post	Vietnam
Seed	Strengthen seed program	Faster diffusion	Ex-post	Argentina, Brazil, Uruguay

considered for release. These include Gahinga, Gashara, Petero, Nseko, and Kinigi. From 1984 to the present, additional advanced materials were introduced, evaluated, and selected. To date, a total of 14 varieties have been released; they show high yield potential, resistance to late blight, and some tolerance to bacterial wilt.

The varieties released by PNAP have almost entirely replaced the old materials that were cultivated in **Rwanda**. Survey results show that Sangema, Cruza 148, and the new variety Mabondo are the ones most frequently cultivated (Table 2).

Survey findings also pointed out needs for trait enhancement of the widely adopted varieties, because farmers and consumers would like to see other favorable characteristics combined. For example, the Mexican variety Cruza 148 (CIP 720118), has a purple vascular ring in its flesh and some unfavorable cooking characteristics. However, farmers like it because it is high-yielding, resistant to late blight, and tolerant to bacterial wilt. The dormancy of its seed tubers between harvest and when they begin to sprout is relatively short, thus this variety can be conveniently re-planted for a second crop within a year.

Table 2 shows that Cruza 148 is seldom used by farmers in the Mutura region, where the volcanic soils are highly fertile and potatoes are grown as a cash crop for the market. On the other hand, it is a preferred variety in less fertile, more isolated zones, where the crop is more important for home consumption.

In **Burundi**, approximately 8,000 germplasm introductions were made in various forms between 1983 and 1991. They were introduced from CIP's headquarters in Lima, CIP's regional distribution center in Nairobi, and PNAP-Rwanda via Programme Régional pour Amélioration de la Culture de la Pomme de Terre et de la Patate Douce en Afrique Centrale et de l'Est (PRAPACE). Several varieties have been released by the Institut des Sciences Agronomiques du Burundi (ISABU) and adoption by farmers has been widespread.

The high rate of farmer adoption of new varieties was documented by the 1992 survey and another done in **Burundi**, when 345 farmers were surveyed from October 1986 to January 1990. In the 1992 survey, 358 farmers in three zones were interviewed to measure the up-take of varietal technologies. Ndinamagara (Cruza 148) was cultivated by over 80% of the farmers in both samples. This variety is preferred because of its resistance to late blight and tolerance to bacterial wilt.

Uganda 11 was the second most frequently planted variety in the hilly

Table 2. Regional distribution of varieties grown by farmers, Rwanda, 1992.

	Region		
Variety	Volcanic soils Mutura	Highland crest Mudasomwa	Highland crest Ramba
Sangema[1]	74	35	56
Cruza 148[1]	2	43	26
Mabondo[1]	16	20	5
Montsama[1]	5	0	4
Kinigi[1]	0	0	7
Muhabura[1]	1	0	4
Gashara	0	1	1
Gahinga[1]	1	1	0
Satuma	2	0	0
Rubengera	0	0	2
Bakou	1	0	0
Kruger	0	1	0
Mariline[1]	1	0	0
Sample size	125	100	100

Source: PRAPACE surveys

[1] Variety released by national program.

Note: As some farmers plant more than one variety, the columns sum to more than 100%.

regions. Farmers prefer this variety for its resistance to late blight, high yield, and large tubers; they report that this variety is a frequent target for theft.

Farmer preferences for Kinigi, Sangema, Muruta, and Muziranzara had declined because they became susceptible to late blight. However, Muruta is grown in swampy areas called *marais*, where late blight pressure is low and potatoes can be grown in the dry season.

The investment in potato research, seed production, and extension in the highlands of East Africa has been extremely profitable. When considered as an investment project spanning only fourteen years from 1978-1991, the internal rate of return is estimated at 91%, which surpasses in profitability the vast majority of development projects and competes very favorably with most of the documented success stories in agricultural research. Because this rate of return estimate is imprecise, CIP chose assumptions that would not result in an upward bias in estimates of profitability. But the best indication of the economic worth of the project is the rapid use of the new high-yielding, late blight resistant varieties by potato farmers on small holdings.

Many actors contributed to the success of the project, which was characterized by both short- and long-term investments, including national research and extension programs in East Africa; donors, especially the United States Agency for International Development (USAID) and the **Belgium** government; international organizations; and the Mexican national program, which was the source of some of the introduced late blight-resistant varieties.

Past success does not imply that the sources of growth in potato production in the highlands of East Africa have been exhausted. Yields remain low and input intensification is only beginning, suggesting a high return to crop management research. New sources of late blight resistance must be diffused to small farmers so that gains from past investments will not be eroded in the future. In response to intense population pressure, expanding potato production to the intervalley *marais* or swamps should yield attractive returns to an investment in applied and adaptive research. Some of the introduced varieties—e.g., Muruta in **Burundi**—have proved high-yielding under such conditions.

Benefits from IPM Practices on Potato Tuber Moth in Tunisia

The economic impact of agricultural research usually stems from increased yields, reduced costs, or enhanced quality. But because of differing local conditions and circumstances, it is difficult to accurately forecast the size of different sources of benefits. After a technology is adopted by farmers, researchers are sometimes surprised to find that the demand for an improved technology is driven by an unexpected or secondary benefit.

For example, in the diffusion of IPM practices to control potato tuber moth (PTM) in **Tunisia**, the indirect benefits proved to be substantially larger and easier to measure than expected direct benefits. Researchers found that potatoes slightly damaged by tuber moth fetched the same market price as did clean tubers. Potatoes heavily damaged with two or more galleries per tuber were typically discounted by 30-50%. Before the adoption of IPM practices, farmers avoided heavy losses by frequently checking the condition of their stores and marketing their crop before serious losses occurred. Thus, economic losses were reflected in lower prices received for sales made shortly after harvest, but were not synonymous with the large quantities discarded or destined for other uses.

Improved PTM control allowed farmers to prolong storage until later, when prices were usually higher. Under these conditions, diffusion of IPM cultural control and pesticide application practices should result in a more stable seasonal distribution of marketed potatoes and prices.

The seasonal price spread was calculated by taking the difference between the average price during the summer storage period (August, September, and October) and the spring harvest period (May, June, and July). Between 1975 and 1990, the seasonal retail price difference fell by about 50% (from $190/ton to $95 ton, in 1990 prices). The seasonal wholesale price difference declined from $130 to $80 over the same period. Using the average potato prices that prevailed at the end of the 1980s, these results imply that the unit cost of storage fell by a factor of between 0.20 to 0.25.

To evaluate the size of the economic benefits generated by the IPM practices, the more conservative estimate of 0.20 was combined with information on the demand for and supply of potatoes in Tunisia. The total value of such benefits are relatively insensitive to assumptions on demand and supply parameters (Table 3). With the most reasonable set of parameter values ($n_1 = 0.4$, $n_2 = 0.8$, $s = 0.2$, $e = 0.90$, and $K = 0.2$), annual benefits amount to US$1.666 million in 1990 dollars, which is about 8% of the gross wholesale value of the spring crop. These estimated benefits from this one project are sufficient to pay for the entire annual costs of the Tunisian government's potato improvement program. When considered as a project with a 25-year life span, a 50% rate of return on investment was estimated with the most conservative economic assumptions. Most of the impact in the program occurred early because existing pest management technologies could be quickly adapted to local conditions through experienced research and extension workers. Given the dynamic nature of pest ecology and the ability of the pest to develop resistance, there will be a continuing need for maintenance research.

Table 3. Welfare effects from a reduction in potato storage costs.[1]

Elasticities[2]				Welfare effects[3]
Demand		Supply		(US$000/yr)
n_1	n_2	σ	e	
0.1	0.2	0.0	0.15	1,715
0.4	0.8		0.60	1,677
0.7	1.4		1.05	1,637
0.1	0.2	0.2	0.45	1,709
0.4	0.8		0.90	1,666
0.7	1.4		1.35	1,626
0.1	0.2	0.4	0.75	1,707
0.4	0.8		1.20	1,659
0.7	1.4		1.65	1,618

[1] The storage supply shift is estimated to be $K = 0.2$.

[2] n_t is the demand elasticity in period t.
σ is the supply elasticity
e is the elasticity of excess supply, $e = (n_1 + \sigma)q_1/q_2$

[3] Change in total social welfare.

Health Effects of Intensive Pesticide Use

In the Andean Sierra, potato cultivation uses more agricultural pesticides than any other field crop. An interdisciplinary case study was begun in 1990 to assess the impact of the use of these pesticides in Carchi, an intensive, year-round, commercial potato-producing area in northern Ecuador. Three types of impact were defined: production, environmental, and health. (Preliminary results of the production and environmental components of the study were reported CIP's 1992 Annual Report). Field work during 1992 generated information on some of the health consequences of intensive pesticide use in potato production in the Andes.

The study of health impacts was confined to the main acute effect: poisonings via farm worker exposure. No study was made of non-direct chronic effects of intensive pesticide use through contaminated food, air, or water. Thus health effects were intimately linked to occupational work safety. This field research seeks answers to these questions: What is the incidence and severity of and risk factors associated with pesticide poisonings? What are the health consequences? What is the economic burden of those consequences?

Past research has shown that estimates of the incidence of pesticide poisoning is likely to be substantially underestimated in a passive surveillance reporting system that relies on voluntary compliance. To guard against this bias, an active surveillance system was established in the study site with the collaboration of the local medical community. Health Ministry forms to report poisoning cases were modified, training was provided for symptom recognition, and individual cases were monitored.

The active surveillance system resulted in an eight-fold increase in the reported incidence of pesticide poisoning cases, from 21/100,000 to 170/100,000.

Accurate responses to health questions require assessment of use, practice, exposure, and outcomes. Exposure is documented in field trials where pesticides are applied and monitored. Initial results show that 80% of pesticide exposure is dermal. Ingestion and respiration are incidental in comparison.

Health problems such as kidney damage can be expected following exposure. These health problems can be detected by various testing procedures. For example, vibration threshold detection and a battery of psychometric tests check for peripheral and central nervous system damage. Studies are now being made of the economic burden of illness among the farm worker population.

◆

Research is now under way to document the ultimate impact of those case studies reported in Table 1 that are not discussed above. Their results will further document the practical results generated by CIP research in collaboration with our partners.

PROGRAM 1

Production Systems

Characterization of Potato Production Constraints and Opportunities

Farmer Participation in the Evaluation of Late Blight Resistant Clones in the Bolivian Andes

The second year of research incorporating the farmer's perspective in the evaluation of promising late blight resistant clones has enhanced knowledge of the advantages and disadvantages of different farmer participatory methods and has sharpened understanding of which traits farmers judge to be most important in varietal evaluation. In 1990-91, men and women farmers from seven communities in the province of Cochabamba, **Bolivia,** compared the performance of 80 new late blight resistant clones from CIP's breeding program with eight traditional varieties. Based on that evaluation, six clones were selected by the farmers. Selection criteria did not differ markedly between farmers, either men or women, and plant breeders.

In 1991-92, groups of farmers from five Cochabamba communities evaluated six previously selected clones. The 63 participating farmers evaluated the six selected clones, along with other promising late blight resistant clones, plus three traditional (control) varieties. Farmers multiplied clones in high-altitude tuber seed production sites. Following one standardizing spray, no fungicides were used on the field and only farmers' field and management practices were used. An average of 13 clones and 3 controls were planted at each site. Although late blight pressure was generally low in 1991-92, the trials generated useful information on farmers' demand for traits and on farmers' participation in varietal evaluation.

Production at all sites was reduced by pilfering of some tubers. Farmers selected favorite clones on the basis of yields of plants judged "whole." Based on productivity per plant, the traditional varieties Waycha, Rosita, and Puka Torralapa generally yielded less than the promising clones and were not preferred. The

Farmers are important evaluators of new clones. Their knowledge and opinions are valued by NARS and CIP scientists.

selected clones gave heavier yields than the rejected clones, but farmers were reluctant to eliminate moderate-yielding clones that displayed other prized characteristics. Moreover, farmers wanted to see how the material performed in a year of more severe late blight stress: they wanted to plant the most promising new clones in the following year.

Four characteristics of the plant were of major importance to farmers: vigorous growth, thick stems, early maturity, and little or no evidence of disease. Abundant flowering and dark or non-yellow-green leaves were secondary considerations.

At harvest, farmers considered "good" eyes (abundant, sprouted, "open," healthy, wide, etc.) to be the most important characteristic. They use this factor to judge high-quality seed that will produce good yields in the future. The second most valued characteristic was healthy tubers, followed by good or high yield, large tubers, smooth skin, and adequate form. A clone's similarity in appearance with a known variety was an indicator of its acceptability, both for home and commercial consumption.

Following the harvest, short interviews were conducted with the 63 farmers. Most farmers considered the evaluation of clones during the harvest to be most important. Nonetheless, approximately one-third of the farmers felt that clonal selection during both flowering and harvest was essential, particularly for the identification of vigor and disease symptoms.

Over three-fourths of the farmers criticized the system of joint responsibility for field-site maintenance. Farmers attributed inadequate supervision, resulting in theft, to the joint responsibility system. The majority suggested that one volunteer be given the responsibility for producing clones in his or her field, with community support and participation.

The group approach relying on farmer syndicates to appoint participants for clonal evaluation also resulted in less than expected participation, particularly among women. In the evaluation, volunteer farmer participants are preferred, rather than those selected by the farmer syndicates.

Based on the overall findings, several modifications are being made in the evaluation emphases and procedures in the 1992-93 planting season. Tuber seed of selected clones are being planted in more lowland, humid sites where disease pressure is higher. One individual in each community will be in charge of plot management. That person and the community will share the output depending on inputs provided, participation, and syndicate needs. Personal evaluations by individuals will replace group interviews. Active participation of women will be encouraged.

Potato Production Systems in Cameroon

Potatoes were introduced to Cameroon at the turn of the century by European settlers, but it was only in the 1940s that cultivation among indigenous farmers became widespread. Women farmers have long been the primary producers of the crop, and have maintained and multiplied several varieties that have now acquired local names.

The study of seed systems clearly shows a sharp dichotomy in production systems. In North West Province, which is the most important production area and where a majority of the farmers are women, potatoes are intercropped with maize, beans, and other food crops. Use of purchased inputs is negligible, and soil fertility is managed through the incorporation or burning of grass prior to planting, green manuring, and the application of fowl droppings. The use of old, degenerated tuber seed is widespread, and yields are low. Marketing is a major constraint to increasing potato production, primarily because of the poor condition of roads during harvest in the rainy season.

Production systems in other regions of Cameroon are more market-oriented and input-intensive. Men farmers are the majority in these more commercial potato-producing ecological niches. Use of fungicides, inorganic fertilizers, and postharvest chemicals is common.

Farmers are very knowledgeable about seed, particularly in the North West Province, which has a longer history of potato production. Farmers are well aware of the need for improved varieties and more productive agronomic and postharvest practices.

Characterization of Sweetpotato Production Constraints and Opportunities

The Role of Sweetpotato in Africa

Baseline research continued in 1992 on the roles of sweetpotato in the food systems of eastern, central, and southern Africa. Collaborative survey projects are underway in **Kenya, Rwanda, Tanzania, Burundi**, and **Uganda**. A great diversity of farmers' varieties is found. Most consumers prefer hard, floury, moderately sweet types. Sweetpotato is a major staple food in Rwanda, Uganda, Burundi, and eastern **Zaire**. Elsewhere in the region it is an important secondary food, widely grown on a small-scale for household food security and for sale. The major field constraints are sweetpotato weevil (*Cylas* spp.), a complex of virus diseases, sweetpotato butterfly (*Acraea acerata*), alternaria fungus, moles, rats, and other rodents.

This comparative diagnostic research was started in 1989 and is scheduled for completion by 1994. The results presented below for Rwanda and Tanzania are indicative of the considerable progress made in the collaborative survey research in 1992.

Sweetpotato is a major staple food in **Rwanda**. According to FAO, average annual per capita production is 120 kilos, one of the highest levels in the world. The national research program has been active for over a decade. Good varieties have been selected, released, and distributed through a national seed program.

With support from the GTZ-funded project in **Rwanda** and IITA/ESARRN, the national root crop program at ISAR has contracted the Division of Agricultural Statistics (DSA) of the Ministry of Agriculture to carry out household surveys of sweetpotato and cassava. The principal source of the Ministry's production statistics is a permanent representative sample of 1250 households, each of which is interviewed every cropping season. The DSA routinely carries out special studies of which the root and tuber survey is one. The field work was completed in 1992, and the final report is scheduled for March 1993. Some of the preliminary results are summarized as follows.

Sweetpotato is grown by 89% of all farmers in **Rwanda**. It is a universal basic staple in all areas of the country except the high-altitude area of volcanic soils in the northwest, where less than a quarter of the farmers grow the crop. Potatoes are a major crop in that zone.

Over 200 varietal names were identified by the farmers in their fields; some identified varieties are duplicates or very closely related phenotypes. Only 10 varieties were identified in more than 20 households. Significant differences were found among the varieties grown in different regions of the country. Most farmers grow several varieties together in the same field.

The most widely grown varieties have firm, white flesh, a floury and starchy consistency, and a moderately sweet taste. Many varieties have been grown by the same farmers for many years; the average for the top three varieties is 11 years, and several have been grown for an average of over 15. Nevertheless, the most widely diffused variety, Magande, has only been adopted recently, having been grown for an average of four years.

Low and declining yields were the major reasons listed for abandoning varieties. The responses to questions on varietal performance imply that Rwandan farmers have a range of suitable varieties available, but there is still a clear demand for higher yielding, early material.

Table 1 lists the average severity levels of the major pests and diseases in the 1991-92 cropping years. Sweetpotato is a rustic crop: problems of pests and diseases were seldom "serious" or "very serious" averaged over the country as a whole. Yield reducers were locationally and seasonally specific. Nevertheless, weevils, alternaria, and viruses are potentially chronic problems throughout the country. These and other pests, particularly the sweetpotato butterfly, are often devastating to an individual farmer in a particular year.

The decentralized national sweetpotato program in **Tanzania** has been receiving support from GTZ through CIP. In the past year, eight research stations have been involved in a program of socioeconomic surveys and in the collection of sweetpotato varieties grown by farmers. These are Ukiriguru, Lake Zone; Horti-Tengeru, Northern Zone; Chollima, Kibaha, and Sokoine University of Agriculture, Eastern Zone; Kizimbani, Zanzibar; Naliendele, Southern Zone; and Uyole, Southern Highlands Zone.

Researchers from the Root and Tuber and Farming Systems Programs attended a planning workshop held in January at Sokoine University to develop goals and agree on diagnostic methods. Each team developed its own questionnaire, and several have written preliminary progress reports. The surveys will be completed in 1993, and another workshop organized to develop the basis for comparative analysis and to feed the information collected into a coordinated data base. The farmers' varieties will be characterized and the highest-performing clones will be selected for a national working collection.

Table 1. Average severity of major constraints on sweetpotato production, Rwanda, 1991-92.

Pest or disease	Farmers (%) reporting damage as		
	Very serious or serious	Moderate or minor	Not a problem
Sweetpotato weevil	6	42	52
Sweetpotato butterfly	5	24	71
Other insect pests	0	5	95
Alternaria	8	55	37
Viruses	2	43	55
Erinose mites	3	44	54
Moles or mole rats	5	24	72
Rats	1	13	86
Other vertebrate pests	0	2	98

Source: Rwalima and Tardif-Douglin, in preparation.

Sweetpotato Production Systems in Asia

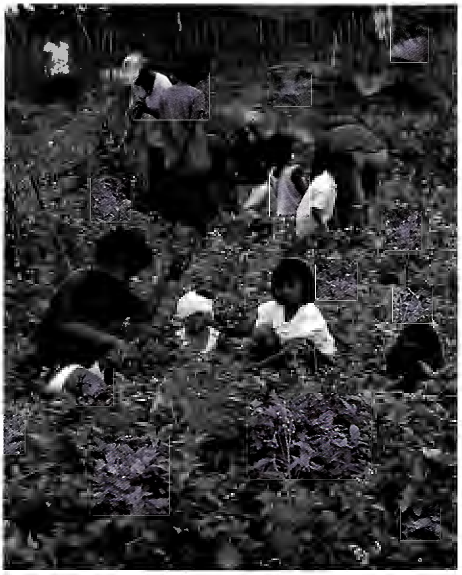
Researchers in the UPWARD (User's Perspective with Agricultural Research and Development) network conduct most of CIP-related research on sweetpotato production systems in Asia. In 1992, research projects were under way by 54 investigators in 7 countries. The first set of projects supported by UPWARD were primarily diagnostic, involving the characterization of whole systems. Projects in 1992 were more specific subject matter inquiries, where socioeconomic, cultural, and technical issues converged, or were second-phase, action-research activities based on the earlier diagnosis.

Two projects in the Philippines illustrate these research emphases in 1992.

Soil Management in Upland Production Systems

Earlier diagnostic research pointed to the potential importance of sweetpotato in farmers' soil management in upland production systems. The subsequent in-depth study of sweetpotato in soil fertility management is cast in a knowledge-systems perspective (that is, in terms of the articulation of the knowledge of farmers, local and R&D organizations, policy makers, NGOs, and the private sector in the management of the environment). The project seeks to identify both successful and problematic knowledge linkages in environmental management.

The **Philippines'** case study identifies a range of indigenous and introduced practices locally available for controlling erosion and the loss of soil fertility, which became locally recognized as a problem stemming from the 1950s (Table 2). The findings indicate that indigenous practices have been fairly consistently applied as a response to the fertility problem, particularly those based on use of sweetpotato; whereas the recently introduced practices have not been accepted. Farmers showed a marked preference for combating soil erosion and fertility problems via the management of existing crops and "weeds," rather than through the introduction of new species. Informal farmer-to-farmer information exchange systems, which are the prevailing means of communicating technical information, have not been used effectively to diffuse information on new practices.



Family members participate in harvesting a women's gene bank in the southern Philippines. Such gene banks serve as centers of conservation and varietal experimentation.

Technology Development for Homegarden Systems

Following a diagnosis of homegarden systems in the northern **Philippines**, an action phase was developed for participative evaluation of new sweetpotato germplasm; multiple and mixed cropping of different root and vegetable crops; composting; and nutritional evaluations. Homegardens and homegardeners vary greatly in function, ecologies, and cultures, and this diversity has complicated analysis. The most successful responses to improved homegarden technology have been in rural and peri-urban areas. Rural homegardens complement the small-scale commercial production of vegetables. Although rice is the principal subsistence food purchased with cash-crop earnings, sweetpotatoes, taro, climbing beans, pigeonpea, squash, and other vegetables offer a more diverse diet to the household.

In peri-urban areas that have been settled recently by migrants, temporarily vacant lands around and beyond the house are used for sweetpotato production. This contributes significantly to family diets during some parts of the year, especially for many families having no stable income source. Both peri-urban and urban homegardeners have two major problems: 1) difficulty in obtaining planting material and 2) low levels of soil fertility and poor soil quality.

Variety testing is popular and widespread. Homegardeners want varieties that produce more, and such testing is also in demand because it represents a source of planting material. In contrast, composting was rejected by home gardeners

Table 2. Indigenous and introduced practices for soil fertility management and erosion control in upland production systems, Matalom, Eastern Visayas, Philippines.

Practices	Description	Benefits	Problems
Indigenous			
Contour grass strips	Strips of soil left unploughed and grass (esp. *Imperata cylindrias*) allowed to grow	Soil erosion control on slopes/labor saving/adapting "weeds"	Efficient?
Fallowing	Practiced when production is observed to decline	Renewal of fertility/disappearance of diseases and pests	Land shortage
Guano fertilizer	Collection and use of the dung of birds and bats which accumulates in caves	Cheaper than commercial fertilizer/easier to apply than compost	Extraction is time consuming/access to caves difficult and dangerous
Rock walls	Use of limestone rocks to build walls to impede loss of topsoil through erosion	Cheap	Efficiency not fully understood/labor intensive
Crop rotation	Planting of different crops in a determined sequence between fallow periods	Control of pests and diseases through elimination of host plants	—
Intercropping/relay cropping	Combining particular crops in the same plot, especially upland rice or corn with sweetpotato and corn with peanuts	Optimizes land use/maintains soil cover to avoid erosion/increases absorption of vegetative matter	—
Cover-cropping of sweetpotato	Planting sweetpotato at onset of rains, as a relay or intercrop	Barrier to sheet erosion during heavy rains/protects soil surface/prevents moisture loss/less tillage/suppresses weeds	Effectiveness is limited by slope and extent of rains/cannot totally eradicate erosion
Mulching of sweetpotato	Use of high level of biomass for incorporation as green manure or as compost	Cheap and abundant source of organic matter	Aids sweetpotato weevil propagation from season to season

continued on next page

Table 2 continued

Practices	Description	Benefits	Problems
Introduced			
Composting	Collect (not burn) vegetative waste/gather in one place for decomposition	More efficient use of vegetables wastes/cheap source of fertilizer	Process slow and long-term/labor intensive/need for high volume compared with inorganic fertilizer
Tree planting	Planting of *ipil-ipil*, *yemane*, and *madre de cacao* for long-term use as timber and firewood	In short and medium-term: erosion prevention, aesthetic improvement, and agricultural use	Short-term food needs not met by trees/insecure tenure makes farmers unwilling to plant perennials/trees planted in public areas benefit households?
Contour hedgerows	Planting of leguminous tree species as hedges along contour lines	Slow down flow of water/trap. eroded soil/enhance formation of terraces/contribute N to soil	Hedge species recommended not useable as food/practice complicated, laborious, and time-consuming/difficult and expensive to obtain tree seedlings
Mura grass	Use of mura grass *(Vetiver sp.)*/common in lowlands on rice bunds for hedges	Plant materials more readily available than leguminous tree species	Time needed to obtain planting material from lowlands/cannot be used as food/high pruning requirements

in spite of soil fertility problems. Women managing the gardens have many other demands on their time, thus community planting-material propagation schemes and alternative solutions to soil fertility problems are being advocated for homegardeners.

Adaptation and Integration of Potato Production Technologies

Providing NARS with Advanced Materials

This research adapts and integrates varietal and agronomic components to the main potato producing agroecologies (the Subtropical Lowlands, Temperate, Highlands, and Arid and Mediterranean; see map foldout (pg. XVI) for a more detailed explanation). The main objectives are 1) to provide NARS with advanced genetic materials for variety selection and release and 2) to develop progenitors to be used for variety breeding in CIP's other breeding activities at headquarters and in regional programs and NARS.

Research is guided by a knowledge of biotic and abiotic production specific to each agroecology and by the understanding of the scope for varietal resistance to function as a solution to these problems. Table 3 provides an updated inventory of limiting factors and available resistances, as classified by agroecology.

The expected near-to-medium-term outputs include:

- New varieties with earlier maturity combining resistance to late blight, PVY, and PVX will be released. This material is now in the regional and NARS testing phase.
- New varieties with late blight, PVY, PVX, and PLRV resistance have already been assembled and are ready for regional testing followed by NARS evaluation and release. These combinations of resistance are particularly oriented to the sub-tropical lowlands and temperate agroecologies.

Table 3. Inventory of resistances and/or tolerances to single constraint factors in CIP's advanced breeding material for major agroecologies.

Resistance and/or tolerance to main constraints	Agroecology			
	Subtropical Lowlands	Temperate	Highlands	Arid and Mediterranean
PVY, PVX[1]	+	+	+	+
PVY, PVX, PLRV[1]	+	+	+	+
Late blight	+	–	+	0
Early blight	+	+	+	+
Bacterial wilt	+	0	+	0
Cyst nematodes	0	+	+	0
Tuber moth	±	0	0	±
Drought	–	±	–	–
Heat	+	0	0	+
Frost	0	–	+	0
Salinity	+	0	0	+

[1] Resistances to the complexes PVY, PVX, and PVY, PVX, PLRV are considered single traits.

+ = presently available, – = not available at present, ± = needs further testing, 0 = no priority in the agroecology

- New varieties with heat tolerance, and combined resistance to PVY, PVX, and PLRV are now being tested by NARS of the Arid and Mediterranean agroecology. New varieties with earliness, virus resistance, and some tolerance to drought and salinity are planned for release for use in the Arid and Mediterranean, Subtropical Lowlands, and Temperate agroecologies.
- Some previous releases should be adequate for processing (french fries and chips).
- New varieties are expected through successful use of biotechnology to transfer genes for resistance to insects and bacterial wilt into locally adapted NARS varieties and CIP's advanced materials that already combine resistance. This material would be valuable for the Arid and Mediterranean (insect resistance) and for the Sub-tropical Lowlands (insect and bacterial wilt resistances).

A set of 41 advanced clones was introduced in CIP's pathogen clean-up program in 1991, and some of these clones have now been cleaned and are ready for distribution. Table 4 shows a list of 22 progenitors most of which—in addition to transmitting immunity to either PVY or PVX, or both—generally combine traits for high yield, earliness, heat tolerance, and wide adaptability.

During the period 1991-1992, 22 new potato varieties selected from CIP's breeding material have been released in several NARS. Table 5 lists the 22 new varieties, seven of which are from materials developed in this project, and 10 of the others in the list have one progenitor also originating from this project. In addition, progenitors developed in this program are now used in CIP's other breeding activities (for insect, bacterial wilt, and late blight resistances; tolerance to salinity and partial drought; TPS; and processing quality).

The Siberian Institute for Agricultural Research at Omsk, **Russia**, provided CIP a set of 35 varieties and breeding clones. Some of these clones have tolerance to drought, as well as a short growing period.

Table 4. Attributes of CIP pathogen tested clones that are ready for distribution.

Clone	Attributes
X86.010	PVX immune simplex, GCA[1] early
Y84.011	PVY immune simplex, GCA yield, early, HT[1]
Y84.027	PVY immune simplex, GCA yield, early, HT
YY.1	PVY immune duplex, GCA early
YY.3	PVY immune duplex, GCA yield
YY.10	PVY immune duplex, GCA yield
YY.12	PVY immune duplex
YY.13	PVY immune duplex, GCA yield, early
XY.1	PVX, PVY immune simplex, GCA yield
XY.2	PVX, PVY immune simplex
XY.6	PVX, PVY immune simplex
XY.7	PVX, PVY immune simplex
XY.9	PVX, PVY immune simplex, GCA yield, early, HT
XY.10	PVX, PVY immune simplex
XY.12	PVX, PVY immune simplex
XY.13	PVX, PVY immune simplex, GCA yield, early, HT
XY.18	PVX, PVY immune simplex, GCA early
XY.19	PVX, PVY immune simplex, GCA early
XY.20	PVX, PVY immune simplex, GCA yield
E86.300	Processing (Chips), GCA Dry matter, HT
E86.694	Processing (Chips), stable quality, HT
E86.695	Processing (Chips), stable quality, HT

[1] GCA: General combining ability HT: Heat tolerance

This material is in the process of being hybridized with CIP's best progenitors.

A population of 7,500 seedlings was grouped in 53 progenies that combine resistances to PVY, PVX, and PLRV. These progenies were screened during the summer in the greenhouse for tolerance to heat and adaptation to long days. This population is targeted for the temperate agroecology, particularly Northern **China** where viruses are a serious yield constraint in potato production in 1,000,000 ha.

A population of 15,000 seedlings is growing in the quarantine greenhouse under long-day condition to select clones adapted to the Temperate and Arid and Mediterranean agroecologies. Another group, targeted for the Subtropical Lowlands and Highlands, is growing under 14-hour daylength conditions. This population carries resistance to the main stresses (late blight, bacterial wilt, PVY, and PVX) for the low- to mid-elevation Highlands and Subtropical Lowlands. The clones selected in the quarantine greenhouse will undergo sequential screenings for resistance to the main diseases, then will be multiplied and sent to various NARS for testing and variety selection.

Many of CIP's selected progenitors and foreign varieties and breeding lines were crossed in the greenhouses at La Molina and Huancayo, **Peru**, in 1991 and 1992. NARS located in the most important potato producing agroecologies have received samples of these populations for variety selection (Table 6). Adequate screening in NARS for disease resistance is critical in achieving the full potential of this material.

Eight clones with combined PVY and PVX immunity have been identified after extensive testing at North Carolina State University in the USA. These clones provide a new source of immunity to these two viruses, and have good quality attributes; they are being introduced rapidly into the advanced crossing block. PVY capsid protein genes have been made available for incorporation into the genome of susceptible plants through particle bombardment.

Over the past six years, the Agricultural Research Institute in **Taiwan** has been testing CIP material having immunity to PVY. Two high-performance clones have been evaluated in farmers' fields and are being multiplied on a large scale for seed production.

In the South Pacific Islands, CIP-bred clones are outyielding all locally cultivated varieties. The best clones are CIP 378597.1,

Table 5. Genetic composition of the new varieties named and/or released by NARS in 1991-92.

Country	CIP number	Name	Pedigree
Burundi	381381.9	Rukinzo	378493.915 × **Bk precoz**
	381381.26	Ingabire	378493.915 × **Bk precoz**
	382147.18	Jubile	**(N568.7XN503.79).31** × BkMex
Cameroon	381381.13	Cipira	378493.915 × **Bk Precoz**
	381406.6	Tubira	378493.915 × Bk Mex.
	386292.3	IRA-92	**Renska** × **7XY.1**
	386298.1	IRA-Babungo	**379703.3** × **7XY.1**
Indonesia	377785.4	Basuki	**Atzimba** × **DTO-28**
Madagascar	377957.5	LT-5	**Snowflake** × **N551.12**
	383256.11	Lava	**CFK-69.1** × **DTO-33**
Panama	381381.13	IDIAP-92	378493.915 × **Bk precoz**
Rwanda	800983	Mabondo	Murca × **378676.6**
	381381.3	Nderera	378493.915 × **Bk precoz**
	381395.1	Ngunda	378493.915 × Bk Mex.
	383120.14	Kigega	VHF-69.1 × Bk Mex.
	383140.6	Mugogo	378493.738 × Bk Plaisted
	386003.2	Mizero	BL-2.9 × **R128.6**
	387233.24	Gikungu	382124.6 × India 1039
Uganda	381379.9	Kisoro	382124.895 × **Bk Precoz**
	381381.20	Victoria	378493.915 × **Bk Precoz**
Zaire	380583.8	—	**Serrana** × **Atzimba**
	380606.6	—	**65-ZA-5** × **CFK-69.1**

— = not known

Note: The parental material from this project are in bold

CIP 378711.7, and LT-7; however, additional work is needed to ensure production of sufficient seed to permit these clones to be released as new varieties.

Three sets of advanced lowland potato clones selected for high yield and long storability (nine months) in diffused light storage (DLS) were evaluated in farmers' fields in the Philippines. Tuber yields of the best of these virus-resistant clones were: CIP 385144.31 (B-71-240.2 × Y84.005), 32.6 t/ha; CIP 385131.52 (Y84.049 × 378015.16), 29.2 t/ha; CIP 385130.11 (Y84.025 × 378015.16), 26.3 t/ha; APC 64, 26.2 t/ha; and CIP 385130.6 (Y84.025 × 378015.16). The farmers' cultivars gave variable yields: Berolina (12.3 - 19.8 t/ha) and Cosima (9.4 - 23 t/ha).

Adaptation and Integration of Sweetpotato Production Technologies

The introduction and testing of sweetpotato germplasm has contributed greatly to increased sweetpotato production in many countries. Elite germplasm with a range of agronomic and quality traits and biotic and abiotic stress resistances is now available from many sources, including breeding programs in developing and developed countries and IARCs. The objectives of this CIP project are to:

- test elite sweetpotato germplasm in selected countries, with a focus on achieving rapid impact

Table 6. True potato seed families distributed to Regions, NARS, and other Institutions from late 1991 to 1992.

Country	Progenies	Seed	Attributes
1991			
Argentina	56	5,600	X,Y,RKN
Cameroon	36	1,800	X,Y,LB,E
China	139	33,700	X,Y,LB,E
Cuba	50	10,000	X,Y,EB
Ecuador	27	6,400	X,Y,LR,LB,EB
Egypt	65	6,400	X,Y
Kenya	11	1,100	BW,E
Nigeria	18	1,800	X,Y,LB,E
Pakistan	18	1,800	X,Y,LB,E
Peru (Huanuco)	20	4,000	X,Y,LB,E
Philippines	73	14,600	X,Y,BW,LB,E
Tunisia	65	6,500	X,Y
Turkey	65	6,500	X,Y
Uganda	6	600	BW
URSS	120	18,000	X,Y,LR,LB,E
Uruguay	25	5,000	X,Y,EB
Venezuela	30	3,000	X,Y,LB,P
Vietnam	20	4,000	LB,BW
Zaire	18	1,800	X,Y,LB,E
1992			
Argentina	41	8,200	X,Y,LR,E
Brazil	141	28,200	X,Y,LR,EB,E
Cuba	60	12,000	X,Y,LB,EB
Ethiopia	8	1,040	Y,LB
Israel	15	3,000	X,Y,LR
Malaysia	35	7,000	LB,P,E
Mauritius	31	6,200	X,Y,LR,E
Mexico	89	71,200	X,Y,LB
Peru (Tacna)	16	16,000	X,Y,LR,EB
Peru (UNA)	128	30,600	X,Y,LR,LB,BW
Philippines	73	14,600	X,Y,LR,BW,LB
Uruguay	65	13,000	X,Y,EB,E
Uruguay	48	9,600	X,Y,LR,E
Total	1,612	353,240	

BW = Bacterial wilt, E = Earliness, EB = Early blight,
LB = Late blight, LR = Potato leaf roll virus,
X = Potato virus X,
Y = Potato virus Y,
P = Processing quality,
RKN = Root-knot nematode

- support variety selection and dissemination efforts by national programs in selected countries
- analyze and report the results of international testing efforts

This project works closely with the Program 5 project on maintenance, distribution, and monitoring of advanced sweetpotato germplasm. Support of national variety selection and dissemination efforts is complemented by similar activities in CIP's project on sweetpotato product development, as reported in Program 6, and by the activities of SAPPRAD, PRAPACE, and ESARRN networks in Southeast Asia and sub-Saharan Africa.

Overview and Analysis of International Germplasm Testing

CIP uses a two-tier approach to distribute and evaluate the performance of elite sweetpotato germplasm. Germplasm is distributed free upon request, either as botanical seed families or as in vitro, pathogen-tested clones. However, at a few key locations—particularly in the major sweetpotato-producing countries of Asia and Africa—special efforts are made to introduce germplasm and to evaluate its adaptation to and potential for varietal selection in important agroecologies. Program 5 provides information on germplasm distribution by country.

Distribution of germplasm as botanical seed offers some advantages over distribution of clones. Botanical seed distribution allows many genotypes to be moved rapidly and relatively cheaply, and these may later be selected for adaptation to local conditions.

In an experiment in **Peru** (Table 7) sweetpotato clones obtained from introduced seed were tested to compare the relative strengths of elite germplasm from various sources. Six families (twenty clones per family) from breeding programs

Table 7. Mean performance of sweetpotato clones at four locations in Peru.

	Canete (summer)				San Ramon (dry season)			
	Yield[2]		DM[3]		Yield		DM	
Source[1]	R	F	(%)	n[4]	R	F	(%)	n
CHGU	685	1237	24.9	9	409	522	28.6	24
JPKY	799	1612	32.2	17	369	691	37.4	9
PERU	548	1923	27.5	9	213	735	35.6	7
RURB	688	2766	28.5	11	349	837	26.4	7
USSC	695	1141	23.7	47	274	587	29.1	30

	Yurimaguas (dry season)				Vitarte (winter)			
	Yield		DM		Yield		DM	
Source	R	F	(%)	n	R	F	(%)	n
CHGU	375	592	29.4	7	218	707	26.8	2
JPKY	450	877	36.7	19	157	1158	34.4	2
PERU	210	818	32.0	2	150	1178	34.3	3
RURB	350	1352	33.6	17	148	1372	31.0	4
USSC	253	551	28.7	27	109	662	26.6	10

[1] CHXU = Guangdong, China; JPKY = Kyushu, Japan; Peru = CIP-Lima; RURB = Rubona, Rwanda; USSC = South Carolina, USA.

[2] R = Root, F = Foliage, both in g/plant.

[3] Dry matter content of selected clones.

[4] Number of selections: 120 clones per source; 6 families of 20 clones each/source; 60-plant, single-row plots, with 3 cuttings per clone; randomized complete block design with 3 replications. Harvested at 120 days after planting.

in China, Japan, Rwanda, Peru (CIP), and the USA were compared at locations on the coast (Arid and Mediterranean agroecology) and the high and low jungle (Humid Tropics) of **Peru**. These findings suggest their potential contribution to breeding and variety selection programs elsewhere. At most locations, materials from Japan produced high root yields and dry matter content, and materials from Rwanda produced high foliage yields. More clones were selected from among the introductions from the USA than from any other source, despite relatively low overall yields and dry matter content, principally because these materials possessed the shapes and colors required for the Peruvian fresh market. Seed from the same sources has been distributed to a number of CIP regional and national programs worldwide.

The distribution of clones has some advantages over distribution from seed, in that some excellent varieties and progenitors have combinations of desirable characteristics that are superior to those of varieties that could be easily selected from segregating seed populations. Findings (principally root yields) from the initial testing of clones from CIP's pathogen-tested list are now available from some locations. Clones from IITA, (TIS-1487, TIS-3290, and TIS-8250), China (Yan Shu 1, Xushu 18), and North Carolina State University (NC 262) are showing consistent performance.

CIP plans to monitor and document the performance of all internationally distributed germplasm by 1995. Recommended evaluation procedures will be distributed with germplasm, and performance will be evaluated with written questionnaires and personal contacts. Training and related activities will be provided for national programs, in collaboration with networks, such as SAPPRAD and PRAPACE, and other groups involved in the international testing of sweetpotato germplasm, such as the Pacific Region Agricultural Project.

Selecting and Disseminating New Sweetpotato Varieties

New varieties released by partners in the developing world are also promoted and reported on by CIP. This assistance includes identifying important selection criteria and developing methods for regional and on-farm testing and freeing the varieties of pathogens. A participatory approach involving farmers is encouraged.

In **Peru,** CIP works with the Instituto Nacional de Investigación Agraria (INIA), local universities, and NGOs. Collaboration with INIA focuses on the Canete Valley, which is the principal commercial sweetpotato production zone supplying the Lima market. Promising introduced and CIP-bred materials are evaluated in on-station trials, and farmers are invited to participate in the harvest. Selected clones are then evaluated in multi-locational trials, both on-station and on-farm, during the summer and winter seasons. The variety Cañetano-INIA, selected by CIP's sweetpotato breeding program in 1988 from a polycross made at the Experimental Station of Tacna University, will be released in 1993. Collaboration in 1993 will emphasize the dissemination of promising germplasm and evaluation methods to NGOs and other cooperators.

In **India,** work is conducted in collaboration with the Central Tuber Crops Research Institute (CTCRI). The promising performance of the early, high yielding varieties Sri Vardhini and Kalmegh was reported last year. Table 8 shows findings from on-farm trials of five varieties at Sonepat and in the Banswara Tribal area in Rajasthan. Farmers evaluated clones for yield, marketability, taste, and quality of foliage for use as fodder. They preferred Sri Vardhini because of its suitability for home consumption and for marketing, and for the palatability of foliage for animal feed. Researchers found that such palatability was related to stem hairiness. This finding will facilitate the selection of dual-purpose varieties, suitable for both root and foliage use.

In **Indonesia,** SAPPRAD has given priority to multi-locational on-farm evaluation of promising clones when grown

Table 8. Performance of local cultivars in farmers' fields, 1991-92.

Cultivars	Yield t/ha[1]	Preferences of farmers for			Farmer's remarks
		Foliage	Marketability	Taste	
Kalmegh	13.1	Hairy	Good, but poor foliage	Semi-dry, good	Early and good yield, poor foliage
Sri Vardhini	11.6	Glossy	Very good tubers and foliage	Semi-dry, very good	Early, foliage very good for cattle
x-24	10.8	Glossy	Good, but flesh pigmented	Moist, flesh pigmented	Good yield, but pigmented flesh not liked by Indians
Kali-Satha	7.9	Glossy	Good/average	Semi-dry	Average yield & foliage
Mungia	4.6	Poor, less quantity	Good	Dry	Very dry, taste not liked

[1] Average from 5 plots.

after rice under rainfed paddy conditions in West and Central Java. Advanced clones initially selected at Kuningan were evaluated in trials at Kuningan, Bogor, Garut, and Salatiga in 1991-92. Indonesian researchers reported large genotype-by-environment interactions in these trials, with some advanced clones performing well at each location, but none performing well in all locations. A modified variety-selection scheme has been proposed to take advantage of local adaptation: farmers and traders will be involved in evaluation at earlier stages of the selection process and in selection of materials for target areas. National sweetpotato variety release regulations will be modified to facilitate this new scheme.

SAPPRAD-sponsored research in **Sri Lanka** identified several promising clones and farmers participated in evaluating varieties for taste and appearance. Most of the clones were judged to be marketable. Table 9 shows the mean dry-matter and production data for the combined trials. CARI-9 produced highest dry-matter levels, although fresh yields for this clone were relatively low. This clone shows potential for use in processing that involves drying or starch extraction. Both CARI-9 and CARI-426 were virus indexed as part of a SAPPRAD collaborative international testing initiative and are available at CIP for international distribution and testing.

Table 9. Mean root yields and dry matter content from multi-locational on-farm trials of advanced sweetpotato clones developed in Sri Lanka.

Clone	Root dry matter content (%)	Mean yield (t/ha)
CARI-426	24.5	26.9
CARI-273	34.9	15.9
CARI-9	39.6	15.0
CARI-242	30.1	12.6
CARI-P2	33.2	19.5
CARI-P3	32.5	17.6
CARI-644	30.4	11.9
Wariyapola (check)	32.6	11.9

Source: SAPPRAD-sponsored reseach conducted by Sri Lankan scientists.

Evaluation of Impact and Sustainability of Potato Production Technologies

CIP's comprehensive approach to impact assessment is highlighted in the preceding special section of this report (see page xxiii).

Training

An In-Country Workshop on Sweetpotatoes in the Food Systems of Tanzania, funded through the CIP/GTZ project, was held in Morogoro, **Tanzania**, in January. The objectives of the workshop were: (1) to develop a common set of goals and procedures for a baseline agroeconomic survey on sweetpotatoes in the farming and food system of Tanzania leading to a common methodology; (2) to collect and characterize the cultivars of landraces grown by farmers; and (3) to develop a budget and workplan for project activities. The workshop was hosted by the Crop Science Department of Sokoine Agricultural University, and it brought together 20 officers from the Root and Tuber and Farming Systems programs and research stations throughout the country. Staff from CIP and the Tanzania/Netherlands National Farming Systems Research Project participated as resource scientists.

Agronomists and social scientists associated with the three potato programs supported by the Swiss Development Cooperation in **Bolivia**, **Ecuador**, and **Peru** met in Cusco in March at an International

Course on Farm Participative Research (FPR). Participants include 8 from PROINPA in **Bolivia**, 7 from FORTIPAPA in **Ecuador**, and 12 from SEINPA in **Peru**. Two participants from PRECODEPA, the potato research network of **Central America**, **Mexico**, and the **Caribbean** also attended the course, which was moderated by a CIAT scientist. The objectives of the course were (1) to gain understanding and analyze the basic elements of farm participative research; (2) to evaluate methodological tools; (3) to analyze ongoing projects; (4) to develop approaches to institutionalize FPR in NARS of participating countries; and (5) to prepare participants to train others in their program on FPR.

A regional workshop on Socioeconomic Aspects of Potato and Sweetpotato Research: Interdisciplinary Experiences and Methods was organized by the PRAPACE network in **Uganda** in June. The workshop was designed to provide an overview of approaches and methods to bring farm-level information into the research process and was organized and managed by CIP's Regional Social Scientist in Nairobi. Arrangements in Uganda were coordinated by the National Potato Coordinator, with the assistance of the Ministry of Agriculture staff. Participants were social scientists and agronomists from the PRAPACE countries, **Burundi** (2), **Rwanda** (3), **Uganda** (5), **Zaire** (2) and five Ugandan observers from the Ministry of Agriculture and the University in Entebbe. The lectures were designed to introduce the participants to the concepts and procedures of interdisciplinary research. The participants gave brief presentations on areas of potential research in their countries. Group discussion in working groups focused on the development of hypothetical workplans. Field trips were organized to visit areas where sweetpotato is a traditional crop, and participants had an opportunity to practice informal interviewing techniques in farmers' fields.

■

1992 Research Projects and Partners

This list contains the titles of research projects, the names of principal partner researchers and their respective country, the responsible CIP scientist, and the names of collaborating researchers.

On-farm trials to introduce cultivars to improve potato production in Burundi and yield improvements through agronomic practices. Ch. Muvira, Z. Nzoyihera, ISABU, **Burundi**/D. Berríos; T. Walker

Estimating yield loss caused by potato late blight (*Phytophthora infestans*) and improving the utilization of horizontal resistance in tropical highland conditions. G. Forbes and J. Korva, **Ecuador**

Evaluation and utilization of potato germplasm for adaptation to warm climates. R. Muyco, MMSU, the **Philippines**/ E. Chujoy, H. Mendoza, A. Golmirzaie, P. Schmiediche

Adoptive strategies and potato varieties management. N. Bezençon, J. Recharte, PROINPA, **Bolivia**

Sweetpotato in African food systems. J. Kabira, A. Okech, **Kenya**, G. Ndamage, D. Tardif-Douglin **Rwanda**, R. Kapinga, S. Jeremiah, G. Ndunguru **Tanzania**; D. Nyongabo **Burundi**; R. Mwanga, C. Ocitti p'Oboya, B. Bashaasha,

Uganda/P.T. Ewell, M. Ngunjiri; T. Walker, S. Nganga, H.M. Kidane-Mariam, L. Skoglund, N. Smit

Sweetpotato in Asian food systems (UPWARD). Cooperating scientists throughout **Asia**/G. Prain

Socioeconomic studies on sweetpotato in **India**. T.K. Pal, K.R. Lakshmi, CTCRI, **India**/M.S. Jairth, M.D. Upadhya, T.R. Dayal; D. Horton, R. Rhoades

Potato Breeding in Chile to Increase Variability. Use of Conventional and Innovative Methods. J. Kalazich, INIA, **Chile**/P. Accatino; H. González, L. Salazar, J. Landeo, H. Mendoza

Combining disease resistances in a hybrid diploid potato population using conventional and non-conventional genetic techniques. W.W. Collins; M.J. Wannamaker, A. Weissinger, E. Echandi, R. Vallejo, P. Shoemaker, G. Kennedy, R. Moll, NCSU, USA

Adaptation and utilization of potato populations in breeding. H. Mendoza; W. Amoros **Peru**

Introduction and utilization of potato germplasm in North China. Cooperating national scientists, Guilin Wong, CAAS, **China**/Song Bofu; E. Chujoy

Sustainable potato production in Dominican Republic. MAG, **Dominican Rep.**/ F. Payton

Improvements of potato cropping patterns to extend the supply of fresh tubers through intercropping in Tunisia. B. Keheder, MINAGRI-ESH, **Tunisia**/ R.Cortbaoui, MENA

Introduction, screening, multiplication and redistribution of potato and sweetpotato germplasm. V.E. Demonteverde, NPRCRTC, Benguet U, the **Philippines**/ E. Chujoy; H. Mendoza, J. Bryan, I.G. Mok

Breeding for resistance to frost, wide adaptability and other major constraints of the highlands. J. Landeo, M. Gastelo, L. Calua **Peru**

Introduction, evaluation and multiplication of sweetpotato germplasm. Scientist at IRA, **Cameroon**, and NCRI, **Nigeria**/C. Martin; J. Koi, E. Carey, J. Bryan

Improvement of sweetpotato in Egypt. T. El-sheikh, N. Wanns, A. El-Amrity, S. Doss, A. El-Khodery, MA, **Egypt**/ R. El-Bedewy; W. Collins, E. Carey

Evaluation of sweetpotato clones in various environments in Peru. J. Molina and others, INIA, **Peru**/C. Fonseca, E. Carey

Evaluation and development of suitable sweetpotato germplasm for **east, central and southern Africa**. National Program Leaders/H.M. Kidane-Mariam; L. Skoglund, N. Smit, P. Ewell, E. Carey

Development of improved sweetpotato germplasm for warm and cool tropics of Southeast Asia. M.T.L. Gerpacio, D.M. Amalin and others, DOAs, **Asia**/E. Chujoy; E. Carey, H. Mendoza, L. Tandang, E. Badol, E. Orolfo, J. Bacusmo

Breeding sweetpotato populations having short duration and high stable yields for tropical and sub-tropical regions of **South Asia**. T.R. Dayal, SWA, **India**/ H.A. Mendoza, T. Carey

Development of sweetpotato germplasm for resistance to diseases and physiological stresses in **Southeast Asia**. Djazuli, Walyuo, Jusuf, Dimyati, **Indonesia**/I.G. Mok

Testing of advanced sweetpotato germplasm in China. Feng Zu-Xia, GAAS, **China**/Song Bofu; X. Chunsheng, H. Hongcheng, Ch. Yingdong

Breeding sweetpotato populations for tropical and subtropical regions of India. B. Vimla, S.K. Nasker, CTCRI, **India**/M.D. Upadhya, T.R. Dayal, SWA

Impact case studies. T. Walker, Song Bofu, A. Chilver, C. Crissman, P. Ewell, K. Fuglie, J. Landeo **Global**

TPS diffusion and use in Indonesia. R. Suherman, A. Koswara, D. Rachmanudin, LEHRI, **Indonesia**/ A.S. Chilver

Agricultural chemical use and sustainability of Andean potato production. J. Antle, S. Capalbo, Montana State U, **USA**/C. Crissman; J. Wagenet, D. Cole, F. Carpio, N. Leon

Health effects of pesticide use in Ecuadorian potato production. J. Antle, Montana State University, **USA**/ C. Crissman; F. Carpio, N. Leon, D. Cole, **Ecuador**

PROGRAM 2

Germplasm, Management and Enhancement

◆

Potato Germplasm Collection and Characterization

Collecting Endangered Wild Potato Species

A CIP expedition in the Department of Cajamarca in northern **Peru** collected a total of 73 accessions, comprising five wild potato species. Members of another expedition to the Olmos Desert in the Department of Lambayeque collected tubers from populations of *Solanum olmosense*. These collections were from plants that grew as a result of unusual rains caused by the El Niño effect in the Pacific Ocean.

Conservation of Potato Genetic Resources

The cultivated potato collection continues to be maintained in the field gene bank, as well as in vitro culture. In vitro tubers from 550 potato accessions are being evaluated to examine the effects of extending the interval between in vitro transfers, under long-term storage conditions. The in vitro thermotherapy method to clean potato cultivars of viruses also has been fully tested, standardized, and implemented. Using this method, 73 new clones in the collection have been added to the pathogen-tested collection.

CIP has assigned high priority to increasing the seed stocks of accessions in the wild potato collection. More than 800,000 seeds were produced with the collaboration of the University of Cusco and CIP's experiment stations at Huancayo and La Molina in **Peru** and at Quito, **Ecuador**.

Potatoes in the collection of native *S. tuberosum* subsp. *tuberosum* from **Chile** produce few flowers in the Peruvian highlands, where the collection is maintained. The Austral University at Valdivia, Chile, donated newly harvested seeds of 156 accessions from its potato collection.

Characterization of Potato Genetic Resources

For 2,212 accessions of the Andean cultivated potato collection grown in the field gene bank, additional data were recorded on characteristics of plant growth, leaf shape, degree of flowering, corolla shape, and pedicel pigmentation. Work continues on the identification of duplicates among accessions donated to the collection by national or private institutions. Of 653 accessions found to be duplicates, 142 are being converted to true seed. The remaining duplicates are from many cultivars that also are maintained in vitro; thus, the plants generated in the field will be compared with those generated from in vitro culture. This second comparison is to ensure exact duplicate identification and avoid genetic losses in the main collection due to mixtures of the different cultivars in the field.

Isozyme analyses of the enzymes Isocitric acid dehydrogenase (IDH), Phosphoglucoisomerase (PGI), Phosphoglucomutase (PGM), Malate dehydrogenase (MDH), Diaphorase (DIA), and Glutamate oxaloacetate transaminase (GOT) have continued, using 1,011 accessions of Andean potato cultivars of *Solanum tuberosum* subsp. *andigena* (ADG). The resolution and reproduction obtained with three other enzymes [Acotinase (ACO), 6Phosphogluconic acid dehydrogenase (6PGDH), and shikimic acid dehydrogenase (SDH)] was inadequate for use in the studies of genetic diversity in Andean potatoes.

Of 670 accessions that showed good resolution for all of the 6 isozymes analyzed, 304 showed banding patterns forming isozyme-alike groups of 2 to 9 accessions each. These groups showed identical banding patterns. Although these 304 cultivars are morphologically different, those within each group appear to be genetically similar for the isozymes studied. Most accessions of these groups were collected in the same geographical region; however, about 30% of the isozyme-alike groups consisted of cultivars collected in geographically distant localities (even in different countries). These findings are being used for selecting a core collection of Andean potato cultivars.

A total of 178 accessions of cultivars of *S. stenotomum* (STN) were compared for the same isoenzymes used with ADG. A comparison of the results obtained in ADG and STN showed that for PGI-1, 10 accessions of STN had a second homozygous band which had not been found in ADG. For PGM-1, of four homozygous bands found in ADG, only one band was found in STN. On the other hand, four new heterozygous banding patterns were found in STN. In MDH-1, the heterozygosity was higher in STN than in ADG. These studies generally support previous findings that the heterozygosity in STN is lower than that of ADG. These two cultivated species also were found to share a large number of banding patterns, indicating that they are closely related.

Tubers of 215 accessions of 42 different wild potato species were screened for resistance to potato tuber moth (PTM). The tubers were stored for four months in a highly infested environment. Preliminary findings indicate that 21% of the species showed some resistance and 71% showed moderate resistance.

A total of 14 clones from the potato collection of native *S. tuberosum* subsp. *tuberosum* maintained by the Austral University in Valdivia, **Chile,** were shown to have high yield potential under conditions of water stress and low levels of soil nutrients.

Distribution of Potato Genetic Resources

Wild potato germplasm was distributed to 7 countries, including 8,050 seeds of 179 accessions of 44 different species.

The potato collection maintained at CIP was used to replace germplasm lost in national or institutional collections. One hundred and five different potato cultivars were returned to the University of Ayacucho to replace lost accessions. This University donated its potato collection to CIP in 1982.

Cultivated Andean potato germplasm was distributed to 18 countries and included 524 pathogen-tested tubers of 69 accessions; 278 in vitro plantlets of 120 accessions, and 2,890 seeds of 61 accessions.

Collaboration Among International Gene Banks

In a joint expedition in Arizona and New Mexico in the **USA,** USDA and CIP gene bank staff collected 32 accessions of wild potatoes. Of these, 22 were classified as *S. fendleri* and 10 as *S. jamesii.* The seed obtained will be used at the USA gene bank to assess changes in genetic diversity between these natural populations and those collected at the same site and maintained ex situ for several decades.

Representatives from the potato gene banks at Braunschweig (**Germany**), Sturgeon Bay (Wisconsin, **USA**), and CIP met for the third time in June 1992. Work continues on the development of an "Intergene Bank Potato Data Base." Final arrangements have been made to produce a common data base, with all the passport data of living materials conserved in these gene banks. Common standards also were established to record evaluation data on potato gene banks. The evaluation data bases will be merged on the basis of collector number, to compare the data obtained when the same accession is subjected to the same biotic stress in different gene banks. The USA gene bank will also collaborate to increase the seed of several wild potato accessions from CIP.

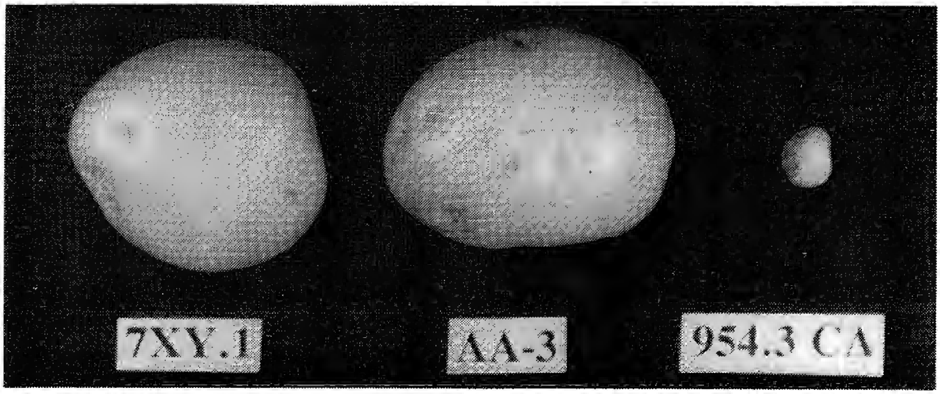
Potato Germplasm Enhancement and Application of Molecular Technology

Exploitation of Wild *Solanum* Genetic Resources Towards Germplasm Enhancement

Fifteen accessions of the wild species *S. bukasovii, S. infundibuliforme,* and *S. pampasense* were inoculated with CIP isolate 204 of *Pseudomonas solanacearum* race 3. Fifty plants of each accession were inoculated at the seedling stage, and preliminary selections were made. These selected clones were examined for latent infection and 90 clones were selected as resistant to *Pseudomonas solanacearum*. The selected clones are being kept in vitro for further evaluation and use, and also to provide for germplasm requests. Some of these clones were crossed with diploid breeding lines and several 2× × 2× true seed families were obtained.

Cytogenic studies to increase the utilization of the disomic tetraploid species *S. acaule* were continued. F1 hybrids between *S. acaule* and 4× *tuberosum* were evaluated in the field in San Ramon for adaptation to sub-tropical conditions. In a sample group of 52 clones, at least 2 showed resistance to bacterial wilt. These selected F1 hybrids were backcrossed to *S. tuberosum* (introgression lines) (Fig. 1). The F1 hybrids and the introgression lines were cytologically evaluated to estimate the percentage of chromosome recombination and further possibilities of gene transfer from *S. acaule* to the cultivated potatoes. The results of cytological analyses in the F1 hybrids predicted the presence of aneuploids in the introgression lines. These aneuploid lines also showed unusual meiotic behavior. These characteristics suggest a special potential for chromosome recombination between the *S. acaule* and cultivated potato genomes. *S. acaule* has resistance to potato leafroll virus (PLRV), potato virus Y (PVY), root-knot nematode (RKN), and PTM; thus these findings point to new opportunities to exploit these sources of resistance. The systematic enhancement methods on *S. acaule* will be applied to

Figure 1. Appearance of tubers of an *S. tuberosum* × *S. acaule* 4× F1 hybrid. 7XY.1, 4× *S. tuberosum;* AA-3, the F1 hybrid; 954.3 CA, 4× *S. acaule.*



other disomic tetraploid species, such as *S. stoloniferum*, which have high levels of resistances such as late blight and PLRV.

Another research area to further exploit the breeding potential of wild potatoes included the non-tuber-bearing species *S. brevidens, S. etuberosum,* and *S. fernandezianum.*

Potential hybrids between cultivated potatoes and these non-tuber-bearing *Solanum* species with resistances to potato leafroll virus and soft rot were field evaluated at Lima, **Peru**, for tuberization, general appearance, and reproductive characters. A group of 59 potential 2× F1 hybrids between *S. brevidens* and cultivated diploid breeding lines consisted of three halfsib families that shared *S. brevidens* as pollinator. The pollen fertility of these potential hybrids ranged from 0% to 90%. Genomic deoxyribonucleic acid (DNA) was isolated from these potential hybrids to test the hybridity. Using species-specific probes from *S. brevidens,* four hybrids were identified, and further molecular characterization is under way. Additional groups of potential F1 hybrids derived from *S. etuberosum* and *S. fernandezianum* were also evaluated under screenhouse conditions to compare morphological and reproductive characteristics. Further confirmation tests will be made using molecular and resistance markers.

Germplasm Enhancement of Diploids

Introgression of useful multigenes to incorporate durable resistance to late blight from diploid resistant potato genetic resources has begun. Numerous crosses of pollen-sterile cultivated dihaploids have been attempted with 20 accessions of wild species not previously used in potato breeding. Evaluations are being made of hybrids identified in difficult inter-specific cross combinations. The best-performing hybrids will be selected for high resistance and production of unreduced gametes, and then will be made tetraploid to provide novel germplasm for breeding of late blight-resistant varieties.

A diploid population, which consists of 30 clonal families (Group 90), was simultaneously evaluated for reaction to potato tuber moth (PTM), bacterial wilt (BW), root-knot nematode (RKN), agronomic traits, and reproductive ability. Selected material included 12 clones with resistance to PTM, 96 with resistance to BW (race 1), 3 with resistance to latent infection of BW, and 17 clones with resistance to RKN. Selection was also based on the crossability with tetraploid breeding stocks; 65 clones were selected for further characterization and utilization for resistance transfer. These diploid clones have new genetic backgrounds including *S. bukasovii, S. infundibuliforme,* and breeding lines from European institutions.

Studies of transmission of resistances from diploid to tetraploid clones were made, comparing glandular trichome properties or analyzing the resistances to potato tuber moth, bacterial wilt, and/or root-knot nematode. Among the selected material made in the 4× × 2× clonal families (Group 91), 8 clones were resistant to PTM, 27 to BW, 1 to latent infection of BW, and 56 clones had resistance to RKN. Resistance levels, as well as field characteristics were evaluated for selected 4× clones, to obtain a better understanding of the transmission of characters from 2× to 4×, and to generate resistant genetic stocks which can be tested as potential varieties. Simultaneously, researchers at ENEA-Cassaccia began research to obtain 4× potato germplasm with glandular trichome properties and Colorado potato beetle (CPB) resistances. Trichome sources were derived from Cornell University breeding germplasm.

A new set of diploid families (Group 91 and Group 92) and 4× × 2× families (Group 92) has been generated, which have potential for use of their glandular trichome, virus, late blight and insect resistances. These seedling families are being evaluated in Lima, Peru, and the clonal families will be further evaluated for utilization in NARS systems.

True seeds from 4× × 2× and 2× × 2× crosses were exported to national breeding programs (Instituto Nacional de Tecnología Agropecuaria (INTA)-Balcarce, **Argentina**; Instituto Nacional de Investigaciones Agropecuarias (INIA)-Osorno, **Chile**; Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA, **Brazil**), where they will be used in breeding programs to reinforce their genetic background and improve the level of resistances.

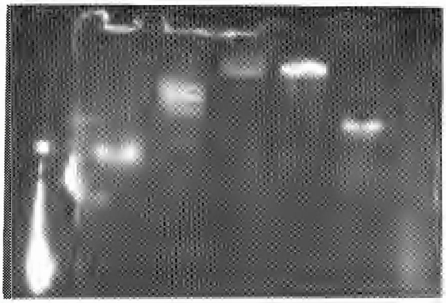
At Cornell University, USA, several somaclones derived from diploid hybrids between haploids of *S. tuberosum* and *S. berthaultii* (which confer glandular trichomes) were tested to cross with tetraploid potatoes. The seeds obtained will be used to study how trichome characters can be transmitted from somaclones. Germplasm enhancement with these diploid somaclones was also attempted, and crosses were made to generate diploid families. Twelve diploid/haploid selected genetic clones have been cleaned of virus and other pathogens, and are available upon request.

Development of Genetic Maps and Use of Molecular Markers

Parental lines for mapping BW, PTM, and RKN resistance loci were surveyed, using a total of 144 markers (Genomic DNA; GP [PstI size-selected potato genomic fragments] and TG [derived from PstI or EcoRI size-selected tomato genomic fragments] probes: complementary deoxyribonucleic acid (cDNA); CP [derived from total mRNA of potato], CD [derived from total mRNA from tomato leaves], and CT [derived from mRNA from tomato epidermal tissue] probes). A total of 67 markers showed mappable polymorphisms. Thus, an average of four markers per potato chromosome (between 10 to 20 cM apart) are available for mapping. In addition, the technology of labeling probes was modified to be better adopted by NARS (national agricultural research systems). Non-radioactive labeling of markers is currently being introduced into hybridization protocols for potato mapping work (Fig. 2).

Due to the presumed high heterozygosity of clonally propagated crops, mapping activities were begun at the F1 level. From the above population, 120 F1 clones were selected for gene mapping. The mapping strategy is based on information from the tomato map, which has high homology in marker alignment with the potato map. Of the 120 F1 clones, 36 were evaluated for bacterial wilt resistance. Segregation was observed by using CIP isolate 204 of race 3 of *Pseudomonas solanacearum*.

Figure 2. Hybridization signals with a non-radio-active labelled RFLP probe. Five 2× potato genotypes were used for the survey.



Additional clones are now being evaluated. We also evaluated PTM resistance in 34 clones of this F1 population; 17 possibly adds were found to be resistant, 10 moderately resistant, and 7 susceptible. Of 22 clones of this F1 population evaluated for RKN resistance, 2 were found to be resistant, 10 moderately resistant, and 10 susceptible.

Characterization of the restriction fragment length polymorphism (RFLP) map continues in collaboration with Cornell University, USA. The main objectives are to: 1) saturate the potato map with RFLP and randomly amplified polymorphic (RAPD) markers; and 2) locate genes in the map that confer resistance to major potato constraints. Characterizations have been made of the chromosomal regions that are responsible for glandular trichome properties and for Colorado potato beetle (CPB) resistances. These characters are thought to be controlled by quantitative trait loci. Two 2× backcrosses were used: 1) a backcross to haploid *tuberosum* (158 clones); and 2) a backcross to 2× *S. berthaultii* (155 clones). Based on the two BC1 populations, the chromosomal regions that are responsible for the traits were tentatively identified. Type A trichome properties were mapped on 3 chromosomal regions on 3 independent chromosomes; Type B trichome properties were mapped on 9 chromosomal regions on 8 independent chromosomes; and CPB resistances were located in 3 chromosomal regions in 3 independent chromosomes. Using the map information, ideal chromosomal genotypes were first selected from the BC1 *tuberosum* population (Fig. 3). Additional studies are now underway to characterize the chromosomal regions, by locating more markers that are adjacent to the target loci. These findings will eventually lead to the application of the marker information to tetraploid breeding stocks.

Molecular markers are also helpful for the characterization of germplasm collections. RAPD markers were used to characterize CIP potato germplasm, and preliminary evaluations indicate detectable and usable levels of polymorphisms among cultivated potato germplasm (Fig. 4). These RAPD markers will be used to identify genetic variation in the potato germplasm, so that appropriate genetic diversity can be maintained in the breeding population.

RAPD markers also are used to identify species-specific signals to monitor introgression from wild species to the cultivated potato gene pool. This work is in

Figure 3. A graphic representation of four ideal genotypes whose chromosomal regions contain the target genes for glandular trichome properties. The selection was made based on RFLP data. Dark regions are from wild species, *S. berthaultii*, and white regions from cultivated potatoes. Lines outlining the chromosomes indicate the regions related to the target genes.

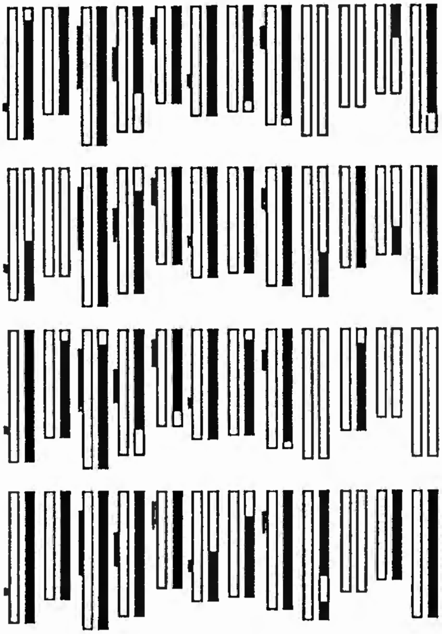
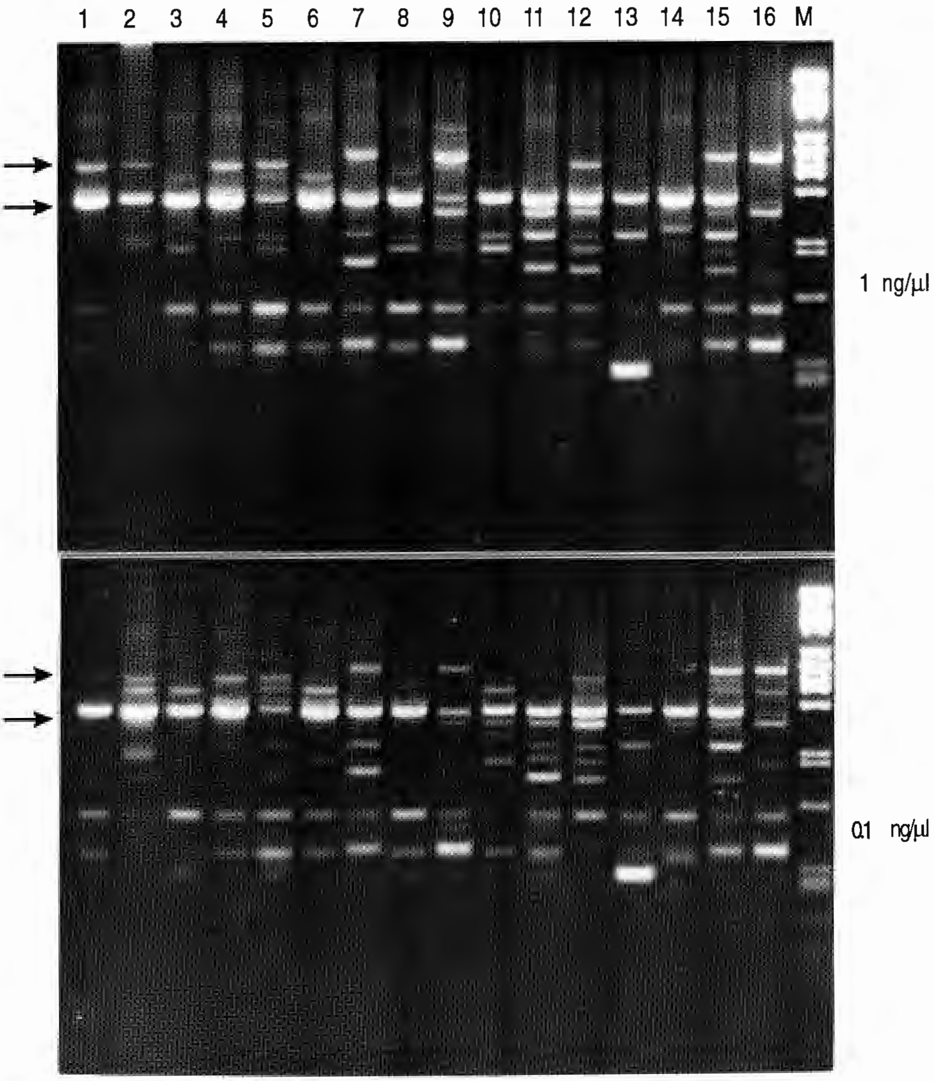


Figure 4. Banding patterns of amplified products with a primer 5'-CACCGATCC-3'. Under two template DNA concentrations, constantly observed bands are dealt with as Phylogenetic markers (Arrows). M = PstI digest of lambda DNA. #1-16 are from various accessions of cultivated potato species from the CIP collection.



collaboration with the University of Washington-Seattle and USDA at Prosser, Washington, USA. The research goal is to identify RAPD markers that could be linked with resistances to late blight and Colombian RKN. These resistances are derived from 2× Mexican wild species *S. bulbocastanum* via protoplast fusion with cultivated potatoes.

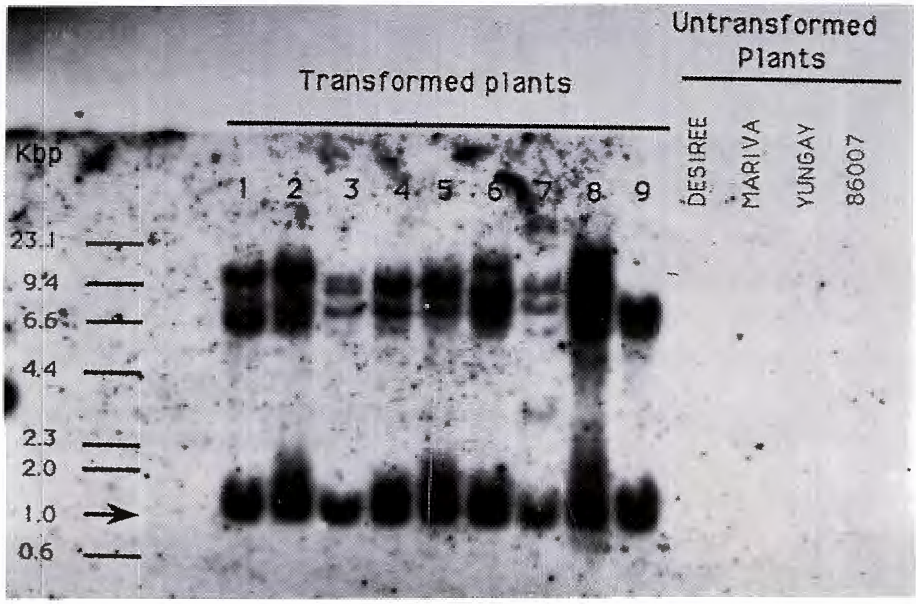
Genetic Engineering with Various Gene Constructs to Improve Potato Cultivars

Several categories of transgenic plants were obtained in 1991-1992 with: 1) antibacterial genes; 2) antiviral genes (especially on coat protein constructs); and 3) the *Bacillus thuringiensis (Bt)* toxic gene for insect resistance.

This transformation work focused on integrating lytic peptide genes to control bacterial diseases, primarily bacterial wilt caused by *Pseudomonas solanacearum*. *Agrobacterium rhizogenes*-mediated transformation was used with the binary vector pBI121 bearing the antibacterial gene (cecropin, attacin, or chicken lysozyme) flanked by a selectable marker gene for Kanamycin resistance and a reporter gene coding for ß-glucuronidase (GUS) which allows an in situ blue-staining of transformed tissues. Kanamycin resistance, GUS-staining, and southern blotting led to the identification of 70 transgenic lines from 4× potato genotypes (Fig. 5).

Using the same set of antibacterial genes, the cultivar Desirée was transformed to obtain resistance to soft rot caused by *Erwinia* spp. Both *A. tumefaciens* and *A. rhizogenes* transformation systems were used for the soft rot resistance experiment in collaboration with the Universidad Católica and INIA in **Chile**. Regenerated plants were tested for the presence of the Kanamycin resistance and GUS genes.

Figure 5. Southern blotting hybridization of DNAs from transgenic plants using the antibacterial gene constructs as a probe. The hybridization signals demonstrate the presence of the antibacterial gene construct in the transgenic plants.



Transgenic Desirée plants were tested for fungal resistance in collaboration with the University of Tuscia, **Italy**. The objective of this work is to better control late blight caused by the fungus *Phytophthora infestans* since the lytic peptides have shown in vitro an antifungal activity. Pathotype 373, which has virulent genes 1, 3, 4, 5, 7, 8, 10, and 11, and pathotype 0 (which does not have virulent genes), were used to challenge the fungal resistance of the transgenic plants. The observed level of resistance was regarded as field-type resistance, rather than vertical-type resistance. In general, the lytic peptide genes did not confer to the transgenic plants a significant inhibition of the rate of lesion expansion with both pathotype strains presumably due to a low level of lytic peptide accumulation.

Virus resistance was engineered in potato using the well-established coat protein-mediated resistance approach. The coat protein gene of PLRV was transferred to 4× potato variety Bintje via the *A. tumefaciens* (4404) transformation system and the binary vector pGA470. Sixteen transgenic plantlets have been identified by selection for Kanamycin resistance and southern blotting analysis.

The regeneration ability of six diploid potato genotypes was optimized, and these were then used for transformation with coat protein gene constructs to study the mechanism of integration of foreign genes into potato chromosomes.

To enhance insect resistance in potato, five potato genotypes were transformed via *A. tumefaciens* (C58C1) and the binary vector pGV2260, which contains the *Bt-2* gene (*CryIA(b)6*). The CAMV 35s promoter drives the expression of both the insect resistance gene and the selectable marker gene for Kanamycin resistance. This work is based on a collaborative research project with Plant Genetic Systems (PGS), **Belgium**. The tetraploid potato genotypes were Spunta, LT-8, Sangema, Perricholi, and Cruza 148. All genotypes showed calli formation, while only Spunta and LT-8 indicated adventitious shoot formation. Regenerated plants will be tested by the enzyme-linked immunosorbent assay (ELISA), as well as by southern blotting. A new *Bt* gene was isolated from *Bacillus thuringiensis* subsp. *Khurstaki* and cloned in the BamHI/SalI site of the pBinAR vector plasmid, and then transferred into strain 4404 of *A. tumefaciens* and strain R1000 of *A. rhizogenes* for further transformation with other potato varieties.

Understanding the molecular mechanism of the cold-hardening process is an important aspect of cold/frost tolerance. Diploid *S. commersonii* has a high level of cold/frost tolerance, and young seedlings of this species were used to generate a cDNA library that includes genes for acclimation to cold-hardening. Research will focus on the identification and isolation of these genes, which are potentially important to improve cold and frost tolerance of potato.

Sweetpotato Collection and Characterization

Collection

In six collecting trips to Latin America and the Caribbean: **Paraguay** (1), **Ecuador** (1), **Cuba** (1), **Mexico** (1), and **Peru** (2), a total of 205 cultivated and wild sweetpotato accessions were collected in 156 locations (Table 1).

In Indonesia, a team from Cenderawasih University, UPWARD, and CIP conducted two collecting expeditions in Irian Jaya, a secondary center of diversity. Sixty accessions of cultivated germplasm were collected at the Anggi Lakes in western Irian Jaya and 450 cultivated accessions were collected in the Balien Valley in eastern Irian Jaya.

A total of 119 sweetpotato germplasm accessions were collected in the form of storage roots or vines from 23 districts in **Bangladesh.**

Table 1. Collection of sweetpotato genetic resources by country.

	Area explored		Type of material collected		
Country	Department	Localities	Cultivated	Wild	Total
Paraguay	5	46	51	23	74
Ecuador	5	17	10	7	17
Cuba	5	81	-	81	81
Peru	2	121	28	3	31
Mexico	1	1	-	2	2
Total	18	156	89	116	205

Taxonomic Identification

Twenty-four wild accessions from recent collecting expeditions were classified as four species of section *Batatas* and ten accessions were found to belong to seven other species of *Ipomoea*, which are not included in section *Batatas*. Of particular interest was the identification of 10 accessions of tetraploid (4×) *I. batatas*, collected in the wild in **Ecuador**, which had probably escaped from cultivation (feral plants).

Maintenance

In 1992, the sweetpotato collection increased with the addition of 813 cultivated accessions. From these 813, 23 were obtained from new collecting activities in **Peru**. Other accessions were donated or re-introduced from material that had been obtained from collaborating NARS; these included 98 from **Paraguay**, 70 from **Argentina**, and 9 from **Saint Vincent**. Additionally, 613 in vitro accessions were received from the sweetpotato collection of the Asian Vegetable Research and Development Center (AVRDC) in **Taiwan**. A duplicate set of 1,224 accessions of the sweetpotato collection was sent to the Instituto Internacional de Estudios Avanzados (IDEA) in **Venezuela**. This is a backup collection maintained for security.

In **Argentina**, 105 accessions have been transferred to in vitro culture and sent to the Instituto de Fitovirología y Fisiología Vegetal de Córdoba for sanitary evaluation, particularly for the presence of sweetpotato feathery mottle virus (SPFMV).

Approximately 110,000 seeds were generated by seed increase of 238 accessions of 11 species of section *Batatas* and six species of other sections.

More than 16,000 seeds were obtained from polycrosses among cultivated accessions having abundant pubescence, high levels of dry-matter content, and white flesh color.

A total of 7,157 seeds were obtained from intraspecific crosses of *I. leucantha*, *I. tiliacea*, *I. trifida*, and *I. triloba* of section *Batatas*. Another 1,702 seeds were obtained from interspecific crosses of 11 hybrid combinations involving the above species as well as *I. cordato-triloba*, *I. cynanchifolia*, *I. grandifolia*, and *I. ramosissima* of section *Batatas*.

Characterization

Morphological characterization of 1,458 accessions of Peruvian sweetpotato cultivars identified 215 potential duplicates. In addition, 76 duplicates were found within the 978 accessions from 10 countries of Latin America and the Caribbean, which are maintained in the quarantine screenhouse.

Sweetpotato accessions collected by CIP-NARS expeditions have been further characterized. A sweetpotato collection of 54 accessions was characterized in **Saint Vincent**, in collaboration with the

Caribbean Agricultural Research and Development Institute (CARDI) in **Trinidad**; no obvious duplicates were found. In the collection maintained at the Bodles Experimental Station in **Jamaica**, seven duplicate accessions were found among 74 characterized. More detailed morphological comparisons are needed to confirm remaining duplicates.

In Caacupe, **Paraguay**, 71 accessions maintained at the Instituto Agronómico Nacional (IAN) were characterized for leaf and vine characters; potential duplicates were identified but additional data from the storage roots will be obtained. In collaboration with INTA in **Argentina**, data for leaf, vine, and storage root characters were recorded in 320 accessions at the station in El Colorado, Formosa. In **Mexico**, additional data on storage root characters was recorded at the Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP) station at Cotaxtla, Veracruz. In the **Dominican Republic**, 32 duplicates were identified within the collection of 191 accessions maintained by the Centro Sur de Desarrollo Agropecuario (CESDA) at San Cristobal.

Evaluation

Screening has continued to identify sources of resistance to race 3 of *Meloidogyne incognita* that causes roo-knot nematode and deforms the root. Evaluation was made on a total of 446 accessions from 17 countries which are maintained in the quarantine screenhouse. Three resistant and eight moderately resistant cultivars were identified during 1992.

In re-evaluations of 3 Peruvian cultivars reported as resistant to *Fusarium oxysporum* (Fusarium rot, is a brown, dry rot restricted to the cortex) last year, accessions DLP 1139 and RCB IN-95 were confirmed as resistant, whereas DLP 144 showed only moderate resistance. Another set of 101 accessions was evaluated for resistance to *F. oxysporum* and *F. solani.* Fourteen cultivars showed resistance to both pathogens. Of another 186 accessions that were screened for their reaction to *Diplodia gossypina* (in java black rot, the root desiccates and becomes very hard), and only one showed resistance.

Several sweetpotato collections maintained by the NARS have been evaluated for agronomic traits. In **Saint Vincent**, 54 accessions were evaluated for yield potential and dry matter content. Cultivars Rasta, Rhode Vine, Barbados, Six Weeks White, Red Sauce, Lover's Name, Black Vine, White Vine, Mandela, and F 84-7 were selected with yields ranging from 9.75 to 29.25 t/ha and dry matter content from 29 to 39%.

In **Jamaica**, most of the 74 accessions evaluated were very late maturing. Thus, 170 days after planting, 27 accessions had no storage roots, 26 had very low yield, and only 21 had yields ranging from 5.7 to 30 t/ha. Some foreign introductions (TIS-5125, Jewel, TIS 1498, and UWI-2) outyielded the local accessions. The best local cultivars were Bready, Manchester Hawk, V. White, Three Weeks, C. Kelly II, and Six Weeks, which had yields ranging from 12 to 16 t/ha.

In the **Dominican Republic**, 191 accessions were evaluated for yield potential and tolerance to weevil (*Cylas formicarius*). The cultivars Haitianita, EAS-20A, Violaceo de Puerto Rico, Ile, and Pie de Gallina had yields between 20 and 25 t/ha. Scant weevil damage was found on about 15% of the storage roots. The clone 10-C-1 had the highest yield (32 t/ha) and showed almost no weevil damage; but, unfortunately, it produced deformed storage roots with deep grooves. CESDA 63 and Tela de Cebolla cultivars showed good weevil resistance, but yielded only about 6 t/ha at 180 days.

In **China**, 4,919 accessions held in XSPRC (Xuzhou Sweet Potato Research Center) and the Guandong Academy of Agricultural Sciences (GAAS) have been evaluated since 1989 for five diseases: black rot (BR), root rot (RR), stem nematode (SN), bacterial wilt (BW), and stem rot (SR); and for one pest, sweetpotato weevil (SPW). About 300 accessions with high disease and pest resistance (27 for BR, 26 for RR, 117 for SN, 73 for BW, 50 for SR, and 8 for SPW) have been selected. Thirty accessions with combined resistance to two or more diseases also have been identified. Additionally, 160 varieties have been evaluated for tolerance to drought and waterlogging, under artificial conditions. Data were recorded on fresh root yield at harvest, along with other indices such as weight of stem and leaf, dry root weight five days after transplanting, leaf area, growth speed of top stem, and waterholding ratio of detached leaves. Forty-eight clones showed high tolerance to both drought and waterlogging. Forty-five out of 260 varieties showed high salt tolerance, based on root yield and vine weight at harvest. In a laboratory test applying 0.8% NaCl concentration to cuttings, 19 out of 180 varieties were selected as having high salt tolerance on the basis of root formation, i.e., root number, root weight, speed of root growth, and survival percent of node. Carotene content analysis of 47 varieties with yellow or orange flesh color showed a range of 0.02 to 20.81 mg/100 g fresh root.

In **Bangladesh**, 172 of 251 local accessions evaluated in single plots showed yields higher than the national average of 10 t/ha. About 10% of these clones yielded between 25 and over 30 t/ha.

In Vitro Maintenance

The in vitro collection consists of 3,745 accessions; 1,742 collected by CIP, 1,073 from the International Institute of Tropical Agriculture (IITA) and 930 from AVRDC.

During 1992, 128 new clones were cleaned up and a total of 218 pathogen-tested clones are now available for distribution. For security, the in vitro sweetpotato collection has been partially duplicated in Venezuela.

Distribution

Genetic materials from CIP's collection were distributed to NARS in Peru, and CIP researchers worldwide, including 1,852 stem cuttings and 1,324 storage roots from 412 accessions. In addition, 2,100 seeds of 135 accessions of wild *Ipomoea* species were distributed to researchers in seven countries.

CIP's sweetpotato collection has again been useful in restoring germplasm lost in national or institutional collections. In 1992, 186 different cultivars were returned to the University of Ayacucho to restore its collection, severely affected by natural and man-made disasters. The 186 cultivars represent 300 accessions that the University donated to CIP in 1985.

Sweetpotato Germplasm and Molecular Techniques

To address specific regional and agroecological needs for sweetpotato improvement, and to facilitate interdisciplinary collaboration, CIP's sweetpotato breeding activities are decentralized across CIP programs and regions. Work in this project includes germplasm enhancement and population improvement using the cultivated species and wild relatives and the application of molecular techniques to sweetpotato breeding.

Germplasm Enhancement and Population Improvement of Sweetpotato Cultivated Species

This project is CIP's principal source of new genetic materials for international distribution and testing, both as seed and as clones. Populations with combinations of characteristics are developed at key locations, using locally adapted germplasm and materials from various sources, including other CIP programs and programs in developing and developed countries.

Much of the population development work has been done at CIP headquarters in **Peru**, with some activities conducted at regional locations. During 1992, subprojects in Peru focused on selection of improved populations with adaptation to the mid-elevation highlands, the humid tropics, and the arid coast. They produced improved genetic materials for export, principally as botanical seed. Several early, high yielding clones, tolerant to soil salinity, and with adaptation to the agroecologies available in Peru have been cleaned up in recent years, and are available for international distribution.

CIP's recent strategic and medium-term planning activities have led to increased decentralization of population improvement activities, allowing for better response to regional differences in the importance of the crop and the distribution of major diseases and pests. Table 2 shows key locations and agroecologies for population development, and the relative importance of biotic stresses at each location.

Except for **Peru**, the countries or regions selected for breeding are in important sweetpotato production regions, and represent the principal agroecologies in each region (Table 2). Peru is CIP's principal location for development of materials adapted to the arid agroecology (Peru's coast) and also provides highland and humid tropical environments for the initial screening of native germplasm.

The decentralized approach allows selection for resistances to important abiotic constraints such as drought, excess moisture, heat, cold, and soil factors, including salinity, low fertility, and acidity, which vary by agroecology. Agronomic and quality traits of importance, such as plant growth habit, and root dry matter content also may vary by region. However, some traits, such as earliness and high root dry matter content are desired by practically all farmers, whenever the crop is grown.

Utilization of Wild Species

The wild relatives of sweetpotato are a potentially valuable source of traits that are not readily available in the primary gene pool of the cultivated species. The limited use of wild relatives in sweetpotato breeding (principally in **Japan** and **China**) has provided new sources of disease and nematode resistance in commercial varieties, and may have contributed to increased yields. CIP's collection of wild relatives represents a large stock of newly collected materials to be evaluated.

The evaluation and use of wild species for sweetpotato improvement presents a number of challenges. First, most of the wild relatives do not cross readily with the cultivated species, due to differences in ploidy level and other incompatibilities. Most are diploid (2×) or tetraploid (4×), while the cultivated species is hexaploid (6×). Second, most wild relatives do not produce storage roots. Thus, to evaluate storage root characteristics. The wild species are crossed into a cultivated or intermediate background species capable of permitting storage root production, then the progenies are evaluated.

Earlier work in this project has focused on the development of 4× tester

Table 2. Principal breeding locations and agroecologies for sweetpotato development populations, and the relative importance of some major diseases and pests at each location.[1]

Breeding Locations:	China		East Africa		Indonesia	Peru
Agroecology:	Subtropical Lowlands	Temperate	Highlands	Semiarid Tropics	Humid Tropics	Arid and Mediterranean
Regional share (%) of agroecology[2]	96.8	98.0	74.2	56.1	88.5	7.0
Total global share (%) of production by agroecology	61.5	21.7	2.1	5.1	3.9	5.7
Total global share (%) excluding China	14.0	3.2	14.8	36.6	28.0	3.4
Weevils						
Cylas formicarius	**			*	***	
Cylas puncticollis			**	***		
Cylas brunneus			**	***		
Nematodes						
Meloidogyne spp.	**	**	*		**	**
Ditylenchus destructor	**	***				
Fungal diseases						
Elsinoe batatas					**	
Ceratocystis fimbriata	**	***				
Fusarium solani	**	**				
Alternaria sp.			**	**		
Virus diseases						
SPFMV	**	**	**	**	**	**
Complex			***	***		

[1] Number of asterisks indicates the relative severity of each stress across agroecoregions

[2] Proportion (%) of total agroecology accounted for by regional production.

genotypes (hybrids between 6× sweetpotato and 2× *Ipomoea trifida*), which produce storage roots, and which might cross relatively easily with wild relatives. Progeny from these crosses could then be evaluated for storage root characteristics, and could also serve as bridges for introgression of selected traits to the cultivated species.

During 1991 and 1992, crosses were made between the 4× tester genotypes and 2× accessions of *I. leucantha* (LCA), *I. triloba*, *I. ramosissima* (RMS), and *I. tenuissima* (TEN). These crosses produced seed only when the 2× wild species were used as females (number of seeds per cross varied from 0.05 to 0.25, depending on species, 2× accession and 4× tester genotype). Seedlings from these crosses looked like their female parents, and chromosome counts revealed that they were diploid. Thus the seeds from these crosses were not the result of interspecific hybridization, but were probably due to parthenocarpy. Strong incompatibility systems appear to operate in the species evaluated, preventing direct hybridization with the tester clones.

A further effort was made to cross *I. leucantha*, *I. ramosissima*, *I. tenuissima*, and *I. cordato-triloba* (CDT) with the 4× tester genotypes. These diploid (2×) species were previously crossed with 2× *I. trifida* (TRF), and then the 2× wild interspecific hybrids were used as males in crosses with the 4× tester genotypes. Seed was produced from only those crosses where *I. trifida* (TRF) had been used as the female parent of the 2× wild interspecific hybrid (Table 3). Even for these crosses, some of the seed (e.g., hybrids involving *I. tenuissima*) were not successful. Seedlings from these crosses were intermediate in appearance to their parents, indicating that they were probably true interspecific hybrids. Chromosome counts and evaluations of pollen stainability indicate that these individuals are triploids and produce a small amount of viable 2n pollen. The ability of these genotypes to produce storage roots is being evaluated. The clones are also being used directly (or following colchicine doubling) in crosses with sweetpotato to attempt to introgress genes from *I. leucantha*, *I. ramosissima* and *I. trifida* to the cultivated gene pool at the hexaploid level, where they may be evaluated for characteristics of potential value.

These findings indicate that *I. trifida* may be used as a bridge species for the introgression of germplasm from wild relatives to sweetpotato, and should facilitate large-scale evaluation and use of wild relatives of sweetpotato in breeding.

Application of Molecular Techniques to Sweetpotato Breeding

In this work, transformation is used to genetically engineer sweetpotatoes with improved characteristics, including insect resistance, virus resistance and improved protein quality. During 1992, work was conducted at CIP headquarters, and in collaboration with the University of Nagoya, **Japan.**

In Lima, **Peru**, transformation and regeneration experiments were conducted using *A. rhizogenes* and *A. tumefaciens*, and the sweetpotato cultivars Regal and Huachano. The cloning vector, plasmid pBI121, was used as it contains genes that confer Kanamycin resistance, and GUS activity. Transformed plants were selected in a tissue-culture medium containing Kanamycin. Subsequently, the incorporation of foreign genes was confirmed through assays of GUS activity, and southern blot analysis. Table 4 summarizes the results, which indicate that both *A. rhizogenes* and *A. tumefaciens* can be used for transformation.

Developed at Nagoya University, transformation experiments used a new reporter gene, the intron-GUS gene. The advantage of the intron-GUS construct, as compared to the standard GUS gene, is that with intron-GUS, ß-glucuronidase

Table 3. Number of pollinations made, and capsules and seeds obtained using hybrids between *I. trifida* and other wild species as males and 4× storage root producing genotypes as females. Peru, 1990 and 1992.

Females[a]	Males							
	LCA × TRF JD 30.1	TRF × LCA JD 9.2	RMS × TRF JD 111.1	TRF × RMS-1 JD 23.1	TRF × RMS-2 JD 23.2	TEN × TRF JD 120.1	TRF × TEN JD 19.1	CDT × TRF JD 93.1
4× HH	0-0-0[b]	20-7-4	0-0-0	8-2-3	30-4-11	0-0-0	0-0-0	0-0-0
	1073-0	159-19	23-0	290-11	587-34	82-0	296-0	508-0

[a] Various accessions were used

[b] $\frac{\text{A seeds-B seeds-C seeds}}{\text{Pollinations-Capsules}}$

Table 4. Transformed roots and plantlets expressing GUS activity from two sweetpotato cultivars inoculated with Agrobacterium.

		Number & type	Regenerated roots		Transgenic
Bacteria	Cultivar	of explants	Total	GUS(+)	plants
A. rhizogenes R1000/pBI121	Huachano	60 internodes	12	9	8
A. tumefaciens LBA4404/pBI121	Regal	125 leaves	19	19	42

activity is not expressed until the GUS gene is incorporated into the plant genome. This eliminates the need for a time-consuming antibiotic treatment to eliminate *Agrobacteria* following transformation. The effectiveness of the intron-GUS system in sweetpotato was demonstrated through *A. rhizogenes*-mediated transformation of the cultivar Chugoku 35.

Also in collaboration with Nagoya and Hokkaido Universities, a chimeric gene was developed containing the ß-amylase promoter from sweetpotato, and a chymotrypsin inhibitor from winged bean. The construct has been incorporated into *A. tumefaciens*, and will be used in experiments to genetically engineer resistance to sweetpotato weevil.

To increase the likelihood of practical impact of our genetic engineering work, the transformation and regeneration experiments use regionally important sweetpotato varieties, such as Xushu-18, which is grown on more than 1 million hectares in China.

Genetic Resources of Andean Root and Tuber Crops

Strategies for the systematic conservation and utilization of Andean root and tuber crops (ARTC) biodiversity have been developed and their implementation is under way in cooperation with Andean NARS and non-governmental organizations (NGOs).

Collecting Activities and Germplasm Donations

All germplasm acquisitions were collected in close collaboration with NARS in the various countries. Usually, the CIP collectors were joined by a national scientist nominated by the collaborating institution. A duplicate of each collected accession was left with each institution, along with photographic, herbarium, and other documentation.

Several small collecting expeditions were made in Peru in cooperation with students from Universidad Nacional Agraria La Molina (UNALM) and scientists from the University of Ayacucho. These expeditions contributed 95 accessions of oca, ulluco, mashua, arracacha, yacon, achira, and mauka.

In a collaborative collecting mission, 94 accessions were collected with the Instituto Nacional de Tecnología Agropecuaria (INTA)/Salta in the Provinces of Jujuy and Salta, **Argentina**. This was the first systematic collection of ARTC in northwestern Argentina. Although the overall diversity found in Argentina was low, as compared with that found in other parts of the Andes, the Argentinean germplasm is adapted to daylength conditions beyond latitude 23. Yacon, and mashua were found to be cultivated on a very limited scale.

The Instituto Nacional de Investigaciones Agropecuarias (INIAP) of **Ecuador,** made an important donation of 60 ulluco

Table 5. Accessions of ARTC germplasm maintained at CIP, December 1992.

Species	Common name	COL	ECU	PER	BOL	ARG	Total
Ullucus tuberosus	ulluco	6	62	126	88	41	323
Oxalis tuberosa	oca	-	25	130	44	55	254
Tropaeolum tuberosum	mashua	-	-	29	-	2	31
Arracacid xanthorrhiza	arracacha	-	-	27	-	-	27
Polymnia sonchifolia	yacon	-	-	17	4	1	22
Canna edulis	achira	-	-	20	2	-	22
Lepidium meyenii	maca	-	-	33	-	-	33
Mirabilis expansa	mauka	-	-	3	-	-	3
	Total	6	87	385	138	99	715

ARG = Argentina; BOL = Bolivia; COL = Colombia; ECU = Ecuador; PER = Peru

and 25 oca accessions, mainly of Ecuadorian origin, which will be used for the study of morphological and isozyme variation.

In Peru, the NGO, Jorge Basadre of Cajamarca, made another important donation of oca, ulluco, and mashua germplasm collected in that Department.

CIP maintained a total of 715 accessions of ARTC in December, 1992 (Table 5).

Conservation

CIP is supporting the field conservation of 560 accessions of oca, ulluco, and mashua from the southern Andes, which are maintained by Centro de Investigación en Cultivos Andinos (CICA) in Cusco.

Each accession of ulluco, oca, and mashua is maintained in triplicate, as mature tubers stored at 3-5°C for up to 2 years; as juvenile plants; and as in vitro shoot tip culture. Yacon is maintained as juvenile plants and as in vitro shoot tip culture; arracacha, achira, and mauka are maintained as juvenile plants in an insect-proof greenhouse. Botanical seeds of maca are maintained in a base collection. Research is now under way to maintain mashua, arracacha, yacon, mauka, and achira as sexual seed.

In vitro shoot tip culture uses a Murashige & Skoog (MS) media with calcium pantothenate (2 ppm), sucrose (2%) and vitamins (thiamine, glycine, nicotinic acid and pyridoxine) to maintain ulluco germplasm, with methods previously established by the Peruvian Universidad Nacional Mayor de San Marcos (UNMSM). In vitro plantlets of oca are maintained in MS media that includes calcium pantothenate (2 ppm), gibberellic acid (0.25 ppm), sucrose (3%), and vitamins, also developed by UNMSM. Difficulties in establishing mashua in vitro culture of shoot tips were overcome by using simple MS with sucrose and naphthalene acetic acid. In establishing in vitro culture of yacon, the main constraints for the study include early senescence, phenol oxidation, and lack of rooting. Strategies are being optimized for routine in vitro propagation and germplasm distribution.

In studies of vegetative propagation of yacon, ulluco, and oca, yacon was found to be most easily propagated through apical cuttings. Best results were obtained when yacon cuttings were planted individually in quartz-sand without hormone solution. Rooting of the cuttings usually occurred within 8 to 10 days in the hot season (19-27°C) and from 6 to 8 days in the cold season (14-20°C) at La Molina, **Peru**. Axillary cuttings also gave good results, while the traditional method of using rhizome off-shoots proved to be the least efficient. Ulluco and oca cuttings should be taken from either axillary or apical young shoots of plants that are not yet tuberizing. Application of hormone solution is not necessary for successful rooting. Ulluco and oca cuttings, either axillary or apical, obtained from tuberizing or senescent plants, will not develop further, but will start to develop miniaturized tubers.

Characterization

In a collaborative work between the University of Ayacucho and CIP, 22 accessions of achira from southern Peru were morphologically characterized and agronomically evaluated under on-farm research conditions.

For biochemical characterization, best results for isozyme analysis of oca were achieved with a continuous histidine-citrate buffer with 0.5-0.6 molarity and pH of 5.7-6.5. Tuber tissue generally gave better results than did leaves. Of eight enzyme systems, the following five were satisfactory for cultivar discrimination: malate dehydrogenase (MDH), esterases (EST), PGI, PGM, glucose-6-phospho-dehydrogenase (G6PDH). Insufficient activity was obtained with acid phosphatase (ACP), alcohol dehydrogenase (ADH) and SDH. Collaborative studies on isozyme analysis in arracacha, by INIAP, the Escuela Politécnica de Chimborazo in Ecuador, and CIP indicated that histidine-citrate buffers obtained best results with PGM, PGI, MDH, EST, and ACP. Polymorphism was observed only in EST and ACP for material from **Ecuador** and **Peru**.

Isozyme analysis has helped to determine the approximate degree of clonal duplication (60-80%) in the collection maintained by CIP. It has also shown that the discriminating power of isozyme analysis is limited for certain plant material, especially arracacha. This is due to lack of polymorphism in several enzyme systems, which is suggestive of comparatively low genetic variation within the cultivated genepool of ARTC. Other problems are insufficient resolution of banding patterns, as well as lack of genetic explanations for the observed zymograms.

The chromosome number was determined for several Bolivian and Peruvian ulluco cultivars. Cultivated ulluco was found to be diploid (2n=24) while spontaneously growing (supposedly wild) ulluco was triploid (2n=36), confirming earlier Finnish results. In addition, the somatic ulluco chromosome number was found to be closely related to the chloroplast number in guard cells. Thus, the number of chloroplasts in guard cells would have potential for ploidy determination in ulluco.

Virological Studies

Collaborative studies by UNMSM and CIP evaluated the health status of 416 in vitro accessions of ulluco (originating from tubers), which are maintained by the university. The penicillinase-based ELISA test revealed that 84% of the ulluco cultivars from a broad geographical range were infected by: PMV/U (papaya mosaic virus strain ullucus), UMV (ullucus mosaic virus), UVC (ullucus virus C) and UMMV (ullucus mild mottle virus). Often the 4 viruses simultaneously infected the same plant. Furthermore, PMV/U was detected in 63% of the accessions, UMV in 46%, UVC in 30%, and UMMV in 29% of the material. PMV/U and UMMV were found to be evenly distributed within the plant; whereas UMV and UVC were detected only from the lower half of the plant. Although thermotherapy treatment followed by meristem culture appears to be an alternative method of virus eradication, preliminary results with micropropagated ulluco, however, suggest that virus elimination from ulluco may be relatively easily achieved by one cycle of meristem culture.

Two hundred and fifty accessions of ARTC maintained as potted plants or in vitro were checked for the potato spindle tuber viroid (PSTVd). More than 80 species of tuber-bearing *Solanum* are known to be susceptible to the PSTVd. Since potato is sometimes grown together with ARTC, information is needed about how PSTVd might infect ARTCs. The nucleic acid spot hybridization (NASH) test yielded negative results for the above accessions, suggesting that the ARTC material was disease-free and that there was no risk of contaminating healthy potato or sweetpotato material. In addition, four-week-old rooted cuttings of 30 ulluco, 20 oca, and 12 yacon accessions were challenged by the disease, using mechanical inoculation. The viroid was not detected by the highly sensitive NASH test after 4, 8, and 12 weeks of inoculation.

The Challenge of Using ARTC Germplasm: Arracacha

Agreements have been made between CIP and three Brazilian institutions—Centro Nacional de Pesquisa de Hortaliças (CNPH)-EMBRAPA, the University of Viscosa and the Crop Research Institute of Campiñas (IAC)—for collaborative research projects on arracacha.

Arracacha is a popular root vegetable in Brazil and is cultivated on 4,000-12,000 ha, in widely dispersed small plots in the upland areas of Southern Brazil. It is an attractive crop for farmers because it requires only a fraction of the inputs used for potatoes, commands premium prices, produces high returns on labor investments, and has demonstrated potential for processing instant food and chips. However, the 11 to 12 month cropping cycle, as well as its narrow genetic range, are severe constraints to arracacha cultivation in Brazil. It seems likely that these constraints could be overcome through the use of Andean arracacha germplasm in breeding programs.

Training

As part of a newly initiated collaborative project between CIP/UPWARD and the University of Cenderawasih (UNCEN), a workshop on collection of sweetpotato germplasm and indigenous knowledge was held in Manohivari, Irian Jaya, **Indonesia**, in February. The objective was for the interdisciplinary team to collect germplasm and associated knowledge regarding varieties and production systems. The workshop started with a brief planning meeting to discuss the method of germplasm and data collection, and to prepare the logistics for a 5-day field collection trip. Four members of UNCEN, one CIP scientist, and one UPWARD scientist participated. In a closing exercise, participants made presentations and discussed collection, evaluation and conservation of germplasm.

UPWARD organized a workshop in May on "Local knowledge and Global Resources: Involving Users in Germplasm Conservation and Evaluation." Held at Alaminos, Pangasinan, **Philippines**, the workshop was jointly sponsored by UPWARD and IDRC. Participants attended from the **Philippines, Indonesia, Vietnam**, and **Nepal**. Program topics included collection, conservation, and users' participation in evaluation of germplasm. Participants shared their experiences by making presentations of past and on-going projects on genetic resources. Discussions of key issues raised by participants, field visits and project proposals development were also part of the workshop program.

CIP joined efforts with IBPGR, CATIE, and CIAT to organize a Latin American course on in vitro germplasm management. The course was held in Cali, **Colombia** at CIAT headquarters in October and included participants from **Guatemala, Peru, El Salvador, Venezuela, Ecuador, Colombia, Bolivia, Panama, Brazil, Honduras, Nicaragua,** and **Cuba.**

■

1992 Research Projects and Partners

This list contains the titles of research projects, the names of principal partner researchers and their respective country, the responsible CIP scientist, and the names of collaborating researchers.

Maintenance and evaluation of potato germplasm from Chile and their improvement for use in marginal but sustainable agriculture. A. Contreras, U Austral, **Chile**/P. Accatino, V. Larenas, H. González; R. Wilkens, U. de Concepción, **Chile**, L. Salazar, Z. Huamán, A. Golmirzaie

Biosystematic studies and long-term conservation of wild potato genetic resources. Z. Huamán, C. Ochoa, P. Schmiediche, A. Salas, P. Jatala, K.V. Raman, H. El-Nashaar, E. French, L. Salazar **Peru**

The maintenance, documentation, distribution and evaluation of potato germplasm. Z. Huamán, R. Gómez, M.R. Herrera **Peru**

In vitro potato germplasm collection. Introduction, maintenance and analysis. A. Golmirzaie, F. Buitrón, Z. Huamán, J. Bryan, R. Salinas, C. Sigüeñas, A. Panta, J. Benavides **Peru**

Maintenance of a back-up duplicate of the potato germplasm in vitro collection in Ecuador. R. García, INIAP, **Ecuador**

Producción de plantas de papa resistentes a *Erwinia* sp. mediante manipulación genética por *Agrobacterium*. P. Oliger, A. Venegas, L. Holuigue, Kalazich, PUC, INIA, **Chile**/J. Dodds, P. Accatino, A. Golmirzaie

Development of potato germplasm resistant to insect pests by means of breeding technologies. A. Sonnino, L. Bachetta, S. Arnone, A. Lai, ENEA, **Italy**

Development of potatoes with resistance to fungal diseases. Ricardo Caccia, Ciro di Pace, University of Tuscia, **Italy**

The utilization of increased genetic variability in the potato breeding program. M. Huarte, INTA, **Argentina**/ K. Watanabe, H. Mendoza, E. Camadro, A. Clausen, C. Cortés, M. Colavita, E. Chaves, E. Vega, A. Melegari, A. Escande, J. Mantecon, N. Zamudio, R. Lobo, E. Cacace, S. Capezio

Characterization of genetic variation in tuber-bearing solanum species by use of RFLP markers. K. Hosaka, **Japan**/ K. Watanabe, J. Dodds, P. Gregory

Germplasm enhancement through the use of haploids and 2n gametes. K. Watanabe, M. Orrillo, H. Mendoza, A. Golmirzaie, J. Landeo, K.V. Raman, H. El-Nashaar, E. French, P. Jatala, U. Jayasinghe, B. Trognitz **Peru**

Exploitation in wide range of wild solanum for potato germplasm enhancement.

K. Watanabe, M. Orrillo, U. Jayasinghe, L. Salazar, K. Raman, H. El-Nashaar, B. Trognitz, E. French **Peru**

Genetic engineering for developing potato varieties resistant to diseases and pests. A. Golmirzaie, C. Sigüeñas, K.V. Raman, L. Salazar, M. Palacios, A. Panta, J. Benavides, F. Buitrón, R. Salinas **Peru**

Introduction of late blight (*Phytophthora infestans*) horizontal leaf resistance (HLR) from wild species into *S. tuberosum* via tuberosum dihaploid × wild species crosses. B. Trognitz, G. Forbes, J. Landeo, C. Ochoa, P. Schmiediche, K. Watanabe **Peru**

Exploitation of potato genetic resources for control of *Pseudomonas solanacearum.* K. Watanabe, H. El-Nashaar, A. Hurtado, J. Benavides, E. French, H. Mendoza, A. Golmirzaie, B. Trognitz, C. Ochoa, S.D. Tanksley **Peru**

In vitro selection of potato mutant tolerant to abiotic stress. L. Monti, F. D'Ambrosio, T. Cardi, U. Napoli **Italy**

Characterization of sweetpotato germplasm in Dominican Republic. P. Gómez CESDA, **Dominican Republic**/Z. Huamán, O. Malamud

Collection, characterization and evaluation of native sweetpotato germplasm in Bangladesh. M.A. Mannan, K.R. Bhuiyan, BARI, **Bangladesh**/ T.R. Dayal, M.M. Rashid, A. Quasem, M.D. Upadhya

Collection of sweetpotato genetic resources and sweetpotato germplasm enhancement. F. de la Puente, Z. Huamán, A. Golmirzaie, P. Accatino, O. Hidalgo, O. Malamud, J. Díaz, K. Manrique **Peru**

The maintenance, documentation, distribution and evaluation of sweetpotato germplasm. Z. Huamán, T. Ames, F. De La Puente, M.R. Herrera **Peru**

In vitro sweetpotato germplasm collection. Introduction, maintenance and analysis. A. Golmirzaie, R. Salinas, Z. Huamán, J. Bryan, F. Buitrón, C. Sigüeñas, A. Panta, J. Benavides **Peru**

Evaluation of a sweetpotato germplasm collection. Sheng Jialian, XISP, **China**/ W. Jingyu

Maintenance of in vitro sweetpotato germplasm in Venezuela. L. Villegas, IDEA, **Venezuela**

Collection, characterization and maintenance of sweetpotato germplasm in several regions in Argentina. A Boy, P. Bianchini, M. Lenskak, INTA, **Argentina**/F. de la Puente, P. Accatino

Interdisciplinary collection of *Ipomoea batatas* germplasm and associated indigenous knowledge in Irian Jaya: an exploratory study. H. Mandabum, T. Swor, Cenderawasih U, **Indonesia**/ G. Prain, I.G. Mok, J. Schneider

Ploidy manipulations for exploitation and enhancement of sweetpotato germplasm. G. Orjeda, E. Carey **Peru**

Sweetpotato populations for hot, humid environments. E. Carey, D. Reynoso, H. Mendoza, I.G. Mok, E. Chujoy, T.R. Dayal, Z. Huamán, P. Jatala, K.V. Raman, G. Prain, H.M. Kidane-Mariam **Global**

Adaptation and utilization of sweetpotato populations in breeding. H. Mendoza, J. Espinoza, L. Díaz, P. Jatala, L. Salazar **Peru**

Evaluation of sweetpotato germplasm for the warm tropics. Feng Zu-Xia, GAAS,

China/Song Bofu, X. Chunsheng, H. Hongcheng, Ch. Yingdong

Germplasm exploration, conservation and utilization of several under-utilized Andean tuber crops. J. Estrella, INIAP, **Ecuador**, G. Meza, CICA, **Peru,** F. Santos, EMBRAPA, **Brazil,** R. Neumann, INTA, **Argentina,** D. Morales, IBTA, **Bolivia,** A. Contreras, U Austral, **Chile**/M. Hermann

PROGRAM 3

Disease Management

Contents continued

At Press Time

New Forms of Late Blight Fungus

CIP and its partners are gearing up to combat new strains of the late blight fungus that have recently been detected in many locations around the world; all indicators suggest that these strains of the fungus are spreading rapidly.

These new strains of the late blight fungus (*Phytophthora infestans*) started a migration in the late 1970s from their place of origin in Mexico. They damage potatoes more severely than does the strain that had previously established itself worldwide, having migrated from Mexico in the 1840s. Most new pathogen strains are of the A2 mating type. Until now farmers have had to deal with only one strain of the A1 mating type.

Combined populations of new A1s and A2s can now be found in virtually all major potato growing areas. These populations are well established in the United States, eastern and western Europe, and in many developing countries of Africa, Asia, Latin America, and the Middle East.

The presence of A1 and A2 in the same location leads to sexual recombination and the production of hardy oospores, thus progenies may be able to survive the winter in North America and Europe. Until recently, cold winter frosts reduced inoculum, and epidemics began later. Now they can begin earlier in the growing season. The implications are that farmers in industrialized countries will have to spray more chemicals more frequently. We are also concerned about reports that *P. infestans* is becoming resistant to fungicides.

Late blight is the number-one potato disease worldwide, and was responsible for the Irish potato famine of the 1840s. What we are now seeing is a new late blight population that is far more aggressive than its predecessor. It may also be more resistant to the fungicides used to control the disease.

These new strains of the late blight fungus and those that will constantly arise from oospores, are undoubtedly going to lead to serious production losses and will greatly complicate efforts to reduce the use of agro-chemicals. This heightens our concern because the potato is already the largest user of agricultural pesticides of all major food crops and most of these chemicals are fungicides used to control late blight.

CIP partners from many different countries are concerned about the problem and are monitoring it. CIP is focusing on the needs of potato producers in developing countries. In recent years, CGIAR-supported research has helped to boost potato yields and expand production in these countries by more than 5% annually. Progress has been particularly rapid in Asia and Africa, where production is expanding much faster than population. Our fear is that this new late blight threat could reduce food supplies and halt the progress that is being made.

We are also concerned about the threat of loss of traditional varieties and wild species found in Peru, the center of origin of the potato. As yet, A2 has not been detected in Peru, but we expect that it will eventually reach here and that it could threaten native species in their natural habitat.

The reason that Peru has not been affected so far is that it does not import potato seed. It is our belief that the A2 mating type was present in tubers imported into Europe in the 1970s and then exported in the form of improved seed tubers. A2 is now found in virtually every country that obtains potato seed from Europe.

We don't anticipate any easy solution to this very serious threat. However, we have devised a strategy based on our ongoing research.

- First, CIP now has most of the traditional Andean farmer varieties and wild species in its gene bank and this germplasm is well protected. While the loss of genetic material in the field may occur, we have the backup to prevent any irreparable losses.
- Second, CIP has two advanced breeding populations that carry high levels of horizontal resistance to A1 and A2. These materials were thoroughly tested this year under extreme disease pressure in Mexico and look very promising. They should be available for wide-scale testing within a year and could be released as varieties within three years.
- Third, we plan to bring together all of the researchers currently working on late blight at a meeting in Mexico in February, 1994. We hope that this will lead to an international initiative involving scientists from industrialized and developing countries.

Discussions at the recently held International Potato Congress in Prince Edward Island, Canada, suggest that the international scientific community is ready to do whatever is necessary to address this problem and will move quickly and decisively in a full-scale collaborative response to the threat.

Based on a Press release by Dr. Hubert Zandstra at International Centers Week on October 29, 1993.

Control of Potato Late Blight

Integrated Control of Potato Late Blight

Late blight (*Phytophthora infestans*) is the major limiting factor to potato production in cool, moist climates. In developing countries yields are reduced by about 30%, while expenditures for fungicides to control late blight exceed US$600,000,000. Integrated control technologies with plant-host resistance are being developed, and the ultimate objective is polygenically-controlled horizontal ("field") resistance. Two breeding populations are being improved stepwise for resistance to late blight and other important diseases, suitable agronomic characters, and wide adaptability. Population A contains vulnerable major genes for resistance (R-genes) in addition to genes for horizontal resistance. Population B is being developed with horizontal resistance alone, thus avoiding the difficulties of selecting resistance in the presence of major genes.


These Panamanian farmers are pleased with the high productivity of the new late blight resistant variety IDIAP-92 (CIP 381381.13).

Approximately 250 agronomically improved clones from population A have been selected for horizontal resistance to late blight (by overcoming major gene resistance with complex races of *P. infestans*). They have been distributed worldwide for potential use as varieties.

During 1992, a new group of 55 outstanding late blight resistant clones from Generation XI of Population A were chosen for distribution to NARS in 27 countries. These clones were selected through a multilocation testing scheme at sites where late blight is endemic and severe (Rionegro, **Colombia**; Ruhengeri, **Rwanda**; and Toluca, **Mexico**). These clones are early maturing and widely adapted, with stable resistance. Resistant cultivars selected from Population A in developing countries are now being released as varieties by NARS in Latin America, and Africa (Table 1).

CIP's breeding work emphasizes the further development of Population B. Use of only non-race specific, late blight resistance in this breeding population will facilitate selection for resistance in any location where the disease is epidemic.

The level of horizontal resistance in Population B is being improved by utilizing selected native *andigena* germplasm and R-gene free, old tuberosum varieties.

At the Quito, **Ecuador**, experiment station, 170 clones from crosses among *andigena* and 130 from *andigena* × *tuberosum* were selected from among 60,000 seedlings, during two seasons of testing for resistance to late blight and desirable agronomic characters. Resistance levels ranged from low to intermediate, as is expected in the early stages of development of horizontal resistance.

Table 1. Varieties released from late blight resistant breeding population A, 1983-1992.

Country	CIP number	Local name
LAC[1]		
Ecuador	384638.1	INIAP STA. RITA
Peru	380389.1	INIAA-Canchán
Venezuela	380013.2	Andina
Guatemala	382170.101	ICTA Xalapan
Panama	381381.13	IDIAP 92
SSA[1]		
Burundi	381381.9	Rukinzo
	381381.26	Ingabire
	382147.18	Jubale
Rwanda	381381.3	Nderera
	381395.1	Ngunda
	382120.14	Kigega
	383140.6	Mugogo
	386003.2	Mizero
	387233.24	Gikungu
Uganda	381379.9	Kisoro
	381381.20	Victoria
Cameroon	381381.13	Cipira
	381406.6	Tubira

[1] LAC = Latin America and the Caribbean and SSA = Sub-saharan African Regions.

In addition, horizontal resistance genotypes free of R-genes are being extracted from population A, a procedure that should speed improvement of population B. Genetic studies must confirm that these genotypes are free of R-genes, and quantify the amount of horizontal field resistance.

Approximately 1,300 new individual plants were selected as R-gene free, as a result of inoculating seedling progenies with race zero of *P. infestans* (that contains no genes compatible with host R-genes). These clones will be further evaluated by inoculating single detached leaves in petri dishes with race zero under controlled environmental conditions. The resistant selections will be used in further breeding.

Estimates of heritability for horizontal resistance to late blight in samples of this new population when tested in **Peru**, **Colombia**, and **Mexico** indicated that it is intermediate to high (a range of 0.41 to 0.71). This suggests that in this population horizontal resistance has been effectively isolated from population A. It is being upgraded for horizontal resistance in the absence of R genes and for other valuable agronomic traits.

Collaborative work among the Centre for Plant Breeding and Reproduction Research (CPRO), the Research Institute for Plant Protection (IPO) of the Netherlands, and CIP is oriented towards searching for potentially superior horizontal

Seedlings tested with race zero of *P. infestans* for the presence of R-genes: seedlings on the left are R-gene free.

resistance among wild relatives of the potato, particularly the Mexican species *S. demissum, S. semidemissum, and S. edinense.* To date, 13 R-gene free clones have been identified among hybrids between *S. demissum* clone 90.1 and Bildstar (an old *tuberosum* variety free of R-genes).

Integrated Control of Potato Bacterial Wilt

Bacterial wilt (BW) is the second most important potato disease, after late blight. CIP's strategy for the integrated control of the bacterium *Pseudomonas solanacearum* that causes BW, comprises three essential components. The most important component is resistance, which has been selected and utilized in breeding. Secondly, the bred populations are evaluated in different agroecoregions to select cultivars. And, thirdly, staff from national programs are being trained in the use of serological techniques to discriminate between resistant and latently-infected tolerant clones and to ensure production of healthy tuber seed.

Further, an effective strategy requires the determination of the worldwide genetic variation of the bacterium.

Variation of *Pseudomonas solanacearum*

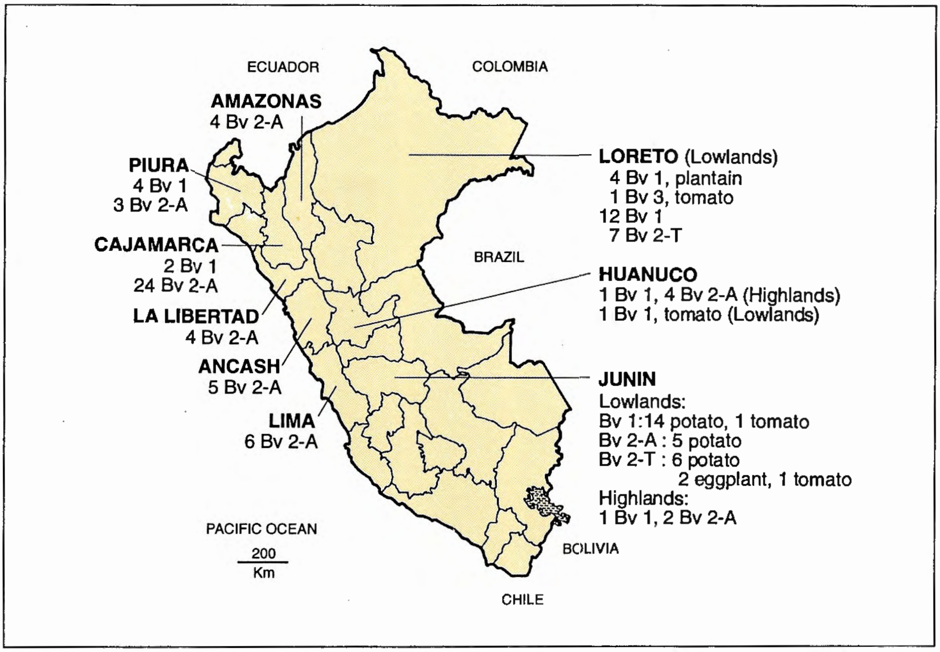
Using CIP's worldwide collection of over 400 accessions of *P. solanacearum*, 72% of potato isolates were identified physiologically as biovar (Bv) 2. Until recently, this biovar had been considered to be race 3, which is essentially restricted to potatoes. The remainder were Bvs 1, 3, and 4, which are classified as race 1, are found in warm climates, and are primarily pathogens of other solanaceous crops and weeds.

Additional physiological and RFLP studies (1992 Annual Report) showed Bv 2 to be two distinct phenotypes. These phenotypes are characterized ecologically as Bv 2-A of Andean origin, which occurs worldwide essentially only on potato (it is synonymous to race 3), and as the tropical Bv 2-T, which has been found only in the lowlands of Peru (Figure 1). Tropical Bv 2-T was shown to wilt eggplant and tomato at San Ramon, Peru (1,150 m).

In greenhouse experiments at high temperatures, Bv 2-T produced more latently infected tubers than did Bv 2-A. At cool temperatures, however, which are more normal for potatoes, the Bv 2-A showed more latently-infected tubers. These findings and the demonstrated feasibility of growing potatoes in the lowlands utilizing highland seed, strongly suggest that Bv 2-A evolved from Bv 2-T, which is indigenous in the lowlands east of the Andes. Bv 2-T may have been carried as latent infection into the cooler highlands, where it evolved in the vegetatively reproduced potato into Bv 2-A, which is more specific to potato.

Worldwide, Bv 2-A causes over 90% of the cases of BW. CIP's integrated control strategy (developed through interaction with many scientists), presented and refined during Planning Conferences and Symposia since 1979, and taught in numerous training courses during the past 14 years, has led to the control or eradication of BW in **Burundi, Costa Rica, India, Peru, Rwanda,** and **Uruguay.** Moderate control has been achieved in several other developing and developed countries. This demonstrates the potential for integrated control of this strain of BW. With the confirmation that the principal target for control is one genetically homogeneous strain that has spread worldwide, CIP can reemphasize and streamline its effective integrated control strategy.

Figure 1. Distribution of *P. solanacearum* biovars throughout Peru.



Breeding for Resistance to Bacterial Wilt

During the summer of 1991, 15 open pollinated progenies from the population bacterial wilt/root-knot nematode (BWH clones) were evaluated in the greenhouse at La Molina, **Peru,** for reaction to *P. solanacearum* races 1 and/or 3 and root-knot. The progenies showed a low (0-7%) resistance to RKN and only progeny BWH-87.289 was resistant to both races of the bacterium (indices < 2). Resistance to both the bacterium and the nematode is desirable, because the two diseases are more damaging than either one alone, and they often occur together in the field in warmer climates.

During the 1991 dry season in San Ramon, 83 parental clones resistant to *P. solanacearum* race 3 were evaluated for their resistance to race 1. Thirty percent were found to have disease indices less than 2 on a scale of 1 (healthy) to 5 (dead).

During the spring-summer season 1992, 56 potato progenies (BW × XY.9 and BW × early maturity) were evaluated for agronomic attributes at La Molina. At harvest time, 342 clones and 36 tuber families were selected and evaluated in fields infested with *P. solanacearum* race 1. Three families (379420.1 × XY.9, AMAPOLA × BWH-87.511R, and TOLLOCAN × BWL-87.13R) were very resistant, providing encouragement to continue this work.

Potato Germplasm Evaluation for Resistance to Bacterial Wilt

In Brasilia, **Brazil,** CIP germplasm for bacterial wilt resistance previously sent as TPS to EMBRAPA and that had been multiplied and selected for agronomic traits was tested for resistance in a field heavily infested with Bv 2-T. Plots with five plants each of 226 genotypes were interplanted with two varieties as controls, susceptible Aracy and resistant Achat, replicated five times in a complete random block design (CRBD). Fifty-six days after planting, the 18 most resistant CIP-bred clones were selected: 385310.5; 385312.2; 388104.2, .8, .12, .14; 388237.6; 388285.12, .14; 388304.5, .8; 388307.4; 388082.5; 388083.9; 388084.6; 589002.2; 589005.1; 589007.1. Some of these had greater or similar resistance to that of Achat. Additional genotypes sent by CIP are being multiplied for future testing. Selected clones will be further tested to determine if they have complete resistance or if only tolerance (carriers of latent infection) is achievable.

In collaboration with the Department of Agriculture, Mindanao, **Philippines,** CIP-bred potato genetic populations were screened for adaptation and resistance to bacterial wilt. Among 34 advanced clones, nine yielded more than 20 t/ha. Six clones had less than 30% BW incidence at 60 days after planting while the local cultivar had 100% wilt. In a separate screening, potato clones selected for resistance to BW in different countries were grown from cuttings and tested in a BW nursery to verify their resistance under Mindanao conditions. Clones with the lowest BW rating were CIP 381064.12, CIP 379420.2, CIP 377850.1, and CIP 800935 with BW ratings (1-5 scale) of 2.0, 2.3, 2.7, and 3.3, respectively, while the local susceptible cultivar Franze had a rating of 4.3.

A field screening test was conducted at Frias, Piura (1,810 m), in collaboration with the Central Peruana de Servicios in Piura (northern **Peru**) where both races 1 and 3 occur. Six of the 85 clones developed wilt later, or the disease progressed slowly, so that the wilt rating was 2.0 to 2.6. The rating of the resistant checks was 3.5 to 4.0 and that of the susceptible check was 4.9 (Table 2). This degree of resistance would confer complete resistance under less stressful conditions (cooler climate, lower inoculum potential, etc.). These clones may therefore be superior in resistance to earlier selections, and could serve as parents in further breeding or pre-breeding work.

Table 2. Degree of wilt incidence (increasing scale of 1 to 5) of the six best clones among 85 tested at Frías, Piura Department, Peru (1,810 m), number of days for symptom initiation, and average yield per plant under wilt-free conditions.

CIP Code	Wilt incidence	Initiation (days)	Yield/plant (kg)[1]
59.5 (BWH87.211 × BWH87.53)	2.0	60	1.20
71.14 (BWH87.493 × BK(LB))	2.4	34	1.98
379673.150 [(BR63.74 × Anita) × Maria Tropical]	2.0	52	0.71
720118.1 (mutant of Ndinamagara)	2.0	45	1.08
703277 (Numurquina, Peru[2])	2.0	52	1.83
703291 (Rosca, Colombia[2])	2.6	38	0.57
Susceptible check:			
Mariva	4.9	45	1.07
Resistant checks:			
800212 (BR-63.5)	3.5	38	1.35
800222 (Molinera)	4.0	45	0.82

[1] Yield in wilt free conditions, Rodeopampa (2,720 m)

[2] *S. phureja* (2 ×)

CIP provided technical assistance in Burundi to improve screening for resistance and detection of latent infection. Cooperation was initiated with the Agricultural University of Butare, Rwanda, by supplying a serological detection kit and training that would allow researchers to initiate a seed program.

Detection of *Pseudomonas solanacearum*

In **Burundi, Rwanda** and **Zaire**, high percentages of potato cultivars showing apparent resistance to bacterial wilt were found to have latent infection. These tolerant cultivars were efficiently detected in field specimens using newly developed techniques in collaboration with ISABU, **Burundi** and Rothamsted E. S. and Sainsbury Laboratory, **UK**. Detection techniques included nitrocellulose membrane dot-blot ELISA (NCM-ELISA) with a polyclonal antibody, a non-radioactive DNA probe, and DNA amplification using specific primers by the polymerase chain reaction (PCR). In a preliminary test, the pathogen was detected frequently with all techniques in different cultivars. In a detailed study, positive detection was limited to PCR in one cultivar. This difference in detection indicated that latent infection is variable by year, season, and cultivar.

Kits of enzyme linked immunosorbent assay (ELISA) and immunofluorescent assay (IFA) reagents were prepared for detection of BW infection in **China**'s seed programs. McAb (monoclonal antibody) ascitic fluid was produced from hybridoma cell lines of Hps3, Hps4, and Hps7, lyophilized or immediately stored at 4°C with sodium azide. Alkaline phosphatase antibody conjugates were prepared by A. Voller's method. Antimouse immunoglobulin fluorescein conjugates were obtained from the Beijing Institute of Biological Products. A preliminary detection procedure for BW latent infection was developed and recommended for practical use. The titer of this monoclonal, as well as its specificity for different strains, is being compared with polyclonal antibodies produced at CIP headquarters.

Existing stocks of polyclonal antibody have been shipped in detection kits from Lima, upon request to national scientists in **Kenya, Madeira Islands, Mauritius, Nepal, Philippines, Sri Lanka, Malaysia,** and **Uganda.**

Combining Resistances to Potato Viruses and Fungi

Viruses produce serious yield losses in potato, necessitating constant seed renewal to maintain crop productivity. Therefore, CIP has bred for combined resistance to the most damaging ones: PVX, PVY, and PLRV. Further, in several agroecologies, late blight and early blight severely limit production. Control with fungicides is costly and may cause environmental pollution. To assist developing country farmers who cannot afford to frequently renew their seed, CIP is developing cultivars that combine the needed virus resistances with good agronomic traits and other resistances to enhance sustainable production.

Breeding for PVY Immunity

CIP's PVY duplex clones, YYyy, were crossed to a large number of European tuberosum cultivars possessing superior agronomic traits. One-sixth of the progeny genotypes should theoretically be YYyy, but they will have more variability for adaptation than the presently used duplex progenitors.

A sample of 20 PVY immune clones from matings among duplex progenitors were test-crossed to identify triplex and quadruplex genotypes. Three clones appeared to be triplex and serological confirmation of these results is in process. In a continued search for PVY triplex and quadruplex clones, 4,488 seedlings from matings among duplex progenitors were screened for PVY immunity. The observed proportion of resistant seedlings was 98.6%. The 734 clones selected for tuber type were field evaluated at La Molina during the 1992 spring in a 75-day growing period and 208 were retained because of good yield and type. After a re-evaluation during the 1993 summer, the selected clones will be test crossed. The expected segregation should result in a combined 25% being triplex and quadruplex with all their progenies expressing immunity to PVY.

Breeding for Combined PVY and PVX Immunities

To select agronomically superior progenitors and clones resistant to both PVY and PVX, 150 progenies of crosses of susceptible tuberosum varieties with PVY and PVX immune progenitors were screened for resistance. Subsequently, the field performance of surviving genotypes was evaluated. After a re-evaluation, the selected clones will be virus tested by the most sensitive method, grafting, to confirm their immunity.

Seedling progenies of four potential PVY and PVX immune duplex clones were virus inoculated, followed by ELISA testing of individual plants for the presence of these inoculated viruses. Two of the four clones were established to be duplexes immune to PVY and PVX.

In the continued search for duplex PVY and PVX immune progenitors, seedlings from crosses among simplex PVY and PVX immune clones were inoculated with both viruses. Symptomless seedlings were grown in the field and 200 high performing clones were selected. Test crossing the selected material is expected to produce 22 clones that are duplex immune at both loci. The duplex progenitors intercrossed and outcrossed will produce 94.5% and 70% of progenies, respectively, immune to both viruses. Moreover, intercrossing duplex progenitors will permit, in the short term, the selection of triplex and quadruplex progenitors that will produce all of their progenies immune to both viruses. This constitutes a final and durable solution for the control of these viruses.

Breeding for Combined Immunities to PVY and PVX with Resistance to PLRV

Breeding for combined resistance continues in response to NARS' high demand for virus resistant material with high yield, earliness, and wide adaptation. A large number of crosses between PVY duplex and PVY and PVX simplex with a wide range of PLRV resistant progenitors has been made.

In 1992, a group of 12 PVY and PVX immune and PLRV resistant clones were identified. These clones were selected after field exposure, for two consecutive years, to a high level of PLRV inoculum. These can be reliably used as multiple virus resistant clones for further breeding work.

A sample of 38 clones selected in **Egypt** from CIP tuber families combining resistances to PVY, PVX, and PLRV that were introduced from CIP-Lima in 1989, was reevaluated in the spring of 1992 (Table 3). These materials showed a high potential for adaptation and high performance under Arid and Mediterranean conditions. Ten of the 38 clones outyielded, and most of them matured as early or earlier than the check Alpha.

Combination of Resistance to Viruses and Early Blight

Resistance to PVY, PVX, and early blight (caused by *Alternaria solani*) has been

Table 3. Performance of the ten best clones from a group of 38 that were selected from tuber families with resistance to PVY, PVX and PLRV. Kafr-El-Zayat, Egypt, Spring 1992.

Clone	Pedigree	Earliness[1]	Yield(kg/Plant)
390182.1	86060 × XY-16	7	3.00
390174.1	Apta × YY-3	7	2.24
390174.2	Apta × YY-3	7	2.24
390186.1	87018 × XY-9	9	2.20
390178.1	CFC-69-1 × YY-6	7	2.20
390172.1	CUP-199 × YY-2	5	2.20
390182.2	86060 × XY-16	7	2.00
388226.1	BR-63.65 × YY-5	5	1.96
389464.1	BR-63.5 × YY-6	5	1.88
390180.1	86008 × XY-16	7	1.80
Alpha	(check)	7	1.80

[1] Scale: 1-2 = late, 3-5 = medium, >5 = early.

combined with good agronomic performance. Previously these components were developed separately.

During 1992, 46 tuber families resistant to PVY and PVX were field evaluated for early blight resistance and agronomic performance. Fifteen of the 46 tuber families had disease ratings of 2 to 3.7 (1 = no damage, 9 = highly susceptible) with early to medium-early maturity.

In another experiment, 25 clones selected for resistance to early blight by EMBRAPA collaborators in **Brazil** were again evaluated for early blight resistance at San Ramon. Most of these clones had a stable resistance over environments and showed good agronomic attributes. This population is therefore nearly ready for release to farmers.

Combination of Resistance to Viruses and Late Blight

Continuing evaluation trials at Mau Narok, **Kenya**, revealed a range of clones with combined horizontal resistance to late blight and to viruses X and Y. Despite the very high incidence of late blight, several clones yielded more than 1 kg/plant (Table 4). The resistance of the five best late blight and virus resistant clones was found to be similar to that of the five previously selected clones that are only late blight resistant.

Table 4. Late blight reaction, yield, and general rating of virus resistant clones (top five) compared to some older late blight resistant clones (bottom five). Mau Narok, Kenya, 1992.

CIP Number	Pedigree	LB Reading[1]					Yield (kg/plant)	General Rating[2]
		1	2	3	4	5		
387969.1	CFK-69-1 × Y84.012	1	1	3	3	5	2.7	1
387419.2	B.71.74.48.11 × 7XY.1	2	2	4	4	5	1.6	1
387419.3	B.71.74.48.11 × 7XY.1	2	2	6	6	7	1.4	1
387969.24	CFK-69-1 × Y84.012	2	3	8	8	8	1.5	2
387967.2	Y84.027 × I-1035	2	2	6	8	8	1.3	1
374080.5	(check)	4	7	9	9	9	0.6	2
Desirée	(check)	2	2	5	8	9	1.4	2
382433.2	P24.2 × Bk tbr	2	2	4	4	5	1.7	1
382136.4	374066.3 × Bk Mex	2	2	4	5	5	1.4	1
381382.34	378493.928 × Bk Early	2	3	6	7	8	1.4	1
381381.20	378493.915 × Bk Early	1	2	4	4	6	1.2	1

[1] Scale: 1 = no damage, 9 = 100% destroyed

[2] General rating: 1 = good, 3 = poor

Results from **Cameroon** showed that selected clones carrying combined resistance to late blight and viruses X and Y also had high yields. Their PVY and PVX immunity will facilitate seed production.

Results on early and late blight are showing a steady progress in combining resistance to viruses and fungi. Both the development of improved virus resistant progenitors and the combination with resistance to early blight and late blight have been significant.

Control of Field and Storage Diseases of Potatoes

Development of Resistance to *Erwinia* spp.

Species of the bacterium Erwinia cause soft rot of tubers in the field and in storage and stem rot or blackleg in the field. Earlier research demonstrated that losses of up to 40% occurring in the tropics and subtropics, during the first generation with certified seed from temperate climates, was due to the undetected latent infection by *E. chrysanthemi*. Methods to control and certify were available for *Erwinia carotovora* ssp. *carotovora* and *E.c. atroseptica.*

CIP has conducted an Erwinia resistance selection and breeding program based on native cultivars of *S. tuberosum* ssp. *andigena* (ADG) for 12 years. During 1992, 22 cultivars that had been found to combine resistance to both soft rot and blackleg were re-evaluated for soft rot by injecting them with a suspension of 5×10^4 bacteria/ml of *Erwinia chrysanthemi* (ECH) isolate CIP 367 and incubating them in a mist chamber. Re-evaluation for blackleg consisted of transplanting stem cuttings of each clone into a perlite substrate infested with a suspension of 5×10^5 bacteria/ml (a concentration 5 times greater than that used last year). Five clones found resistant to both soft rot and blackleg under these more severe conditions were: ERW 90-72.06, ERW 90-74.23, ERW 90-74.16, ERW 90-76.15, and ERW 90-77.03 (checks had at least double the amount of soft rotted tuber tissue and 100% blackleg versus 0 to 20% in the test clones).

Tubers of 30 families generated in 1991 from a 6 × 6 diallel design cross between ADG progenitors with moderate resistance to soft rot, were evaluated in 1992. The statistical analyses showed significant differences for General Combining Ability (GCA) between the progenitors used. The clonal selections OCH 6400.4 and CIP 703264.1 derived from ADG cultivars had the highest GCA. The best family was OCH 6400.4 x CIP 703264.1 which produced the following genotypes: 3% highly resistant (<1 mm rot diameter), 68% resistant (1.0-3.9 mm), and 29% moderately resistant (4.0-6.9 mm). Furthermore, this experiment showed that the additive variance was the most important component in the inheritance for this resistance, suggesting that this resistance is controlled polygenetically. Non-significant differences were found for the reciprocal effects. However, more resistant genotypes were obtained in the two families in which OCH 6400.4 and OCH 6175.2 were used as female progenitors, than were obtained in families from reciprocal crosses.

Tubers of a population of 1,234 clones were also screened for dry rot resistance caused by *Fusarium sambucinum*. The inoculation method consisted of: removing a cylinder of the cortical tissue with a cork borer; adding a fungus block growing on PDA medium to the well; and reinserting the cylinder of tissue. The six best clones combining resistance to dry rots with moderate resistance to soft rot were ERW 91-11.11, ERW 91-12.07,

ERW91-13.06, ERW 91-14.41, ERW 91-42.11 and ERW 91-47.24.

Integrated Control of Erwinia Diseases

Research on the integrated control of soft rot and blackleg in southern Chile began in 1992, with collaboration of private seed companies, INIA, and CIP.

Latent tuber infection, which can be expressed after planting during stressful wet weather conditions, ranged from 40 to 100%, as determined in laboratory tests. The subspecies of *Erwinia* causing disease was predominantly *E. c.* subsp. *atroseptica.*

The latent infection rate (LIR) for certified seed tubers increased 20 to 50% in one generation in five of seven farmer smallholdings studied (Table 5).

When four other varieties with 20 to 50% LIR of seed tubers were planted at the Remehue and La Platina Experiment Stations in **Chile**, the postharvest LIR remained the same or increased greatly (61% average increase) at Remehue, whereas at La Platina it decreased 1.8%. However, the proportion of plants lost to Erwinia through both blanking (non-emergence) and blackleg, at La Platina, with irrigation farming, was double that at Remehue, with rainfed conditions (21.3% vs. 10.4%).

Table 5. Latent infection rate (LIR) of tubers planted (generation 3 certified seed) and harvested, and incidence of blackleg in potato varieties in seven smallholdings in southern Chile, 1991 - 1992.

Variety	LIR(%) in tubers		Blackleg (%)	Missing plants (%)
	Planted	Harvested		
Desirée	30	60	0.5	1.6
Desirée	50	90	0.7	1.6
Yagana	20	70	0.8	4.4
Yagana	20	40	1.0	4.0
Yagana	20	00	1.0	10.0
Yagana	20	20	1.0	5.0
Yagana	20	50	–	–

Source: INIA data.

When Erwinia-free plantlets from in vitro culture were multiplied in a greenhouse of the seed program in Osorno (southern **Chile**), the LIR varied from 0 to 30%, depending on the potato variety. Infection in the subsequent field generation ranged from 0 to 40%. These results indicate that further studies are needed on ways to reduce the recontamination rate in the greenhouse and field during seed multiplication stages.

Additional integrated control components are needed. Scientists at the Universidad Austral in Valdivia, **Chile**, investigated biological control methods. They successfully isolated numerous Actinomycete fungi from potato plants, that were found to be antagonistic to Erwinias in laboratory tests. The three most inhibitory fungus strains were further tested in vitro against 14 Erwinia isolates. All combinations resulted in inhibition halos ranging from 8 to 18 mm. It was also determined that the Actinomycetes were not pathogenic to potatoes, since germinating seedlings were not affected by any of the three strains. These microorganisms will be tested in the field, utilizing various carriers and methods of infestation to achieve a practical biological control method.

Resistance to soft rot was tested in 15 of the most popular varieties in **Chile** using two strains of Erwinia and three methods of tuber inoculation so as to test different possible resistance mechanisms at different depths in tubers: 1) inoculating to a depth of 3 mm by cortical tissue removal with a cork borer; 2) microsyringe injection to about 5 mm depth; and 3) vacuum infiltration. Rot was assessed by weight loss after removal of rotted tissue. Variety Pimpernel was found to be the most resistant by all three methods.

Detection of Erwinias by serology

Contract research at SCRI, **Scotland**, developed polyclonal and monoclonal antisera to identify *E. c. atroseptica.* The polyclonal antisera were not as effective as combining two monoclonals, one for *E. c. atroseptica* serogroup I and another for serogroup XXII. As more than 90% of *E. c. atroseptica* strains from potatoes belong to serogroup I, the McAbs were considered satisfactory for commercial use.

Detection of latent infection is an important aspect of Erwinia control. Previous work had shown that ELISA serology was not sensitive enough to detect less than 10^5 bacterial cells/ml in tuber peel extract. This is needed since the threshold level for blackleg development is 10^2 cells/ml. Three methods to attain the desired level of sensitivity have been developed by SCRI.

SCRI has collaborated with IVIA, Spain, in the quantification under standard conditions of DAS-ELISA, which is applied following enrichment of the test material for Erwinias in the same microtitre plates.

An SCRI innovation is the automation of the enumeration from color film exposures of the microscope fields of view (using a Millipore Bioimage system) for immunofluorescence colony staining. This allows the detection of viable cells in 48-72 h, with colony enumeration at 40x magnification under UV.

A promising novel approach combines immunomagnetic cell separation and DOT-ELISA. The recovery efficiency is high (70%) and the bacteria can be detected and quantified by applying chemiluminescence technology with a sensitivity equivalent to radioactivity. The assay is completed within 3 hours.

Integrated Control of Pathogens in the Tunisian Potato Seed Program

Research by INRAT and CIP in **Tunisia** on damage by both seed and soil borne pathogens during seed production has shown them to play an important role at sprouting and during plant growth. Thermohydric requirements (22 to 30°C and a high relative humidity) have been shown to be similar for *Erwinia chrysanthemi, Verticillium dahliae, Colletotrichum coccodes,* and *Fusarium solani.*

A very marked synergism between the various microorganisms has been found. Fungi associated with Erwinias intensified the symptoms of blackleg and enhanced wilting during plant growth as well as soft rots at harvest.

Detection and Control of Potato Viruses

Virus Detection

The major objective for 1992 was the production of a new, highly specific, polyclonal antiserum for PLRV, the most economically important potato virus. To achieve success, the previously established procedure was re-evaluated and modified as to plant species used to propagate the virus, virus purification method, immunization protocol, and enzyme conjugation method. These changes provided sufficient amounts of purified virus and PLRV conjugates with minimal nonspecific reactions. ELISA kits and antisera for the detection of potato viruses were distributed to 18 countries.

Under the collaborative project with the private company Diagnósticos Vegetales in **Argentina**, NCM-ELISA was introduced using CIP antisera. Now both DAS and NCM-ELISA are routinely used to detect viruses (PLRV, PVX, PVY, and PVS) in seed potato stocks.

Variability of PLRV

The variability of some selected PLRV geographical isolates available in CIP were tested using six McAbs obtained from SCRI. Results indicate the existence of serological variability in the PLRV isolates tested, thus causing nonreproducible results in virus diagnosis.

Resistance

The immunity to PVX of potato cultivars Huayro, Curipamba, 28/75, P111, Nata, Santanllalla, Sipancachi Carnera, and 29/14 was confirmed in **Peru.**

A total of 200 clones were selected for their yields and tuber shape from more than 550 clones previously selected for resistance to PLRV.

The resistance to PLRV in potato clones Chacay INTA, CIP 704111, G-1, Huacha Paceña, and Guantiva was confirmed. New sources of resistance to aphids have been identified. One clone, CIP 384069.104, exhibited resistance (antixenosis) similar to that of cv. Tomasa Condemayta.

Components of resistance Research done at SCRI, **Scotland**, under CIP contract indicates that resistance to multiplication of PLRV is not linked with resistance to infection. Clones which have a high degree of resistance to multiplication and infection have been identified. Combining such high levels of both types of resistance in new cultivars, could render potatoes practically immune to PLRV, eliminating virus spread.

Four clones with resistance to infection (Pentland Crown, G7032(5), G7445(1), and G8107(1)) were transformed with the PLRV-coat protein gene (genetically engineered resistance). These clones expressed a high level of resistance to multiplication of PLRV.

Studies on Sexually Transmitted Viruses and Viroids in TPS

Studies on the possible mechanisms for PSTVd and PVT transmission used several TPS parental clones in controlled pollinations, utilizing either infected or non-infected plants.

The PSTVd NASH test was positive for TPS produced by crossing non-infected female to infected male plants (non-infected × infected). However, tests conducted with the berry tissue (pulp) were always negative. Tests of seed from infected × infected crosses that was treated at -30°C, -70°C, and 50°C were also positive. Average seed weight depended on the particular cross. When tested on indicator plants, 10% of the pollen from PSTVd-infected AVRDC-1289 and 20.9% from R.128.6 was shown to carry PSTVd.

In tests of PVT transmission, TPS of Serrana × 4.1 DI and of AVRDC × R.128.6 were shown to be positive, when the female parent was infected. Also, the number of seeds per berry of Serrana × 104.12LB was shown to differ when the male parent was infected with PVT.

In north **China,** PSTVd is a serious, widespread disease, both at research institutions and in farmers' fields. During phase I of a collaborative project on PSTVd detection techniques, NASH and RGE were developed. The incidence of PSTVd infection in principal varieties, TPS parents and some breeding materials was determined during phase II. Up to 100% infection was found in some varieties at the beginning of the project (1989) but by 1992 the highest level found was 22%. Efforts are being made to eradicate PSTVd from the principal varieties, TPS parents, and some breeding materials.

Identification and Control of Sweetpotato Viruses

Virus Identification and Characterization

Viruses have been found to reduce yields by more than 50%. Identification and characterization of viruses is a major priority in sweetpotato research and some strains or isolates require further characterization. For example, in 1992, isolate I-287 was found infecting some plants of one of the 13 SPFMV-resistant accessions (ARB 426) after a field exposure trial in Ica, Peru. Isolate I-287 shared more common antigenic determinants with strains RC, C, and 835 than to YV and C-1, but in other characteristics it resembled all strains of SPFMV.

Studies on the sweetpotato chlorotic fleck virus (SPCFV, isolate C-2) have conclusively shown that C-2 is not serologically related to other filamentous viruses from sweetpotato (SPFMV, SPMMV, SPLV and C-6) nor to the potato viruses PVA, PVM, PVY, PVS, PVX, and PVT. An isolate of SPCFV recently found in a Colombian accession (Col-1) is more closely serologically related to isolate C-5 (related to the group of Japanese origin) than to C-2 (South American group). Attempts to purify C-4 by modifying the method used for Luteoviruses (e.g., PLRV), successfully yielded virus particles, but the purified preparations still contained large amounts of undesirable host protein components. The C-6 (elongated) virus is restricted to the Convolvulaceae and is not transmitted by the aphid *Myzus persicae* Sulz. or through the botanical seed of *Ipomoea nil* or *I. setosa*.

Contract research by North Carolina State University, Raleigh, USA, was primarily directed to the characterization of the quarantinable whitefly-transmitted agent of sweetpotato virus disease (SPVD-WF). Only one viruliferous whitefly (*Bemisia tabaci*) is enough to transmit the agent to *I. nil* having acquisition, latent, and access periods of 1 hour, or less. The persistence of the agent in the vector is 24 to 48 h. Three distinct double-stranded (ds) RNA species of this agent were detected with Mw of 6.3, 5.2, and 2.3 × 10^6, respectively. A mini-prep method to detect at least the top two of these ds RNAs from 150 mg of infected tissue was developed as an alternative rapid detection system of this pathogen.

Virus Incidence and Distribution

Efforts to determine the importance and prevalence of sweetpotato viruses are being conducted in collaboration with institutions in **Peru**, **Argentina**, and **Kenya**. CIP conducted a survey in six coastal valleys (Ica, Canete, Chincha, Palpa, Pisco, and Nazca) in southern **Peru**. SPFMV and SPCFV were the only viruses found, with Ica the locality with the highest viral incidence. SPFMV was found in 8.34% of the samples and SPCFV in 0.54%. However, some fields in Ica had 97.5% of plants infected with SPFMV.

A survey carried out by the Instituto Nacional de Tecnología Agropecuaria (INTA) in four provinces of **Argentina** (Tucuman, Santiago del Estero, Buenos Aires, and Cordoba) indicated that SPFMV and SPMMV were the most prevalent viruses.

The results obtained in a survey which was carried out in **Kenya** during a CIP survey/training course indicated that sweetpotato viruses can occur in mixed infections of up to five different viruses. SPFMV was the most frequently found virus in 27.6% of samples, followed by C-6 (23.3%), SPLV (8.2%), SPCFV (4.2%), and SPMMV (2.1%).

Detection Methodology

So far NCM-ELISA has been the most efficient technique for large-scale testing for all viruses in sweetpotatoes. To overcome problems of strain specificity in the detection of SPFMV, a mixture of polyclonal antisera to strains RC and C-1, or the use of a polyclonal antiserum against strain C, has been found to be the most convenient approach.

Virus Resistance Studies

The 13 SPFMV-resistant sweetpotato accessions obtained at CIP in previous years were distributed in 1992 to eight countries (**Uruguay, Kenya, India, Indonesia, Philippines, Vietnam, China,** and **Israel**). Researchers at the Agricultural Research Organization, Volcani Center, in **Israel** tested seven of the accessions for susceptibility to SPVD (caused by the synergistic effect of SPFMV and a whitefly-transmitted agent, WF). Five became infected with both SPFMV and the WF agent, and two did not become infected with the SPFMV component. These results support the value of the resistance to SPFMV obtained at CIP. Crosses between four resistant (DLP-1913, S-24, DLP-886, and DLP-2247) and three susceptible accessions were obtained and the progenies tested by grafting with SPFMV-infected scions. Results indicated that DLP-886 and S-24 transmit the resistant condition with higher frequency than DLP-1913 and DLP-2247 (Table 6).

The search continues for new sources of resistance to SPFMV and other sweetpotato viruses. Accessions have been examined for symptoms and virus infection by NCM-ELISA and by grafting the indicator host *I. setosa* onto healthy plants. SPFMV-free accessions were graft-inoculated with SPFMV-infected *I. nil* scions. The remaining virus-free plants were challenged with SPMMV- and SPLV-infected *I. nil* scions. Seventeen of 103 accessions were not infected with SPFMV and SPLV, and eight were also free of SPMMV.

Table 6. Reaction of genotypes generated from seven sweetpotato progenitor clones to feathery mottle virus (SPFMV).

Progenitor	Reaction to SPFMV[1]	Total genotypes tested	Number of resistant clones (%)
S-24	R	108	84 (78)
DLP-886	R	143	105 (73)
DLP-1913	R	167	110 (66)
DLP-2247	R	176	92 (52)
ARB-9996	S	131	66 (50)
YM88.030	S	189	85 (45)
RCB-IN238	S	124	48 (39)

[1] R=Resistant, S=Susceptible

Control of Bacterial and Fungal Diseases of Sweetpotato

Establishing the Importance of Sweetpotato Diseases

Sweetpotato has a reputation for hardiness and for not suffering losses due to pests and diseases. However, this notion appears to result from a developed country bias, where a few varieties fill limited agroecological niches that supply the small market demand. Research stimulated or conducted by CIP shows that it is necessary to prevent the spread of prevalent diseases, as well as those diseases mandated by the quarantine laws of most countries.

Disease Surveys

CIP had to determine the incidence and severity of diseases in **Peru** in order to manage its sweetpotato germplasm collection and utilize its resistance genes. This process began three years ago for the coastal and jungle producing areas. Symptomatic foliage and storage roots collected in the field were taken to CIP's San Ramon laboratory, where pathogenic fungi and bacteria were isolated and identified. Samples from Ancash Department were found to contain three fungal pathogens: *Sclerotium rolfsii, Rhizopus stolonifer,* and *Macrophomina phaseolina.* Fusarium rot and wilt fungi were isolated from La Libertad Dept., *F. lateritium* was found in Canete, Lima Dept., and *Erwinia chrysanthemi,* causing a soft rot, was found at San Ramon, Junin Dept. Of 867 clones from CIP's germplasm collection grown in Canete, 47 were found to be infected with *F. lateritium,* the cause of chlorotic leaf distortion.

The same pathogens previously reported (Annual Reports 1991 and 1992) were found in samples collected in San Ramon. However, *Erwinia chrysanthemi,* often isolated from storage roots, was found to attack both roots and stems of Fanshu cultivar in the field. This Erwinia, which causes soft rot of storage roots, was also shown by artificial inoculation to attack potato tubers. Therefore, rotating potato with sweetpotato could be problematic.

Thesis research by a student from UNALM identified three species of Fusarium in diseased specimens from the field, market, and storage in different parts of **Peru**: *Fusarium oxysporum, F. solani,* and *F. lateritium.* Pathogenicity tests showed that these fungi are physiologically specialized as to the plant organ they attack. Isolates of *F. oxysporum* originating in storage roots were less aggressive in causing wilt than those from stems, and those from wilting stems were less aggressive in causing storage root rot. In screening for resistance to storage root rot and stem wilt, 14 clones were found to be resistant to both. The distribution of *F. lateritium* that causes SP Chlorotic Leaf Distortion (CLD) was found to be generalized.

Sweetpotatoes are the staple crop in some African agroecologies and an important complement in the diet in others. Therefore, CIP began disease surveys three years ago, in order to address the pathological problems in **East Africa.**

A survey of farmers' fields in **Kenya,** conducted in collaboration with NAL, identified *Phomopsis ipomoeae-batatas, Alternaria* spp., *Colletotrichum* sp., and *Fusarium lateritium* as the most frequently occurring pathogens. Incidence of each of these four pathogens often exceeded 50%. Disease severity was less than 25% with *P. ipomoeae-batatas* and *Colletotrichum* sp., but was frequently greater than 25% with *Alternaria* spp. and *F. lateritium.* Sweetpotato feathery mottle virus (SPFMV) was the most common virus of sweetpotatoes in Kenya, Rwanda, and Tanzania. The virus coded as C-6 was also found in all three countries.

The Kenyan nationwide survey of diseases, conducted by CIP on sweetpotato in farmers' fields was completed in 1992. A total of 113 farmers in 13 districts were included in the formal survey. Seven fungi and an unidentified disease were recorded on leaves and stems in the field. The most commonly occurring of these are shown in Table 7. A full manuscript is in preparation and a computerized database on diseases of sweetpotato has been established.

Activities on the identification and distribution of viruses in **Tanzania, Rwanda,** and **Kenya** were started in 1992. Plants were sampled from research plots in Tanzania and Rwanda. Plants in the KARI/Muguga, Kenya, virus collection were randomly sampled. Virus identification was by NCM-ELISA. SPFMV was the most frequently identified virus in northern and western **Tanzania.**

Most of the world's sweetpotato production, consumption, and industrialization takes place in South and Southeast Asia.

Table 7. Frequency of the most commonly occurring fungal pathogens of sweetpotato in farmers' fields in Kenya, by Province and Districts.

Province District	Pathogen[1]			
	P.i.	*A.*	*C.*	*F.l.*
Total	66	48	16	17
Central				
Kiambu	3	6	6	2
Kirinyaga	6	7	0	2
Muranga	4	4	0	0
Nyeri	5	6	0	0
Coast				
Kilifi	3	2	2	0
Kwale	3	1	1	0
Eastern				
Embu	0	1	0	0
Machakos	8	1	0	1
Nyanza				
Kisii	5	3	0	0
Kisumu	12	4	0	0
S.Nyanza	10	2	4	11
Rift Valley				
Kericho	0	6	0	0
Western				
Kakamega	7	5	3	1

[1] *P.i.-Phomopsis ipomoeae-batatas, A.-Alternaria* spp., *C.-Colletotrichum* sp., *F.l.-Fusarium lateritium.*

Disease incidence is being observed in a network of trials in China and SAPPRAD countries. In collaboration with the Natural Resources Institute of the United Kingdom, biological studies are beginning on S. E. Asia's most severe problem: leaf and stem scab caused by *Elsinoe batatas.*

Molecular Approaches for Detection and Control of Pathogens

Virus

Resistance Mechanisms

Molecular techniques developed for virus and viroid studies are being widely utilized at CIP-Lima as well as in the regions. These enable sensitive and rapid detection of viruses and viroids in seed programs and quarantine units and the study of virus/host interactions in attempts to develop virus resistant genotypes.

The genomic RNA of PVX, strain HB (resistance-breaking strain), has been cDNA cloned, entirely sequenced, and used for analysis and comparison with the other known non-resistance breaking PVX strains (PVXCP, PVX-X3, and PVX-S). Computer analysis and translation of the PVXHB sequence confirmed the general structure was conserved among all PVX strains.

Comparison of coat protein amino acid sequences of PVXHB with other PVX strains, suggests a high similarity in the general structure. However, the findings indicate some differences limited to a small number of amino acids. Ten points of relevant variability in the PVXHB coat protein amino acid sequence were found. Computer directed mutational analysis and secondary structure predictions confirmed that, within the ten amino acid residues examined, only three determined variations in the protein structure.

Substitution in position 70 determines one additional turn of the protein in that position. When lysine (K) is substituted with a threonine in position 121, the alpha helix is converted to a beta sheet structure in that region. Substitutions in position 226 (A - V) also cause a slight alteration of the structure. These results suggest that one or more of the observed sequence divergences are responsible for the biological differences between PVXHB and the other non-resistance breaking strains, as was shown for amino acid substitutions in the coat proteins of several other viruses.

SPFMV is the most important virus infecting sweetpotatoes worldwide. As a first step to developing transgenic resistant plants, molecular cloning and sequencing data are fundamental requirements. The coat protein (CP) gene was partially mapped in 1992. Purified SPFMV cDNA was sequenced and the alignment comparison of the SPFMV-C1 CP gene with the corresponding sequences of the RC and C strains, showed identities ranging from 60 to 95% and 65 to 100%, respectively, for the different paired comparisons.

The mechanism of resistance available in sweetpotato to SPFMV was analyzed by infection of protoplasts with virions, through electroporation. Electroporated protoplasts of *I. batatas* cvs. S24 (resistant to SPFMV) and Nemanete (susceptible) supported extensive virus replication, suggesting that the inability to detect virus infection in leaves of S24 is a result of restricted virus movement rather than resistance to virus infection and replication. Protoplasts electroporated with viral RNA-supported virus replication and synthesis of non-structural proteins.

Molecular Probes for Detection

Cloning procedures and molecular hybridization techniques have been applied to develop and promote the use of more sensitive molecular probes. These are used for routine testing of viroids and viruses in the CIP collection and in the pathogen-tested seed program, as well as in NARS programs.

International exchange of potato germplasm is often in the form of true potato seed (TPS). Therefore, detecting the presence of viruses in TPS poses quarantine problems and requires reliable, large-scale testing methods. The literature reports that PSTVd and five viruses (PVT, Arracacha virus B-Oca strain, TRSV-Calico strain, APLV, and potato yellowing virus) can be transmitted via TPS. The NASH test is the only method presently available for large-scale viroid detection. Researchers at CIP are constructing a recombinant probe by the combination of restricted fragments from cDNAs of each virus and viroid for the simultaneous detection of PSTVd and of all other viruses transmitted through TPS.

NASH has been used to monitor the presence of PVT and its distribution in the potato plant. A higher concentration of PVT in the apical part of the infected plant has been found. It has been confirmed that there is no negative interference in the simultaneous detection of PSTVd and PVT from doubly infected leaves or seeds, using a combination of the two specific probes. In one experiment, 10 of 20 infected seeds gave a strong signal in NASH. However, the sensitivity of the test can be further improved by modifying sample extraction conditions. A first recombinant probe is being constructed by subcloning the PVT cDNA together with the PSTVd sequence.

A recombinant, wide-spectrum probe for the detection of viroids was constructed by combining restricted fragments of PSTVd, HSVd, CEVd, and CSVd cDNAs. This polyvalent type probe has been successfully used in the detection of viroids in different cultivated species.

PSTVd, the only known viroid that infects potato, is readily transmitted through mechanical contact, sap inoculation, and by infected tools and farm equipment. No vector transmission has been conclusively shown for PSTVd.

PSTVd infection is often associated with PLRV presence. Experiments were conducted to study the association between PSTVd and PLRV, and to determine the possible transmission mechanism of PSTVd by aphids.

Preliminary results indicated that aphids are unable to transmit PSTVd, unless PLRV is present in the inoculum source. PLRV-aided aphid transmission of PSTVd was very efficient. Further experiments are under way to confirm these findings which might have great epidemiological importance (i.e. aphid transmission of PSTVd).

CIP's new initiative on Andean root and tuber crops has created concern for their phytosanitary condition. As a first step, all CIP accessions of: *P. sonchifolia* (yacón), *U. tuberosus* (ulluco), *O. tuberosa* (oca), *A. xanthorrhiza* (arracacha), *C. edulis* (achira), and *Araceae*, have been tested for PSTVd, using NASH. Results were negative.

Training

In **Burundi**, 21 agronomists from 12 rural development projects participated in an in-country training course on Pests and Diseases of Potato held in Bujumbura in March-April. The course was attended by trainees from the seed multiplication project of the ISABU Potato Program. The course objectives were to: (1) train field technicians on detection, identification and control of pests and diseases of potato in Burundi; (2) exchange knowledge and experience among the participants; and (3) establish linkages between persons and institutions involved in potato production. Instructors and resource scientists were from the national potato and crop protection programs, and CIP.

A two-location workshop on Late Blight Testing of Genetic Materials was held in Rionegro, **Colombia** and Quito, **Ecuador** in May. Participants attended from **Brazil, Bolivia, Colombia,** and **Ecuador**. At Quito, participants were introduced to the theory of genetic resistance, the breeding program, and characteristics of the pathogens. At Rionegro, they observed the behavior of genotypes under heavy incidence of the disease with natural and artificial inoculation.

An in-country course on Bacterial Wilt Detection Techniques at La Trinidad, **Philippines** was organized by the Northern Philippine Root Crops Research and Training Center (NPRCRTC), and was sponsored by CIP and Rothamsted Experiment Station. Held in May, the course was attended by 12 participants from 6 institutions. The course consisted of lectures, field visits, and laboratory exercises to test samples collected from the areas visited. Topics covered included instruction on bacterial wilt detection techniques and development of research workplans on the control of bacterial wilt.

A course on Basic Virology of Potato and Sweetpotato was held in Nairobi, **Kenya** in June, with participants attending from **Uganda, Tanzania, Kenya, Burundi, Rwanda, Madagascar,** and **Zaire**. Instructors were from CIP's regional office and the Kenyan Agricultural Research Institute (KARI) in Nairobi. CIP and the Ugandan country program provided resource scientists. The course was funded by PRAPACE, GTZ bilateral program, and CIP.

AVRDC and CIP cosponsored a Bacterial Wilt International Symposium at Kaohsiung, **Taiwan**, in October. The symposium addressed basic research issues regarding bacterial wilt and the Pseudomonas bacterium. Symposium objectives were to: (1) develop up-to-date strategies for breeding and screening techniques that would facilitate control of BW through host-plant resistance; (2) understand the principles that govern the genetic and physiological bases of resistance in various hosts; (3) standardize methods used to assess aggressiveness, virulence, and genetic differences in strains of the bacterium; (4) develop methods to detect, differentiate, and classify strains, using traditional and molecular techniques; and (5) prioritize future research needs.

Combined Training for Programs 3 and 4

Visiting scientists from **Brazil** and **Italy** were trained for one week at CIP's experiment station at Quito, **Ecuador**. They were instructed on inoculation procedures with *P. infestans* and screening for detecting R-genes, using the detached-leaf method in petri dishes.

A CIP adjunct scientist at IPO, the Netherlands, instructed a scientist from **Rwanda** on virulence testing and cryogenic preservation of *P. infestans.*

PRECODEPA's project coordinator provided on-the-job training on procedures for selecting breeding materials with horizontal resistance to late blight and variety releases. Besides professionals trained in the country, participants included 12 scientists from **Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica,** and **Panama.**

Individual training on detection, isolation, purification and identification of *P. solanacearum* was provided at the Rothamsted Experiment Station, under the auspices of an ODA project and with the support of the Natural Resources Institute (NRI), of the **UK**. Participants included plant pathologists from the Kenyan Agricultural Research Institute (Kakamega Regional Research Centre), **Kenya**, and Madeira (Regiao Autonoma de Madeira, Direçao de Servicios de Investigaçao Agricola), **Madeira Islands.**

An International training workshop on the detection, identification and integrated control of P. solanacearum was held at Nairobi, **Kenya,** in November. It was organized by the CIP regional office and partially supported by the NRED/CIP project. Participants attended from **Burundi, Egypt, Kenya, Malawi, Mauritius, Reunion, Rwanda, Uganda, UK,** and **Zaire.** Workshop recommendations have been published.

CIP and the MAG of **Chile** are collaborating in a program to eradicate BW from most of central Chile. Antisera detection kits are being supplied for the surveys, and two staff members trained.

Chile's principal investigator of research on the integrated control of Erwinia-caused diseases of potato received short-term training on bacteriological techniques at CIP Lima.

Also at CIP, 15 professionals from the NARS of **Peru, Ecuador, Checoslovakia, Sri Lanka, Italy, Colombia, Burundi, Tanzania,** and **Ethiopia** were trained on the detection of viruses. A manual has been prepared that includes all the techniques presented in this virology training.

In **China,** virus detection techniques to improve seed quality were taught to some provincial programs through training courses and demonstrations. Antisera against PVX, PVY, PVS, and PLRV, for use in DAS-ELISA and NCM-ELISA were prepared and distributed as serological kits to other projects and institutions.

Training activities in **Kenya** included individual training for one scientist, as well as two in-country training courses in general sweetpotato pathology and a two-week regional training course in virology.

The Sweetpotato Disease Data Base is being expanded to other countries, and the data are being published. A handbook on pests and diseases of sweetpotato in East Africa is in draft form.

Group and individual training courses have been organized both in Lima, **Peru,** and in the regions, based on use of radioactive and non-radioactive NASH procedures for detection of the virus PSTVd.

Hands-on training for virus detection has proven successful in China and many other countries.

1992 Research Projects and Partners

This list contains the titles of research projects, the names of principal partner researchers and their respective country, the responsible CIP scientist, and the names of collaborating researchers.

Collaboration to develop fundamental information for late blight work. L. Turkensteen, IPO, **Netherlands**

Integrated management and control of potato late blight. N. Estrada, PROINPA, **Bolivia**, and Bolivian National Scientists/ J. Landeo, E. Fernández-Northcote

Evaluation of genetic material from CIP for resistance to late blight and bacterial wilt. J.L. Zapata, O. Trillos, ICA, **Colombia/**J. Landeo; G. Forbes, O. Hidalgo, H. El-Nashaar, O. Pérez, J. Llano

Epidemiological and biological studies related to the efficiency of selection for horizontal resistance to late blight (*Phytophthora infestans*) and to the durability of this resistance. G. Forbes, **Ecuador/** J. Landeo; L. Skoglund. H.M. Kidane-Mariam, D. Berríos, M. Soto, P. Tegera, C. Muvira, **East Africa**

Breeding for late blight resistance with populations A and B. J. Landeo, G. Forbes. M. Gastelo, L. Calúa, H. Pinedo **Peru**

Inheritance of horizontal resistance to late blight in advanced potato hybrids. E. Roncal, INIA, **Peru/**J. Landeo, M. Gastelo, L. Calúa

Racial structure of *Phytophthora infestans* in the **Philippines**. Tran Xuan Ai, UPLB, the **Philippines**. E. Chujoy

Selection of resistance to late blight of potato. M. Villarreal, INIFAP, **Mexico**; J. Landeo, G. Forbes, M. Cadena

Management of bacterial wilt. S. Ajanga, KARI, **Kenya**/L.G. Skoglund, H.M. Kidane-Mariam

Screening potato germplasm for resistance to *Pseudomonas solanacearum* in **S.E. Asia.** F.A. Saldívar, LEHRI, **Indonesia**/E. Chujoy and Il Gin Mok, the **Philippines**; A.S. Tumapon, L. Duna, E.S. Maape, S. Sahat

Basic research in controlling bacterial wilt of potatoes. He Liyuan, CAAS, **China**/Song Bofu

Ecology, taxonomy and strategy to control *Pseudomonas solanacearum*. E. French, P. Aley and U. Nydegger **Peru**

Breeding for resistance to bacterial wilt. R. Anguiz/H. Mendoza; E. French, P. Jatala **Peru**

IPM for the control of root-knot nematodes in potato, for the integrated control of bacterial wilt. P. Jatala, H. Mendoza, K. Watanabe, E. French, H. El-Nashaar, R. Anguiz, E. Guevara, R. Delgado de la Flor, R. Haddad, T. Boluarte, L. Gavilano, P. Aley **Peru**

Technology development for control of bacterial wilt of the potato caused by *Pseudomonas solanacearum*. J. Elphinstone, Rothamsted, UK/H. El-Nashaar

Evaluation of CIP's advanced potato genetic materials in four Andean countries. National programs scientists and R. Pineda, E. Hernández, ICA, **Colombia**, M. Sola, J. Revelo; INIAP, **Ecuador**; R. Egúsquiza UNA, V. Huanco, INIA, **Peru**; R. León, E. Ortega, FONAIAP, **Venezuela**/ O. Hidalgo, J. Landeo, J. Bryan

Evaluation of advanced potato genetic materials with emphasis on virus resistance. M. Fahem CPRA, **Tunisia**/ C. Carli

Evaluation of advanced potato genetic materials in Egypt. N. Farag, A. El-Amrity, H. Makramalla, MA, **Egypt**/ R. El-Bedewy; H. Mendoza, A. Golmirzaie, J. Bryan, R. Cortbaoui

Evaluation of advanced potato genetic materials for **Cameroon** and neighboring countries with emphasis on disease resistance. National Breeders/Agronomists of **West** and **Central Africa**/ C. Martin, H. Mendoza, J. Landeo

The development of pest resistant populations. R.L. Plaisted, M.W. Bonierbale, W.M. Tingey, B.B. Brodie, J.C. Steffens, E.E. Ewing, Cornell University, **USA**/ K. Watanabe

Breeding and selection of potato clones with disease resistances and other appropriate horticultural characteristics. H.M. Kidane-Mariam, H. Mendoza, J. Landeo, L. Skoglund **Kenya**

Breeding for early blight resistance. H. Mendoza. R. Anguiz, H. Torres **Peru**

Genetic studies and breeding for virus and viroid resistance in sweetpotato. H. Mendoza, U. Jayasinghe, L. Salazar, E. Mihovilovich, C. Chuquillanqui **Peru**

Breeding potatoes resistant to the potato leafroll virus, PLRV. K.M. Swiezysnki, IZ, IPR, **Poland**

Evaluation of potato germplasm for disease resistance. J.A. Buso, CNPH-EMBRAPA, **Brazil**/E. French, R. Anguiz

Evaluation of advanced potato breeding material in **South America**. M. Huarte, INTA, **Argentina**; A. Buso EMBRAPA, **Brazil**; A. López Min. Agr., **Paraguay**; F. Vilar, CIAAB, **Uruguay**/H. Mendoza, F. Ezeta

Selection of advanced virus-resistant potato materials with adaptation to **North Africa** and the **Middle East**. R. Rousselle, INRA, **France**

Evaluation of potato germplasm for earliness and resistance to PVY, PVX, PLRV and *Alternaria solani*. J. Vilaro, C. Crisci, INIA, **Uruguay**/H. Mendoza

Erwinia disease in different phases of the Tunisian potato seed program. M. Mahjoub, M. Romdhani ESH, **Tunisia**/ R. Cortbaoui

Integrated control of soft rot and blackleg of potato (*Erwinia* spp.) in the Décima Región of Chile. I. Acuña, J. Kalazich, INIA, **Chile**/P. Accatino; A. Aguila, O. Werner, E. French

Strategic and applied research to control Erwinia diseases of potatoes. Detection of seed contamination, and nature of disease resistance. M. Perombelon, SCRI, **Scotland**

Development of improved native potato germplasm. Selecting resistance to *Erwinia* spp. Z. Huamán, L. de Lindo, E. French; C. Aguilar, H. Mendoza, H. Torres **Peru**

Contribution of genetic and biological control to Erwinia disease in potato. M. Gutiérrez, L. Ciampi, R. Carrillo, U Astral, **Chile**, J. Kalazich/P. Accatino

Development and standardization of effective screening procedures to determine resistance to blackleg and soft rot. L. Gutarra, UNALM/E. French **Peru**

Pathogenic variability of pectolytic Erwinia in Peru. A.M. Taboada, UNALM/E.R. French, L. Gutarra **Peru**

Development and utilization of virus detection techniques. Zhang Heling, U. Inner Mongolia, **China**/Song Bofu; L.F. Salazar

Test application of modern technology for of potato pathogens. A.M. Escarra, **Argentina**/L.F. Salazar

Mechanism of resistance and variability of potato leafroll virus (PLRV). U. Jayasinghe, L.F. Salazar, H.A. Mendoza, K. Watanabe, E. Fernández-Northcote **Peru**

Characteristics of the transmission of potato viruses and viroids through TPS. P. Malagamba, C. Barrera, L. Salazar, N. Maza, J. Bryan, N. Pallais **Peru**

Antiserum production and improvement of serological techniques for virus detection. Ch. Delgado, R. Orrego, L. Salazar **Peru**

Inheritance of and screening for components of resistance to potato leafroll virus in potato. H. Barker, SCRI, **Scotland**

Development of virus testing procedures for sweetpotatoes. J. Moyer, NCSU, **USA**/L. Salazar

Virus diseases of sweetpotatoes: genetic resistance. G. Loebenstein, **Israel**, H.J. Vetten, **Germany**, S. Fuentes, L.F. Salazar

Identification and characterization of sweetpotato viruses. S. Fuentes, L. Salazar/J. Moyer, A. Brunt **Peru**

Etiology of sweetpotato chlorotic leaf distortion. C.A. Clark, R.A. Valverde, D.R. La Bonte, LSU, **USA**

Fusarium species pathogenic to sweetpotato (*Ipomoea batatas*) in Peru. W. Pérez Barrera, UNALM, **Peru**/E. French; T. Ames

Molecular analysis of genetic resistance to viruses and development of molecular probes. M. Querci, L. Salazar **Peru**

Molecular analysis of genetic resistance of sweetpotato to viruses and development of molecular probes. M. Querci, L. Salazar **Peru**

Genome structure and expression of sweet-potato feathery mottle virus C1 (SPFMV C1). J. Nakashima, U Birmingham, **UK**; K.R. Wood, L.F. Salazar

Virology of Andean tuber and root crops. R. Estrada, UNMSM, **Peru**/ U. Jayasinghe, M. Hermann

Partial characterization of a virus isolated from Oxalis tuberosa Mol. Andres Antola, UNALM, **Peru**

PROGRAM 4

Integrated Pest Management

The integrated pest management (IPM) research program deals with the ecologically-compatible management of insect and nematode pests of potato and sweetpotato. These two crops pose different situations in terms of protection against pests. Among food crops, potato is the largest single user of pesticides, and providing this protection leads to high production costs. Sweetpotato, however, is one of the few crops that can be produced economically in many parts of the world with almost no use of pesticides. The sweetpotato weevil is considered this crop's most important pest.

An ecological approach is valid for pest management in both crops despite their differences. This approach has two phases: the development of component technology, followed by the integration of these components through pilot programs. Components include breeding for resistance and tolerance, development of biological, cultural, ethological control measures, and selective use of chemicals. At the integration phase, local pest characterization and population dynamics information serves as the basis for adaptive research to apply the components in farmers' fields.

The potato research emphasis centers on: (1) potato tuber moth, a pest found worldwide, which is particularly injurious where the weather is warm and dry (several **South American countries, Central America, Mexico, Northern Africa**); (2) the Andean potato weevil, an important pest in **Bolivia, Peru, Ecuador, Colombia, Venezuela**; (3) the leafminer fly, which is becoming very important in many parts of the world, as a result of heavy insecticide use (coast of **Peru, Brazil, Central America, Kenya, Egypt**, and other countries); and (4) the potato cyst nematode, a pest endemic in the Andean region and also found in some other parts of the world.

Sweetpotato research focuses on the management of sweetpotato weevil and root-knot nematode. The weevils are of two types: the South American weevil that is distributed primarily in **South** and **Central America** and the **Caribbean**; and the Asian weevil found in the Caribbean, **North America**, and **Asia**. There are two Asian weevil related species in Africa. Although research on these weevils is relatively new, use of pheromones to control the Asian weevil is an important breakthrough. Management of root-knot nematode is based on the development of resistant cultivars.

Measures of IPM program effectiveness are based on several factors including the pest problem, the complexity of the agroecosystems, and the cultural and economic characteristics of the farmer. Immediate program results include reduced pesticide use, replacement of wide-spectrum toxic compounds by less toxic, selective products (including bio-insecticides), and reduced costs for protecting crops from pests. Less tangible, but more important effects are related to the sustainability of the system; this includes management to avoid development of pest resistance to insecticides and prevent new pests that might flourish when natural enemies are weakened. Such management also includes protecting the environment against toxic compounds and reducing human and animal health risks.

Potatoes with Resistance to Major Insect and Mite Pests

Developing plant resistance to pests is a primary component of integrated pest management programs. Resistant cultivars have the advantage of being compatible with other techniques that need to be integrated into a particular agroecosystem. Therefore, the objective of this work is to develop and improve resistance to major insect and mite pests in potato clones. Among these pests are the potato tuber moth (PTM), a pest distributed worldwide; the leafminer fly (LMF), a pest which is becoming increasingly more destructive in areas with heavy pesticide use; the Andean potato weevil (APW), a serious pest in the Andean mountain region; the Colorado Potato Beetle (CPB), a pest in some temperate areas; and thrips and red and white mites which are important pests in some tropical areas.

CIP's research methodologies include identifying sources of pest-specific resistance in modern and primitive cultivars —even wild species—and transferring resistance traits to genotypes that have other desirable characteristics: high yield, resistances to diseases, earliness, and traits desired in specific localities. Intensive screening and breeding work uses both conventional and non-conventional plant transformation techniques. Institutions collaborating with CIP in screening and breeding for resistance to potato pests include the Universidad Nacional Agraria La Molina (UNALM) in **Peru**; the Instituto Colombiano Agropecuario (ICA) in Colombia; the University of the Philippines, Los Baños (UPLB); Comitato Nazionale per la Ricerca e per lo Sviluppo dell'Energia Nucleare e delle Energie Alternative (ENEA) in **Italy**, Plant Genetics Systems (PGS) in **Belgium**; and Cornell University and Michigan State University in the **USA**.

Potato Tuber Moth Resistance

Potato tuber moth damages foliage and tubers and the mechanisms of resistance involved in these two types of damage do not seem to be related. Useful sources of resistance for tuber damage have been identified in wild potato germplasm and at the diploid level in breeding program materials. The resistance traits discovered in wild materials (*Solanum bukasovii, S. commersonii, S. medians, S. megistacrolobum, and S. sparsipilum*) take longer to transfer to advanced clones, because wild species have many undesirable primitive characteristics. However, use of these materials significantly widens the range of new sources of resistance. As a result, resistance becomes more stable.

The tested diploid materials included a group of clones whose parents were resistant to the main virus diseases (PLRV, PVY, and PVX) and a second group of parents resistant to bacterial wilt, potato cyst nematodes, and root-knot nematodes. The best materials selected will be crossed with tetraploids to produce potatoes having both good agronomic characteristics and resistances.

Advanced clones selected in previous years have been improved from crosses, and tests have confirmed good levels of resistance (of the antibiosis type) and good yields (14 resistant and 21 moderately resistant). Likewise, disease resistance has been identified in a new group of advanced clones from the TPS program, and these materials will be tested again next year to confirm this attribute.

New populations are being developed by crossing European varieties with CIP's PTM-resistant clones. The higher-performance families selected from this group are being evaluated for resistance under storage conditions.

Advanced clones that perform well and are resistant to potato tuber moth are now ready for multiplication and testing in larger plots under field conditions in a range of agroecologies, including regional evaluation (Table 1). New materials, including transformed plants, are also being developed in collaboration with PGS in **Belgium**.

Table 1. Performance of the 11 best potato tuber moth resistant clones, La Molina, winter, 1992.

Clone	Resistance level	Yield/plant (kg)
P87425.16	MR	1.685
P87425.12	MR	1.675
P87439.4	MR	1.470
P85031.5	MR	1.300
P87424.3	MR	0.870
P87476.6	MR	0.720
P85136.1	R	0.620
P85115.1	R	0.600
PALM148.3	R	0.370
P85075.2	R	0.310
P85112.1	MR	0.300

MR = Moderately resistant
R = Resistant

Leafminer Fly Resistance

The leafminer fly, *Liriomyza huidobrensis*, is rapidly gaining importance in areas of the world where pesticide use is heavy. This pest is difficult to eliminate with insecticides; for example, the pest was recently introduced into the Netherlands and other parts of Europe and immediately became the most difficult pest to control in vegetable production. Combining plant resistance with the use of natural enemies has been found to be the most effective approach to LMF control. Therefore, an intensive search for sources of resistance is under way, including testing of advanced materials from different breeding programs, from the pathogen tested group, and from materials with glandular trichomes (Table 2).

Resistant and moderately resistant materials with excellent yields have been selected, following several years of testing and selecting clones under screenhouse and field conditions. Some of these clones, such as CIP 380496.6 (P7), CIP 381263.2 (F8), and CIP 720086 (Ica Guantiva), which yielded 1.3, 2.5, and 1.2 kg per plant, are ready for multiplication and large-scale field testing. Seven other top performing, moderately-resistant clones include four from the TPS breeding program breeding, as well as 662LM86-B, 136LM86-B, and 282LM87B. Clone

Table 2. Density frequency of trichomes in hybrid families, La Molina, 1992.

Cross	Family	Genotype	Trichome Type	Density		
				High	Medium	Low
trichomes × trichomes	7	611	A+B	40.6	50.8	0.0
PTM × trichomes	9	961	A	0.0	12.4	87.4
trichomes × PTM	9	297	A	0.0	0.0	100.0
trichomes × leaf miner fly	11	418	A	2.8	16.3	81.4
Leaf miner fly × trichomes	12	618	A	0.0	28.5	71.5
TM[1] × P	12	783	A	0.0	21.5	77.4
TM × T	18	890	A+B	0.0	23.0	77.0
trichomes × TPS	71	7055	A	21.3	23.6	55.9
TPS × trichomes	63	7110	A	10.9	14.1	75.9
Total	212	18743				

[1] Trichomes × resistance to leafminer fly.

Table 3. Performance of the three best leafminer fly resistant clones, La Molina, winter, 1992.

			Tuber characters			
Clone	Yield/plant (kg)	Dry matter	Overall rating	Color	Shape	Uniformity
282LM86B	2.710	23.34	9	9	7	9
136LM86B	1.695	28.05	8	9	7	9
662LM86B	1.440	20.66	8	9	9	9

Scale: 1 = poor; 9 = best

136LM86-B ise now being cleaned of viruses to ready it for multiplication and testing in the regions (Table 3).

In most materials the resistance mechanism serves to reduce the feeding habits of adult flies and to reduce the oviposition (egg laying) capacity of the female flies. No effects have been observed in larval development, but investigations on the mechanisms of resistance involved are still under way.

Several of the above mentioned materials are ready for multiplication and large-scale field testing and use in IPM pilot programs in agroecosystems where LMF is a serious pest.

Andean Potato Weevil Resistance

Andean potato weevil is the predominant potato pest in **Bolivia, Peru, Ecuador, Colombia,** and **Venezuela.** Resistant materials, although highly desirable, must first be adopted by farmers who have a strong preference for their local varieties. Therefore, resistance is being evaluated in cultivars from these areas and in advanced clones judged as good possibilities for acceptance by Andean farmers.

Over the past three years, field tests in Cajamarca, **Peru,** have identified 15 cultivars having consistent resistance levels. The tubers of three of these clones have also shown resistance in closed containers (no-choice) tests indicating the occurrence of an antibiosis mechanism of resistance. The resistance of the other materials may be attributed to a non-preference (antixenosis) mechanism. Screening and breeding for resistance against the Andean weevils is in the initial phase. Much searching is needed before resistant materials might be ready for large-scale field trials.

Potatoes with Glandular Trichomes

Glandular trichomes (hairs) are a general, non-specific mechanism of resistance, whose effects are being evaluated against various insect pests and spider mites. There is also interest in evaluating the effects of glandular trichomes on harmless natural enemies of pests.

Evaluated materials include a group of clones produced both at Cornell University and CIP. Selection criteria are dense formation of trichomes A (tetralobulate) and B (monolobulate), and the reduction of red spider mite infestations under greenhouse conditions.

In tests on one of the most advanced clones, CIP 801023 (L235-4) of the Cornell-CIP collaboration, glandular trichomes were found to affect the reproduction capacity and nymphal survival of the aphid *Myzus persicae,* the most important vector of potato virus diseases. Some genotypes did not affect either PTM oviposition or larval development, while others affected the oviposition capacity. Leafminer flies were highly affected in their feeding habits, longevity, and oviposition capacity. Clone L235-4, which has only type A trichomes, was not as effective as clone K419-8 which has type A and B trichomes.

A group of trichome hybrid families is now being evaluated in the TPS breeding program. Clones with high trichome density, high resistance levels, and good yields will be selected for field testing.

Although glandular trichomes are an effective mechanism of resistance against several insect and mite pests, advanced materials having good agronomic traits and disease resistances TUB×BERTH hybrids must be evaluated before large-scale testing in farmers' fields.

Transforming Plants for Resistance

The first potato plants transformed by PGS in **Belgium** using the gene that produces the endo alfa toxin of *Bacillus thuringiensis* were tested against PTM in 1992. Preliminary results from these tests suggest that larval survival is reduced, the duration of first larval instar is extended, and surviving larvae are less vigorous.

These trials are in an initial phase and testing methodology is in the process of refinement. New materials from PGS and generated at CIP will also be tested. In these first tests, the transformed plants appeared to be rather weak, as compared with the non-transformed plants.

Controlling Potato Tuber Moth Using IPM

The potato tuber moth, *Phthorimaea operculella*, is distributed worldwide and is particularly injurious in both fields and stores in warm, dry areas. Two related species are restricted in their distribution: (1) to the Andes, *Symmetrischema plaesiosema*, and (2) to Central America, *Tecia solanivora*. CIP's goal is to develop IPM components for managing these pests and adapting these components to specific agroecological conditions.

NARS throughout the world cooperate in this project, including UNALM, Instituto Nacional de Investigación Agropecuaria (INIA), and Semilla e Investigación en Papa (SEINPA) from **Peru**; Instituto Colombiano Agrícola (ICA) in Colombia; Proyecto de Investigaciones de la Papa (PROINPA) in Bolivia; the Programa Regional Cooperativo de Papa (PRECODEPA) network in **Central America** and the **Caribbean**; the Egyptian Ministry of Agriculture; Institut National de la Recherche Agronomique de Tunisie (INRAT) in **Tunisia**; and the Kenyan Agricultural Research Institute (KARI) and the International Centre for Insect Physiology and Ecology (ICIPE), in **Kenya**.

CIP has developed several IPM components for potato tuber moth control, including the use of sex pheromones for trapping male moths; multiplication, formulation, and use of a granulosis *Baculovirus* on stored potatoes; identification, evaluation and mass rearing of a poliembrionic parasitoid (*Copidosoma koheleri*); identification and use of repellant plants for stored potatoes; the identification of resistant potatoes (reported in the previous section); and the use of cultural practices, particularly timing of planting and harvesting, hilling-up, and irrigation management.

Farmers, particularly of medium and large holdings, protect their potatoes against this PTM in the field and in stores through intensive pesticide use. Therefore, a first objective has been to reduce insecticide use. Methods used include the monitoring of the PTM population density with sex pheromone trapping to determine better timing for sprays, and intensifying mass trapping for field infestations. Use of granulosis *Baculovirus* and repellant plants was effective for store infestations. Other studies are under way on use of *Baculovirus* in the field; on adoption of resistant varieties; and on use of selective products to replace more toxic compounds. Because fumigants may be required in some exceptional, emergency situations, the effect of fumigants on the pest and stored tubers also requires study.

Selective chemicals and biological agents, including *Bacillus thuringiensis*, are being investigated in **Tunisia** (Table 4), **Egypt**, and **Bangladesh**. The mass production and use of granulosis *Baculovirus* is under way in **Tunisia, Egypt, Peru**, and **Bolivia**. An increasing demand for this virus has encouraged development of technologies for "cottage production" of the virus.

Tests of good crop management practices, including extra irrigation and early harvesting, have successfully reduced PTM infestations in **Egypt** and **Tunisia**. In Leon, Guanajuato, **Mexico**, the use of sex pheromones for monitoring pest density has reduced chemical use by about 50% for the second year.

Preliminary studies of the highland agroecosystems in Cajamarca and Arequipa, **Peru**, are under way to adapt CIP's technologies for future IPM pilot programs. These programs will be initiated in farmers' fields in 1993 and researchers expect that two to three years will be needed for adjustments to the agroecological and socioeconomic conditions of the farmers. Following these preliminary studies, the program will be ready for diffusion to other agroecologies where PTM is a major pest.

Table 4. PTM control in potato stores using biological pesticides, Tunisia, 1992.

	PTM damage over 3 months		
Treatment	Month 1	Month 2	Month 3
Control	3.67 a	15.00 a	16.67 a
Thuricide	0.33 b	1.33 b	2.67 b
Granulosis virus	1.67 ab	1.00 b	2.00 bc
Thuricide + GV	0.00 b	0.00 b	2.00 bc
Bactospeine	3.00 a	1.67 b	0.33 c
Bactospeine + GV	0.33 b	0.33 b	0.33 c
Decis	0.67 b	0.00 b	0.00 c
DF = 6 Alpha =	0.05		
MSE	1.34	2.23	1.20
LSD	2.31	2.98	2.19

Integrated Methods for Control of Sweetpotato Weevil

Sweetpotato weevils are considered the most injurious of sweetpotatoes pests. *Cylas formicarius* is the dominant species in Asia, North America, and the Caribbean; *C. Puncticollis* and *C. brunneus* in Africa; and *Euscepes postfasciatus* occurs in South America and a few other areas.

NARS collaborating in research on these pests include those from **Peru**, the **Dominican Republic, Cuba**, the **Philippines, India, Sri Lanka, Thailand, China, Bangladesh, Indonesia, Kenya, Burundi**, and the Universities of Mississippi and Florida in the **USA**.

Some clones resistant to the South American weevil have been identified at CIP's headquarters in **Peru**, but resistance to *Cylas* spp. is still being sought in breeding work at several institutions. Research at Mississippi State University has now been contracted to build resistance to practical levels. Moderate resistance has been identified, and several different breeding methods, family and individual plant selections, and testing methodologies are being evaluated. Resistance has been increased to 7% over that of the most resistant control (cv. Regal), and researchers expect the level of resistance to increase more rapidly in subsequent selection cycles. Those clones selected as most resistant to weevil (Table 5) will be used to obtain seedling polycross progenies for further selections.

Table 5. Sweetpotato weevil injury to storage roots of clonal selections compared to family means. Mississippi State University, 1992.

	Percentage non-injured root number					
	1991		1992		Mean	
Parent[1]	Family[2]	Selection[3]	Family	Selection	Family	Selection
W244	81	55	70	63	76	57*
Resisto	67	66	78	93	72	80
W250	61	76	80	87	71	81*
MS741	61	67	76	74	68	71
W263	56	54	80	71	68	62
S US-1	57	58	74	68	66	63
MS 114	57	77	74	69	66	73
NC 902	43	59	85	72	65	66
S US-2	46	63	69	88	58	76*
MS 105	51	75	54	85	52	80*

[1] Entries were polycross progenies from the listed parents.

[2] Mean of 5 seedling plants from the families with highest percentage non-injured roots and yield in 1990.

[3] Mean of 5 clonal plants of each of the 2 highest performing (% non-injured roots and yield) seedling plants from each family in 1990.

Sex pheromones use is the most important individual component available for managing the *Cylas formicarius* weevil. Although the method is used primarily to monitor weevil populations, there is also some evidence that mass trapping can reduce pest infestations. Research to verify this is under way in collaboration with Manejo Integrado de Plagas (MIP) a private organization in the **Dominican Republic,** Bangladesh Agricultural Research Institute (BARI) and Tropical Crops Research Center (TCRC) in **Bangladesh,** and national programs in **Cuba** and **India.** Presently no sex pheromones are available for the African *Cylas* species; this research is a high priority for weevil control in Africa.

No effective parasitoids of sweetpotato weevils have been found, despite extensive worldwide sampling. In **Cuba,** however, predatory ants seem to play an important role in the weevil's destruction. More research is needed to confirm this finding and to explore the feasibility of mass rearing these predatory ants. Tests being conducted in the **Philippines, Bangladesh,** and **Dominican Republic** will determine the efficiency of the white muscardine fungus, *Beauveria bassiana.* Similar tests were conducted in **Peru** against the South American weevil, but results have not been consistent. Research at UPLB in the **Philippines** showed that some local *Bacillus thuringiensis* have an insecticidal effect against the weevil. This opens new possibilities for the control of the weevil through use of conventional spray applications of this insecticide, as well as using other biotechnological procedures. More research is needed on biological control of this pest.

Studies in **Kenya** on the biology of two African *Cylas* species are filling the gap in basic knowledge about these weevils.

The pests' role in sweetpotato agroecosystems has been studied extensively worldwide, including complementary research and information gathering on other sweetpotato pests and cultural practices of sweetpotato farmers in **Kenya**

Scientist from INIVIT in Cuba work closely with CIP colleagues to improve sweetpotato production in the island. This partnership has led to establishment of a large-scale pheromone program to control infestations of sweetpotato weevil. This technology has led to reductions in seasonal pesticide applications from 15-20 to only 3.

(KARI), **Bangladesh** (BARI), (Table 6) and **Peru** (SEINPA, INIA).

Sweetpotato Nematode Control Using IMP

Polyphagous and widely distributed root-knot nematodes (RKN), *Meloidogyne* spp. are the most common nematode pests of sweetpotatoes. In some areas of **China**, the root rot nematode, *Ditylenchus destructor*, is reported as very injurious to this crop. RKN management is based on plant resistance, and complemented by cultural practices and other measures, including the use of biological control agents.

Extensive screening for resistance has identified many resistant genotypes over the last three years. The materials used included CIP's sweetpotato germplasm accessions, advanced breeding materials, crosses with the wild species *Ipomoea trifida*, and imported or locally generated virus-free materials.

The most recent tests included clones from **Cuba, Guatemala, Mexico, Dominican Republic, Colombia, Ecuador, Venezuela,** and the **USA** (Table 7). Of 551 genotypes only seven clones were resistant. Overall, eight clones of various breeding programs have been identified as resistant, 59 in crosses of the wild species *Ipomoea trifida*, including 14 highly resistant clones, and 13 from the group of the virus-free clones from the pathogen tested program. In **Burundi**, CIP 440033 (Rusenya) was the only resistant variety from a group of local varieties evaluated.

A high yielding clone, CIP 187012.12 (ME12), early maturing and highly resistant to *M. incognita* and *M. javanica*, was released as Alto Urubamba by the

Table 6. Weevil rating, weevil damage by weight, weevil population, and yield in 20 varieties/lines of sweetpotato, Bangladesh, 1992.

Variety/line	Root damage by number(%)	Root damage by weight(%)	Marketable yield (t/ha)
Local (SP-106)	10.67 fgh	9.00 f	6.00 d
AIS-243-2	14.00 def	14.33 abcd	6.67 d
CI-478-9	17.00 bcd	17.67 a	9.00 bcd
BNAS white	10.67 fgh	11.00 def	8.33 d
Cinjhi	11.00 efgh	11.33 cdef	9.33 bcd
Tripti	11.33 efgh	9.33 f	22.67 a
Local (SP-109)	10.00 fgh	10.33 ef	10.00 bcd
Belalu(SP-067)	9.33 h	10.00 ef	8.67 cd
Local (SP-135)	9.33 h	8.33 f	9.00 bcd
Local (SP-123)	9.67 gh	9.33 f	8.00 d
Macana	14.33 cdef	8.67 f	9.00 bcd
Local (SP-134)	8.33 h	12.00 bcdef	11.00 bcd
CI-478-3	19.67 ab	9.67 f	10.67 bc
AIS-272-9	18.00 abc	16.00 ab	8.00 d
CI-478-10	15.00 cd	14.00 abcde	10.67 bc
CI-0117-25	22.00 a	15.33 abc	9.33 bcd
Local (SP-069)	10.00 fgh	17.00 a	8.67 cd
R.S.4	14.67 cde	9.00 f	8.33 d
CI-489-2	12.00 defg	10.33 ef	9.67 bcd
AC-6	11.33 efgh	9.33 f	9.33 bcd

Means followed by the same letter in the same column do not differ significantly from each other at 0.01 level by DMRT.

Table 7. Reaction of some sweetpotato clones to *Meloidogyne incognita*, La Molina, 1992.

	Host reaction[1]				
Origin	HR	R	MR	S	Total
Cuba	0	0	1	65	66
Guatemala	0	0	6	79	85
Mexico	0	0	0	48	48
Dominican Republic	0	0	0	39	39
Other countries[2]	0	7	36	280	323
Ipomoea trifida	14	45	33	163	255
CIP's breeding material	0	8	13	134	155
Total	14	60	89	808	971

[1] Host reaction based on the combined root galling and root necrosis responses
(HR = highly resistant,
R = resistant,
MR = moderately resistant,
S = susceptible)

[2] Colombia, Ecuador, Venezuela, USA

Universidad del Cusco and a coffee producing cooperative in Alto Urubamba, Quillabamba, Cusco, **Peru**, to replace their late, poor yielding local varieties. A program for intensive field multiplication of this clone is under way to provide sufficient seed (cuttings) to farmers in Cusco using pathogen-tested material provided by CIP.

IPM Control Methods for Andean Potato Weevil

The Andean potato weevil (several species of *Premnotrypes* and related genera) is the most injurious potato pest in the Andes. Tubers continue to be damaged in the field despite the use of pesticides. Weevil control is complicated for small farmers (those 80% who do not benefit from owning large fields suitable for crop rotation).

CIP has developed important methods for managing this pest under smallholder conditions. Research included gaining a thorough knowledge of its life cycle, behavior, and seasonal occurrence; identifying resistant plants; selecting effective cultural practices; developing mechanical protection against insect migration; and enhancing biological controls.

After the verification of the effectiveness of the control of components, the next step was to integrate them into a program. When a pilot program for the control of the weevil in farmers' fields was initiated, several of the original control techniques had to be modified to adjust them to the socioeconomic conditions and agricultural practices prevalent in the region: small farmers and peasant communities with poor resources.

The design of a pilot IPM program for the Community of Huatata, Chinchero, Cusco, **Peru**, was based on a previous study of the agroecosystem to find the sources of field infestation (overwintering places), the migration patterns of the insect to the potato field, its spatial distribution within the fields, and the program also investigated the effects of the parasitic fungus *Beauveria brogniartii*; the feasibility of turning the infested soils in winter, the acceptance of mechanical, plant, and chemical barriers; the attitude of farmers in relation to phytosanitary measures; adequate handling of harvested potatoes, night picking of adult weevils, and destruction of voluntary plants. Farmers responded positively, the damage by the weevil has decreased for a second year and more farmers requested to be incorporated into the program. The fungus *Beauveria brogniartii*, which is effectively used in rustic stores, is being tested in the field.

A study was made of the influence of planting and harvesting timing on tuber infestation. Findings favored early planting and early harvesting. After verification for one more season, the technology will be incorporated into the program.

Two new sites will be incorporated as IPM pilot programs, to include the three main weevil species of the Andean region: *P. vorax* in Cajamarca, *P. suturicallus* in Huancayo, and *P. latithorax* in Cusco. PROINPA in **Bolivia** is running a similar program against *Rhigopsidium tucumanus* and *P. latithorax*.

Through the IPM program in Huatata, damage at harvest has been reduced to less than half of the average damage found in the surrounding area (Fig. 1). As a result, new communities are interested in participating in similar programs. CIP will not be directly involved in this new dimension, but a strategy is being devised to make the program self-sustaining and self diffusing through the active participation of farmers and local NGOs (Fig. 2)

Training is a very important component of the IPM program in Huatata. Four field days demonstrated the benefits of the program to farmers. During the fourth field day, both the techniques and the rationale behind them were explained by members of one community to members

Figure 1. Decreasing infestation by APW leads to more available food.

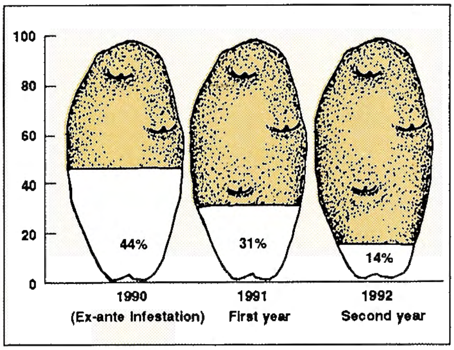
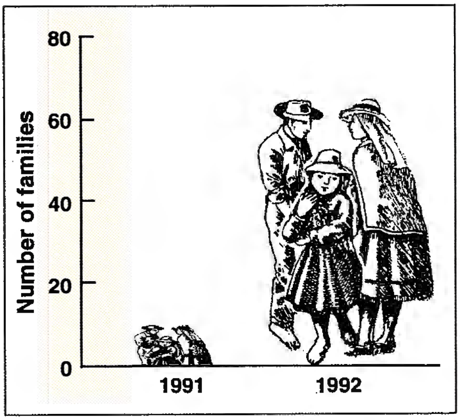


Figure 2. In just one year the numbers of families participating in IPM in Huatata increased by five times.



of other communities in their own language. Short courses were held for government technicians and NGOs, preparing them for their future role in the maintenance, diffusion, and improvement of current programs. To facilitate future training efforts, CIP is preparing training material for farmers (largely pictorial) and technicians–bulletins, slides, and videotapes.

Integrated Methods for Controlling Potato Nematodes

Potato cyst nematode (PCN) *Globodera pallida*, a potato pest in the Andes and in a few other temperate areas: **India, Panama**, and the **Philippines**, and false root-knot nematode (FRKN), *Nacobbus aberrans*, a serious pest in the Southern Andean Altiplano, of **Peru** and **Bolivia** are the focus of this work. The full extent of the PCN problem worldwide is still under study. The objectives of this work are to produce clones resistant or tolerant to PCN and develop IPM components for managing PCN and FRKN.

Of the several races of PCN, the most common are P4 and P5, but P6 is the most aggressive, though limited in distribution. Research on PCN resistance included selecting several advanced clones resistant to races P4, P5, and P6. These new selections have traits superior to María Huanca a resistant P4 and P5 variety previously released. The clones selected in 1992 yielded more than 1 kg/plant and were also resistant to late blight and frost. Most of these materials have the good qualities required for future consideration as new cultivars. Screenhouse testing has promising progenies of less-advanced genotypes that have other sources of resistance and combinations of traits. Once resistance is confirmed, they will be selected under field conditions for other traits, and the best will become candidates for new cultivars.

For a third year, IPM components were tested under farmer field conditions in Porcon, Cajamarca, **Peru**. Trials demonstrated the advantages and benefits of planting resistant and tolerant cultivars; incorporating organic matter into the soil, particularly chicken manure; and of reducing PCN populations by rotating potato with corn, olluco, faba beans, wheat, and oats. Use of the fungus *Beauveria brogniartii* significantly increased yields of Yungay (tolerant) and Revolución (susceptible), but not María Huanca (resistant). The effect of the fungus on the nematode population was not evident in the treated plots, but the resistant cultivar, María Huanca, reduced the nematode population. These tested technologies are ready to be used in commercial fields or pilot programs, after minor adjustments for specific situations.

Most of the false root-knot nematode research was conducted in **Bolivia** where yield losses range from 10-40% (Cochabamba, Chuquisaca, Potosi, and Tarija). The closed-container technique developed for detecting *N. aberrans* in soil samples has proved to be very reliable and has been adopted by organizations dedicated to potato seed production.

Management of this nematode is based on planting resistant cultivars. Resistance was recorded in 63 native Bolivian cultivars, but the occurrence of different races may complicate the screening work. Cultivar Gendarme, resistant in most localities, was susceptible in Potosi, indicating the presence of a different race, more aggressive than in other areas. New sources of resistance have been identified in several native *Solanum* species. Crosses including *S. bulbocastanum, S. phureja, S. goniocalyx,* and *S. brevidens* produced new resistant materials that are now in the selection process.

CIP will continue screening for new sources of resistance and breeding and selecting materials combining nematode resistance with other favorable traits. Although resistance is the basic component of FRKN management, another component under investigation is the use of organic fertilizer. Cow and sheep manure increased yields in nematode-infested soils, but no reduction in the nematode multiplication rate was observed. The system will include combinations of resistant cultivars and organic matter fertilization.

Training

A course on integrated control of sweetpotato pests and diseases was held in Bujumbura, **Burundi**, in June, organized by the sweetpotato program of ISABU in collaboration with CIP. Participants included researchers and extension workers from ISABU and special projects, and 1 participant from **Zaire**.

In Cusco, **Peru**, CIP and INIA held the first course on management and utilization of the fungus *Beauveria brogniarttii* for the biological control of the Andean Potato Weevil (*Premnotrypes* spp.) in April. Participants attended from NGO's (8) and government agricultural research and extension agencies (7); 4 instructors were from INIA and 1 from CIP. Topics included handling the beneficial parasite in the laboratory and methods for utilizing the fungus in farmers' potato storage.

A symposium on potato and sweetpotato pest management was organized by CIP within the IV International IPM Congress in Tegucigalpa, **Honduras**, in April. The program included oral presentations by staff from CIP and PROINPA, as well as video and slide presentations about potato tuber moth, Andean potato weevil, integrated management of sweetpotato weevils, and aphid monitoring. The instructors also demonstrated the formulation of pheromones and bacculovirus. The symposium concluded with a round table discussion.

At Lima, **Peru**, 11 potato specialists from the Andean region met in Lima, Peru with CIP scientists for a Workshop on Integrated Management of the Andean Weevil in September. Workshop objectives were to: (1) evaluate advances and constraints for the application of integrated control of this pest in the Andean region; (2) share experiences on IPM of the weevil that could be extrapolated to neighboring countries; (3) provide information about the latest developments on IPM of other important pests common to the Andean countries. The workshop included presentations and discussions in Lima, followed by a trip to Cusco, where participants visited the pilot program for IPM of potato weevil in Chinchero.

1992 Research Projects and Partners

This list contains the titles of research projects, the names of principal partner researchers and their respective country, the responsible CIP scientist, and the names of collaborating researchers.

Breeding for resistance to insect pests (potato tuber moth, leaf miner flies and aphids) of potato. A. Golmirzaie, K.V. Raman, K. Watanabe, M. Palacios, J. Tenorio **Peru**

Field evaluation of insect resistant clones. A. Golmirzaie, J. Tenorio, M. Palacios **Peru**

Evaluation of transgenic potatoes with insect resistance. A. Golmirzaie, C. Sigüeñas, M. Palacios **Peru**

Integrated pest management (IPM) for the control of potato tuber moth in Bangladesh. G.P. Das, M.M. Rashid, TCRC, BARI, **Bangladesh**/ M.D. Upadhya, K.V. Raman

Potato tuber moth in North Africa and the Middle East. On-farm research and evaluation of an IPM approach. H. Ben Salah, M. Fahem, A. Rizk, A. Kandyl, A. Hanafi, M. Faqir, A. Saef, I. Kohlani, **Egypt, Yemen, Morocco, Tunisia**/A. Lagnaoui, R. El-Bedewy

Integrated management of potato tuber moth *Phthorimaea operculella* in Bolivia. R. Andrew, R. Calderón, PROINPA, **Bolivia**/K.V. Raman, J. Alcázar; Y. Zurita

Management of potato and sweetpotato insect pests of importance in Region I. L. Valencia, ICA, Colombia/ K.V. Raman; I. Valbuena, R. Pineda

Management of the Andean weevil. L. Valencia, ICA, **Colombia**/ K.V. Raman; I. Valbuena

Management of potato insect and mite pests of global and regional importance. K.V. Raman, M. Palacios, A. Golmirzaie, K. Watanabe, J. Bryan, Z. Huamán, F. Cisneros, J. Alcázar, V. Canedo, O. Fabián, N. Mujica, K. Fernández **Peru**

Integrated methods for the control of PTM in the Dominican Republic. P. Alvarez, V.C. Escarraman, MIP, **Dominican Rep.**/M. Palacios, J. Alcázar

IPM for sweetpotato pests in Kenya. K.N. Saxena, ICIPE, G.B. Allard, IIBC, **Kenya**/N. Smit; O. Magenya, K.V. Raman, B. Parker, S. Nganga, P. Ewell, H.M. Kidane-Mariam, L. Skoglund

Management of sweetpotato weevil (SPW), *Cylas formicarius* Fabr. (*Coleoptera: Curculionidae*) through natural factors and its role in IPM. D.M. Amalin, **the Philippines**/E. Chujoy and P. Schmiediche. K.V. Raman; E. Vásquez; L. Villacarlos, ViSCA, R.P. Laude, P.A. Baculod, A.A. Barion, IBS, UPLB; E. Ines, MMSU-Batac

Integrated pest management (IPM) for sweetpotato weevil in Bangladesh. G.P. Das, M.M. Rashid, BARI, **Bangladesh**/M.D. Upadhya, T.R. Dayal, K.V. Raman

Integrated control of sweetpotato weevil. K.S. Pillai, CTCRI, **India**/T.R. Dayal

Development of host-plant resistance to the sweetpotato weevil *Cylas formicarius* *elegantulus.* P. Thompson, J.C. Schneider, B. Graves, Miss U, USA

Development of IPM strategies against the sweetpotato weevil and its socioeconomical implications. H. Kokubu, MIP, **Dominican Rep.**/A. Swindale. P. Gómez, V. Escarraman, O. Malamud

Use of sex pheromone and entomopathogenic nematodes for control of sweetpotato weevil, *Cylas formicarius.* R. Jansson, U. Florida, **USA;** R.R. Gaugler, R.R. Heath, M. Campus

Integrated management of important nematodes of sweetpotato. P. Jatala. H. Mendoza, R. Ortega, R. Chávez, E. Guevara, D. de la Flor, T. Boluarte, L. Gavilano, R. Haddad, J. Espinoza **Peru**

Utilization of RKN resistant clones in Peru. P. Jatala **Peru**

The design and execution of an integrated control program for the Andean potato weevil in Huatata, Chinchero, Peru. M. Pacheco, INIA, **Peru**/J. Alcázar, K. Raman, T. Walker, O. Ortíz, W. Catalán, H. Torres, F. Cisneros, O. Hidalgo

Development of mass production methods for *Beauveria* sp. parasitic to the Andean potato weevil (APW) and the West Indian sweetpotato weevil. H. Torres, M.A. Pacheco, Palomino, M. Villena, J. Salazar, K.V. Raman, T. Ames **Peru**

Integrated methods for the control of APW in Peru and Colombia. National Scientists with ICA, **Colombia,** and INIA, **Peru**/J. Alcázar, F. Cisneros

Integrated methods for the control of APW in Bolivia. R. Andrew, PROINPA, **Bolivia**/J. Alcázar

Integrated methods for the control of Gusano Blanco in farmers' fields. L. Valencia, FUNDAGRO, P. Gallego, INIAP, **Ecuador**/J. Alcázar

Integrated control of potato cyst nematode. M. Canto, J. Landeo; A. González, L. Calua, A. Matos **Peru**

Evaluation of germplasm and selection for cyst nematode resistance. R. Eguiguren, INIAP, **Ecuador**/ O. Hidalgo

Management of FRKN in Peru (Puno). J. Franco, PROINPA, Peru/J. Arcos, R. Cahuana, INIA, **Peru**/K.V. Raman, O. Hidalgo

Breeding and screening for resistance to PCN. R. Egúsquiza, M. Canto-Sáenz, UNALM, **Peru**

Integrated management and genetic control of PCN and PFRKN. J. Franco, N. Estrada, PROINPA, Bolivian National Scientists, IBTA, **Bolivia**

Integrated management of false root-knot nematode (FRKN) and potato cyst nematodes (PCN) in Bolivia. J. Franco, N. Estrada, R. Montecinos, W. García, R. Montalvo, PROINPA, **Bolivia**

PROGRAM 5

Propagation and Crop Management

Propagation of Healthy Clonal Potato Planting Materials in Diverse Agricultural Systems

Research Support to In-country Seed Programs

Collaborative seed programs throughout the world are showing consistent gains in production efficiency and seed quality as they adapt and use clonal propagation techniques developed by CIP and partner institutions, and several in-country seed programs are introducing important local modifications.

For example, local farmer participation is a key aspect of research at SEINPA, the national potato seed program of **Peru**. In Cajamarca, farmers helped select eight advanced late blight resistant clones from an original set of 120 developed at CIP. These clones are being re-evaluated by a team of farmers and breeders trained within the project, which will select potential varieties and incorporate them into the seed multiplication process.

SEINPA produced 742 t of basic seed (pre-basic, basic 1, and basic 2), although severe drought conditions reduced production by 20% compared to 1991 (Table 1).

Previous field surveys of potato varieties native to the Andean highlands were used to plan the introduction of new and/or traditional varieties. SEINPA now supplies sufficient seed of improved varieties to meet the seed requirements of several important potato production zones of the country. This includes seed of traditional cultivars that have regional importance, such as Ccompis, Huayro, Olones, Mactillo, and Imilla Negra. Because most traditional cultivars have a highly localized distribution, improved seed of these cultivars must be produced by sources other than the national program. Alternative strategies are being proposed by the project to obtain quality seed of those cultivars for use by farmers in specific highland locations.

Table 1. Basic seed production in different Peruvian institutions, SEINPA 1992.

	Area Planted (ha)	Total Production (t)
INIA Centers	53	411
Universities	13	154
Non-Government Organizations	19	177
Total	85	742

In Cusco, basic seed of 54 native cultivars—mostly *Solanum* × chaucha—from CIP's germplasm collection were re-introduced in two highland communities. Farmers participated in experiments to select native cultivars that would have the potential for introduction through the national SEINPA system of seed production.

The national research system of Peru also implemented a new administrative and financial scheme to improve fund and resource management for more efficient seed production. Under this scheme, decisions concerning fund management and seed distribution are made by a committee that includes representatives from several institutions.

A total of 65 seed-production committees have been organized by the project at the national level. These committees manage collective funds for purchasing improved potato seed that is distributed in remote highland areas.

SEINPA trained 98 technicians in potato seed production, while 88 farmers affiliated with project-sponsored seed production committees were trained in Cajamarca, Huancayo, Cusco, and Puno.

Also in Peru, low-cost rustic greenhouses are being used in a pilot project for the production of quality potato seed for distribution to small farmers in the highland areas (Puno) that typically suffer from drought and frost.

In a small (19.5 m^2) area, which is manually irrigated and protected from frost by a framed polyethylene sheet, farmers produce enough seed tubers to plant larger fields in following seasons. In Puno, farmers in 174 communities of this Peruvian high plateau built 624 new rustic greenhouses and they now have more than 900 operational greenhouses. Over 440 farmers have benefitted from 14 courses on potato seed production techniques using rustic greenhouses. These farmers produced 31.5 t of high-quality seed of native varieties Imilla Negra, Ccompis, and Piñaza, as well as of the improved variety Andina. This production was obtained despite a severe drought and extremely low temperatures (-5 to -10°C) which caused extensive damage to the crops grown in the open.

The improved variety Canchan-INIA, which was derived from CIP's breeding materials, has shown resistance to *P. infestants* in a series of on-farm experiments conducted in Cajamarca where the disease is endemic. In all cases, Canchan-INIA needed only three applications of fungicides as compared with the six or seven applications used on traditional varieties. Following these positive findings, basic seed production of Canchan-INIA has begun using pathogen-tested material by CIP.

Techniques to reduce costs and improve the efficiency of the basic seed production process were evaluated and have now been introduced as standard practices. For example, researchers found that planting microtubers (3.5-8.5 mm in diameter) in open fields, instead of using greenhouse facilities, is a practical procedure to reduce production costs, while maintaining the quality of basic seed.

Positive selection methods to decrease the level of virus infection were not effective in the production of quality seed of potato varieties native to the highlands of **Peru.** Neither farmers nor technical staff were able to differentiate healthy from infected plants. Differentiation was especially difficult in plants infected with PVX and PVY, which are the predominant viruses in these local cultivars. Virus incidences are 20.6% for PVY and 9% for PVX, according to a recent study.

In **Uganda,** which produced about 20 t of prebasic and 100 t of basic seed of adapted varieties, the national potato seed program has given top priority to selecting varieties that are adapted to the ecological conditions where they will be grown. These selected varieties must also be resistant to late blight and bacterial wilt, the two major potato production constraints in Uganda.

Compared to farmer's seed, potato yields of crops grown by using basic seed were increased by 51-139% (Table 2).

Crop yields from the program's basic seed were Rutuku (46.5 t/ha); Cruza (32 t/ha), and Sangema (14.3 t/ha), representing substantial increases over the average national potato yield of 8.5 t/ha.

Adapted varieties have been used to study the relationship of climate to vector avoidance. The low rates of degeneration of these varieties, plus the adoption of appropriate cultural practices (pre-mature

Table 2. Performance on-farm of crops grown from high quality seed compared with farmer's seed in Uganda.

Variety	Yield (t/ha)	Increase (%)
Rutuku	38.8	139
Crusa	21.5	67
Sangema	19.5	51
Farmers' seed	12.9	–

C.V. 20.7%; LSD 0.05 = 11.8

haulm killing as soon as aphids attain critical threshold), have helped in the development of a sustainable basic seed production system. Data on weekly aphid incidence are being compiled during the crop season.

Multiplication rates of up to 1:50 have been achieved in using rapid multiplication methods with rooted stem cuttings. About 2,000 kg of pre-basic planting material were produced from cuttings obtained from mother plants of three improved varieties CIP 381381.20 (Victoria), CIP 374080.5 (Kabale), CIP 381379.9 (Kisore), and of CIP clones 575049, 381388.34, 381171.15, and 381582.34.

ELISA tests showed negative results on all mother plants and on the pre-basic crop raised during 1992, indicating the potential value of this multiplication technology.

Clonal multiplication involves selecting apparently healthy true-to-type tubers from single hills of the adapted varieties. Large tubers from these single hill selections were used as initial stocks of seed categories A, B, and C that were developed within three stages of multiplication. In Stage 1, about 3,000 tubers of three adapted varieties (Sangema, Cruza, and Rutuku) and 500 tubers of Marirahinda were planted at a wide spacing to avoid contamination by mechanically transmitted viruses. The crop was examined three times during the growing season for disease and genetic purity. Healthy plants were harvested individually and the tubers planted in the following crop season as Stage 2 are observed frequently for disease symptoms. Facilities for virus testing developed for the initial planting material improved the sanitary condition and efficiency of the multiplication scheme.

In Stage 3, healthy clones within a variety are bulked (as pre-basic seed) and increased to produce basic seed. About 100 t of basic seed are produced every year. Of these, 20 to 30 t of basic seed are used as foundation seed at Kachewekano (800 m) in the southwest, and at Buyinyanya in the eastern part of Uganda.

Crop management research on the relationship between seed size and spacing confirmed earlier results. Planting densities of 48,000 to 70,000 plants/ha produced the highest yields, and the greatest proportion of seed-size tubers. Medium-size tubers planted at 70 × 20 cm or 70 × 30 cm were ideal for maximizing yields of seed-size tubers.

A seed production scheme is in full operation in **Cameroon** and the first pre-basic seed were produced from micropropagated plants of the newly released varieties. New screenhouse facilities provide a total of approximately 600 m^2 of insect-proof area.

Also, simple in vitro facilities were completed at IRA-Bambui, and pre-basic seed of the four late blight resistant clones was produced through large-scale micropropagation. Three of these CIP clones, 720055, 381406.6, and 381381.13, were released as new varieties.

Farmers' fields in the western highlands were surveyed during the main potato season to assess the relative importance of PLRV, PVX, PVY, and PVS and to identify areas with the potential for seed multiplication. DAS-ELISA tests showed that about 40% of the samples were infected with at least one virus. At the important production sites of Banso, Dschang, and Santa (altitudes of 1,800-2,300 m), virus studies showed a low level of spread in all three locations, except for PVS.

Cameroon has two main potato production systems. One system is located in the North West Province–the major potato producing region–where farmers mainly intercrop potatoes with a combination of maize, beans, cocoyams, and other crops on small plots (normally between 0.1-0.5 ha). In this system, farmers are totally dependent on an informal supply of seed potatoes.

The other main potato production system is found primarily in Bafou (West Province), Upper Fontem (South West Province), and Ngaoundere and Tibati (Adamawa Province). Potatoes are monocropped and farmers buy most of their seed from a formal seed system. Potato production is part of a market gardening system in which chemicals are intensively used for year-round production. The formal seed system consists of two local organizations that have multiplied and sold seed potatoes there.

In both systems, farmers cited lack of quality seed as a major constraint to improving productivity. Low yields, as well as the prevalence of late blight and in some cases black wilt, were related to poor quality seed. In those areas where potatoes are grown year-round, farmers often harvest before full maturity, but will leave a section of the field for seed production. As it comes out of dormancy, this seed is used for staggered planting.

Potatoes produced in the two systems are quite different. Those grown from seed purchased in the formal seed system are larger, merit a higher price in the market, and are mainly grown for sale outside the area of production.

The "Centre Agricole de Meng (CAM)," a non-governmental organization in Adamawa Province, and the "Centre d'Etudes et de Production de Semences (CEIPS)," a parastatal organization, are using the IRA/CIP project as a source of basic seed to multiply and to sell to farmers as an alternative to importing basic seed stocks. They are primarily interested in seed of varieties adapted to the mid-elevation areas of Cameroon. Both organizations plan to use technical support from the project to enable them to maintain the quality of the seed tubers they produce.

The IRA/CIP project has held training courses on seed multiplication for staff of public organizations of North West Province at two locations: Santa and Mbiyeh. These trainees will play a key role in ensuring that seed and related technology are relayed to farmers.

As improved varieties become available for multiplication in mid-1993, private seed multipliers are being brought into the seed scheme; those varieties identified in North West and West Provinces are shown in Table 3.

Table 3. Basic seed-tuber production from rooted cuttings transplanted into the field.[1]

Clones/varieties	Local name	Plants	Tubers
381381.13	CIPIRA	1,815	10,657
381406.6	TUBIRA	1,093	4,872
720055	BAMIRA	588	2,147
381382.34	–	808	3,556
8011007	TIBATI	71	119
Total		4,375	21,351

[1] Cuttings transplanted at Upper Farm (2,000 m); harvested at 90 days.

Sexual Potato Propagation

Breeding for Improved TPS Families

Testing Commercial growers require that seed supplied to them will germinate rapidly and uniformly under field conditions. Thus, as production of potatoes using TPS becomes a profitable alternative to the traditional method in several parts of the developing world, extensive adoption depends on availability of optimum-quality TPS. This is particularly true when TPS transplants are used for direct production of the potato crop. To help meet this need, CIP is developing a seed quality standard for TPS. The seed testing laboratory at CIP headquarters ensures that only high-quality TPS is exported to the regions for on-farm testing. Seed quality is monitored free of cost to national programs and private TPS producers. As shown in Table 4, the Germination Vigor Index developed at CIP was used to produce high-quality TPS. Lot-1, produced a significantly higher commercial yield at 90 days after transplanting TPS seedlings than did the viable, but low-quality TPS of Lot-2.

Table 4. Effect of seed quality on the emergence (%) under favorable conditions and final commercial yield (>30 mm) of Serrana × LT-7.[1]

TPS lots		Emergence (%) (days after sowing)		Commercial yield[2]
	GVI	6	15	(t/ha)
Lot-1	86	72	98	20.5
Lot-2	1	1	96	14.2
P =	<0.001	<0.001	0.003	0.039

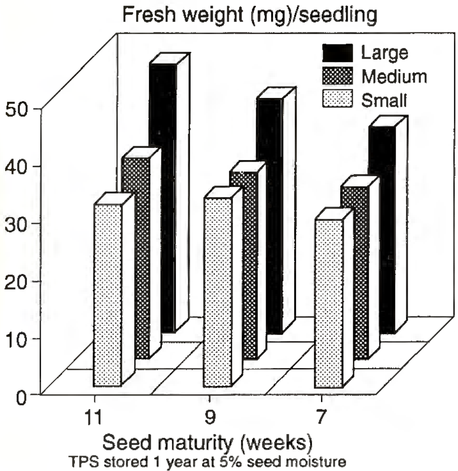
[1] Harvested at 90 days after transplanting seedlings (Lima, Peru, Sept-Dec, 1992).

[2] Estimated in the laboratory using CIP's germination vigor index (GVI).

TPS vigor and storage Many factors interact in the production of high-quality seed. For example, larger seed size and increased seed maturity at harvest have been associated with more vigorous TPS. However, to measure the relationship of these factors to TPS vigor, seed vigor must be tested periodically throughout storage, due to the masking effect of seed dormancy. When TPS of Serrana × AVRDC - 1289.19 were tested after only 4 months of storage, only larger seed size was shown to be positively related to seed vigor. However, when tested at 8 months of storage, large TPS (1/16") that had been harvested at the optimum stage of seed maturity (11 weeks post-pollination) produced significantly more vigorous seedlings than did large TPS harvested at 9 and 7 weeks post-pollination (Fig. 1).

TPS dormancy and postharvest handling Rapid, vigorous, uniform seedling emergence of TPS is possible under most field conditions when non-dormant and high-quality TPS are used. Dormant TPS germinate unevenly and seedling growth is impaired. This delays a uniform fieldstand and harvest maturity. Related moisture and storage temperature experiments show that TPS genotypes differ in their requirements for specific environmental conditions during seed drying and subsequent storage to release TPS dormancy (after-ripening). Each genotype of the most important TPS hybrids require continuous evaluation for these factors as they are advanced or become selected at CIP.

Figure 1. The effect of true seed size and maturity (weeks post-pollination) on seedling vigor of Serrana × AVRDC - 1289.19.



TPS stored 1 year at 5% seed moisture at 15°C. TPS size: Large (>1/16"); Medium (1/18"); Small (1/20").

Generally, however, it can be recommended that soon after harvesting, the seed of the mature (9 weeks post-pollination) potato berries should be extracted and disinfested and the TPS should be dried in a low-moisture environment at 30°C (± 5°C) until the seed moisture content (SMC) is about 4% (± 1%). Then, TPS should be hermetically sealed in a dark container and stored at (30-40°C) for 3 to 12 months. Periodic testing for germination under these high temperature storage conditions is necessary for proper TPS after-ripening. It is important to determine when the seeds have lost sufficient dormancy so that the storage temperature can be lowered to 5 to 20°C. The germination test to ensure seed vigor is conducted at a 27°C temperature regime. After dormancy is lost, even properly dried seeds eventually begin to deteriorate when held for too long under high temperatures; and moist seeds (6% SMC) deteriorate at logarithmic rates. Innovative detailed studies are now under way to reduce the time needed for safely after-ripening TPS of CIP's selected and newly advanced progenies. Preliminary findings suggest that some TPS genotypes may be after-ripened more quickly.

TPS Breeding and Selection

Agronomic and reproductive characters of 60 progenies from a TPS population derived from crosses with virus-resistant clones were evaluated in warm tropical environments of **Peru**. Some families were selected for further evaluation at the regional level. Many of the selected clones have a high general combining ability for agronomical and TPS characters, and those shown to be well adapted to warm tropical environments will be added to the pathogen-tested list and made available for use in TPS production programs in client countries. Of 45 new hybrids evaluated for seedling-tuber production, 24 advanced progenies were selected for improved agronomic characteristics and then grown in the field. They were grown as transplants and as seedling tubers at Lima and San Ramon, Peru.

Regional field tests using progenies selected in previous years, showed that Serrana × LT-7, MF-I × TS-3, LT-8 × LT-7, and MF-I × 104.12 LB are best adapted across locations. TPS hybrids such as Atzimba × R 128.6, Serrana × LT-7, or HPS-II/113, performed equally well when used either as transplants or seedling tubers. Fifteen superior progenies have been selected and included in the TPS International Verification Trials. Three additional progenies (Chiquita × 4.1 DI; LT-9 × 104.12 LB; and 4.1 DI × 104.12 LB) were identified as better adapted to Andean zones, due to their high yield and desirable tuber characteristics.

In **India**, from among 218 accessions tested, 96 clones were selected for high yield levels and other desirable traits. In addition, 13 other clones were selected for their yield potential and flowering characteristics. TPS-67 was used as the standard male tester to test 28 crosses from newly selected elite lines. These tests were made at mid-elevation, from June to October, and 31 new cross combinations were developed for evaluation and parental-line selection. Progenies of HPS-I/13, HPS-II/13, and HPS-7/67 produced excellent seedling tuber yields. Crops raised from transplanted seedlings at Deesa, Jorhat, and Chindwara produced better tuber yields than did those of local cultivars. Seedling tubers (5 to 35 mm) from five families produced tuber yields of 28.8 t/ha to 32.6 t/ha. Many farmers reported seedling tuber yields of more than 5 kg/m^2 in directly seeded beds. During the previous growing season (December/January), the Kufri Bahar variety suffered damages of 70-75% due to late blight (depending upon crop stage) whereas no late blight infection was noticed on TPS crops raised from seedling tubers in farmers' fields.

Selection for TPS progenies adapted to East African conditions are progressing rapidly and several advanced hybrid TPS progenies, such as KP90163 and KP90183, were selected in **Kenya**. These selections were based on seedling vigor and ability to regenerate after field transplanting. Acceptable tuber yields with adequate uniformity have been found in an extensive trial of about 60 open-pollinated (OP) progenies. Progenitors of some of the best OP progenies will be used as parental lines for generating hybrid progenies. In a 1992 verification trial in **Tunisia**, the superior progenies 978004, 985003, 989006, and Achirana Inta × LT-7 yielded between 11.0 and 11.5 kg/m^2 of seedling tubers in field beds; all showed acceptable tuber uniformity. Most progenies selected from the TPS in 1992 matured after 114 days, and about 90% of the harvest was of marketable size.

Of 50 TPS progenies evaluated in **Bangladesh** (1 from Peru, 4 from India (CIP), and 45 (26 hybrids + 19 OPs) of local origin), the most promising were HPS-I/67, II/67, 7/13, Serrana × LT- 7, MF-II × 1282-19, MF-II × 1282-17, and P-230 × P-305. The progenies were evaluated for seedling tuber production in beds. Progenies HPS-7/67, II/67, 7/13, and I/67 were shown to be most suitable for Bangladesh in the 1st and 2nd clonal generations trials conducted at 5 locations.

Several TPS progenies evaluated in **Uganda** since 1980 show promise for potato production, when grown from either seedling tubers or seedling transplants. Yields ranged from 4.9 kg/m^2 to 12.6 kg/m^2 for 16 TPS progenies tested for seedling tuber production in field beds in over 35 trials. The number of tubers per m^2 ranged from 220 to 425. Transplants yielded well also, with a mean yield of 43.5 t/ha of 13 progenies in 27 trials. An open-pollinated progeny (CIP 982002) was among the top-yielding progenies; it out-yielded all hybrid progenies. Phenotypic uniformity in foliage and tuber characteristics compared favorably with the crop raised conventionally from tubers.

Outstanding Cases of Recent Commercial Adoption of TPS

TPS has achieved greatest farmlevel impact in **Egypt**. Progenies of Serrana × DTO-28 and Serrana × LT-7 were officially released as varieties by the Egyptian Ministry of Agriculture. Tubers from these two progenies can be used for the second multiplication as planting materials with only minor reduction in yield. Local private interests produced about 250 t of seedling tubers of Serrana × LT-7. In continuing evaluations to identify TPS progenies better adapted to Egyptian conditions, Maine-28 × 104.12LB and CKF-69-1 × 104.12LB had seedbed yields of more than 11 kg/m^2 of seedling tubers. Superior crops were obtained from seedling tubers of Achirana × LT-7, CKF-69-1 × 4.1 DI, LT-8, and LT-9 × 104-12LB and CKF-69-1 × 104-12LB, comparing very well with crops grown with the commercial variety Alpha.

Recent increases in the number of public and private institutions involved in potato production using TPS serves as a measure of the short-term impact projected for TPS production in **India**. This list now includes the National Program of India (CPRI/ICAR); the Department of Agriculture of the State of Tripura; the Comprehensive Area Development Corporation in the State of West Bengal; the National Seeds Corporation in New Delhi;

Duncan Biotech Limited in Calcutta; and Kalyani Agro Limited, in collaboration with ESCAgenetics (USA). Interest in TPS also expanded from India to other countries in the region. It is estimated that TPS and 1st and 2nd generation seedling tubers produced in India during 1992 will be used to grow about 2,000 ha of potatoes in India, 200 ha in Bangladesh, 50 ha in Nepal, and 10 ha in Sri Lanka.

Potato production from TPS is now a commercial reality in **Nicaragua**. Estimates of the extent of the TPS impact in Nicaragua require visits to local wholesale markets, as it is difficult to track the production of the many small farmers who grow potatoes with TPS-derived materials. These materials, which have evolved from CIP-donated TPS over the last 5 years, have often been locally multiplied from one to seven times. About 40% of the potatoes available in the marketplace during 1992 are estimated to have been produced with TPS materials. The wholesale market price of potatoes decreased to a record low (20% lower) while traditional importation of potatoes during the peak seasons (August, December) decreased by more than 90%. The Nicaraguan national potato program (Ministerio de Agricultura, MAG) works closely with ten efficient, strategically-located farm units, which produce highquality seedling tubers. Two TPS progenies were officially named as TPS varieties by the national potato program: Serrana × LT-7 (Estela) and Atzimba × 7XY.1 (Papanica). Estela is preferred by merchants due to its reportedly higher resistance to storage decay under warm temperatures.

Nicaraguan farmers have discovered important characteristics of the Papanica, a CIP TPS hybrid. They have found that, although about 40% of the progeny of Papanica needs to be "cleaned" (rogued out of susceptible genotypes) during the first two multiplications, the remaining seedling tubers of this progeny can be multiplied successfully at least seven times with no decreases in yield. Papanica is preferred by farmers because the seedling tubers have little dormancy which permits them to plant three crops per year.

Farmers and technical agricultural schools in **Paraguay** bought 15 t of high-quality seed tubers produced with TPS by the national potato program. Such production is unprecedented in a country that has traditionally imported about 90% of the 20,000 t of potatoes consumed each year.

The potato program is recommending TPS as an appropriate technology for increasing local potato production and, in collaboration with the Italian government, the program plans to produce about 100 t of seed tubers next year. The national program also has promoted certification of TPS-derived seed tubers, and manufacture and dissemination of appropriate farm implements. A newly published technical guide for producing seed tubers using TPS includes information on preventing potato tuber moth damage.

Widespread and endemic droughts in 1992 led to serious deficits of seed tubers throughout **Peru**, and TPS use expanded significantly. CIP donated about 12 kg of TPS progenies adapted to the Andean highlands in 1992. Coastal farmers bought seed of adapted TPS progenies selected at CIP from a private TPS producer in **Chile**. These farmers plan to grow about 65 ha of TPS transplants during the early season (March-July) of 1993. Near Lake Titicaca in Puno, the national potato program Proyecto de Apoyo a la Producción de Semilla e Investigación para Mejorar la Productividad de Papa en el Perú (SEINPA) has initiated seed tuber production with TPS in rustic greenhouses, which were initially designed for producing clean tuber seed materials. In the highlands of Ayacucho, about 2,500 subsistence farmers are producing small patches of potatoes from TPS seedlings, in collaboration with technicians from Instituto de Promoción Agropecuaria y Comunal (IPAC). In Huaraz (3,400 m), Dominican priests initiated the use of TPS for producing potatoes for their 80 rural schools, which feed about 1,000 students. Private growers also have started two large-scale farm (30 and 15 ha) operations in Ica, and on-farm trials are being conducted in Huacho and Piura.

Sweetpotato Production Through Improved Management Techniques

Crop Management Practices

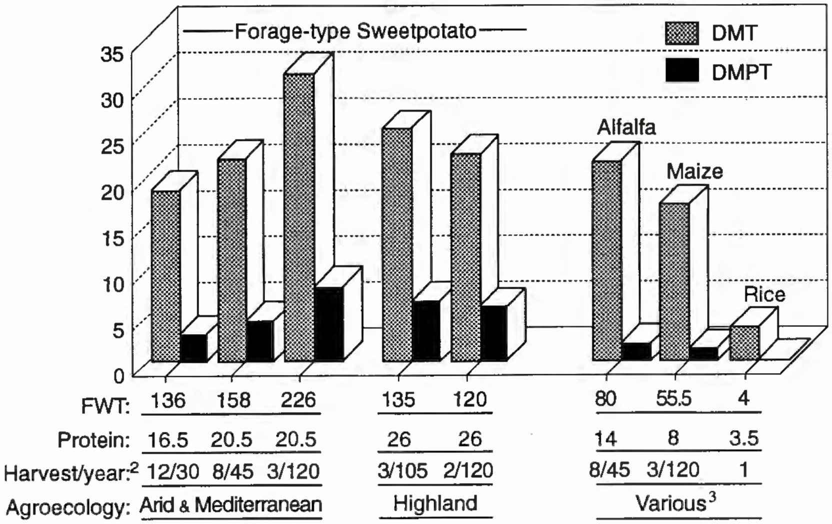
Forage-type sweetpotato as a perennial crop for fresh forage, silage and/or erosion control In field and on-farm studies in **Peru**, selected forage-type sweetpotato cultivars have been shown to provide a highly productive, alternative forage crop having excellent nutritional value (Fig. 2). Several types of livestock were studied under a range of environmental conditions. This usage of sweetpotato has great global potential because farmers in some agroecologies are frequently forced to feed their livestock nutrient-poor fodder due to environmental constraints that limit production of more nutritious forage species. For example, in the mid-elevation highlands of northern Peru, farmers often have only rice straw to feed their cattle during the dry season. Traditional forage species are usually difficult to establish in the Arid and Mediterranean areas of China and Latin America, and the tropical mid-elevations of Latin America, Asia, and sub-Saharan Africa.

Shoot-tips from the tops of sweetpotato plants are popular as a fresh and cooked vegetable in some countries. And tops from plants that produce edible-roots are used in some countries for animal forage, after the roots are harvested. But the plant-tops of the traditional edible sweetpotatoes are not traditionally grown as a forage crop per se. Traditional types of sweetpotato have been selected as a single-harvest crop to produce good root yields, rather than plant-tops. Fortunately, CIP's germplasm collection contains forage-type sweetpotato accessions that produce a large plant-top yield, but do not produce storage roots; these cultivars are now being studied for their forage crop potential.

Forage-type sweetpotato cultivars (Fig. 2), when grown as a perennial forage crop, yield periodic harvests for at least two years. In experiments with plant-tops harvested at 30, 45, and 120 day intervals under arid coastal conditions and 105 day intervals under mid-elevation conditions, the plants resprouted vigorously and covered the ground within 12-14 days after harvesting in all of the locations. These cultivars show consistently high yields and excellent nutrient value throughout the year, which indicates that these plants have the potential to equal or surpass several traditional forage crops. Farmers can use them as an alternative crop for fresh forage and/or silage. For low-income families in marginal areas, a few garden plants can produce a steady supply of low-cost, fast-growing forage for their animals.

CIP is collaborating with INIA and other Peruvian institutions to study the nutritional value of sweetpotato fresh forage and silage for different animal species, in addition to studies of on-farm production and forage palatability trials. The tested animals readily accepted the plant-tops as fresh forage and as silage, and all

Figure 2. Annual forage yield totals (t/ha) of clone CIP 420068.[1]



[1] DMT = Dry Matter Total; DMPT = Dry Matter Protein Total; FWT = Fresh Weight Total

[2] Figures indicate numbers of harvests per year/days between harvests.

[3] Average yields across several Peruvian agroecologies.

Note: To be released as Forrajero "Helen" in 1993.

The plant tops of forage-type sweetpotato were readily accepted as fresh forage and silage by black bellied and traditional wool sheep, cows, horses, rabbits, and cuyes (guinea pigs), all of which made excellent weight gains.

showed weight gains equal to those usually obtained with nutritionally balanced diets.

In addition to its value as an animal feed, forage-type sweetpotato is excellent to control erosion. Forage-type sweetpotato cultivars rapidly produce heavy, vigorous stems up to 2 to 3 m long, with a dense canopy of large thick leaves, and a heavy mass of roots that penetrate 0.5 m or more. The dense leaf canopy helps prevent soil run-off during heavy rain and suppresses weed growth.

The plant tops of forage type sweetpotato are ready for the first harvest at 6-8 weeks after the cuttings are planted. In addition to the superior animal fodder qualities, the forage-type sweetpotato has an excellent potential to prevent erosion or rehabilitate eroded soils, because of the heavy top growth and deep and extensive root-mass.

Crop Management Studies

Salinity

Through a research contract with the University of Tacna (Jorge Basadre Grohmann), **Peru,** 23 superior sweetpotato clones were selected over several seasons for high yield, root quality, and salinity and drought tolerances. These clones were tested for performance stability at six locations with differing arid and saline conditions. After testing, the University released six new varieties (Yarada, Nacional, Tacna, Caplina, Atacama, and Costanero) for use in southern Peru. These varieties tolerate soil salinity of 6 to 13 mmh/cm; have a yield potential of over 20 t/ha in 120 days (the local checks showed lower yields in 180 days), and a dry matter content of 22 to 40%. They have also shown moderate resistance to *Meloidogyne incognita*. On the day of the release, planting material of the new varieties was distributed to local farmers. Sweetpotato roots are already reaching local markets.

Using N-fixing Associations

Nitrogen-fixing associative bacteria, such as *Azospirillum*, are natural, environment-friendly organisms that can be used to improve the growth and yield of plants, without the expense or adverse effects of chemical fertilizers. Four sweetpotato cultivars inoculated with four selected *Azospirillum* strains showed substantial increases in yields of leaves, stems, fibrous roots, and storage roots, as compared with yields of cultivars that were not inoculated. The strain SP7 was especially effective.

Sweetpotato Yields and Sunlight

Sweetpotato plant growth is strongly affected by sunlight, and yields can be influenced by the stage of plant growth at which shade from an associated crop reduces the amount of sunlight that reaches the sweetpotato plants. Studies comparing shaded and unshaded plants in the **Philippines** have shown that the number of storage roots is reduced in plants that are shaded in the early stage of growth, and storage roots are smaller in plants that are shaded later in the growing season.

Abiotic Stresses and Potato Crop Management

Sixteen African countries are participating in a potato germplasm evaluation scheme to ensure rapid, accurate, and systematic identification of clones that have improved tolerance to abiotic stresses. Several participating countries, including **Rwanda, Madagascar,** and **Burundi,** have released new, widely-adaptated varieties from germplasm supplied by CIP. In **Uganda,** on-farm tests of three newly released varieties indicate that these varieties have stability over sites, seasons, and years, as compared with both existing improved varieties and native cultivars. In addition to high yield and wide adaptability, the three varieties have shown some field resistance to late blight. Although the three varieties are highly responsive to fertilizer, their performance without fertilizer was also impressive. This is important because farmers in Uganda usually cannot afford to apply fertilizer.

Two other promising advanced genotypes (CIP 382171.4 and CIP 800945) have shown outstanding adaptation characteristics to different growing conditions in Uganda. CIP 382171.4 has adapted to growing conditions in both high and low elevation areas and has a high tolerance to drought. During severe drought, caused by a shorter than normal rainy season, this genotype yielded 32 t/ha (with fertilizer) and 21.9 t/ha (without), as compared to 10.6 t/ha for the local cultivar. CIP 800945 is a very early clone that matured in 65-70 days at Kalengyere (2,500 m), where existing improved cultivars (Sangema, Cruza, and Rutuku) mature in 120-135 days. All Ugandan selections exhibit field resistances to LB and BW.

Tolerance to Abiotic Stresses

Studies on the inheritance of frost tolerance in native **Bolivian** germplasm indicated that this character is quantitative. Results estimated heritability at an intermediate level: $h^2 = 0.32$. Greater progress in frost tolerance is expected with new breeding cycles and in combination with other valuable traits. Thus, early maturity is a major factor being incorporated into frost tolerant populations, together with other characters such as resistances to cyst nematodes and LB, and immunities to PVY and PVX.

Significant improvements were made in earliness and agronomic performance of 62 early maturing clones selected from the frost tolerant population (see facing photo top).

Field trials with the most advanced early maturing frost tolerant clones showed that their yield levels were similar to those of the local late varieties. Selected frost tolerant clones (such as 84FF119.4, which was distributed for testing in several Peruvian locations) were much earlier maturing and their crop yields in Cajamarca (3,300 m) were 30 to 50% greater than those of local cultivars (see facing photo bottom). Advanced clones and tuber families of these populations were distributed to potato programs in the highlands of **Latin America** and **Africa.**

When grown under low temperature conditions in **Chile,** potato cultivars showed marked differences in growth pattern and productivity. Studies of a wide range of potato genotypes known to adapt well to various environments enabled CIP to identify different patterns of yield development. Tuber initiation time and early foliage development appear to be the most critical factors associated with yields.

Different strategies for identifying cDNAs specific to the cold hardening process are being used in collaborative research at the University of Naples, Italy. Researchers there are using explants of *Solanum commersonii*, a wild tuber-bearing species capable of withstanding temperatures

Seedling screening for frost tolerance is clone in a growth chamber at -4°C. Tolerant families (left) and susceptible controls (right).

Frost tolerant clones at harvest in the altiplano experiment station at Puno, Peru (3,900 m).

that normally cause frost damage in potato. A cDNA library was successfully obtained, amplified, and plated on *Escherichia coli* strain PLK-F'. The ratio of recombinant to non-recombinant phage particles obtained by the blue/white color selection of the amplified cDNA library accounted for 93% of recombinant phages. The vector contains the pBluescript plasmid sequence that can be easily rescued by in vivo excision, thus combining the high efficiency of a lambda library construction with the convenience of a plasmid system with blue/white color selection.

In an experiment in **Peru**, adaptation to high temperature was tested using a 7,500 seedling population grouped into 53 families that were screened in the greenhouse during the summer in Lima. The minimum night temperature was 18 to 21°C and the maximum day temperature fluctuated between 32 and 35°C. A 17-hour daylength was simulated using 400-watt mercury vapor lights. Tested material was mainly from crosses of PLRV-resistant clones to either PVY– or PVY + PVX– immune clones. Due to high plant density and competition, the foliage senesced early and the plants were harvested about 2-1/2 months after transplanting. Tuberization and selection varied significantly as affected by temperature and daylength. The **Polish** cultivars Orlix, Fregata, and PW-31 showed excellent tuberization characteristics. Progenies of Orlix and Premiere had the highest selection rate. These progenies, despite the stressful heat and daylength conditions, produced large, excellently-shaped tubers.

In **Uganda**, where potatoes are usually grown at high altitudes, extending potato cultivation to lower altitudes subjects the crop to other stresses. Many genotypes selected in 1991 were evaluated in both 1992 cropping seasons for their performance under the two different soil/water regimes: the "long rains" season (September to January) and the "short rains" season (February-March to June-July). The plants showed a wide range of adaptability, and about 150 promising genotypes with tolerance to water stress were identified. Selected promising genotypes showed yield and general adaptation advantages over traditional cultivars when evaluated on-farm in several locations. (Table 5).

In **Peru**, through a research contract with University of Tacna, 525 selected potato clones were tested for tolerance to salinity and partial drought conditions. These are common conditions in extensive areas of the Coast of Peru. Forty-three clones were selected in both the winter and summer seasons. The best performing clones were C89.170 (LT-9 × Y84.011), C89.242 (XY.9 × 575049), and C90.185 (B71.74.48.11 × XY.9). These clones yielded from 500 to 750 gr/plant in 90 days. They are now being multiplied for further testing.

Table 5. Performance of promising genotypes in on-farm water stress trials in Uganda.

Genotype/varieties	Trials	Yield (t/ha)
Promising genotypes		
CIP 381381.20	11	35
CIP 381379.9	12	28
CIP 374080.5	10	24
CIP 575049	11	24
Mean		28
Existing improved varieties		
Cruza	6	19
Rutuku	6	17
Sangema	3	14
Mean		17
Traditional cultivars		
Local white	1	14
Kabera	2	13
Mean		13

In **Italy**, calli and plantlets regenerated from irradiated protoplast cultures of the cultivars Spunta and Atlantic were subjected to inhibitive concentrations (0.5 mm) of a proline analogue and then used for selecting mutants with potential tolerance to abiotic stresses. High proline synthesis in plant tissue has reportedly been associated with drought and temperature tolerance. A mutant clone (AR1A) derived from Spunta was selected and showed normal in vitro growth under inhibitive rates of the proline analogue.

Training

In **Nigeria**, 21 participants representing several potato growing areas attended an in-country course on potato production, storage and seed technology at Jos-Nigeria. The course was sponsored by CIP in collaboration with the Plateau State of Agricultural Development Programme and the National Root Crops Research Institute. Dr. Julius Oronkevo, Coordinator of the potato program at Vom-Jos, made local arrangements and very successfully coordinated the program that included lectures, practicals, and visits to farmers' fields and the local experiment station.

The sweetpotato workshop for West and Central Africa took place in Dovala, **Cameroon** in July. Eighteen persons attended the meetings, including nationals from **Cameroon, Nigeria, Mali, Côte d'Ivoire, Ghana,** and **Togo**. Sixteen papers were presented followed by active and constructive discussions. The participants were grouped into two teams to prepare recommendations regarding collaboration with CIP and among themselves in order to address sweetpotato constraints of regional scope and common interest.

An in-country potato production course was organized at D.F.I. Bulegeni, **Uganda,** in August and was attended by 24 participants. The staff included 3 researchers, and 13 extensionists. The other 8 participants were progressive farmers. The course dealt mainly with improved agrotechniques, seed production principles, and production methods through farmers' varietal improvement programs for highlands and lowlands. Other topics included potato production through TPS, both as transplants and as seedling tubers; utilization of first generation tubers as propagating material; common potato diseases and pests in Uganda and control measures; and storage of seed and ware potato. Morning lectures and afternoon practicals provided an opportunity for trainees to gain hands-on experience on sowing TPS in nursery beds and in identification of viral, fungal, and bacterial diseases in potato fields.

A four-day training course on TPS production was attended by 8 potato researchers and extensionists from INIA's regional offices of Cusco and Puno, **Peru,** in September. The southern Peruvian highlands are frequently affected by severe drought that limit availability of seed tubers to farmers. Peruvian agronomists see TPS as an alternative technology to ensure supply of healthy seed in areas where potato is a staple. Participants in the course were taught the fundamentals of botanical seed production as well as the agronomic factors determining high productivity and successful production.

The CIP-sponsored TPS workshop in Asia was held at the Lembang Horticultural Research Institute, Lembang, Indonesia in October. Participants from **China, Sri Lanka, Vietnam, Korea, India, Bangladesh, Philippines,** and **Indonesia** presented TPS research papers and CIP scientists lectured on genetic improvement, and advances in seed production and seed quality. Round table discussion topics included production practices, production costs, development of TPS for local conditions, and dissemination of TPS. As a final exercise, workshop participants made oral presentations of workplans for future work.

CIP and GTZ jointly sponsored an in-country sweetpotato course in **Uganda** for one week in November. Participants included 25 extensionists and research technicians from throughout the country. CIP regional staff and scientists from Namulonge Research Station and Makerere University served as instructors. The goal of the course was to provide extension staff with better methods to advise farmers on sweetpotato technologies. Topics included the characteristics of major varieties available in Uganda, identification of weevils, viruses, and other pests, and practical pest management. Participants were taught to interpret and adopt research results to local conditions and constraints.

In **Peru**, SEINPA conducted 47 seed potato production-related activities, including group courses, individual training, workshops and field days. Participants totalled 201 technicians, 1,640 farmers, and 184 students.

■

1992 Research Projects and Partners

This list contains the titles of research projects, the names of principal partner researchers and their respective country, the responsible CIP scientist, and the names of collaborating researchers.

Potato basic seed production in Burundi. A. Sinduhije, C. Muvira, Z. Nzogihera, ISABU, **Burundi**/D. Berríos

On-farm potato seed production. C. Muvira, ISABU, **Burundi**/D. Berríos

Development of a propagation system for potato in Cameroon and other countries in the region. Various Institutes and National scientists in **West Africa**/ C. Martin, A. Odaga; U. Jayasinghe, J. Bryan, E. Fernández-Northcote

Potato seed research and production in Uganda. L. Sikka, **Uganda**

Research and technical assistance in seed potato production in Colombia and Venezuela. P. Corzo, A. Rodríguez, Y. Rodríguez, ICA, **Colombia**; FONAIAP, **Venezuela**/O. Hidalgo, P. Espinoza; P. Rodríguez, C. Crissman

Seed tuber production by rapid multiplication in Paraguay. M. Mayeregger, IAN, A. López, SEAG, **Paraguay**/ A. Strohmenger

Research and production of prebasic seed in Bolivia-PROINPA. G. Aguirre, A. Devaux, PROINPA, J. Aguilera, C. Villarroel, IBTA, **Bolivia**/O. Hidalgo, J. Bryan

Agronomy and physiology of adapting the potato and sweetpotato to warm climates. G.B. Opena, M. Callueng, MMSU, **Philippines**, Truong Van Ho, Nguyen Van Uyen, **Vietnam**/E. Chujoy

Production and evaluation of TPS families for sub-tropical areas. (A) breeding for TPS parental lines. K.C. Thakur, **India**/M.D. Upadhya; H. Mendoza, A. Golmirzaie

Evaluation of TPS progenies and production of hybrid seed. A.A. Asandhi, National Scientists, LEHRI, **Indonesia**/ A.S. Chilver

True potato seed hybrid families in different agroecological zones of India. National Scientists, M.S. Kadian, CPRI, **India**/M. Upadhya; P. Malagamba, K.C. Thakur

True potato seed, on-farm trials in India. National Scientists, M.S. Kadian, CPRI, **India**/M.D. Upadhya; P. Malagamba, K.C. Thakur

Potato production from true potato seed. A. Sharara, I. Abou Hadeed, A. Abd El-Naby, MA, **Egypt**/ R. El-Bedewy; P. Malagamba, A. Golmirzaie, R. Cortbaoui, H. Mendoza

Potato production from true potato seed in Tunisia. M. Fahem, CPRA, **Tunisia**/ C. Carli; M. Souibgui

Screening of true potato seed families as transplants and seedling tubers as planting materials. National Scientists, M.S. Kadian, CPRI, **India**/ M.D. Upadhya; P. Malagamba, K.C. Thakur

Studies on TPS production in Bangladesh. H. Rashid, BARI, A. Quasem, TCRC, **Bangladesh**/M.D. Upadhya

Breeding, selection and distribution of appropriate TPS progenies and/or parental lines in the **east** and **southern Africa**. H.M. Kidane-Mariam, **Kenya**/A. Golmirzaie, N. Pallais, P. Malagamba

Development of true potato seed (TPS) parental lines and progenies for agronomical and reproductive characters. A. Golmirzaie, J. Tenorio **Peru**

Screening of advanced TPS progenies and production technology. P. Malagamba, J. Bryan, R. Cabello **Peru**

Physiological studies on true potato seed (TPS) quality, storage and handling. N. Pallais **Peru**

TPS production in warm climates. P. Malagamba, R. Cabello **Peru**

Development of improved TPS progenies for various environments of China. Z. Dongyu, CAAS, **China**, National Scientists/Song Bofu; E. Chujoy, J. Xinya, Y. Hewei, Z Xiyi

Use of TPS for potato production in Nicaragua and Haiti. F. Torres, **Nicaragua**, M. Bastiat, **Haiti**/ N. Pallais, P. Malagamba

Soil management fertilizers and mineral nutrition of sweetpotato under different soil, climate and farming conditions Latin America (LAC), Peru. S. Villagarcía, UNALM, **Peru**; O. Loli, G. Aguirre

Study of interaction between *Azospirillum* spp. and sweetpotato (*Ipomoea batatas* Lam.) roots. C. Romero, UNALM, **Peru**/P. Malagamba; S. Villagarcía, R. Cabello

Evaluation of sweetpotato germplasm for tolerance to certain abiotic stresses under arid conditions. R. Chávez, U Tacna, **Peru**/H. Mendoza, J. Espinoza, L. Díaz

Introduction, development, maintenance and distribution of potato germplasm. S. Nganga, KARI, **Kenya**/H.M. Kidane-Mariam

Production of hybrid true potato seed. K.C. Thakur, CPRI, **India**/ M.D. Upadhya; M.S. Kadian, S.N. Bhargava

Introduction, screening, multiplication and redistribution of potato and sweetpotato germplasm. V.E. Demonteverde, NPRCRTC, Benguet U, the **Philippines**/ E. Chujoy; H. Mendoza, J. Bryan, I.G. Mok

Maintenance, multiplication and distribution of pathogen-tested potato production of low virus seed. J. Bryan;

A. Golmirzaie, L. Salazar, P. Malagamba, H. Mendoza, J. Landeo, Z. Huamán, J.L. Marca **Peru**

Maintenance, multiplication and distribution of sweetpotato pathogen-tested materials. J. Bryan; E. Carey, A. Golmirzaie, L. Salazar, H. Mendoza, Z. Huamán **Peru**

Collaboration with national programs in the evaluation and selection of TPS progenies and superior clones. National Plant breeders and various institutes of **east** and **southern African** countries/H.M. Kidane-Mariam; H. Mendoza, J. Landeo, J. Bryan

Studies on the effect of NK fertilizers on the production and processing of potato. S. Villagarcía, SQM, **Chile/** F. Payton; G. Aguirre, L. Tomassini **Peru**

Breeding for resistance to frost, wide adaptability and other major constraints of the highlands. N. Estrada, PROINPA, **Bolivia/**J. Landeo, J. Bryan; and other Bolivian scientists

Breeding for resistance to frost, wide adaptability and other major constraints of the highlands. J. Landeo, M. Gastelo, L. Calua **Peru**

Consultancy on potato improvement in Central Africa (potato seed research and production in Uganda). R. Kanzikwera, R. Ruhera, S. Kasule, J.B. Birikunzira and D.R. Akimanzi, Ministry of Agriculture, Animal Husbandry and Fisheries, **Uganda/**L. Sikka; S. Nganga, H.M. Kidane-Mariam, J. Landeo, J. Bryan

PROGRAM 6

Postharvest Management, Marketing

Expanding Utilization of Potato in Developing Countries

Storage

Nearly all farmers in developing countries store some potatoes–in the ground, in their homes, or in a separate structure–as a means of ensuring the availability of both seed and ware tubers over a longer time than seasonal planting periods would otherwise permit. No accurate estimates are available of the percentage of the potato crop stored in any given year in developing countries. But estimates for individual countries range up to 40% of production, based on cropping cycles, temperature changes, market transactions, and consumption levels. Most stored potatoes are for sale or for direct use as table potatoes, with most stored above ground under rustic conditions. As potato output expands in the developing world, improvements in rustic storage are a key component of efforts to strengthen postharvest systems.

The importance of storage is especially critical in the lowland plains of **South Asia,** where seasonal production in response to drastically different climatic conditions is largely restricted to the winter months, November to February. This region currently produces nearly 20 million t of potatoes a year, and recent projections are that output in India alone will increase by an additional 15 million t or more by the end of the decade. Refrigerated cold storage capacity–currently around 5 million t–will not be able to grow fast enough to absorb this projected increase. Consequently, pressures on the existing distribution system (i.e., transport, marketplace capacity) must be relieved by refining and diffusing improved rustic storage practices.

To capitalize on emerging opportunities, CIP hired an experienced storage specialist to work in South Asia, beginning in 1993.

Efforts to improve rustic storage practices in **India** have progressed along three tracks: improved design and management of rustic storage structures; experiments to quantify gains from storage in different media (see CIP 1992); and surveys of current rustic storage practices. Improvements are envisioned in each of these areas that will combine to form a set of improved rustic storage recommendations, from which farmers will select to suit their particular needs and capabilities.

Rustic store designs vary considerably. For example, they can be made with or without evaporative cooling, on a false floor, or to include installations (e.g., chicken wire to prevent vermin infestation). Thesis research in Bareilly, **India,** describes a rustic store that was constructed from brick stones, which are plastered with mud and cowdung. The outside walls are painted white to reflect sunlight and reduce heating. The floor is constructed of split bamboo panels, supported by bricks set in cement. As a result, either ambient air or water-cooled air can flow up through the floor to cool stored potatoes. In particular, cool, moist air passing through the pile of loosely stored tubers is intended to reduce weight loss due to dehydration. Two other stores were built with a modified design. Comparisons then were made between different types of rustic storage, cold storage, and simple storage in bags. The thesis notes that storage involves not only the type of physical environment the potatoes are kept in, but also the variety, grade, and handling of the tubers.

This thesis research involved the use of a data logger to record temperature and relative humidity. The data were logged each hour at the two most important spots in the rustic stores, at 5 cm (incoming air level) and at 80 cm from the floor. In addition, manual thermometers were placed in the center of the pile at 45 cm from the floor. The weekly average of daily (day and night) outside temperature rose from 27°C on April 10 to 35°C on June 12. Relative humidity started at 25%, rose to 45% by May 22, and fell to 37% by June 12.

Weight losses in the rustic stores were: 3.87% (with evaporative cooling), and 3.84% (without cooling). When stored for 2-1/2 months, these losses were 8.05% (with cooling) and 12.51% (without cooling). During roughly this same period, potato prices per 100 kg more than doubled, from US$4.41 to US$8.87. The estimated financial gains from rustic storage were higher after two months storage than after three months storage under the prevailing prices (Table 1). More importantly, these findings confirm that rustic storage of potatoes is profitable for later sale: profitable storage for two or even three months seems quite possible, if farmers carefully monitor potato prices and use appropriate handling and storage practices.

Two additional theses on rustic storage are planned in 1993. One thesis will focus more closely on the economics of storage by obtaining better estimates of the costs of building and managing such structures, while documenting the actual (as opposed to estimated) revenues. The other thesis will analyze rustic storage from a rural sociologist's perspective, addressing questions such as: Who operates a rustic store? Why? If not, why not? These studies should complement earlier technical work by providing a better picture of the human dimension in postharvest technology, thus helping to accelerate improvement and transfer.

Based on these results and the wealth of scientific information available on rustic storage design and management (see CIP Annual Reports 1990, 1991, 1992), these technologies will be tested at the farm level during the 1993-94 cropping season. These tests will be in collaboration with the Indian Council of Agricultural Research's Central Potato Research Institute and scientists based in the Uttar Pradesh plains of **India** as well as with similar organizations in neighboring

Table 1. Financial results for various postharvest options for potatoes in India.

	Period	Quantity (t)	Gain (US$/100kg)	Gain/capital[1] (%)
Rustic storage for the market	1 month	40	0.38	11.6
	2 months	40	2.05	26.9
	3 months	40	1.88	24.4
Village level processing from rustic stores	whole season	60	3.32	25.5
		75	4.11	35.4
Village level processing from a cold store	whole season	60	2.65	19.4
		75	3.44	28.0
Village level processing with market potatoes	whole season	60	1.33	8.9
		75	2.13	15.7

Source: Potato storage and processing on a low-cost basis in the Gangetic Plain of India by A.J. de Buck.

[1] The gain/capital ratio was calculated as follows: (financial gain of option)/(needed investments + operating capital) * 100%.

countries. Further refinements from this on-farm research can be made by institutions in **India, Bangladesh**, and **Pakistan** to diffuse a tested and verified set of recommendations to help sustain continued growth in production. Although such production is highly seasonal, the technologies can help prevent a sharp fall in prices at harvest time or excessive shortfalls in availability in the one to two months after harvest.

The survey of farmer storage practices in **India** continued in Meghalaya and Gujarat States during 1992, complementing surveys completed in other states (e.g., Tripura, West Bengal) and reported in previous years (see CIP Annual Report 1991). Evidence of storage in field structures or in homes was widespread in both Meghalaya and Gujarat, with Meghalaya storing as much as 40% of output (Table 2). Likewise, a wide variety of structural designs, construction materials, storage containers (e.g., baskets, gunny bags), handling techniques (e.g., the application of sawdust on harvested tubers that have been rained on while in the field), and cooling devices (coolers, exhaust fans, ceiling fans) have been noted. Farmers report that these indigenous methods of rustic storage are being used in both locations. They are also actively experimenting with their own modifications to existing practices.

Although farmers in both areas report profits of up to 40% from potatoes stored under rustic conditions, these reports must be qualified with the observation that these farmers also reported having

Table 2. Potato cultivation and storage in two states in India.

	Meghalaya	Gujarat
Areas surveyed	East Khasi Hills district West Khasi Hills district	Khera district
Potato cropping season	February to June July to November	Nov-Dec to Feb-March
Varieties grown	K. Jyoti, K. Megha K. Garo Khasi, Local	K. Badshah, K. Lavkar K. Jyoti, Sanga 1 (S1) K. Chandramukhi
Area under potatoes (ha)	16,715 (During 1989-90)	4500 (During 1986-87)
Production (000t)	105	93
Yield (t/ha)	6.3	20.7
No. of cold stores in the area	Nil (till date)	22 (as of March 1985)
Estimated quantity of potatoes stored indigenously (000t)	40	9
Type of stores (indigenous)	Stores made of wood, tin and thatch	Structures made with pillars and thatch Structures made of cement bricks and RCC sheets
Capacity of stores (t)	0.5 to 5	10 to 100
Duration of storage (days)	60 to 150	45 to 90
Purpose of storage	Ware and seed	Ware
Who stores potatoes	Farmers & traders	Farmers
Reported rottage	1 to 12%	2 to 5%
Reported weight loss	10%	5%

no knowledge of actual physiological weight losses.

In 1993, survey work in India will be extended into major potato producing states such as Uttar Pradesh. Similar survey work is planned for Bangladesh for 1993-94. Results of these field studies will then be synthesized to ensure the more precise evaluation of indigenous practices. Thus, researchers will determine how these practices might be improved upon, documented, and more broadly diffused in conjunction with the other rustic storage experiments that are focused on structural design, building materials, management, and storage media. The information will be combined into a multicomponent set of recommendations on rustic storage.

Marketing and Demand for Potatoes

Through research in **Colombia** on the market for semi-industrial and industrial processed potato products under the auspices of the cooperative program for research on potatoes in the Andean region, a collaborative agreement was signed between the private sector and the national potato program for the equivalent of over US$20,000 to support research on breeding potato varieties for processing. This development attracted the attention of other Latin American countries that have shown strong growth in demand for potatoes to be used in the rapidly expanding fast food industry. To meet these needs, CIP is evaluating advanced clones adapted to tropical conditions. These clones will have good processing characteristics for use in Latin America, as well as for South Asia (**India** and **Bangladesh**) and Southeast Asia (the **Philippines**). CIP is also expanding its role as a facilitator of initiatives involving public research organizations and private enterprises in these countries.

Breeding for Processing

In developing countries, urban processors are increasing their demand for appropriate raw material to produce french fries, potato chips, and other snack foods. CIP is responding to this need by continued development of populations and clones that have good processing characteristics and are adapted to tropical growing conditions.

In **Peru**, at La Molina and San Ramon, during winter, 1991, plantings were made of 400 clones from crosses between progenitors with processing attributes (high dry matter content and low reducing sugar) and PVX- and PVY-immune clones, and from a group of new varieties from Bangladesh and progenitors. At La Molina, 26 clones have shown good yield and processing characteristics (high dry matter content ranging from 22.09% to 25.73%, low reducing sugar ranging from 0.01% to 0.05%, and good color for chips or french fries), and good yields. Some of these clones are immune to PVX and/or PVY. At San Ramon, 16 showed good processing attributes. The 26 selected clones were planted again at La Molina during the summer of 1992, under very hot conditions. Of these clones, six have performed well for processing and have produced acceptable yields. Some of these clones have shown good stability for processing attributes in all three environments: La Molina in winter and summer, and San Ramon in the dry season (Table 3).

A new group of 400 clones, selected from a population combining processing attributes and virus resistance (PVX and PVY), was planted at Huancayo, Peru, during summer, 1992. From these, 40 clones were selected that had good processing attributes: high dry matter content ranging

Table 3. Clones selected for processing attributes in Peru.

Name	Site	Early	Yield (kg/plant)	Use	DM (%)	Gluc. (%)	Resistance	Fried color
(LM86.235 x XYbk)103	1	5	0.73	F	25.4	2	A	1.2
	2	6	0.51	F	24.4	4	A	1.0
(LM86.230 x XYbk)567	1	3	1.20	F	25.3	1	AB	1.0
(LM86.240 x XYbk)535	1	5	0.90	F	25.1	4	AB	2.0
	3	3	1.00	F	22.1	1	AB	1.0
(LM86.666 x BWbk)440	1	5	0.71	C	24.3	2	-	1.0
	2	5	0.69	C	23.6	5	-	1.0
(LM86.320 x XYbk)544	1	7	0.79	C	23.6	2	AB	1.0
	2	7	0.32	C	21.8	2	AB	1.0
	3	1	0.40	C	21.7	7	AB	1.5
(LM86.666 x XYbk)325	1	5	1.26	F	23.5	3	-	1.0
	2	7	0.63	F	10.1	9	-	1.3
(LM86.320 x YYbk)502	1	5	1.10	F	22.9	0	B	2.5
	2	6	0.85	F	22.2	6	B	2.0
(LM86.686 x LT-7)358	1	3	1.00	C	22.7	2	-	1.0
	2	7	0.80	C	20.5	2	-	1.0
(LM86.320 x XYbk)546	1	3	0.75	C	22.5	1	-	1.0
	3	3	0.45	C	21.1	3	-	1.5

Site: 1, La Molina winter 1991; 2, San Ramon winter 1991; 3, La Molina summer 1992. Early: 9 = very early, 1 = very late.
Use: C = Chips, F = French fries. DM = Dry matter. Gluc = Glucose; A = Resistant to Potato Virus X; B = Resistant to Potato Virus Y.
Fried color: 1 = lightest color, 5 = darkest color, 3 is acceptable.

from 21.07% to 26.50%, low levels of reducing sugar ranging from 0.01% to 0.12%, and good chip color. These selected clones are again being planted at La Molina (spring 1993) to check their performance.

Since 1990, 90 clones have been evaluated for processing and yield in La Molina (winter and summer) and at San Ramon. In the last evaluation at La Molina (winter 1992), only six clones performed well. This group of 6 clones was planted at San Ramon during winter 1992, but all the plants were severely affected by bacterial wilt; however a clone (GRANOLA × Y84.011)21 survived, which has acceptable yield and processing quality.

A population combining processing attributes as well as PVX and PVY immunities was assembled to generate the next recurrent cycle, and to identify clones and progenies having good processing attributes and virus resistance. At La Molina, during winter 1991, ten progenies were identified with high average dry matter content (ranging from 23.15% to 27.09%) and low levels of reducing sugar (0.03% to 0.05%). The same population was planted as tuber families at La Molina and San Ramon during summer 1992. All clones of the population at San Ramon died due to a severe attack of bacterial wilt. At La Molina seven progenies showed adequate processing attributes. The progeny ATLANTIC × LT-7 performed well in the winter 91 and summer 92 at La Molina.

To increase genetic variability for earliness, yield, and quality, a new population of 6,800 genotypes, grouped in 34 progenies from crosses between good European processing varieties with PVX- and PVY-immune clones, was screened for PVX and PVY. The surviving materials were transplanted to the field at La Molina during winter 1992. Nearly 700 clones were selected for their agronomic attributes and these clones will be evaluated for yield and agronomic and processing characteristics under high-temperature conditions at La Molina during the summer of 1993. Table 4 shows that seventeen progenies of this population were found to produce a high frequency of genotypes with high levels of dry matter content, low levels of reducing sugars, and good frying color.

Growth in the fast food industry has been particularly strong in Southeast Asia, where rising per capita incomes, tourism, rapid urbanization, and growing female participation in the formal work force have combined to generate a strong demand for snacks and meals that can be served rapidly and efficiently to many customers. Thus, CIP scientists continue to evaluate selected clones for promising agronomic and processing characteristics for this area. In the **Philippines** (Ilocos Norte), 17 potato clones were tested for chipping quality. Most of these materials had been selected in previous years for their high yield and virus resistance. Table 5 shows that ten of the clones had a general rating of eight or higher, indicating adequate quality for making chips.

Plans are well under way to expand these trials in 1993 by incorporating materials selected in **Peru**, in collaboration with local university researchers and the private sector. The goal is to have some selected clones ready for multiplication and distribution to growers by 1995-96.

Tacna, one of the promising clones which has very good prospects in the fast food industry.

Table 4. Progenies with processing attributes previously screened for PVX and PVY immunity at La Molina, 1992.

Pedigree	DM[1] %	Glucose %	Good quality chips (%)
XY.1 × ATLANTIC	25	3	89
XY.7 × ATLANTIC	26	1	92
XY.20 × ATLANTIC	23	5	68
ATLANTIC × XY.14	24	2	90
R.BURBANC × XY.9	25	3	66
DELCORA × XY.16	24	2	92
DELCORA × XY.20	23	4	85
ERNSTELTOLZ × XY.16	26	5	81
ATLANTIC × I-1039	24	0	86
DELCORA × XY.4	22	1	100
ERNSTELTOLZ × XY.4	23	1	98
SHEPODY × XY.13	23	1	91
ATLANTIC × XY.9	26	2	100
DELCORA × XY.9	24	3	90
ERNSTELTOLZ × XY.9	24	2	84
Y84.027 × ATLANTIC	25	1	83
SHEPODY × XY.9	25	1	94

[1] DM=Dry matter

Although **India** annually produces over 15 million t of potatoes, only about 50,000 t are processed. For most processing, traditional techniques are used at the village level. Processors are eagerly searching for raw materials from potato varieties with good yields and appropriate processing characteristics to meet the demands of the national population of over 850 million; the rising incomes of a growing urban middle class; and the desire to diversify diets away from the standard rice- or wheat-based meals. Because such materials are in short supply, contacts were made with CIP in 1992 to test for high-yielding, disease-resistant TPS tuber families for their processing performance. In tests of 5 hybrid TPS families at CPRS, Modipuram, 3 families showed higher levels of dry-matter content than did 2 cultivars grown extensively in western Uttar Pradesh (Table 6). In private industry, tests of the chipping quality of the TPS

Table 5. Evaluation for chipping quality of 17 potato clones at MMSU, Batac, Ilocos Norte, Philippines, 1992.

Clone/Cultivar	Color	Texture	Flavor	General Rating
Conchita x K. Jyoti.5	8.8	8.4	9.0	8.6
385110.59 x 384515.9 Bk	7.8	8.8	7.8	8.6
385130.5	8.2	9.4	8.0	8.4
385080.9	8.0	8.0	8.8	8.4
384085.1	9.0	8.2	8.4	8.4
385144.31	7.8	9.2	8.4	8.2
APC 318	7.8	9.4	8.0	8.0
BW2	7.8	9.6	8.0	8.0
Berolina	5.4	9.8	8.4	8.0
385130.6	6.6	9.4	8.2	8.0
BW1(465)	7.6	9.4	7.6	7.6
384071.17	5.2	8.2	8.0	7.6
Cosima	6.4	6.8	7.8	7.0
384011.3	4.2	8.4	8.2	7.0
Kufri Sindhuri	4.6	8.0	6.8	5.8
Mean	7.1	8.5	8.1	7.8

Rating Scale: Chip color: 1 = dark brown to 9 = light yellow; chip texture: 1 = rubbery to 10 = crunchy/crisp;
chip flavor: 1 = bland to 10 = full chip flavor; general acceptability rating: 1 = disliked very much to 10 = liked very much

hybrids, the tubers were judged as acceptable for use when they become commercially available. Over 100 t of materials have been sold to processors directly by growers who produce the tubers from these TPS hybrids.

Table 6. Dry matter (%) of tubers from TPS families against other cultivars from Uttar Pradesh, India, 1991-92.

Family	Dry matter
HPS-1/13[1]	21.33
HPS-II/13[1]	20.80
HPS-7/67[1]	22.03
Kufri Bahar[2]	16.90
Kufri Badshah[2]	18.27

[1] TPS families.

2 Uttar Pradesh cultivars.

Product Development for Sweetpotato in Developing Countries

Limited demand for fresh roots and lack of alternative markets are among the most important constraints to increased sweetpotato production in many developing countries. CIP's sweetpotato product development project focuses on collaborative research and training activities to increase demand in key countries. These activities include identifying the demand for processed products made from sweetpotato and the available techniques to produce them; transferring existing technologies and developing new ones to process sweetpotato and related by-products; evaluating existing elite clones for processing potential and breeding new materials; and designing new products and processes to provide alternative end-uses of sweetpotato.

Breeding for Processing

As an integral part of CIP's sweetpotato breeding program, research on breeding for processing in Program 6 focuses on the generation of genetic materials with improved utilization characteristics, and on the strengthening of national program abilities to test and select varieties with suitable characteristics for processing.

Raw sweetpotato roots have been reported to have poor digestibility as compared to other crops, such as maize, when used in animal feed rations. Cooking or drying roots prior to feeding improves digestibility, but requires energy and increases costs. Thus, CIP is continuing work initiated by the Asian Vegetable Research and Development Center (AVRDC), to improve sweetpotato digestibility through breeding. Poor starch digestibility and high trypsin inhibitor activity (TIA) have been identified as possible reasons for low digestibility. Collaborative research to improve sweetpotato digestibility has been under way at North Carolina State University (NCSU), USA, since 1990, and related work has begun at CIP headquarters.

Researchers at NCSU have estimated the genetic parameters for in vitro starch digestibility and TIA in a genetically diverse population. Their findings suggest that it should be relatively easy to breed for improved sweetpotato nutritional quality, including high starch digestibility and content, increased protein content, and reduced TIA. Clones have been identified that have starch digestibility better than or equal to the maize control (Table 7). These are being cleaned up for international distribution and testing. Animal feeding trials will confirm the improved nutritional values of selected clones. In countries such as China, methods and germplasm from these trials can contribute to the development of varieties with improved nutritional value, thus enhancing the use of raw sweetpotato as animal feed.

Table 7. Mean in vitro starch digestibility index values of two sets of sweetpotato clones from trials at various locations in North Carolina, USA.

	Set 1		Set 2	
Clone	Digest. Index[1]	Clone	Digest. Index	
Puerto Rico	88.3 a[2]	A-205	108.8 a	
Jewel	84.9 a	1740	96.6 b	
Beauregard	83.8 a	1741	81.2 c	
Cordner	78.3 b	273-5	79.1 cd	
Carolina Nugget	75.3 bc	A-18	78.4 cd	
MD 8-10	73.4	A-159	77.0 cd	
White Delite	69.9 d	1554	67.3 e	
A-21	65.2 e	1618	55.5 e	
MD 88-26	61.5 e	A-187	55.2 e	

[1] Digestibility Index = (Weight loss in sample/Weight loss in com starch) x 100.

[2] Means with the same letter are not significantly different by Duncan's multiple range test at 0.05.

The availability of non-sweet varieties (which lack ß-amylase activity) can create opportunities for increased sweetpotato use in developing countries. Non-sweet materials have potential for use in potato-like processed food products, (e.g., french fries) and for improving the bulk handling characteristics of dried chips for balanced animal feed manufacture. Early, high yielding, non-sweet genetic materials with high dry matter content and tropical adaptation are being developed at CIP headquarters. During 1992, botanical seed families having the non-sweet trait were distributed to CIP and national program collaborators in Asia and Africa. Over the next few years, locally adapted, non-sweet clones selected from introduced seed by national programs will be evaluated for processing quality in **China, Vietnam, Indonesia, Philippines, Kenya**, and **Peru**. In addition to generating new materials suitable for processing, CIP will capitalize on gains made by other breeding programs through the distribution and testing of existing materials (clones), and seed populations derived from them. Many clones with diverse quality characteristics have now been pathogen-tested and distributed to CIP regional offices and national programs (see report of Program 5). Table 8 lists characteristics and potential uses of some available materials. Evaluation for agronomic and use performance in developing countries will determine the suitability of these materials for use in processing.

CIP also seeks to strengthen national program abilities to select varieties suitable for processing. A sub-project has been initiated to assist in varietal selection for processing in **China** (Sichuan Province), **Indonesia, Philippines, Vietnam**, and **Kenya**. The sub-project supports multilocational agronomic and processing evaluations, and involves agronomists, farmers, utilization specialists, and processors. The most important types of processing and quality characteristics required vary by country and region. CIP focuses on utilization forms (such as dried chips in animal feeding) that are likely to have wide use. This work is coordinated with network activities, such as those of SAPPRAD, which have similar objectives. The goal is to generate a set of promising new varieties with processing potential for use in each of the cooperating countries.

SAPPRAD-sponsored researchers in **Thailand** are studying the potential for expanded sweetpotato production as a post-rice crop in the northern plains, for use in the starch industry. This work entails on-station and on-farm evaluation of promising sweetpotato clones, including IITA Tis 8250. They use a multidisciplinary approach, involving agronomic evaluations (yield, canopy cover, earliness, etc.) and participation of farmers and processors in quality assessment. In follow-up visits, social scientists determine the adoption of new materials. The Department of

Table 8. Characteristics of some pathogen-tested sweetpotato clones available at CIP with potential for use in processing.

Clone	Source	Characteristics	Product/Use
LM 87.045	CIP	32.5% DM	Starch
Xushu 18	China	28% DM, vigorous foliage, red skin, white flesh	Starch, dried chips
IITA-TIS 3290	IITA	33% DM, cream skin, white flesh, medium dry texture, moderately sweet	Starch, dried chips
Hi-Dry	USA	40% DM, white flesh, low sweet, dry texture	Starch, dried chips
CN 1448-49	AVRDC	36% DM	Starch, dried chips
CARI-9	Sri Lanka	40% DM, white flesh	Starch, dried chips
Tamayutaka	Japan	Low oxidation, yellow skin, cream flesh, dry texture	Steam and dried chips
Satsumahikari	Japan	Non-sweet, white flesh, dry texture	Food products, dried chips
Sumor	USA	28.5% DM, cream skin, white flesh, moist texture, low sweetness	Bakery products, processed food
CARI-426	Sri Lanka	25% DM, orange flesh, moist texture, sweet	Ketchup, bakery products, fruity products
SR 88.050	CIP	28% DM, yellow skin, orange flesh, moist texture, sweet	Ketchup, bakery products
Morada INTA	Argentina	Purple skin, light orange	Dessert products, bakery products
CEMSA 78-326	Cuba	Early, foliage production	Foliage, silage
Maria Angola	Peru	Purple skin, orange flesh	Foliage, silage
Camote Sal	Peru	Does not produce storage roots	Foliage, silage
CN 1232-9	AVRDC	High starch digestibility	Raw roots as animal feed
CN 1448-59	AVRDC	High starch digestibility	Raw roots as animal feed
CN 1108-13	AVRDC	High starch digestibility	Raw roots as animal feed

Agriculture rapidly multiplies the planting materials for widespread distribution. Commercial-scale evaluation of clones for starch extraction is being done in collaboration with private industry.

Processing

The project area supports development of new and innovative sweetpotato processing techniques, as well as the optimization, transfer, and adaptation of existing processing techniques. Specialist collaborators include scientists and processors, mostly in developing countries.

Use of sweetpotato for processing (principally starch for food products) and animal feeding has increased in China since the mid-1970s. CIP collaborates with the Food Science Laboratory at the Sichuan Academy of Agricultural Sciences to improve village-level sweetpotato processing. Sichuan produces more sweetpotato than any other province in China. Hence, the ample supply of raw material makes local processing highly attractive. This work focuses on developing improved methods and machinery for noodle production, and has established pilot production units to test and monitor the technology. In Santai County, where the project was initiated, the economic benefits of pilot plants have been amply demonstrated, and the local government has invested in the establishment of 100 units involving 1000 families (Table 9).

Table 9. Value (000 R.M.B.[1]) of sweetpotato processing in Santai County, Sichuan, China.

	1989	1990	1991	Total
Total value of fresh production and processed products	24,582	42,025	61,236	127,843
Value of fresh production	10,647	16,981	18,984	46,612
Value of processed products	13,935	25,044	42,252	81,231
Tax revenue generated by sweetpotato processing	919	1,551	4,869	7,343

[1] US$1 = 5.71 Renminbi

This work merited designation as "outstanding" at the Chinese National Fair display of "Spark Plan" projects. The machinery for starch extraction and noodle extrusion has been lauded for filling a need for appropriate small-scale processing equipment. Orders for 70 sets of machinery were placed at the Leshan and Xiangfan national fairs for new products and techniques. Chinese and English language videos of the results of the project have been prepared and broadcast on Chinese national television. A demonstration center for small-scale processing techniques is being established in Sichuan to display and promote new sweetpotato processing techniques from all over China. This will help to promote transfer of these technologies both within and outside China.

In several other Asian countries, sweetpotato is used mostly for fresh consumption, with only small amounts used for processing. SAPPRAD is sponsoring projects in **Indonesia, Philippines,** and **Thailand** to identify or create products that might increase earnings for growers and local processors. In **Indonesia,** local researchers are working on production and characterization of sweetpotato flour, and production of a vermicelli composite flour. At ViSCA in the **Philippines,** pilot processing lines are being established to produce chips, hot cakes, powder, and noodles from sweetpotato. In **Thailand,** a total of 71 food products including snacks, desserts, main dishes, condiments, starch, and flour were prepared in a project to survey and develop consumer-acceptable products suitable for small-scale processing. Information on the results of these projects should lead to expanded sweetpotato use in each country.

Little processing is done in **Africa,** where sweetpotato is an important crop in rural areas of a number of countries. The crop is usually stored in the ground until harvest, and then boiled or roasted for consumption. Development of processed products acceptable to urban consumers can help farmers to avoid losses due to weevil during in-ground storage and increase incomes. In **Kenya,** a thesis project involving Cornell University, Kenya Agricultural Institute (KARI), and the University of Nairobi has studied consumer acceptance of eight products based on both traditional and non-traditional recipes. These products included ugali, uji, dried crisps, fried crisps, bread, chapati, and mashes made from reconstituted chips and flakes, which incorporate sweetpotato in varying proportions. In general, consumers preferred chips, a non-traditional product. Consumer reactions to the ugali and uji depended on whether they had had previous experience with the addition of other flours to the traditional maize-based foods. Although lack of consumer acceptance was found to be the most likely obstacle to increased use of the new products, the study suggests a

Sweetpotato noodles are readily available to consumers in the Zhong guancon market in Beijing, China.

promising role for sweetpotato in urban diets. It also provides a basis for future collaborative research and development.

Use of fresh ground sweetpotato roots as a substitute for wheat flour in breadmaking is a relatively new and promising technique developed by the private sector in **Peru.** CIP continues to transfer and adapt this technology in Burundi and Cameroon, where sweetpotato is relatively cheap compared to imported wheat flour. In **Burundi,** work supported by the development agency of the Belgian Government, Administration Generale de la Coopération au Dévelopement (AGCD) has been conducted with the Food and Agriculture Organization of the United Nations (FAO), the Institut des Sciences Agronomiques du Burundi (ISABU), and private bakeries. A sweetbread of excellent nutritional and organoleptic quality is made by substituting grated sweetpotato for 30% (on a fresh weight basis) of wheat flour. This bread is cheap to produce and the method has been adopted by at least one private bakery and by the kitchens at several secondary schools. This work will be expanded.

In **Cameroon,** CIP is collaborating with the Institut de Recherche Agronomique (IRA) in Cameroon, FAO, the northwest provincial delegation of agriculture, local bakeries, and farmer groups. An acceptable quality bread is made by substituting freshly grated sweetpotato for 25-30% of wheat flour, at a cost that is low enough to quickly pay for the grating machine. Sweetpotato bread will become even more profitable when the government removes wheat price subsidies. In Cameroon, researchers also have studied the use of sweetpotato flour in traditional snacks, and in high-value bakery products. Several acceptable products have been developed, and flour from a sweet variety was shown to reduce sugar requirements in recipes, thus lowering costs. The local high yielding variety has the low sweetness required for a staple type, and the sweet variety was selected from seed introduced from the USA. A recipe book is being published to disseminate these techniques. Similar work will expand to other provinces, including training of processing groups, establishment of a revolving fund for credit to processors, and additional work on packaging and marketing of sweetpotato flour.

Nutrition

Sweetpotato is a particularly useful crop in that both leaves and roots are edible. Studies of yield potential and nutritional value usually focus on the roots. However, CIP has sponsored the publication of a comprehensive book entitled *Sweetpotato: an untapped food resource*, by Jennifer Woolfe (see publication list). Published in 1992, the book reviews existing literature on chemical composition, nutritional value, and livestock feeding and discusses factors limiting consumption and use of sweetpotato tops. Although leaves and vine tips are eaten as a vegetable by people in several countries, few studies have been made of the potential of these plant parts as highly nutritious sources of protein, vitamin A, B vitamins, and minerals. Use of vine tips as a vegetable is restricted by low leaf tip yields, difficulty of harvest, and lack of suitably tender and mildly flavored varieties. Table 10 lists percentages of recommended daily intakes of major nutrients that can be provided by 85g of sweetpotato leaves.

Expanded use of vines as animal feed also shows promise. In **China**, tops are an important feed source and are fed (principally to pigs) raw, cooked, ensiled, or as a dried meal. Tops may be harvested 4-5 times in a production season, and can produce 135 t/ha of fresh material, enough green feed for 105 hogs. These yields are confirmed by work conducted at CIP (see report of Program 5) which is looking at the ensilage of sweetpotato tops, and their nutritional value for feeding animals including sheep, cows, guinea pigs, and pigs.

Table 10. Recommended daily intakes (%) of major nutrients provided by 85 g of cooked sweetpotato.

Age group (years)	Protein	Vit. A	Thiamin	Riboflavin	Folic acid	Ascorbic acid	Iron	Calcium
1-3	16	60	13	30	30	50	13-40	26-33
4-6	13	60	10	22	30	50	11-30	26-33
7-9	10	60	7	18	15	50	7-20	26-33
Adolescent male								
10-12	9	50	6	15	15	50	7-20	19-22
13-15	7	40	5	14	9	30	4-13	19-22
16-19	7	40	5	13	8	30	7-20	22-26
Adolescent female								
10-12	9	50	7	17	15	50	7-20	19-22
13-15	9	40	6	16	9	30	4-12	19-22
16-19	9	50	7	16	9	30	3-10	22-26
Adult male	7	40	5	13	8	30	7-20	26-33
Adult female	9	50	7	18	9	30	3-10	26-33

Source: Woolfe, J. Sweetpotato. Lima, CIP. 1992

Information and Training

Information

Potato An updated manual on potato storage is under way to synthesize and distill the 10 to 12 years of applied research on potato storage in developing countries. This publication will bring together material from several workshops and conferences that focused on this topic. Contents will include information about the set of technological recommendations on rustic storage of table potatoes under tropical conditions, and on diffused light storage of seed potatoes, especially the most recent developments in the application of these basic principles under tropical conditions. Target users are scientists, rural development specialists, and extension personnel working in South Asia, who can help in managing the increasingly large seasonal supply of potatoes. The manual will be extensively pretested in the field and in workshops.

As Program 6 phases out of potato marketing research as a major priority, CIP has received requests for research guidelines from developing country researchers in public institutions, universities, and NGOs. Research Guidelines for local use are found in CIP's publications of a series of country case studies. A Spanish-methods manual for agricultural marketing research covering several topics (Table 11) has met with immediate acceptance in the Spanish-speaking market and the volume is currently in its second printing. An English version is now in preparation. These publications can serve as a basis for country-level and regional workshops, which could be held in collaboration with other CGIAR Centers, and as reading material in academic training.

CIP's Information Unit prepared an extensive, annotated bibliography—with over 800 citations—on postharvest aspects of sweetpotatoes, based on the information available from the headquarter's library. The document includes cross listings on over 200 topics, arranged by both subject matter and country. While postharvest problems are generally considered to be a major bottleneck to expanded sweetpotato production and use, major research findings are often unavailable in developing countries. Also, limited access to the results of this work is limited outside their country of origin. Permanent bibliographic updates can overcome this constraint and become a valuable tool for expanding and improving the use of existing practices, as well as for developing new processes and products from sweetpotato in developing countries.

Sweetpotato Two sets of training materials on sweetpotato product development sweetpotatoes in developing countries were published:

(1) The proceedings of the workshops on root and tuber crops processing, marketing, and utilization held at ICTA, **Guatemala** and ViSCA, **Philippines**, include:

- Reports on the current status of sweetpotato processing and utilization in **China** (including **Taiwan**), **India**, **Korea**, **Thailand**, **Indonesia**, the **Philippines**, the island states of the **South Pacific**, and **Vietnam** as well as similar chapters on potato for **Costa Rica**, **Mexico**, **Guatemala**, **Colombia**, **Peru**, and **Panama**;
- Assessments of the potential for sweetpotato processing in **Vietnam**, the **Philippines**, and **Peru**, as well as for potato in **Colombia**;
- Research advances in product processing such as the use of sweetpotato for animal feed in **Cuba**, and noodle-making in **China**;

Table 11. Agricultural Marketing: Applied Research Methods for Developing Countries.

Author(s)	Level	Focus	Source of Data	Method(s)
Immink/Alarcon	farmer	nutrition	formal surveys and others	econometric model
Budget	farmer	profitability	cost and income records	accounting
Benavides/Fano	farmer/consumer	production/consumption	formal surveys	descriptive statistics
Bustamante	institutional	distribution	formal surveys	descriptive statistics
Vilca	national	demand	secondary data	formal model
Della V./Brieva	farmer	demand	formal survey	formal model
Prain	farmer	distribution	multiple informal methods	open interviews
Carlier/Janssen	consumer	preferences	formal survey	econometric model
Lee *et al.*	consumer	consumption/spend	formal survey and others	econometric model
Kruseman	consumer	consumption	formal surveys	econometric model
Scott	farmer/consumer	production/consumption	multiple	inform surveys
Izquierdo *et al.*	consumer	consumption	formal surveys	descriptive statistics
Esquite/Perez	trader	sales	formal surveys	descriptive statistics
Morris	sub-sector	distribution/profitability	multiple	informal survey
Scott	food system	production/distribution/ consumption	secondary data	literature review
La Gra	food system	system	multiple	
Tschirley	urban market	prices/volumes	secondary data	econometric model
Ordinola	urban market	prices/volumes	secondary data	econometric model
Mendoza	urban and rural market	margins	formal survey	formula

- Discussion of pilot processing plants for potatoes and their expansion into commercial potato processing in **India** and **Peru.**

The proceedings contain a wealth of highly useful information that is often available only in the originating countries, or scattered in unpublished, ad hoc project reports. They list recommendations for market assessment, products and processes research, and pilot plants, as well as national representatives' views on how their respective countries could collaborate with institutions from neighboring nations in product development studies.

(2) A manual on product development for root and tuber crops prepared in collaboration with colleagues at CIAT and IITA. Intended as a practitioner's guide for those interested in processing initiatives, this document summarizes the experience of the three centers and their national partners. The document covers 12 case studies from Latin America, Africa, and Asia.

Training

In **China,** a sweetpotato processing course was held at Santai, Sichuan Province, in October, co-sponsored by CIP and the Sichuan Academy of Agricultural Sciences (SAAS). A total of 120 persons from 10 Chinese provinces attended the four-day activity which included situation reports, technological developments, and visiting processing units in Santai county. The cooperative project "Further Improved and Popularized Sweetpotato and Potato Processing Techniques" produces starch and noodles in small-scale processing units using improved equipment made at the Santai machinery factory. Participants observed the plant in operation and asked about specific technological aspects of processing sweetpotato.

Another training course on sweetpotato food processing was held at Huairou, a county in the suburbs of Beijing later in October. The course included training on a technique for making "Dan Shao Su" (Crispy Sweetpotato Cake), for use by a food manufacturer. This technique was developed by a cooperative project between CIP and SAAS. Participants included 12 farmers and rural technicians.

■

1992 Research Projects and Partners

This list contains the titles of research projects, the names of principal partner researchers and their respective country, the responsible CIP scientist, and the names of collaborating researchers.

Rustic stores for ware and seed potato and village level processing of potatoes. S. Mehra, J. Singh, V.S. Khatana, S.K. Roy, IARI, **India**/R. Nave, S. Wiersema, N.P. Sukumaran, P.K. Patel

Storage of ware and seed potatoes. A. Sharara, S. Doss, N. Farag, MA, **Egypt**/R. El-Bedewy; G. Scott, R. Cortbaoui

Screening for potato tuber sprout inhibitor of potato tubers (*Solanum tuberosum* L.) using plants belonging to *Labiatae* family. E.G. Quintana, O.K. Bautista, UPLB, **Philippines**

Potato and sweetpotato breeding for processing in tropical countries. H. Mendoza, W. Amorós, M. Ato, A. Golmirzaie, J. Landeo **Peru**

Improved sweetpotato processing in China. A.F. Tang, SAAS, **China**/Song Bofu

The utilization of sweetpotato roots and flour in bakery products in Cameroon. R. Wanzie, PDA, Cameroon/ A. Odaga, J. Koi, C. Martin; V. Deffo, IRA, **Cameroon**

Introducing and diffusing a new method for making bread with pure sweetpotato in Burundi. M. Beavogui, A. Bikorimana, A. Hagoye, ISABU-FAO, **Burundi** CTP/D. Berríos, G. Scott, P. Ewell

Breeding sweetpotatoes with enhanced nutritional quality for human food and animal feed. W.W. Collins, Zhang Da Peng, NCSU, **USA**

Increasing sweetpotato's role in western Kenyan urban dietaries: The processing possibilities. E.N. Gakonyo, T.T. Poleman, J.N. Kabira, E. Karuri, Cornell U, USA; KARI, U. Nairobi, **Kenya**/ P.T. Ewell, G. Scott

Development of alcoholic beverages from sweetpotato fresh roots. Shengwu Wang, IFST, UPLB, the **Philippines**; V.V. García

INFORMATION AT CIP

Information and communication processes at CIP were systematically reviewed in 1992, with CIP staff participating in the internal assessment of these functions. Recommendations are now being implemented, including the following. Three Units of the Information Sciences Department have been reorganized to meet the demands of a restricted budget. The Information Unit has been reorganized and a Unit Coordinator named. Similarly, the Computer Unit now has a Coordinator, and a computer maintenance facility has been established. The Communication Unit has been restructured into two Units: a Media Design Sub-Unit, for editorial services, and a Media Production Sub-Unit.

CIP Information Services

Library information services for national programs continue to expand, with additional services for both CIP staff and NARS. Information searches were made for 375 users, and over 170 selective dissemination of information profiles (SDI's) were provided on a regular basis throughout the year. Retrospective searches reached a high of 727 for CIP and national program staff. SDI profiles are continuously evaluated and modified based on feedback received, documenting the value of these services for national programs. CIP information services were evaluated through a Master's Thesis research project.

Specialized bibliographies were produced based on user demand and CIP program priorities. Support was provided for the production of national bibliographies related to Andean root and tuber crops, specifically the *Bibliografía sobre tubérculos, raíces y cormos andinos subexplotados*, compiled by Mario Tapia with the support of the CIP Information Unit; the *Catálogo de tesis universitarias con énfasis en cultivos andinos 1962-1991*, compiled by the Centro de Investigación en Cultivos Andinos (CICA) (Cusco, Peru); and the *Bibliografía sobre raíces y tubérculos andinos*, compiled by Michael Hermann et al. For Andean crops, diverse information and documentation from local collections is assembled for more generalized use in other countries of the region.

CIP's bibliographic data base has grown during this year by more than 2,700 entries, reaching a total of over 40,600 bibliographic references on potato and sweetpotato research relevant to developing countries' needs. CIP's bibliographic data base is strengthened by keeping all documents in the CIP library and making them available for document delivery to national researchers.

CIP's policy is to provide a limited number of photocopies free of charge with each search or SDI provided to national programs. Over 25,700 photo copies were requested by researchers and delivered for their review for research purposes in 1992.

CIP complements the services provided from its data base with those provided by AGRIS, CABI, and PASCAL databases. These are housed in CIP's VAX system and available through the headquarters network, as well as those required through external on-line services available in DIALOG.

Communication Accomplishments

This year has been highly productive in communication outputs. CIP produced 37 new titles (nearly 40,000 copies in total), 15 reprints, two videotapes, and one poster in three languages, all of which document and support research progress, institutional strategies and policies, and training activities.

Among the new titles, three were copublications: *Sweet Potato: An Untapped Food Resource*, copublished with Cambridge University Press (England); *La Papa*, copublished with Editorial Hemisferio Sur (Montevideo, Uruguay); and *Mercadeo Agrícola: Metodologías de Investigación*, copublished with IICA (San Jose, Costa Rica). In addition to the Annual Report in English and Spanish, all books and publications were produced in CIP's print shop and included the *Compendio de Enfermedades de la Batata, Meeting the Challenge: the International Potato Center Strategy for the 1990s and Beyond*, and *Semilla Sexual de Papa en Latinoamérica*. CIP Research Guides accounted for 15 of the new titles, which were published in Spanish or English.

Computer Accomplishments

The Computer Unit was thoroughly reviewed to consolidate its management to ensure that computer facilities meet the Center's needs, funding and staff. New strategic and operational plans are under way to exploit flexible and economical systems development, using contract staff to rapidly respond to short-term requirements. Extensive support was provided to the Accounting Department for the development of responsive budgeting and reporting systems to be made available online for CIP staff in management positions. The internal Computer Maintenance Facility was established for quality repair of PC hardware available via an onsite contractor.

The upgrading of information systems continue to meet CIP's research and administrative requirements, based on a collaborative policy promoting the installation of local network servers for project groups, instead of centralized systems. Thus the VAX network has been extended with the purchase of a MicroVAX network server to support CIP's accounts processing, and a small network server has been installed in Quito. Several other network servers are planned for 1993. The user network continued its expansion reaching a total of 65 PC computers online, plus 35 terminals.

Telecommunication facilities were improved at CIP through the installation of a microwave link that will permit CIP regional staff and selected national staff electronic access to headquarters systems information. CIP is exploring the possibility of linking Andean national programs electronically for efficient development, and has started to use the Peruvian Scientific Network for Internet access. Contacts have been made with the Andean academic communication networks to support regional communication. INFOANDINA is an effort that is designed to be a new information system to link those working in the Andean Agroecosystem, particularly through the use of electronic communication mechanisms, as well as printed bulletins and other communications.

Other computer-related activities this year include the increased use of electronic mail through the network. An application has been developed that will permit an efficient transfer of information to and from CIP through the VAX network, to benefit from the new microwave link recently installed. The aim is to provide transparent desk-to-desk electronic mail, both internally in CIP and externally with the regions and other partner institutions. Access to scientific, bibliographic, administrative, and accounting data bases is planned to be commonly available to all CIP local and regional personnel and partners via the network, exploiting economical international links such as Internet and X.25 packet-switched communications.

Cross-program Training Courses

The following courses cross CIP Program areas; they are reported here to reflect their more general nature.

The ISABU Potato and Sweetpotato Program in collaboration with CIP of **Burundi** organized an in-country course on basics of computer word processing and data spreadsheets which was attended by 6 technicians at Gisozi, ISABU Station.

An International Workshop on Andean Agro-ecosystems was held in March at CIP headquarters. The workshop was attended by 60 researchers from the Andean region, including representatives of technical cooperation organizations and funding agencies. The objective of the meeting was to assess the existing knowledge on and research methodologies for management of the Andean ecosystem for the purpose of establishing priority areas of work and cooperation among countries of the Andean region.

In June, CIP instructors, including a statistician computer technologist and science writer, presented a course on Statistical Methods for Potato Research and Writing of Research Reports at Quito **Ecuador,** for technical personnel associated to FORTIPAPA. This is a special project sponsored by the Swiss Technical Cooperation, which supports potato research in Ecuador. The 16 participants learned about general statistical methods and on two statistical computer programs, MSTAT-C and Freelance. They also prepared research project proposals and to make oral presentation of these projects for judgment by their peers and instructors as part of the training and evaluation process.

A planning workshop on the Biodiversity of Root and Tuber Crops was held at CIP headquarters in August to develop a planning matrix for a special project on the subject utilizing the participative planning methodology. The meeting was moderated by a consultant from the Swiss Development Cooperation in Berna. Participants were selected from institutions concerned with biodiversity of root and tubers in **Bolivia, Brazil, Ecuador** and **Peru.** There were also representatives from SDC, IBPGR, IDRC and the University of Kossel in **Germany.**

CIP, CIAT and CIMMYT joined efforts to offer a Regional Course on Statistics and the Use of MSTAT-C for Data Analysis. The course which was held at Egerton University, Njoro, **Kenya,** in September was attended by 26 participants. The course was taught by staff from the three international centers and KARI. Trainees had direct access to the computers for intensive hands-on practical sessions.

Publication List

Selected CIP Publications

Centro Internacional de la Papa. 1992. Annual Report 1992. Lima, Peru: CIP.

Centro Internacional de la Papa. 1992. CIP 1994-1998. The International Potato Center's medium-term proposal. Lima, Peru: CIP.

Centro Internacional de la Papa. 1992. Potato Tuber Moth Baculovirus (BCP), a powdered biological insecticide. (Also in Spanish.) Training Bulletin No. 1. Lima, Peru: CIP.

Centro Internacional de la Papa. 1992. Seis nuevas variedades de camote para la costa peruana. Tacna, Peru: Universidad Nacional Jorge Basadre Grohmann; Lima, Peru: CIP.

Centro Internacional de la Papa. 1992. Semilla sexual de papa en Latinoamerica: Trabajos presentados al taller. Lima, Peru, Sept. 1991. Lima, Peru: CIP.

Centro Internacional de la Papa. 1992. Sustainable management of natural resources in the Andean ecoregion. Lima, Peru: CIP.

Centro Internacional de la Papa. 1992. Synopsis, conclusions and recommendations. International Workshop on the Andean Agroecosystem. (Also in Spanish.) Lima, Peru: CIP.

Cisneros, F.H. 1992. El manejo integrado de plagas. Research Guide 7. Lima, Peru: CIP.

Clark, C.A. and J.W. Moyer. 1991. Compendio de enfermedades de la batata. Translation from English by T. Ames de Icochea. Lima, Peru: CIP.

Espinoza, N., R. Lizárraga, C. Sigüeñas, F. Buitrón, J. Bryan, and J.H. Dodds. 1992. Tissue culture: Micropropagation, conservation, and export of potato germplasm, 2nd Edition. (Also in Spanish.) Research Guide 1. Lima, Peru: CIP.

Fano, H. and A. Achata. 1992. Métodos y técnicas de la investigación en finca: La experiencia de las Ciencias Sociales en el CIP. Research Guide 20. Lima, Peru: CIP.

Fano, H. and M. Benavides. 1992. Los cultivos andinos en perspectiva: producción y utilización en el Cusco. Centro Internacional de la Papa; Centro de Estudios Regionales Andinos "Bartolomé de las Casas." Lima, Peru: CIP.

Fernández-Northcote, E.N. 1992. Tamizado de plántulas de papa para resistencia a los virus X e Y mediante la técnica de inoculación masal con pistola asperjadora (IMPA). Research Guide 37. Lima, Peru: CIP.

Fuglie, K., H. Ben Salah, M. Essamet, A. Ben Temime, and A. Rahmouni. 1992. The development and adoption of integrated pest management of the potato tuber moth, *Phthorimaea operculella* (Zeller) in Tunisia. Social Science Department Working Paper Series 1991-7. Lima, Peru: CIP.

Heling, Z. and B.F. Song. 1992. Seed potato production in China: Report of a workshop. From the Workshop held in Huhehaote, China, 13-19 Jul. 1992, Huhehaote, China: Inner Mongolia University Press.

Hermann, M. 1992. Andean roots and tubers: Research priorities for a neglected food resource. (Also in Spanish.) Lima, Peru: CIP.

Hermann, M., V. Casali, C. Nieto, J. Estrella, and C. Arbizu. 1992. Bibliografía sobre raíces y tubérculos andinos (excepto *Solanum spp. e Ipomoea batatas).* Lima, Peru: CIP.

Horton, D. 1992. La papa: Producción, comercialización y programas. Montevideo, Uruguay: Ed. Hemisferio Sur; Lima, Peru: CIP.

Huamán, Z. 1992. Systematic botany and morphology of the sweetpotato plant. (Also in Spanish.) Technical Information Bulletin 25. Lima, Peru: CIP.

Huamán, Z. 1992. Morphologic identification of duplicates in collections of *Ipomoea batatas.* (Also in Spanish.) Research Guide 36. Lima, Peru: CIP.

Instituto de Investigaciones Agropecuarias (INIA); Centro Internacional de la Papa (CIP). 1992. El camote, nueva alternativa a Workshop held 3 Oct. 1991, La Platina, Chile. Serie la Platina-INIA No. 35. La Platina, Chile: INIA-Estación Experimental la Platina.

Janssen, W., C. Crissman, G. Henry, M. López Pereira, L. Sanint, and T. Walker. 1992. Papel del CIAT, el CIMMYT y el CIP en la investigación agrícola de America Latina y el Caribe. From the meeting held in Cali, Colombia, June 1991. Lima, Peru: CIP.

Jayasinghe, U. and C. Chuquillanqui. 1992. Uso de plantas indicadoras para la detección de virus de papa. Research Guide 21. Lima, Peru: CIP.

Kabira, J.N. and P.T. Ewell. (eds.). 1992. Current research for the improvement of potato and sweetpotato in Kenya: Proceedings of a KARI/CIP technical workshop on collaborative research held in Nairobi, Kenya, Nov. 1991. Nairobi, Kenya: CIP.

Lizárraga, R., A. Panta, N. Espinoza, and J.H. Dodds. 1992. Tissue culture of *Ipomoea batatas*: Micropropagation and maintenance. Research Guide 32. Lima, Peru: CIP.

Nolasco, J. 1992. Diagnóstico del sistema de producción y comercialización de la papa en la República

Dominicana. Documento de Trabajo 1992-1. Lima, Peru: CIP.

Raman, K.V. and J. Alcázar. 1992. Biological control of potato tuber moth using *Phthorimaea Baculovirus.* (Also in Spanish.) Training Bulletin No. 2. Lima, Peru: CIP.

Reynoso Tantaleán, D. 1992. Usos y programas de mejoramiento genético del camote (*Ipomoea batatas* (L.) Lam.) en Japón. Reporte final de la visita a Japón del 1 Sept. - 18 Oct. 1992. Lima, Peru: CIP.

Sala, F. 1992. Diffusion of agricultural information from the International Potato Center: A case study. Lima, Peru: CIP.

Santos Rojas, J. and P. Accatino (eds.). 1992. Metodología para mejorar el uso, producción y almacenamiento de tubérculos-semilla de papa. Boletín Técnico No. 194. Lima, Peru: INIA-CIP.

Schmiediche, P. 1992. The taxonomy of wild potato species and their use in breeding. Research Guide 27. Lima, Peru: CIP.

Scott, G.J., S. Wiersema, and P.I. Ferguson. (eds.). 1992. Product development for root and tuber crops. V.1: Asia. From the International Workshop on Root and Tuber Crop Processing, Marketing, and Utilization in Asia. Baybay, Philippines, 22 Apr. - 1 May 1991. Lima, Peru: CIP.

Scott, G.J., J.E. Herrera, N. Espinola, M. Daza, C. Fonseca, H. Fano, and M. Benavides. (eds.). 1992. Desarrollo de productos de raíces y tubérculos. V.2: America Latina. Taller Colaborativo sobre Procesamiento, Comercialización y Utilización de Raíces y Tubérculos en América Latina. Villa Nueva, Guatemala, 8-12 Apr. 1991. Lima, Peru: CIP.

Swindale, A. 1992. Sistemas de producción de batata en la República Dominicana: Comparación de dos zonas agroecológicas. Documento de Trabajo CIP No. 1992-2. Lima, Peru: CIP.

Tapia, M. 1992. Bibliografía sobre tubérculos, raíces y cormos andinos subexplotados. Lima, Peru: CIP.

UPWARD. 1991. Sweetpotato cultures of Asia and South Pacific. Proceedings of the 2nd Annual UPWARD International Conference. Laguna, Philippines, 2-5 Apr. 1991. Los Baños, Philippines: CIP.

Woolfe, J.E. 1992. Sweet potato: An untapped food resource. UK: Cambridge University Press.

Journal Articles & Book Chapters

Accatino, P. 1992. Importancia de la semilla en los sistemas de producción de papa en los países en desarrollo. In: *Metodología para mejorar el uso, producción y almacenamiento de tubérculos-semillas de papa,* R. Santos Rojas, and P. Accatino. Santiago, Chile: INIA. Boletín Técnico No. 194. pp. 13-15.

Andrew, R., J. Herbas, J. Alcázar, and V. Lino. 1992. Manejo integrado de la polilla de la papa en Cochabamba, Bolivia. *CIP Circular* 19(2):8-9.

Arbizu, C. and M. Tapia. 1992. Tubérculos andinos. In: *Cultivos marginados: Otra perspectiva de 1492,* J.E. Hernández Bermejo and J. León (eds.). FAO, Roma, Italia; Jardín Botánico de Córdoba, España. pp. 147-161.

Bailón, Y. and V. Otazú. 1992. Aspectos económicos del control de la rancha (*P. infestans*) de la papa en los Andes Centrales del Perú. *Fitopatología* (Perú) 27(1):33-37.

Bejarano, M. C., G.A. Watson, R.N. Estrada, and J. Gabriel. 1992. Evaluación y selección de factores por agricultores y técnicos en clones de papa con resistencia a tizón tardío (*Phytophthora infestans*). *Revista de Agricultura* (Bolivia) 49(21):34-41.

Ben Salah, H. and R. Aalbu. 1992. Field use of granulosis virus to reduce initial storage infestation of the potato tuber moth, *Phthorimaea operculella* (Zeller), in North Africa. *Agriculture, Ecosystems and Environment* 38:119-126.

Berrios, D. 1992. Sweetpotato bread in Burundi: An update. *CIP Circular* 19(1):9.

Brandolini, A. 1992. Genetical variation for resistance to *Alternaria solani* in an advanced population of potatoes. *Annals of Applied Biology* 120(2):353-360.

Brigneti, G. and U. Jayasinghe. 1992. Eficiencia de diferentes especies de áfidos en la transmisión del virus del enrollamiento de la hoja de papa (PLRV). *Fitopatología* (Perú) 27(1):1-7.

Canto-Sáenz, M., P. Jatala, A. González, and R. Delgado de la Flor. 1992. Control integrado del nemátodo quiste de la papa. *Agronomía* (Perú) 40(1):38-39.

Carey, E.E., E. Chujoy, T.R. Dayal, H.M. Kidane-Mariam, H.A. Mendoza, and I.G. Mok. 1992. Combating food shortages and poverty: Sweetpotato breeding in CIP's client countries. *CIP Circular* 19(1):1-6.

Chandra, R., G.J. Randhawa, D.R. Chaudhari, and M.D. Upadhya. 1992. Efficacy of triazoles for in vitro microtuber production in potato. *Potato Research* 35(3):339-341.

Das, G.P., E.D. Magallona, K.V. Raman, and C.B. Adalla. 1992. Effects of different components of IPM in the management of the potato tuber moth in storage. *Agriculture, Ecosystems and Environment 41:321-325.*

Díaz, J., F. de la Puente, and D.F. Austin. 1992. Enlargement of fibrous roots in Ipomoea section Batatas (*Convolvulaceae*). *Economic Botany* 46(3):322-329.

Ekanayake, I.J. and J.P. de Jong. 1992. Stomatal response of some cultivated and wild tuber-bearing potatoes in warm tropics as influenced by water deficits. *Annals of Botany* 70:53-60.

Ekanayake, I.J. and D.J. Midmore. 1992. Genotypic variation for root pulling resistance and its relationship with yield under water-deficit stress. *Euphytica* 61(1): 43-53.

Fernández-Northcote, E.N. 1992. Potyvirus taxonomy: Potyviruses that affect solanaceous crops. In: *Potyvirus Taxonomy*, O.W. Barnett (ed.). New York, USA: Springer-Verlag. pp. 221-222.

Franco, J., R. Montecinos, and N. Ortuño. 1992. *Nacobbus aberrans*, nematodo fitoparásito del cultivo de la papa en Bolivia: Desarrollo de una estrategia para su manejo integrado. *Revista de Agricultura* (Bolivia) 49(21):11-22.

Gálvez, R., H.A. Mendoza, and E.N. Fernández-Northcote. 1992. Herencia de la inmunidad al virus Y de la papa (PVY) en clones derivados de *Solanum tuberosum* ssp. *andigena*. *Fitopatología* (Peru) 27(1):8-15.

Gandarillas, A. and A. Devaux. 1992. Estrategia de desarrollo colaborativo del PROINPA. (Also in Spanish and French.) *CIP Circular* 19(2):2-5.

Golmirzaie, A.M. and F. Serquén. 1992. Correlation between early and late growth characters in an improved true potato seed population. *HortScience* 27(4):350-352.

Golmirzaie, A.M. and J.O. York. 1992. Interrelationship of brown and purple testa genes with pericarp and other testa genes in sorghum bicolor. *Journal of Heredity* 83:330-334.

Gunadi, N., M.J. Potts, R. Sinung-Basuki, and G.A. Watson. 1992. On-farm development of potato production from true seed in Indonesia. *Experimental Agriculture* 28:31-39.

Herrera Lobatón, J.E. 1992. Importancia y potencial económico de la papa en América Latina. *Revista Papa* (FEDEPAPA, Colombia) 6:12-16, 18-21, 23.

Horton, D.E. 1992. La papa: Verdadero cultivo mundial. *Revista Papa* (FEDEPAPA, Colombia) 6:4-6, 8-9.

Jatala, P. and R. Delgado de la Flor. 1992. Problemática agraria en Arequipa. Agro Enfoque (Peru) 7(52): 14-16.

Kadian, M.S., P.C. Pande, and M.D. Upadhya. 1992. Seedling tubers from true potato seed (TPS) as planting material for north-west Indo-Gangetic plains of India. *Crop Research* (India) 5(3):499-504.

Khatana, V.S. and M.D. Upadhya. 1992. Flat bed cultivation of potatoes in Gujarat: An example of farmer generated, farmer tested and farmer adopted technology. *Honey Bee* (India) 3(2):8-10.

Lowe, J., C. Newell, F. Buitrón, F. Medina, and J. Dodds. 1992. Development of plant regeneration systems in sweetpotato (*Ipomoea batatas*). *In Vitro Cellular & Developmental Biology* 28(3):121A.

Midmore, D.J. and R.K. Prange. 1992. Growth responses of two *Solanum* species to contrasting temperatures and irradiance levels: Relations to photosynthesis, dark respiration and chlorophyll fluorescence. *Annals of Botany* 69:13-20.

Midmore, D.J. and J. Roca. 1992. Influence of production and storage conditions on subsequent growth and tuber yield of crop (*Solanum* spp.) in the hot tropics. *Journal of Agricultural Science* 119(1):45-58.

Ochoa, C.M. 1992. New synonyms in the tuber bearing *Solanum*. *Phytologia* 73(2):166-168.

Ochoa, C.M. 1992. Determinations of chromosome number (2N) and endosperm number (EBN) in some little known tuber bearing *Solanum*. *Phytologia* 73(3): 180-182.

Ochoa, C.M. 1992. *Solanum lobbianum* Bitter, a little known Colombian tuber bearing species. *Phytologia* 73(3):183-185.

Ochoa, C.M. 1992. *Solanum saxatilis*, a new wild potato species from Peru. *Phytologia* 73(5):378-380.

Palacios, M., V. Cañedo, and K.V. Raman. 1992. Control integrado de la polilla de la papa *Phthorimaea operculella* (Zeller). *Agronomía* (Peru) 40(2):43-45.

Pallais, N. and N. Espinola. 1992. Seed quality as affected by nitrogen during true potato seed production and moisture conditions during storage. *American Potato Journal* 69(2):85-93.

Potts, M.J., G.A. Watson, R. Sinung-Basuki, and N. Gunadi. 1992. Farmer experimentation as a basis for cropping systems research: A case study involving true potato seed. *Experimental Agriculture* 28:19-29.

Querci, M., E.N. Fernández-Northcote, I. Bartolini, and L.F. Salazar. 1992. Detection of PVX^{A} and PVX^{0} serotypes by nucleic acid spot hybridization using a broad spectrum recombinant probe. *Fitopatología* (Peru) 27(1):38-44.

Querci, M., S. Fuentes, and L.F. Salazar. 1992. Construction, cloning and use of radioactive RNA probes for the detection of Peruvian strain C1 of sweetpotato feathery mottle virus. *Fitopatología* (Peru) 27(2): 93-97.

Rincón, R. H. 1992. Funciones del autor: Preparación de las partes del artículo científico. *Agro Enfoque* (Peru) 7(50):36, 38.

Roux, O., R. von Arx, and J. Baumgartner. 1992. Estimating potato tuber moth, *Phthorimaea operculella* (Zeller), damage in Tunisian stores. *Journal of Economic Entomology* 85(6):2246-2250.

Salazar, L.F. and M. Querci. 1992. Detection of viroids and viruses by nucleic acid probes. In: *Techniques for the rapid detection of plant pathogens,* J.M. Duncan and L. Torrance (eds.). Oxford, UK: Blackwell Scientific. pp. 129-144.

Scott, G.J. 1992. Sweetpotato as animal feed in developing countries. *CIP Circular* 19(1):7-8.

Seal, S., J.G. Elphinstone, L. Skoglund, and D. Berrios. 1992. Comparison of new techniques for the detection of latent infection in seed potatoes during their multiplication in Burundi. Australian Centre for International Agricultural Research. *Bacterial Wilt Newsletter* 8:2-3.

Siri, C. 1992. Red internacional del CIP. In: Proceedings of the Meeting on Andean Networks of Information Sciences and Technology. Sucre, Bolivia. 31 Aug. - 2 Sep. 1992. pp. 1-6.

Tapia, M. 1992. Cultivos marginados de la región andina. In: *Cultivos marginados: Otra perspectiva de 1492,* J.E. Hernández Bermejo and J. León (eds.). FAO, Roma, Italia; Jardín Botánico de Córdoba, España. pp. 123-128.

Tello, J., M. Hermann, and A. Calderón. 1992. La maca (*Lepidium meyenii* Walp): Cultivo alimenticio potencial para las zonas alto andinas. *Boletín de Lima* (Peru) 19(81):59-66.

Tung, P.X., J.G.T. Hermsen, P. Vander Zaag, and P. Schmiediche. 1992. Effects of resistance genes, heat tolerance genes and cytoplasms on expression of resistance to *Pseudomonas solanacearum* (E.F. Smith) in potato. *Euphytica* 60(2):127-138.

Tung, P.X., J.G.T. Hermsen, P. Vander Zaag, and P. Schmiediche. 1992. Effects of heat tolerance on expression of resistance to *Pseudomonas solanacearum* (E.F. Smith) in potato. *Potato Research* 35(3):321-328.

Valkonen, J.P.T., G. Brigneti, and E. Pehu. 1992. Resistance to *Myzus persicae* (Sulz.) in wild potatoes of the series Etuberosa. *Acta Agriculturae Scandinavia, Section B: Soil and Plant Science* 42:118-127.

Valkonen, J.P.T., G. Brigneti, L.F. Salazar, E. Pehu, and R.W. Gibson. 1992. Interactions of the *Solanum* spp. of the Etuberosa group and nine potato-infecting viruses and a viroid. *Annals of Applied Biology* 120(2):301-313.

Valkonen, J.P.T., E. Pehu, and K. Watanabe. 1992. Symptom expression and seed transmission of alfalfa mosaic virus and "Andean Potato Yellowing Virus" (SB-22) in *Solanum brevidens* and *S. tuberosum. Potato Research* 35(4):403-410.

Vallejo, R.L. and H.A. Mendoza. 1992. Plot technique studies on sweetpotato yield trials. *Journal of the American Society for Horticultural Science* 117(3): 508-511.

Villarroel, C.L., J. Franco, and R. Montecinos. 1992. Efecto de la interacción *Globodera* spp. - *Nacobbus aberrans* en cuatro cultivares de papa. *Revista de Agricultura* (Bolivia) 49(21):23-28.

Watanabe, K., C. Arbizu, and P.E. Schmiediche. 1992. Potato germplasm enhancement with disomic tetraploid *Solanum acaule.* 1: Efficiency of introgression. *Genome* 35(1):53-57.

Watanabe, K., H.M. El-Nashaar, and M. Iwanaga. 1992. Transmission of bacterial wilt resistance by first division restitution (FDR) 2n pollen via 4× X 2× crosses in potatoes. *Euphytica* 60:21-26.

Watson, G.A. 1992. La investigación integrada en el programa de pre-extensión del IBTA-PROINPA. In: *Pre-extensión e investigación integrada,* J.C. Gumucio. La Paz, Bolivia: Instituto Boliviano de Tecnología Agropecuaria. pp. 55-66.

Watson, G., N. Estrada, and C. Bejarano. 1992. Evaluación con agricultores andinos, de clones resistentes al tizón tardío. *CIP Circular* 19(2):6-7.

Published Proceedings, Abstracts and Conference Papers

Accatino, P. 1992. Colaboración profesional e institucional para mejorar la productividad y uso de la papa. Presentado en la 7ma Reunión Nacional de la Asociación Chilena de la Papa. (ACHIPA), Frutillar, Chile, 28-29 May 1992. Santiago, Chile: CIP. 3 p.

Accatino, P., H. López, V. Larenas and C. Covarrubias (eds.). 1992. El camote, nueva alternativa agrícola para Chile. Conclusiones y acuerdo del seminario/taller. Serie La Platina No. 35. Chile: INIA; CIP. 17 p.

Alvarez, V., A. Gandarillas and E.N. Fernández-Northcote. 1992. Selección positiva, una técnica de producción de tubérculo semilla de papa. Manual Técnico 2/92. Cochabamba, Bolivia: IBTA-PROINPA. 11 p.

Antle, J.M., S.M. Capalbo, and C.C. Crissman. 1992. Integrated economic, environmental, and health analysis of policy options for the Carchi project. Presented at a workshop on measuring the health and environmental effects of pesticides, Bellagio, Italy, 30 Mar. - 3 Apr. 1992. Quito, Ecuador: CIP. 35 p.

Asandhi, A.A. and A.S. Chilver. 1992. TPS research and development in Indonesia. Presented at TPS in Asia workshop. Lembang, Indonesia, 26-30 Oct. 1992. Bandung, Indonesia: CIP. 22 p.

Brandolini, A., P.D.S. Caligari, and H.A. Mendoza. 1992. Breeding for resistance to PLRV and immunity to PVX and PVY. In: *Proceedings of the joint conference of the EAPR Breeding & Varietal Assessment Section and the EUCARPIA Potato Section.* F. Rousselle-Bourgeois and P. Rousselle (eds.). Landemeau, France, 12-17 Jan. 1992. Station d'Amélioration de la Pomme de Terre et des Plantes à Bulbes. Ploudaniel, France: INRA. pp. 133-134.

Caccia, R., C. de Pace, G.T. Scarascia Mugnozza, S. Trinca, J. Dodds, P. Magro, and G. Chilosi. 1992. Response of transgenic potato clones to *Phytophthora infestans* infection. Ibid. pp. 81-86.

Casper, R., A. Shah, H. Stegemann, R. Estrada, M. Gálvez, N. Hilshmann, L. Schilde, Z. Huamán, and P. Schmiediche. 1992. Biochemisch-genetische Charakterisierung der Hochanden-Knollenpflanzen Oca (*Oxalis tuberosa*), Mashua (*Tropaeolum tuberosum*) und Ulluco (*Ullucus tuberosus*) fur Genbanken in Lima, Peru. In: *Biologische Bundesanstalt fur Land- und Forstwirtschaft in Berlin und Braunschweig.* Jahresbericht 1991. Braunschweig, Germany. p. 74.

Chilver, A.S., A. Koswara, and D. Rachmanudin. 1992. A preliminary evaluation of the economic viability of true potato seed (TPS) in Indonesia. Presented at the workshop TPS in Asia, Lembang, Indonesia, 26-30 Oct. 1992. Lembang, Indonesia: CIP. 13 p.

Chilver, A.S. and R. Suherman. 1992. Patterns, processes and impacts of technology diffusion: The case of true potato seed (TPS) in Indonesia. Presented at the 2nd Asian Farming Systems Symposium, Colombo, Sri Lanka, 2-5 Nov. 1992. Bandung, Indonesia: CIP. 24 p.

Crissman, C.C. and P. Espinosa. 1992. Agricultural chemical use and sustainability of Andean potato production: Project design and pesticide use in potato production in Ecuador. Presented at a workshop on measuring the health and environmental effects of pesticides, Bellagio, Italy, 30 Mar. - 3 Apr. 1992. Quito, Ecuador: CIP. 27 p.

Dayal, T.R. 1992. Potato production and improvement in India: A perspective. Presented at Seminar on Horticulture in India: Perspectives, Palampur, India, 13 May 1992. Abstract.

Dayal, T.R. and R.P. Sharma. 1992. Place of potato and sweetpotato in sustainable food production. Presented at National Symposium on Resource Management for Sustained Crop Production, Bikaner, India, 25-28 Feb. 1992. Abstract.

Forbes, G.A. and J.T. Korva. 1992. The effect of using a horsfall-barratt scale on accuracy and precision of visual estimations of potato late blight severity. Annual Meeting of the APS. Portland, USA, 8-12 Aug. 1992. *Phytopathology* 82(10):1112.

Franco, J., R. Montecinos, and N. Ortuño. 1992. Resistance to the false root-knot nematode, *Nacobbus aberrans* in cultivated potatoes. 21st International Symposium of the European Society of Nematology, Albufeira, Portugal, 11-17 Apr. 1992. *Nematológica* 38(4):412.

Golmirzaie, A., J. Jaynes, J. Dodds, J. Benavides, F. Buitrón, A. Panta, R. Salinas, C. Sigüeñas, and V. Zambrano. 1992. Genetic engineering applied to potato for bacterial disease resistance. In: *Abstract supplement of the first international crop science congress*, Iowa State University; Crop Science Society of America. Ames, Iowa, USA, 14-22 Jul. 1992. p. 35.

Golmirzaie, A.M. and J. Tenorio. 1992. Breeding potato for resistance to insect pests. In: *Proceedings 8th international symposium on insect-plant relationships*, S.B.J. Menken, J.H. Visser, and P. Harrewijn. (eds.), Wageningen, Netherlands, 9-13 Mar. 1992. Dordrecht, Netherlands: Kluwer Academic. pp. 321-322.

Hayward, A.C., L. Sequeira, E.R. French, H. El-Nashaar, and U. Nydegger. 1992. Tropical variant of Biovar 2 of *Pseudomonas solanacearum.* 1991 APS Caribbean Division Annual Meeting. San Jose, Costa Rica, 20-25 May 1991. *Phytopathology* 82(5):608.

Herrera, J.E. 1992. Importancia y potencial económico de la papa en América Latina. Presented at Curso Internacional de Papa-FEDEPAPA, Pamplona, Colombia, 8-10 Oct. 1992. 17 p.

Korva, J.T. and G.A. Forbes. 1992. A non-destructive technique for the assessment of healthy and diseased leaf area. Annual Meeting of the APS. Portland, USA, 8-12 Aug. 1992. *Phytopathology* 82(10):1112.

Lopes, C.A., J.A. Buso, and P. Accatino. 1992. Screening CIP potato germplasm for resistance to bacterial wilt in Brazil: Methods and preliminary results. Presented at the Bacterial Wilt International Symposium. Taiwan, 28-30 Oct. 1992. Abstract.

Malagamba, P. 1992. Sistemas de uso de semilla sexual de papa para diferentes ambientes. In: *Semilla sexual de papa en Latinoamerica*, Sept. 1991. Lima, Peru: CIP. pp. 3-9.

Malagamba, P. and R. Cabello. 1992. Producción de semilla sexual en diferentes ambientes. Ibid. pp. 21-25.

Medina-Bolívar, F. and J. Dodds. 1992. Efficient shoot organogenesis from leaves, roots and internodes of sweetpotato. Annual Meeting of the American Society of Plant Physiologists. Pittsburgh, USA, 1-5 Aug. 1992. *Plant Physiology* (Suppl.) 99(1):49.

Mendoza, H.A. 1992. Breeding potatoes for combined resistance or tolerance to the main biotic and abiotic stresses. Brandolini, A., et al. Op. cit. pp. 123-130.

Pallais, N. 1992. Storage of true potato seed. 89th Annual Meeting of the ASHS. Honolulu, USA, 30 Jul. - 6 Aug. 1992. *HortScience* 27(6):577.

Pallais, N. and R. Falcón. 1992. Calidad de la semilla sexual y manejo en poscosecha, In: *Semilla sexual de papa en Latinoamérica*, Set 1991. Lima, Perú: CIP. pp. 11-20.

Payton, F.V. and R. Arbona. 1992. Generación y adaptación de tecnologías para el uso de semilla sexual de papa (SSP) en la producción de material de siembra local en la República Dominicana. Ibid. pp. 77- 84.

Puente, F. de la and J. Díaz. 1992. Colección de recursos genéticos de camote (*I. batatas* (L) LAM) en el Perú. Presented at III Congreso Nacional de Investigadores Agrarios. INIAA, Lima, Perú, 13-16 Jul. 1992. Abstract.

Sawyer, R.L. 1992. Biotechnology and biosafety developments at the international agricultural research centres. In: *Opportunities and problems in plant biotechnology*, W. Powell et al. (eds.). Symposium, Edinburgh, UK, 10-12 Apr. 1991. *Proceedings of the Royal Society of Edinburgh, Section B: Biological Sciences* 99(3/4):165-172.

Scott, G.J. 1992. Sweetpotatoes as animal feed in developing countries: Present patterns and future prospects. In: *Roots, tubers, plantains and bananas in animal feeding*, D. Machin and S. Nyvold (eds.). FAO Expert Consultation, Cali, Colombia, 21-25 Jan. 1991. Rome, Italy: FAO. pp. 183-202.

Suherman, R. and A. Chilver. 1992. The impact and lessons of TPS difussion in Indonesia. Presented at Workshop on TPS in Asia, Lembang, Indonesia, 26-30 Oct. 1992. Bandung, Indonesia: CIP. 20 p.

Thakur, K.C. and M.D. Upadhya. 1992. True potato seed production. Presented at Seminar on Recent Advances and Future Strategies in Seed Research and Technology, Solan, India, 9-11 Jun. 1992. Abstract.

Torres, H. 1992. Manejo y aplicación del hongo *Beauveria brongniartii* para controlar el gorgojo de los Andes. Presented at the course organized by INIAA, Cusco and CIP, Cusco, Peru, 20-24 Apr. 1992. INIAA, Cusco; CIP.

Watanabe, K., M. Orrillo, and K. Ishiki. 1992. Cytology on wild polyploid tuber-bearing *Solanum* species. 76th Annual Meeting of the PAA. *American Potato Journal* 69(9):614.

Watanabe, K., S. Vega, and M. Orrillo. 1992. Characterization of S. acaule introgression lines. 76th Annual Meeting of the PAA. *American Potato Journal* 69(9): 613-614.

Watanabe, K., M. Orrillo, and S. Vega. 1992. Sexual hybrids between 2× potato breeding lines and non-tuber-bearing *Solanum* species. 76th Annual Meeting of the PAA. *American Potato Journal* 69(9):614.

Watson, G.A. 1992. Incrementalism and flexibility in technology development and difussion. Presented at the Meeting of CGIAR Social Scientists, The Hague, Netherlands, ISNAR, 21 Aug. 1992. 9 p.

Watson, G.A. and J. Quiroga. 1992. Participatory research in germplasm management. Ibid. 4 p.

Asociación Peruana de Nematología; Universidad Nacional de Cajamarca. II Congreso Peruano de Nematología: Programa y Compendios. Cajamarca (Perú). 6-11 Sept. 1992:

Atakuziev, B., A. González, A. Marcelo, E. Arbaiza, J. Olivera, E. Grishin, and P. Jatala. 1992. Efectos de extractos de algunas muestras biológicas sobre la emergencia y movilidad de *Globodera pallida*, raza P4A. p. 47.

Bautista, W.R. and M. Canto-Sáenz. 1992. Efecto de filtrados vegetales y exudados radiculares de plantas antagónicas sobre el movimiento, mortandad e infectividad de *Pratylenchus flakkensis*. p. 47.

Boluarte, T. and P. Jatala. 1992. Desarrollo del esquema internacional de clasificación de razas fisiológicas en *Nacobbus aberrans*. p. 20.

Cáceres, F., M. Canto-Sáenz, and A. González. 1992. Rotación de cultivos para el control de *Globodera pallida* en Porcón-Cajamarca. p. 49.

Canto-Sáenz, M. and A. González. 1992. Efecto antagónico de filtrados de tres especies de *Capsicum* en la emergencia, movilidad e infectividad de juveniles (J2) de *Globodera pallida*, raza P4A. p. 46.

Canto-Sáenz, M. and A. González. 1992. Efecto de algunos componentes de control cultural, Aldicarb 15G, y *Beauveria brongniartii* en la reproducción de *Globodera pallida* y el rendimiento del cultivar tolerante de papa Yungay. p. 62.

Canto-Sáenz, M. and A. González. 1992. Integración del control químico con resistencia, tolerancia y susceptibilidad de papa al nematodo quiste *Globodera pallida*, en Cajamarca. pp. 39-40.

Canto-Sáenz, M. and A. González. 1992. Integración del uso del hongo *Beauveria brongniartii* con resistencia, tolerancia y susceptibilidad de papa en el control de *Globodera pallida*. p. 48.

Canto-Sáenz, M. and A. González. 1992. Uso de gasolina en la separación de quistes de *Globodera pallida* y materia orgánica en muestras extraídas del suelo. p. 23.

Canto-Sáenz, M., J. Landeo, A. González, and L. Calúa. 1992. Evaluación en campo (Porcón-Cajamarca) de tolerancia a *Globodera pallida* en clones de papa resistentes a heladas. p. 58.

Canto-Sáenz, M., J. Landeo, A. González, and L. Calúa. 1992. Evaluación en campo de tolerancia a *Globodera pallida* en clones de papa resistentes a *Phytophthora infestans*. p. 59.

Canto-Sáenz, M., J. Landeo, A. González, and L. Manrique. 1992. Evaluación en campo de resistencia a *Globodera pallida* en clones avanzados de papa obtenidos en mejoramiento para resistencia al nematodo. p. 57.

Canto-Sáenz, M., J. Landeo, A. González, and L. Manrique. 1992. Evaluación en campo de tolerancia y resistencia a *Globodera pallida* en clones de papa, obtenidos en mejoramiento para resistencia a este nematodo. p. 58.

Chávez, S., M. Canto-Sáenz, and A. Martos. 1992. Nematodos asociados a los principales cultivos de la provincia de Celendín-Cajamarca. pp. 23-24.

Delgado de la Flor, R., E. Guevara, and P. Jatala. 1992. Efecto de varios clones de batata (camote) sobre las poblaciones de *Meloidogyne incognita* en campo. p. 54.

Flores, D. and H. Mendoza. 1992. Evaluación de resistencia o tolerancia en clones de papa al nemátodo quiste (*Globodera* sp) en clones de papa en el distrito de Chaclla-Huánuco, campaña 1989-92. pp. 55-56.

Flores, R., P. Jatala, E. Guevara, and R. Chávez. 1992. Evaluación de resistencia de cultivares de camote *Ipomoea batatas* (Lam.) a *Meloidogyne incognita* en suelos árido-salinos en Tacna, Perú. pp. 53-54.

González, A. 1992. Evaluación de resistencia de la papa a *Globodera pallida* en la prueba en platos petri. p. 55.

González, A. and M. Canto-Sáenz. 1992. Efecto de algunos componentes de control cultural, Aldicarb 15G y *Beauveria brongniartii* en la reproducción de *Globodera pallida* y el rendimiento del cultivar resistente de papa María Huanca. pp. 62-63.

González, A. and M. Canto-Sáenz. 1992. Efecto de algunos componentes de control cultural, Aldicarb 15G, *Beauveria brongniartii* en la reproducción de *G. pallida* y el rendimiento del cultivar susceptible de papa Revolución. p. 61.

González, A. and M. Canto-Sáenz. 1992. Efecto de cultivares de papa resistente, parcialmente resistente y tolerante en la multiplicación de *Globodera pallida* en Cajamarca. p. 61.

González, A. and M. Canto-Sáenz. 1992. Efecto de enmiendas orgánicas en el control de *Globodera pallida*. p. 33.

González, A., M. Canto-Sáenz, and I. Bendezú. 1992. Integración de resistencia, tolerancia y susceptibilidad de papa con cultivos de plantas no hospedantes para el control del nematodo quiste. pp. 48-49.

Guevara, E. and P. Jatala. 1992. Evaluación, selección y utilización de resistencia al nematodo del nódulo de la raíz *Meloidogyne incognita*. pp. 52-53.

Guevara, E., P. Jatala, and H. Mendoza. 1992. Progresos en el desarrollo de clones de camote, con resistencia al nematodo del nódulo de la raíz. p. 53.

Guevara, E., P. Jatala, and M. Zegarra. 1992. Rol de las rhizobacterias promotoras de desarrollo de plantas (PGPR), en el control de *Meloidogyne incognita* en papa y tomate. p. 45.

Huerta, B., E. Carey, H. Mendoza, and P. Jatala. 1992. Herencia de la resistencia del camote al nematodo *Meloidogyne incognita*. p. 54.

Jatala, P. and T. Boluarte. 1992. Estudio para determinar agentes biocontroladores de nematodos fitoparásitos en campos de trigo y maní. p. 43.

Jatala, P., R. Delgado de la Flor, and E. Guevara. 1992. El éxito de los agricultores en el control biológico de nematodos fitoparásitos en el departamento de Lambayeque. pp. 44-45.

Jatala, P. and L. Gavilano. 1992. Determinación de la presencia de metabolitos secundarios activos contra *Meloidogyne incognita* en hongos aislados en los campos de trigo y de maní. p. 43.

Jatala, P. and L. Gavilano. 1992. Estudio electroforético de los patrones proteicos de los huevos de *Globodera pallida* y *G. rostochiensis*. p. 19.

Jatala, P., L. Gavilano, P.S. Jatala, and I. Delgado. 1992. Utilización de extractos de plantas para el control de nematodos. pp. 45-46.

Jatala, P. and A. González. 1992. Ciclo biológico de un nuevo nematodo que ataca el cultivo de la papa en el Perú. p. 28.

Jatala, P., E. Guevara, R. Delgado de la Flor, and R. Ortega. 1992. Alto Urubamba, una nueva variedad de camote resistente al nematodo del nódulo de la raíz. p. 55.

Jatala, P. and R. Haddad. 1992. Infección secuencial "in-vitro" y cambios histopatológicos inducidos por *Nacobbus aberrans* en raíces del cultivar de papa "Desiree". pp. 28-29.

Jatala, P. and R. Haddad. 1992. Observaciones al microscopio electrónico de barrido de *Ditylenchus dipsaci* colectado de ajo en Arequipa-Perú. p. 20.

Lara, C. and M. Canto-Sáenz. 1992. Efecto de algunos insecticidas y fungicidas en el nematodo quiste de la papa *Globodera pallida* (Stone) Behrens Raza P5A. p. 39.

Matos, A. and M. Canto-Sáenz. 1992. Control de *Globodera pallida* con siete enmiendas orgánicas en microparcelas. pp. 34-35.

Mayorga, A. and P. Jatala. 1992. Patrones de proteínas nativas de *Nacobbus aberrans, Meloidogyne incognita, Globodera pallida* y un nematodo aún no descrito mediante electroforesis sobre poliacrilamida. p. 19.

Olivera, J., A. Marcelo, A. González, M. Tazhmoukhamedov, and P. Jatala. 1992. Emergencia de J2 de *Globodera pallida* raza P4A frente a fracciones polipeptídicas de diferentes muestras vegetales. p. 67.

Pacheco, M.A., M. Scurrah, and M. Canto-Sáenz. 1992. G87131-12 posible nueva variedad de papa resistente al nematodo quiste para la zona sur del país. p. 56.

Posadas, C. and M. Canto-Sáenz. 1992. Escala de evaluación de la reproducción *Globodera pallida* (Stone) Behrens 1975 en pruebas de maceta en invernadero. pp. 56-57.

Torrel, R. and M. Canto-Sáenz. 1992. Efecto de nueve enmiendas orgánicas en el control de *Globodera pallida* raza P4A. p. 34.

Colegio de Biólogos del Perú. X Congreso Nacional de Biología: Resúmenes y Programación de Actividades. Lima (Perú). 2-7 Aug. 1992:

Asmat, R.H. and Z. Huamán. 1992. Identificación de "Duplicados" en una colección de germoplasma: Caso del camote (*Ipomoea batatas* (L) Lam.). p. 65.

Benavides, J., F. Buitrón and A. Golmirzaie. 1992. Transformación genética de camote mediante la transferencia de DNA via Agrobacterium. p. 62.

Díaz, J., F. de la Puente, and D.F. Austin. 1992. Flujo de genes en la sección Batatas (*Convolvulaceae*). p. 57.

Herrera, M. del R. and Z. Huamán. 1992. Identificación de duplicados en la colección de germoplasma de papa a través de electroforesis de proteinas e isoenzimas. p. 64.

Marcelo, A., B. Atakouziev, M. Tashmoukhamedov, E. Arbaiza, J. Olivera, L. Lenci, A. González, B. Lizárraga, and E. Grishin. 1992. Efecto de diferentes productos naturales en *Globodera pallida* (Stone), raza P4A. p. 56.

Orrillo, M. and K. Watanabe. 1992. Nuevo pre-tratamiento para observación de cromosomas en papa. p. 66.

Puente, F. de la and J. Díaz. 1992. Colección de germoplasma silvestre de Ipomoea (*Convolvulaceae*) en el Perú. p. 66.

Río, A. del and M. Hermann. 1992. Uso de isoenzimas en la conservación de recursos genéticos andinos. p. 65.

Salazar, L.F. 1992. La importancia del conocimiento molecular de los virus para el control de virus en plantas. p. 49.

Salinas O.R. and A.M. Golmirzaie. 1992. Utilización de las técnicas de ingeniería genética en el Centro Internacional de la Papa (CIP). p. 64.

Tenorio, J. and A.M. Golmirzaie. 1992. Desarrollo de híbridos con androesterilidad y su posible uso para la producción de semilla sexual de papa. p. 63.

Toledo, J. and U. Jayasinghe. 1992. Estudios sobre la distribución de 4 virus en *Ullucus tuberosus* Loz. p. 63.

W.A. Hill, C.K. Bonsi, and P.A. Loretan (eds.). Sweetpotato technology for the 21st century. Tuskegee, Alabama, USA: Tuskegee University. Jun. 2-6, 1991:

Carey, E.E., E. Chujoy, T. Dayal, H.M. Kidane-Mariam, H.A. Mendoza, and I.G. Mok. 1992. Helping meet varietal needs of the developing world: The International Potato Center's strategic approach to sweetpotato breeding. pp. 521-532.

Dodds, J.H., J. Benavides, F. Buitrón, F. Medina, and C. Sigüeñas. 1992. Biotechnology applied to sweetpotato improvement. pp. 7-19.

Gregory, P. 1992. Feeding tomorrow's hungry: The role of root and tuber crops. pp. xxvii-xxviii.

Huamán, Z. 1992. The use of sweetpotato in bread making. pp. 460-461.

Jansson, R.K. and K.V. Raman. 1992. Applications of new technologies to integrated pest management. pp. 495-506.

Orjeda, G., M. Iwanaga, and R. Freyre. 1992. Use of *Ipomoea trifida* germplasm for sweetpotato improvement: Evaluation of storage root initiators. pp. 546-558.

Kabira, J.N. and P.T. Ewell (eds.). Current research for the improvement of potato and sweetpotato in Kenya. Nairobi (Kenya). From the meeting held in Nov. 1991. Nairobi (Kenya). KARI; CIP:

Gatumbi, R.W., A.W. Kihurani, and L.G. Skoglund. 1992. Severity of *Phomopsis ipomoeae batatas* (Punith) in sweetpotato in Kenya. pp. 92-96.

Gethi, M., J.W. Irungu, and H.M. Kidane-Mariam. 1992. Preliminary observations on the reaction of sweetpotato germplasm to various pests of economic importance. pp. 78-85.

Irungu, J.W. and H.M. Kidane-Mariam. 1992. Adaptation trials of potato germplasm preliminary results from Embu. pp. 22-26.

Irungu, J.W. and H.M. Kidane-Mariam. 1992. Collection and evaluation of sweetpotato (*Ipomoea batatas* (L) Lam.) genetic resources in the central region of Kenya. pp. 72-77.

Maingi, D.M., N.M. Nganga, and H.M. Kidane-Mariam. 1992. Collection and evaluation of farmers' informally released varieties in Kenya. pp. 16-21.

Maingi, D.M., N.M. Nganga, and H.M. Kidane-Mariam. 1992. Evaluation of the potential of true potato seed for seed tuber production. pp. 35-39.

Maingi, D.M., N.M. Nganga, and H.M. Kidane-Mariam. 1992. Systematic evaluation and screening of potato germplasm resources. pp. 10-15.

Munga, T.L., A. Abubaker, and C. Carli. 1992. Effect of different growing methods on the yield of sweetpotato: Preliminary results. pp. 86-87.

Munga, T.L., A. Abubaker, S.T. Gichuki, and C. Carli. 1992. Response of sweetpotato to different rates of fertilizer. pp. 88-91.

Mutuura, J.N., P.T. Ewell, A. Abubaker, T. Munga, S. Ajanga, J. Irungu, F. Omari, and S. Maobe. 1992. Sweetpotatoes in the food systems of Kenya: Results of a socioeconomic survey. pp. 51-66.

Nandasaba, J., S. Ajanga, and H.M. Kidane-Mariam. 1992. Preliminary screening and adaptability trial of advanced potato germplasm in Western Kenya. pp. 27-29.

Ngaah-Taracha, C.O. and N. Smit. 1992. Biological control of potato tuber moth. pp. 40-42.

Njoroge, P.K. and C. Carli. 1992. Rapid multiplication systems for production of good quality seed: Kenya's experience. pp. 30-34.

Smit, N., O. Magenya, and G. Maisiba. 1992. Integrated pest management of sweetpotato in western Kenya. pp. 97-105.

PROSEMPA; PRONAPA; IBTA-PROINPA. II Reunión nacional de la papa: Resúmenes. Cochabamba (Bolivia). 22-25 Sept. 1992:

Aguilera, J. and A. Devaux. 1992. Potencial de adaptación de cultivares y clones de papa en diferentes zonas agroecológicas de Bolivia. p. 41.

Andrew, R., J. Herbas, R. Calderón, V. Lino, Y. Zurita, and J. Alcázar. 1992. Implementación y ejecución de un programa de manejo integrado de la polilla de la papa *Phthorimaea operculella* (Zeller) en el Valle de Mizque, Cochabamba, Bolivia. p. 18.

Balderrama, F., J. Franco, and R. Montecinos. 1992. *Beauveria brongniartii* como potencial biocontrolador del "Rosario" de la papa *Nacobbus aberrans* (Thorne, 1935) Thorne y Allen, 1944. p. 31.

Devaux, A. and J. Vallejos. 1992. Evaluación agro-económica de niveles de aplicación de fertilización inorgánica. p. 36.

Equise, H., N. Bezençon, J. Gabriel, and N. Estrada. 1992. Selección y evaluación de clones avanzados con resistencia al tizón tardío. p. 7.

Estrada, N., J. Gabriel, and W. García. 1992. Utilidad de varias especies silvestres de papa para incorporar resistencia al "Tizón" (*Phytophthora infestans*) mediante cruzamientos. p. 12.

Gabriel, J., N. Estrada, W. García, R. Ibarra, R. Casso, N. Bezençon, H. Equise, J. Cárdenas, and A. Moreira. 1992. Selección y evaluación de clones promisorios por su resistencia al tizón, a la verruga, rizoctoniasis, tolerancia a la sequía, adaptación y rendimiento en cinco departamentos de Bolivia. p. 10.

García, W., N. Estrada, J. Gabriel, and M. Ugarte. 1992. Germoplasma de tubérculos andinos. p. 8.

González, S. and A. Devaux. 1992. Estudio de sistemas de almacenamiento de tubérculos-semillas a nivel de agricultores. p. 38.

Montalvo, R., J. Franco, and R. Montecinos. 1992. Pérdidas en el cultivo de la papa causadas por *Nacobbus aberrans* en Cochabamba. p. 30.

Montecinos, R., J. Franco, and R. Montalvo. 1992. La fertilización inorgánica en el manejo integrado de *Nacobbus aberrans* en papa. p. 29.

Navia, O. and J. Parker. 1992. Detección de la verruga (*Synchytrium endobioticum*) en bioensayo. p. 2.

Tapia, S., E. Uberguaga, J. Franco, and R. Montecinos. Diagnóstico de nematodos fitoparásitos en el Departamento de Chuquisaca. p. 28.

Vallejos, J., A. Devaux, J. Franco, R. Montecinos, and R. Montalvo. 1992. Comportamiento de siete cultivares de papa al ataque de *Nacobbus aberrans*. p. 25.

Villarroel, C.L., J. Franco, and R. Montecinos. 1992. Efecto de la interacción *Globodera* spp. - *Nacobbus aberrans* en cuatro cultivares de papa. p. 27.

Watson, G.A., C. Bejarano, and E. López. 1992. Encuesta de rendimientos de siembra grande: Cochabamba, Potosí y Chuquisaca. p. 49.

Watson, G.A., J. Quiroga, H. Cardoso, R. Casso, R. Andrew, and O. Navia. 1992. Diagnóstico del valle de Iscayachi, Tarija. p. 50.

Resúmenes de la XXIV Reunión Anual de ONTA. Islas Canarias, España. 27 Apr. - 1 May 1992. Nematrópica 22(2):

Atakuziev, B., A. González, A. Marcelo, E. Arbaiza, J. Olivera, B. Lizárraga, E. Grishin, and P. Jatala. 1992. Efectos de extractos de algunos especímenes biológicos sobre la emergencia y movilidad de *Globodera pallida*, raza P4A. p. 118.

Boluarte, T. and P. Jatala. 1992. Development of an international race classification scheme for determination of physiological races of *Nacobbus aberrans*. p. 119.

Cáceres de Vilca, F., M. Canto-Sáenz, and A. González. 1992. Effect of some Andean crops on *Globodera pallida* in Peru. p. 119.

Canto-Sáenz, M. and A. González. 1992. Some cultural and biological control measures for *Globodera pallida* in Peru. p. 119.

Franco, J., R. Montecinos, and N. Ortuño. 1992. Potato nematode problems in the Andean countries of Latin America. p. 123.

González, A. and M. Canto-Sáenz. 1992. Effect of resistant, tolerant, and susceptible potato cultivars on *Globodera pallida* in Cajamarca, Peru. p. 125.

González, A., M. Canto-Sáenz, and I. Bendezú. 1992. Comparison of resistant and susceptible potato cultivars with non hosts for control of *Globodera pallida* in Peru. p. 125.

Jatala, P. 1992. Nematode parasites of root and tuber crops and their management. p. 127.

Jatala, P., R. Delgado de la Flor and E. Guevara. 1992. El éxito de los agricultores en el departamento de Chiclayo, Perú. p. 128.

Jatala, P., E. Guevara, R. Delgado de la Flor, and R. Ortega. 1992. "Alto Urubamba", a new sweetpotato cultivar resistant to root-knot nematodes. p. 128.

Jatala, P., E. Guevara, and M. Zegarra. 1992. Search for resistance to *Ditylenchus destructor* in sweetpotato, *Ipomoea batatas*. p. 127.

Jatala, P. and R. Haddad. 1992. Histopathology of potato roots infected with *Nacobbus aberrans*. p. 127.

Jatala, P., H. Mendoza, and E. Guevara. 1992. Progress in the development of sweetpotato clones with resistance to root-knot nematodes. p. 127.

Jatala, P., K. Watanabe, and E. Guevara. 1992. Advances in breeding and screening potatoes for resistance to *Meloidogyne incognita*. p. 128.

Resúmenes de los trabajos presentados en el XII Congreso Peruano de Fitopatología. Arequipa (Peru). 19-22 Aug. 1992. Fitopatología (Peru) 27(2):

Aley, P. and T. Ames. 1992. Influencia del tipo de envase de almacenamiento sobre la incidencia de patógenos fungosos de postcosecha en raíces reservantes de camote (*Ipomoea batatas* (L.) Lam.). p. 54.

Anguiz, R., H. Mendoza, and H. El-Nashaar. 1992. Determinación de habilidades combinatorias para resistencia a marchitez bacteriana (*Pseudomonas solanacearum*) y caracteres agronómicos en papas inmunes a los virus Y (PVY) y X (PVX) de la papa. p. 66.

Barrera, C. and L.F. Salazar. 1992. Detección simultánea de cinco virus de papa utilizando DAS-ELISA modificado. p. 50.

Barrera, C. and L.F. Salazar. 1992. Reutilización de antisuero en la detección de PVX y PLRV utilizando DAS-ELISA. pp. 49-50.

Barrera, C. and L.F. Salazar. 1992. Reutilización de placas sensibilizadas en la detección de PVX y PLRV utilizando DAS-ELISA. p. 50.

Cadenas, C. and T. Ames. 1992. Comportamiento de ciento noventa y seis clones de *Ipomoea batatas* L. ante la pudrición negra de Java (*Lasiodiplodia theobromae* (Pat) Griff & Maubls SYN. *Diplodia gossypina* Cke.). p. 61.

Calderón, C., J. Parker, and E.N. Fernández-Northcote. 1992. Patogenicidad y agresividad de *Rhizoctonia solani* Kuhn, asociada con esclerocios y piel escamosa de la papa. pp. 54-55.

Chuquillanqui, C. and U. Jayasinghe. 1992. Heredabilidad de los componentes de resistencia al virus del enrollamiento de la hoja de papa (PLRV) en *Solanum acaule*. p. 53.

Delgado, C., R. Orrego, L.F. Salazar, and C. Paredes. 1992. Método alternativo de conjugación enzimática. p. 53.

Espejo, M. and U. Jayasinghe. 1992. Detección del virus X de la papa (PVX), virus Y de la papa (PVY) y virus S de la papa (PVS) por DAS-ELISA empleando la enzima penicilinasa como enzima conjugada. pp. 52-53.

Franco, J., R. Montecinos, N. Estrada, and W. García. 1992. Tamizado para resistencia a *Nacobbus aberrans* en diverso material genético de papa. pp. 67-68.

Fuentes, S. and U. Jayasinghe. 1992. Un nuevo virus, amarillamiento de la papa. p. 52.

Fuentes, S. and L.F. Salazar. 1992. Identificación de un nuevo virus de camote. p. 49.

Gabriel, J., N. Estrada, and W. García. 1992. Evaluación de híbridos tetraploides (2n=4x=48) por su resistencia de campo al tizón tardío de la papa (*Phytophthora infestans*). pp. 55-56.

Gamarra, D., H. Torres, J.A. Zavala, and J. Carhuamaca. 1992. Obtención de inóculo para el incremento de *Beauveria brongniartii*. pp. 61-62.

García, W., N. Estrada, J. Gabriel, and J. Franco. 1992. Prueba de resistencia al nematodo del rosario de la papa (*Nacobbus aberrans*). p. 68.

Icochea, T. and P. Aley. 1992. Distorsión clorótica de la hoja: Una enfermedad de la batata (*Ipomoea batatas* (L). Lam) en el Perú. p. 65.

Marín, J.E. and H.M. El-Nashaar. 1992. Patogenicidad de los fenotipos A y B Biovar 2 de *Pseudomonas solanacearum*. pp. 65-66.

Maza, N., C. Barrera, P. Malagamba, and L. Salazar. 1992. Transmisión de PVT y PSTVd en polinizaciones controladas en papa. p. 51.

Montecinos, R. and J. Franco. Efecto de tres nematicidas (carbofuranes) sobre la multiplicacion de *Nacobbus aberrans* y el rendimiento de papa (Var. Waych'a y Alpha). p. 39.

Montecinos, R., J. Franco, and N. Ortuño. 1992. La fertilización inorgánica en el manejo integrado de *Nacobbus aberrans* en papa. p. 67.

Nakano, M., E. Velit, S. Fuentes, and L.F. Salazar. 1992. Caracterización parcial de un virus isométrico aislado de camote. pp. 51-52.

Navia, O. and J. Parker. 1992. Detección de la verruga de la papa (*Synchytrium endobioticum*) en bioensayo. p. 56.

Ortega, A.M. and H. Torres. 1992. Incremento masivo de *Beauveria brongniartii*, controlador biológico del "Gorgojo de los Andes" de la papa. p. 62.

Parker, J., O. Navia, and P. Condorio. 1992. Validación de estrategias a nivel agricultor para el control químico del tizón tardío (*Phytophthora infestans*). p. 69.

Pérez, W., R. Anguiz, H. Torres, and A. Gandarillas. 1992. Identidad del grupo de anastomosis de *Rhizoctonia solani* Kuhn aislado de papa en Bolivia. p. 57.

Pérez, W. and T. Ames. 1992. Comportamiento de 101 clones de camote a la inoculación de *Fusarium oxysporum f.* sp. *batatas* y *F. solani*, causantes de marchitez de las plantas y pudrición de las raíces reservantes respectivamente. p. 57.

Querci, M., C.O. Vargas, and L.F. Salazar. 1992. Un nuevo viroide como agente de enfermedad en palto (*Persea americana* Mill.) p. 52.

Rocha, J.L. and U. Jayasinghe. 1992. Metodología para purificar el virus del enrollamiento de la hoja de papa (PLRV). pp. 53-54.

Toledo, J., U. Jayasinghe, J. Anguerre, R. Estrada, and M. Hermann. 1992. Avances en los estudios de cuatro virus que infectan *Ullucus tuberosus* Loz. p. 51.

Villarroel, C.L., J. Franco, and R. Montecinos. 1992. Efecto de la interacción *Globodera* spp. - *Nacobbus aberrans* en cuatro cultivares de papa. p. 68.

Zavala, J.A., D. Gamarra, and H. Torres. 1992. Producción de conidias del hongo entomopatógeno *Beauveria brongniartii* en medios de cultivo. p. 58.

Scott, G.J., S. Wiersema, P.I. Ferguson (eds.). Product development for root and tuber crops. V.1: Asia. International Workshop on Root and Tuber Crop Processing, Marketing, and Utilization in Asia. Sponsored by CIP, CIAT, IITA, At Visca, Baybay, the Philippines, 22 Apr. - 1 May 1991. Lima, Peru: CIP:

Best, R., G.J. Scott, and C. Wheatley. 1992. Research in support of product and process development. pp. 171-185.

Nave, R.W. and G.J. Scott. 1992. Village-level potato processing in developing countries: A case study of the SOTEC Project in India. pp. 331-353.

Scott, G.J. 1992. Transforming traditional food crops: Product development for roots and tubers. pp. 3-20.

Scott, G.J. 1992. The three "R's" of writing a research report: Getting it written, getting it right, getting it read. pp. 377-383.

Scott, G.J., D. Wong, M. Alvarez, and A. Tupac Yupanqui. 1992. Potatoes, mixes and soups: A case study of potato processing in Peru. pp. 355-370.

Wheatley, C. and G.J. Scott. 1992. Identification of product opportunities. pp. 115-124.

Scott, G.J., J.E. Herrera, N. Espinola, M. Daza, C. Fonseca, H. Fano, and M. Benavides. (eds.). Desarrollo de productos de raíces y tubérculos. V. 2: América Latina. Taller Colaborativo del CIAT, IITA, ICTA y CIP sobre Procesamiento, Comercialización y Utilización de Raíces y Tubérculos en América Latina. Villa Nueva, Guatemala, 8-12 Apr. 1991. Lima, Perú: CIP:

Best, R., G.J. Scott, and C. Wheatley. 1992. Investigación de apoyo al desarrollo de nuevos productos y procesos. pp. 201-218.

Herrera, J.E. and G.J. Scott. 1992. Tendencias en la producción y uso de la papa en América Latina: Un análisis comparativo. pp. 155-165.

Ostertag, C. and J.E. Herrera. 1992. La yuca en América Latina. pp. 145-154.

Scott, G.J. 1992. Preparación, corrección y difusión: Tres claves para el éxito de un informe de investigación. pp. 369-375.

Scott, G.J. 1992. Transformación de los cultivos alimenticios tradicionales: Desarrollo de productos a base de raíces y tubérculos. pp. 3-22.

Scott, G.J., D. Wong, M. Alvarez, and A. Tupac Yupanqui. 1992. Papa, mezclas y cremas: Un estudio de caso del desarrollo de productos procesados de papa en el Perú. pp. 335-350.

Wheatley, C. and G.J. Scott. 1992. Identificación de oportunidades para el desarrollo de nuevos productos. pp. 133-143.

Sociedad Entomológica del Perú. Programa y resúmenes. XXXIV Convención Nacional de Entomología. Lima (Perú). 8-12 Nov. 1992:

Alcázar, J. 1992. Uso de *Baculovirus phthorimaea* para el control de la polilla de la papa *Phthorimaea operculella* (Zeller). p. 99.

Alcázar, J., K.V. Raman, F. Cisneros, O. Hidalgo, W. Catalán, O. Ortiz, and H. Torres. 1992. El CIP y la implementación de un programa de control integrado del gorgojo de los Andes en el área andina. p. 59.

Cañedo, V. and K.V. Raman. 1992. Efecto de la saponina de la quinua en las principales plagas de papa en condiciones de invernadero. p. 56.

Catalán, W. and J. Alcázar. 1992. Distribución espacial de la población invernante y la población migrante del gorgojo de los Andes, *Premnotrypes latithorax* Pierce. p. 57.

Fabián, O., M. Palacios, and K.V. Raman. 1992. Determinación de resistencia a *Bacillus thuringiensis* en poblaciones de "polilla de la papa" *Phthorimaea operculella*. p. 61.

Mujica, N., M. Palacios, and K.V. Raman. 1992. Efecto de los tricomas glandulares en la biología del ácaro rojo *Tetranychus urticae* Koch. p. 56.

Palacios Lazo, M. 1992. Uso de feromonas en el control de la polilla de la papa, *Phthorimaea operculella* (Zeller). p. 98.

Palacios Lazo, M. and K.V. Raman. 1992. El Centro Internacional de la Papa y su papel en la difusión de programas de manejo integrado de la polilla *Phthorimaea operculella* (Zeller). p. 60.

Raman, K.V. 1992. Manejo integrado de plagas y la búsqueda de plantas resistentes a insectos en papa. p. 65.

Torres, H. 1992. Uso de *Beauveria* para el control del gorgojo de los Andes (*Premnotrypes* spp.). p. 103.

Villano, W., W. Catalán, and J. Alcázar. 1992. Emergencia de adultos de *Premnotrypes latithorax* Pierce y su ocurrencia estacional en campos de cultivo de papa en Cusco. p. 58.

In Memory

We have lost one of the most loved and respected members of the CIP family with the death of Kushalya, Mrs. Lyle Sikka, on November 12, 1993. We extend our deepest sympathies to Lyle and her family. Together, throughout their international career of 17 years in Bangladesh, Kenya, Peru, and Uganda, the Sikkas have provided a model for caring and giving to the developing world.

CIP Staff in 1992

DIRECTORS

Hubert Zandstra, PhD, Director General

Jose Valle-Riestra, PhD, Deputy Director General for Finance and Administration

Peter Gregory, PhD, Deputy Director General for Research

Kenneth J. Brown, PhD, Senior Advisor for Management of International Cooperation (until November)

Roger Cortbaoui, Associate Director for International Cooperation (from December)

Internationally Recruited Staff

The following is a listing of CIP's internationally recruited staff and the positions they occupied in 1992. During the year, CIP's move to project-based research management resulted in a re-ordering of the person year allocation. The priority setting process that was initiated in late 1991 and continued throughout 1992 also helped to refine the person year distribution. The new organization of staff by program, fully in place by the end of 1992, will be reflected in next year's Annual Report.

PROGRAM LEADERS

Production Systems
Thomas S. Walker, PhD

Germplasm Management and Enhancement
Ali Golmirzaie, PhD

Disease Management
Edward R. French, PhD

Insect and Nematode Management
Kandukuri V. Raman, PhD

Propagation, Crop Management
Patricio Malagamba, PhD

Postharvest Management, Marketing
Gregory J. Scott, PhD

REGIONAL REPRESENTATIVES

Latin America and the Caribbean
Oscar Hidalgo, PhD

Central America and The Caribbean
(regional office closed in 1992)
Oscar Malamud, PhD, *Colombia* ‡

Sub-Saharan Africa
Sylvester Nganga, PhD, *Kenya*

Middle East and North Africa
Roger Cortbaoui, PhD, *Tunisia* *
(until November)

West and Central Africa
(regional office closed in 1992)
Carlos Martin, PhD, *Cameroon*

South and West Asia
Mahesh Upadhya, PhD, *India*

East and Southeast Asia and the Pacific
Michael Potts, PhD (until April), *Indonesia*
Peter Schmiediche, PhD (from May), *Indonesia*

China
(regional office closed in 1992)
Song Bofu, PhD, *China*

Departments

Breeding and Genetics

Humberto Mendoza, PhD, Geneticist,
Head of Department
Primo Accatino, PhD, Breeder, *Chile*
Edward Carey, PhD, Breeder
Enrique Chujoy, PhD, Geneticist, *the Philippines*
T.R. Dayal, PhD, Breeder, *India*
Il Gin Mok, PhD, Breeder, *Indonesia*
Haile M. Kidane-Mariam, PhD, Breeder, *Kenya*
Juan Landeo, PhD, Breeder

Genetic Resources

Ali Golmirzaie, PhD, Geneticist, Head of Department
Carlos Arbizu, PhD, ARTC Consultant *
Fermín de la Puente, PhD, Germplasm Collector
Michael Hermann, PhD, Andean Crop Specialist,
Ecuador *
Zósimo Huamán, PhD, Germplasm Curator
Carlos Ochoa, MS, Consultant
Bodo Trognitz, PhD, Geneticist
Kazuo Watanabe, PhD, Cytogeneticist, *USA*

Nematology and Entomology

Parviz Jatala, PhD, Nematologist, Head of Department
Aziz Lagnaoui, PhD, Entomologist, *Tunisia*
Nicole Smit, MS, Associate Entomologist, *Uganda* *
Luis Valencia, PhD, Entomologist,
Colombia * ‡

Pathology

Edward R. French, PhD, Bacteriologist, Head of Department (until Jan.)
Luis Salazar, PhD, Virologist, Head of Department (from Feb.)
Hossien El-Nashaar, PhD, Bacteriologist
Enrique Fernández-Northcote, PhD, Virologist
Gregory A. Forbes, PhD, Mycologist, *Ecuador*
Upali Jayasinghe, PhD, Virologist
Maddalena Querci, Dot. Biol., Associate Scientist
Linnea G. Skoglund, PhD, Mycologist, *Kenya*
Lod J. Turkensteen, PhD, Adjunct Scientist,
The Netherlands

Physiology

Patricio Malagamba, PhD, Physiologist,
Head of Department
Helen Beaufort-Murphy, PhD, Physiologist
James E. Bryan, MS, Senior Seed Specialist
Carlo Carli, Ing. Agr., Seed Physiologist, *Kenya* *
Ramzy El-Bedewy, PhD, Scientific Associate, *Egypt*
Jukka Korva, MS, Agronomist, *Ecuador* *
Noël Pallais, PhD, Physiologist
Frederick Payton, PhD, Agronomist,
Dominican Republic ‡
Michael Potts, PhD, Agronomist,
Indonesia ‡

Social Science

Thomas S. Walker, PhD, Economist,
Head of Department
Alwyn Chilver, MS, Associate Expert,
Indonesia *
Charles Crissman, PhD, Economist,
Ecuador
Peter Ewell, PhD, Economist, *Kenya*
Adhiambo Odaga, PhD, Geographer, *Cameroon* *
Gordon Prain, PhD, Anthropologist, *The Philippines*
Gregory J. Scott, PhD, Economist
Jurg Schneider, PhD, Associate Expert,
Indonesia * †

Research Support

Fausto Cisneros, PhD, Entomologist, Head of Department
Francisco Muñoz, PhD, Head of Quito Station, *Ecuador*
Victor Otazu, PhD, Superintendent of San Ramon Experiment Station

Training

Fernando Ezeta, PhD, Head of Department
Pons Batugal, PhD, Technology Transfer Coordinator †

Information

Carmen Siri, PhD, Head of Department
James Bemis, PhD, Senior English Writer/Editor ‡
Christine Graves, MA, Senior English Writer/Editor
Hernán Rincón, PhD, Head of Communications Unit

Directors' Offices

Office of the Director General
Edward Sulzberger, MS, Assistant to the DG
Office of the Deputy Director General for Finance and Administration
William A. Hamann, BS, Assistant to the DDGF&A
Office of the Deputy Director General for Research
José Luis Rueda, PhD, Andean Natural
Resources Management Coordinator

Special Country Projects

SEINPA, *Peru*
Efraín Franco, MS, Economist, Team Leader *
FORTIPAPA, *Ecuador*
Alberic Hibbon, PhD, Economist, Team Leader *

PROINPA, *Bolivia*

André Devaux, PhD, Seed Specialist, Team Leader *
Nicole Bezençon, I.R., Associate Expert *
Nelson Estrada, PhD, Breeder *
Javier Franco, PhD, Nematologist *
E. Fernández-Northcote, PhD, Virologist *
Joanne Parker, PhD, Fungi Mycologist * ‡
Greta Watson, PhD, Human Ecologist *

Burundi

Donald Berríos, Agronomist *

Uganda

Lyle Sikka, MS, Consultant on Seed Technology *

Networks

PRAPACE

Marco Soto, PhD, Coordinator, *Rwanda* *

SAPPRAD

Eufemio T. Rasco Jr., Coordinator, *the Philippines*

UPWARD

Gordon Prain, PhD, Anthropologist, Coordinator, *the Philippines*

Controller's Office

Carlos Niño-Neira, CPA, Controller
Oscar Gil, CPC, Internal Auditor

Office Of The Executive Officer

César Vittorelli, Agr. Eng., Acting Executive Officer
Adrián Fajardo, MS, Executive Officer (on sabbatical)

Nationally Recruited Staff

At the end of 1992, CIP's nationally recruited staff at headquarters and in the regions included close to 600 people. This figure represents an 11% reduction in comparison to the outset of the year, brought about by the Center's need to adjust to severe budget constraints while ensuring that basic program requirements are not compromised. The following is only a partial listing of our nationally recruited staff, whose contribution is fundamental to CIP's successful operations.

Departments

Breeding and Genetics

Walter Amorós, MS, Ing. Agr., Associate Geneticist
Jorge Espinoza, MS, Ing. Agr., Associate Geneticist
Hugo González, Ing. Agr., Agronomist, *Chile*
Pamela Jean López, MS, Breeder, *the Philippines*
K.C. Thakur, PhD, Breeder, *India*

- Research Assistants

Raúl Anguiz, MS
Miguel Ato, Ing. Ind. Alim.
Luis Calúa, MS
Luis Díaz, BS
Manuel Gastelo, MS
Elisa Mihovilovich, Biol.
Daniel Reynoso, MS

Genetic Resources

Fausto Buitrón, Ing. Agr., Tissue Culture Coordinator
Gisella Orjeda, MS, Biologist
Alberto Salas, Ing. Agr., Taxonomist
Roxana Salinas, Ing. Agr., Biotechnologist

- Research Assistants

César Aguilar, BS
Humberto Asmat, BS
Milciades Baltazar, Ing. Agr.
Jorge Benavides, Lic. Biol.
Jaime Díaz, MS
Walberto Eslava, Ing. Agr.
René Gómez, Ing. Agr.
Rosario Herrera, Biol.
Ana Hurtado, BS
Ana Panta, Biol.
Carmen Sigüeñas, Biol.
Jorge Tenorio, BS
Judith Toledo, BS
Fanny Vargas, BS

Nematology and Entomology

Jesús Alcázar, MS, Ing. Agr., Agronomist
Alberto González, MS, Phytopathologist
Erwin Guevara, Ing. Agr., Agronomist
María Palacios, Biol., Biologist

- Research Assistants

Verónica Cañedo, Lic. Biol.
Favio Delgado de la Flor, Ing. Agr.
Oder Fabián, Ing. Agr.
Lily Gavilano, Biol.

Rossio Haddad, Lic. Biol.
Angela Matos, Ing. Agr.
Norma Mujica, BS

Pathology

Christian Delgado, MS, Biochemist
Hebert Torres, MS, Ing. Agr., Agronomist
José Luis Zapata, MS, Plant Pathologist, *Colombia*

- Research Assistants

Pedro Aley, MS
Ciro Barrera, MS
Ida Bartolini, MS
Miguel Cervantes, Lic. Biol.
Carlos Chuquillanqui, Ing. Agr.
Miguel Espejo, Biol.
Violeta Flores, Biol.
Segundo Fuentes, MS
Josefa Gamboa, Biol.
Liliam Gutarra de Lindo, Ing. Agr.
Charlotte Lizárraga, Biol.
Ursula Nydegger, Tech. Dip.
Ricardo Orrego, Ing. Agr.
Hans Pinedo, Ing. Agr.
Emesto Velit, Biol.

Physiology

Vilma R. Amante, MS, Horticulturist, *the Philippines*
Faustino B. Aromin, MS, Agronomist, *the Philippines*
Rolando Cabello, Ing. Agr., Asst. Agronomist
Nelly Espinola, MS, Nutritionist
MS Kadian, PhD, Agronomist, *India*
John Kimani, MS, Agronomist, *Kenya*
Joseph Koi, MS, Agronomist, *Cameroon*

- Research Assistants

Rosario Falcón, BS
José Luis Marca, Ing. Agr.
Norma de Mazza, Q.F. ‡
Jorge Roca, BS

Social Science

Cherry Bangalanon, MS, Family Resource Management, *the Philippines* *
Hugo Fano, Economist
José E. Herrera, Lic., Economist
V.S. Khatana, PhD, Socioeconomist, *India*
Margaret Ngunjiri, MS, Sociologist, *Kenya*
Maricel Piniero, BS, Human Ecologist, *the Philippines*
Virginia N. Sandoval, PhD, Anthropologist, Asst. Coordinator, *the Philippines* *

Víctor Suárez, BS, Statistician
Inge Verdonk, Ir., Nutritionist, *the Philippines* *

- Research Assistants

Marisela Benavides, MS*
Miguel Daza, Sociol.
Cristina Fonseca, MS
Oscar Ortíz, MS

Research Support

Lombardo Cetraro, Biologist, Field & Greenhouse Supervisor, San Ramón
Roberto Duarte Piskulich, Eng. Agr., Greenhouse Supervisor, La Molina
Lauro Gómez, Acting Supervisor, Huancayo
Hugo Goyas, Ing. Agr., Supervisor, Yurimaguas
Abilio Pastrana Ramírez, Accountant, San Ramon
Mario Pozo, Eng. Agr., Superintendent, La Molina
Miguel Quevedo, Ing. Agr., Off-station Field Supervisor, Cajamarca

- Statistics Unit

Beatriz Eldredge, Biometrist, Research Data Base Assistant
Alfredo García, MS, Biometrist, Coordinator

Training

Nelson Espinoza, Training Specialist
Américo Valdéz, MS, Ing. Agr., Training Material Specialist

Information

- Communication Unit

Marciano Morales-Bermúdez, Coordinator, Comunication Unit ‡
Emma Martínez, MS, Supervisor Media Production
Jesús Chang, MS, A.V. Section Coordinator

- Computer Unit

Anthony Collins, Coordinator †
Jorge Palomino, VAX and Network Manager
Roberto Castro, Systems Development Manager
Pía María Oliden, Database Manager
Jorge Apaza, PC Manager

- Information Unit

Fiorella Sala de Cabrejos, MS, Coordinator
Martha Crosby, BA, Librarian
Cecilia Ferreyra, Circulation and Reference, User Services
Carmen I. Podestá, Archives and Verification

Controller's Office

Miguel Saavedra, CPA, General Accountant

Rebeca Cuadros, Senior Accountant
Edgardo de los Ríos, CPA, Senior Accountant
Vilma Escudero, BS, Accountant

- Accounting Unit

Eliana Bardalez, CPA, Senior Accountant
Jorge Bautista, BS, Accountant
Blanca Joo, CPA, Accountant
Eduardo Peralta, Accountant

- Budget Unit

Mónica Merino, CPA, Accountant
Alberto Monteblanco, CPA, Accountant

- Treasury Unit

Luz Correa, CPA, Accountant
Sonnia Solari, Chief Cashier

Office Of The Executive Officer

- Auxiliary Services

Mónica Ferreyros, Supervisor

- Equipment and Maintenance

Gustavo Echecopar, Ing. Agr., Supervisor

- Foreign Affairs Liaison

Marcela Checa, Liaison Officer

- Logistics

Lucas Reaño, CPC, Supervisor
Arturo Alvarez, Local Purchasing and General Services Officer
Jorge Luque, MBA, Warehouse Officer
José Pizarro, Importations Officer

- Personnel and Labor Relations

Guillermo Machado, Supervisor ‡
Estanislao Pérez Aguilar, Paymaster
Martha Piérola, BS, Social Worker
Germán Rossani, MD, Medical Officer

- Security

Aldo Tang, Comdt., Supervisor
Jorge Locatelli, Coordinator

- Transportation

Carlos Bohl, Supervisor
Hugo Davis Paredes, Chief Vehicle Maintenance
Jacques Vandemotte, Chief Pilot
Percy Zuzunaga, Co-Pilot

- Travel

Ana María Secada, Supervisor

Visitor's Office

Rosa Rodríguez, Head of Visitor Services

---

† Staff who joined during the year
‡ Staff who left during the year
* Staff funded by special projects

Board of Trustees

EXECUTIVE COMMITTEE

Chairperson
Dr. Lindsay Innes
Deputy Director
Scottish Crop Research Institute
Dundee, Scotland, United Kingdom

Dr. Stachys Muturi †
Agricultural Consultant
Nairobi, Kenya

Dr. Klaus Raven
Professor
Universidad Nacional Agraria
Lima, Peru

Dr. Setijati Sastrapradja ‡
National Centre for Research in
Biotechnology
Indonesian Institute of Sciences
Bogor, Indonesia

Dr. Hubert G. Zandstra
Director General
International Potato Center
Lima, Peru

PROGRAM COMMITTEE

Chairperson
Dr. Stachys Muturi †
Dr. Setijati Sastrapradja ‡

Dr. Durward Bateman
Dean
College of Agriculture and
Life Science
North Carolina State University
North Carolina, USA

Dr. Alfonso Cerrate
Executive Director
Instituto Nacional de
Investigación Agraria (INIA)
Lima, Peru

Dr. K. L. Chadha ‡
Deputy Director General
(Horticulture)
Indian Council for Agricultural
Research
New Delhi, India

Dr. Franz Winiger †
Head
Department of Potato
Production
FAP Zurich-Rechenholz
Zurich, Switzerland

AUDIT COMMITTEE

Chairperson
Dr. Klaus Raven

Dr. Aureliano Brandolini †
Florence, Italy

Dr. Toshihiro Kajiwara
Japan Plant Protection
Association
Tokyo, Japan

Ms. Martha ter Kuile ‡
CIDA Representative
Canadian Embassy
Guatemala City, Guatemala

NOMINATIONS COMMITTEE

Chairperson
Dr. Klaus Raven

Dr. K. L. Chadha ‡

Dr. Shen Jinpu ‡
Deputy Director
Chinese Academy of Agricultural
Sciences
Beijing, People's Republic of China

Dr. Stachys Muturi ‡

Dr. Franz Winiger ‡

† Until April 1993
‡ As of May 1993

Abbreviations and Acronyms

Terminology

6-PGDH	6-Phosphoglucodehydrogenase
ACO	aconitase
ACP	acid phosphatase
ADG	andigena
ADH	alcohol dehydrogenase
APW	Andean potato weevil
ARTC	Andean root and tuber crops
BR	black rot
Bt	*Bacillus thuringiensis*
Bv	biovar
BW	bacterial wilt
CD	derived from total mRNA from tomato leaves
cDNA	cloned deoxyribonucleic acid
CLD	chlorotic leaf distortion
cM	centimorgan
CP	derived from total mRNA of potato
CPB	Colorado potato beetle
CRBD	complete random block design
CT	derived from mRNA from tomato epidermal tissue probes
DAS	double-antibody sandwich
DAS-ELISA	double-antibody sandwich enzyme-linked immunosorbent assay
DIA	diaphorase
DLS	diffused light storage
DNA	deoxyribonucleic acid
DOA	Department of Agriculture
ds	double-stranded
ECH	*Erwinia chrysanthemi*
ELISA	enzyme-linked immunosorbent assay
E.S.	experiment station
EST	esterases
FRKN	false root-knot nematode
G6PDH	glucose-6-phospho-dehydrogenase
GCA	general combining ability
GOT	glutamate oxaloacetate transaminase

GP	genomic DNA; [*PstI* size-selected potato genomic fragments]
GPA	green peach aphid
GUS	ß-glucuronidase gene
GV	granulosis virus
ha	hectare
HLR	horizontal leaf resistance
IARC	international agricultural research center
IDH	isocitric acid dehydrogenase
IFA	immunofluorescent assay
IPM	integrated pest management
LB	late blight
LIR	latent infection rate
LMF	leafminer flies
MA	Ministry of Agriculture
MAG	Ministerio de Agricultura
McAbs	monoclonal antibodies
MAS	marker assisted selection
MDH	malate dehydrogenase
MFR	Ministry of Foreign Affairs
mmh/cm	milimohs/centimeters
MS	Murashige & Skoog
NARS	national agricultural research systems
NASH	nucleic acid spot hybridization
NCM	nitrocellulose membrane
NGO	non-government organization
OP	open-pollinated
PCN	potato cyst nematode
PCR	polymerase chain reaction
PFRKN	potato false root-knot nematode
PGI	phosphoglucoisomerase
PGM	phosphoglucomutase
PLRV	potato leafroll virus
PMV/U	papaya mosaic virus strain ullucus
PSTVd	potato spindle tuber viroid
PTM	potato tuber moth

PVA	potato virus A
PVM	potato virus M
PVS	potato virus S
PVT	potato virus T
PVX	potato virus X
PVY	potato virus Y
R&D	research and development
RAPD	randomly amplified polymorphic DNA
RFLP	restriction fragment length polymorphism
RGE	retum gel electroforesis
RKN	root-knot nematode
RR	root rot
RS	research station
R-genes	vulnerable major genes for resistance
SDH	shikimic acid dehydrogenase
SDI	selective dissemination of information
SMC	seed moisture content
SN	stem nematode
SP	special project
SPCFV	sweetpotato chlorotic fleck virus
SPFMV	sweetpotato feathery mottle virus
SPFMV C1	sweetpotato feathery mottle virus C1
SPLV	sweetpotato latent virus
SPVD	sweetpotato virus disease
SPW	sweetpotato weevil
SR	stem rot
STN	*S. stenotomum*
TG	derived from *Pst*I or *Eco*RI size-selected tomato genomic fragments
TIA	trypsin inhibitor activity
TPS	true potato seed
UMMV	ullucus mild mottle virus
UMV	ullucus mosaic virus
UVC	ullucus virus C
WF	whitefly-transmitted agent
VAX	virtual address extension

Organizations

AARI	Aegean Agricultural Research Institute, Turkey
ABSP	Agricultural Biotechnology for Sustainable Productivity, MSU, USA
AGCD	Administration Generale de la Coopération au Dévelopement, Belgium
AIDAB	Australian Intemational Development Assistance Bureau, Australian Center for Intemational Agriculture
ARCS	Austrian Research Centre at Seidersdorf
AREA	Agricultural Research and Extension Authority, Yemen
AVRDC	Asian Vegetable Research and Development Center, Taiwan
BARI	Bangladesh Agricultural Research Institute
Benguet U	Benguet State University, the Philippines
BID	Banco Interamericano de Desarrollo
CAAS	Chinese Academy of Agriculture Sciences
CAM	Centre Agricole de Meng, Nigeria
CARDI	Caribbean Agricultural Research and Development Institute, Trinidad
CARI	Central Agricultural Research Institute, Sri Lanka
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica
CEIPS	Centre d'Etudes et de Production de Semences, Cameroon
CERRGETYR	Centro Regional de Recursos Genéticos de Tubérculos y Raíces, U Cuzco, Peru
CESDA	Centro Sur de Desarrollo Agropecuario, San Cristóbal, Dominican Republic
CGIAR	Consultative Group for Intemational Agricultural Research, USA
Chiang Mai U	Chiang Mai University, Thailand

CIAAB	Centro de Investigaciones Agrícolas A. Boerger, Uruguay
CIAT	Centro Internacional de Agricultura Tropical, Colombia
CICA	Centro de Investigación en Cultivos Andinos, Peru
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo, Mexico
CIP	International Potato Center, Peru
CNCQS	Chinese National Centre for Quality Supervision and Test of Feed
CNPH	Centro Nacional de Pesquisa de Hortaliças, Brazil
Cornell U	Cornell University, USA
COTESU	Cooperación Técnica Suiza
CPRA	Centre de Perfectionnement et de Recyclage Agricole de Saïda, Tunisia
CPRI	Central Potato Research Institute, India
CPRO	Centre for Plant Breeding and Reproduction Research, the Netherlands
CPRS	Central Potato Research Station, India
CRIFC	Central Research Institute for Food Crops, Indonesia
CSD	Crop Service Division, Ghana
CTCRI	Central Tuber Crops Research Institute, India
CTGS	Cooperación Técnica del Gobierno Suizo, Switzerland
CUC	Catholic University of Chile
DAI	Development Alternatives International, USA
DSA	Division of Agricultural Statistics, Ministry of Agriculture, Rwanda
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuaria, Brazil
ENEA	Comitato Nazionale per la Ricerca e per lo Sviluppo dell'Energia Nucleare e delle Energie Alternative, Italy
ESARRN	East and Southern Africa Root Crops Research Network, Malawi
ESEAP	East and Southeast Asia and the Pacific, CIP region
ESH	Ecole Supérieure d'Horticulture, Tunisia
FAO	Food and Agriculture Organization of the United Nations, Italy
FICAH	Food Industry Crusade Against Hunger, USA
FONAIAP	Fondo Nacional de Investigaciones Agropecuarias, Venezuela
FORTIPAPA	Fortalecimiento de la Investigación y Producción de de Papa, Ecuador
FUNDAGRO	Fundación para el Desarrollo Agropecuario, Ecuador
GAAS	Guandong Academy of Agricultural Sciences, China
GTZ	German Agency for Technical Cooperation
IAC	Crop Research Institute of Campinas, Brazil
IAN	Instituto Agronómico Nacional, Paraguay
IAO	Istituto Agronomico per l'Otremare, Italy
IARI	International Agricultural Research Institute, India
IAV	Institut Agronomique et Vétérinaire, Morocco
IBPGR	International Board for Plant Genetic Resources, Italy
IBS	Institute of Biological Science, Philippines
IBTA	Instituto Boliviano de Tecnología Agropecuaria, Bolivia
ICA	Instituto Colombiano Agropecuario, Colombia
ICAR	Indian Council of Agricultural Research
ICIPE	International Centre of Insect Physiology and Ecology, Kenya
ICTA	Instituto de Ciencia y Tecnología Agrícolas, Guatemala
IDEA	Instituto Internacional de Estudios Avanzados, Venezuela
IDRC	International Development Research Centre, Canada
IESR/INTA	Instituto de Economía y Sociología Rural del Instituto Nacional de Tecnología Agropecuaria, Argentina

IFAS	Institute of Food and Agricultural Sciences, USA
IFPRI	International Food Policy Research Institute, USA
IFST	Institute of Food, Science and Technology, UPLB, Philippines
IIBC	International Institute of Biological Control, Kenya
IICA	Instituto Interamericano de Cooperación para la Agricultura, Costa Rica
IIN	Instituto de Investigación Nutricional, Peru
IITA	International Institute of Tropical Agriculture, Nigeria
INIA	Instituto Nacional de Investigaciones Agropecuarias, Uruguay
INIA	Instituto Nacional de Investigación Agraria, Peru
INIA	Instituto Nacional de Investigación Agraria, Chile
INIA	Instituto Nacional de Investigaciones Agropecuarias-Osorno, Chile
INIAP	Instituto Nacional de Investigaciones Agropecuarias, Ecuador
INIFAN	Instituto Nacional de Investigaciones Forestales y Agrícolas Nacionales, Peru
INIFAP	Instituto Nacional de Investigaciones Forestales y Agropecuarias, Mexico
INIVIT	Instituto Nacional de Investigaciones, Cuba
INRA	Institut National de la Recherche Agronomique, France
INRAT	Institut National de la Recherche Agronomique de Tunisie
INTA	Instituto Nacional de Tecnología Agropecuaria, Argentina
IPAC	Instituto de Promoción Agropecuaria y Comunal, Peru
IPO	Research Institute for Plant Protection, The Netherlands
IPR	Institute for Potato Research, Poland
IRA	Institut de Recherche Agronomique, Cameroon
ISABU	Institut des Sciences Agronomiques du Burundi
ISAR	Institut des Sciences Agronomiques du Rwanda
IVIA	Instituto Valenciano de Investigaciones Agropecuarias, Spain
IZ	Instytut Ziemniaka, Poland
JAAS	Jiangsu Academy of Agricultural Sciences, China
JICA	Japanese International Cooperation Agency
Jorge Basadre	Universidad Nacional Jorge Basadre Grohmann de Tacna, Peru
KARI	Kenyan Agricultural Research Institute
Kellogg	The Kellogg Foundation
Kobe U	Kobe University, Japan
LAC	Latin America and the Caribbean, CIP region
LEHRI	Lembang Horticultural Research Institute, Indonesia
LSU	Louisiana State University, USA
MAE Belgium	Ministère des Affaires Etrangères, du Commerce Extérieur et de la Coopération au Dévelopement
McMaster U	McMaster University, Canada
MDC	Minister for Development Cooperation, the Netherlands
MENA	Middle East and North Africa, CIP region
MIP	Manejo Integrado de Plagas, Dominican Republic
Miss U	Mississippi State University, USA
MMSU	Mariano Marcos State University, the Philippines
MoSU	Missouri State University, USA
MSU	Michigan State University, USA
Nagoya U	Nagoya University, Japan
NAL	National Agricultural Laboratories, Kenya
NCRI	National Crop Research Institute, Nigeria
NCSU	North Carolina State University, USA
NPRCRTC	Northern Philippine Root Crops Research and Training Center

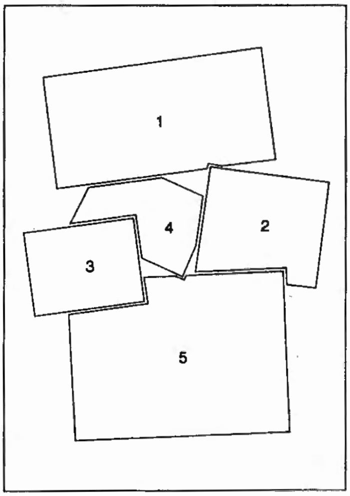
NRI	Natural Resources Institute, UK
ODA	Overseas Development Agency, UK
OPEC	Organization of Petroleum Exporting Countries Fund for International Development
Oxford U	University of Oxford, England
PCARRD	Philippine Council for Agriculture & Resources, Research & Development, the Philippines
PDA	Provincial Delegation of Agriculture, Cameroon
PGS	Plant Genetic Systems, Belgium
PNAP	Programme National pour l'Amélioration de la Pomme de Terre, Rwanda
PRACIPA	Programa Andino Cooperativo de Investigación en Papa, CIP network
PRAPACE	Programme Régional de l'Amélioration de la Culture de la Pomme de Terre et de la Patate Douce en Afrique Centrale et de l'Est, CIP network
PRECODEPA	Programa Regional Cooperativo de Papa, CIP network in Central America and the Caribbean
PROCIPA	Programa Cooperativo de Investigaciones en Papa, CIP network
PROINPA	Proyecto de Investigaciones de la Papa, Bolivia
PUC	Pontificia Universidad Católica, Chile
REDSO/ESA	Regional Development Services Office/East and Southern Africa, USAID
RES-UK	Rothamsted Experiment Station, United Kingdom
Rockefeller	Rockefeller Foundation, USA
SAAS	Sichuan Academy of Agricultural Sciences, China
SAPPRAD	Southeast Asian Program for Potato Research and Development, CIP network
SARIF	Sukamandi Research Institute for Food Crops, Indonesia
SCRI	Scottish Crop Research Institute
SDC	Directorate for Development Cooperation and Humanitarian Aid
SEAG	Servicio de Extensión Agrícola y Ganadera, Paraguay
SEINPA	Semilla e Investigación en Papa, Peru
SPPC	Seed Potato Production Center, Yemen
SQM	Sociedad Química y Minera de Chile
SSA	Sub-Saharan Africa, CIP region
Stanford U	Stanford University, USA
SWA	South and West Asia, CIP region
TCRC	Tropical Crops Research Center, Bangladesh
U Ambato	Universidad de Ambato, Ecuador
U Austral	Universidad Austral, Chile
U Australia	Australian National University
U Ayacucho	Universidad Nacional San Cristóbal de Huamanga, Peru
U Birmingham	University of Birmingham, England
U Cajamarca	Universidad Técnica de Cajamarca, Peru
U Cuzco	Universidad Nacional San Antonio de Abad, Peru
U Florida	University of Florida, USA
U Gent	University of Gent, Belgium
U Georgia	University of Georgia, USA
U Huancayo	Universidad Nacional del Centro, Peru
U Ica	Universidad San Luis Gonzaga de Ica, Peru
U Inner Mongolia	University of Inner Mongolia, China
U Nairobi	University of Nairobi, Kenya
U Napoli	University of Napoli, Italy
U Quito	Universidad Central del Ecuador
U Tacna	Universidad de Tacna, Peru
U de Concepción	Universidad de Concepción, Chile
UCRI	Upland Crops Research Institute, China
UFLA	University of Florida, USA
UNA	Universidad Nacional Agraria, Peru
UNALM	Universidad Nacional Agraria La Molina, Peru
UNCEN	University of Cenderawasih, Indonesia

UNCP	Universidad Nacional del Centro del Peru, Peru
UNDP	United Nations Development Program, USA
UNMSM	Universidad Nacional Mayor de San Marcos, Peru
UPLB	University of the Philippines, Los Baños
UPWARD	Users' Perspective with Agricultural Research and Development, CIP network
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
ViSCA	Visayas College of Agriculture, the Philippines
Viterbo U	Universitá Degli Studi Della Tuscia, Italy
Wageningen U	Wageningen University, the Netherlands
XISP	Xushou Institute of Sweet Potato, China
XSPRC	Xuzhou Sweet Potato Research Center, China
YGPPP	Yemeni/German Plant Protection Project
YNU	Yunnan Normal University, China

Photo Captions and Credits

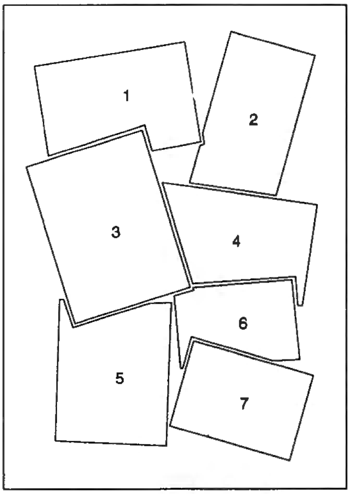
Captions

Collage, page vi



1. Farmers in Cajamarca relay their experience and CIP-based information about Andean potato weevil control to neighboring potato producers. They have learned that the benefits are multiplied by sharing their know-how. (Photo by Jesús Alcázar).
2. Research Director Peter Gregory analyzes a sequencing gel, working with CIP molecular biologists to identify sequence divergences among virus isolates. (Photo by Gigi Chang).
3. Hubert Zandstra, CIP's Director General (left) discusses collaborative work on important potato viruses with Steen Nielsen of the Danish Institute of Plant and Soil Science. (Photo by Gigi Chang).
4. Elaborately designed sweetpotato fields in the northern Philippines may include letter shapes and triangles; they are said to assist in drainage, but also are prepared for decorative and even romantic reasons.
5. The success of marshy valley potato production in the PRAPACE countries demonstrates the potato crop's compatibility with rice. Here, potatoes are planted in the four-month dry season following rice. Farmers can harvest a potato crop at 90 days, without fungicides, because of the absence of late blight during that period. Four CIP-introduced varieties have proved very suitable for these marshy conditions. (Photo by Donald Berríos).

Collage, page xxii



1. An IPM strategy to reduce pesticide use involves sorting tubers up to three times before storage to eliminate infested potatoes. (Photo by Aziz Lagnaoui).

2. Harvesting a field of Ndinamagara, Burundi's most popular potato variety. Over 80% of potato farmers in Burundi have adopted this highly profitable clone. Developed by the Mexican potato program and distributed by CIP, Cruza 148, as it was originally called, is prized for its high levels of resistance to bacterial wilt. (Photo by Michael Potts).

3. Farmer participation in sweetpotato variety evaluation and classification in Irian Jaya, Indonesia, is only one of UPWARD's many research projects in Asia. (Photo by Gordon Prain).

4. In Tunisia, potato tubers are coated with natural biocontrols, Bt or GV, then stored under 20 cm of straw to eliminate storage pests. (Photo by Aziz Lagnaoui).

5. The example of Nicaragua eloquently illustrates true seed's potential. In 1992, the market was flooded with potatoes produced from 5 kg of TPS donated by CIP. Almost 40% of the tubers marketed were grown from true seed. (Photo by Noël Pallais).

6. Sweetpotato's use as a diversification crop in lowland farming systems is shown here. In Sri Lanka, sweetpotato is grown in rice fields in "off" years, when there is not enough rain for the rice crop. (Photo by Gordon Prain).

7. With very small investment, national programs in PRAPACE countries have developed local in vitro laboratories where trained technicians can produce high quality planting materials for potato and sweetpotato, the two PRAPACE crops. In less than two years, this laboratory produced enough basic seed to plant 40 hectares of potatoes. (Photo by José Luis Rueda).

Photo Credits

pg. xi	Gigi Chang
pg. 2	P.I. Ferguson
pg. 6	Gordon Prain
pg. 23	Raymundo Medina
pg. 25	Genetic Resources Dept.
pg. 27	Genetic Resources Dept.
pg. 28	Genetic Resources Dept.
pg. 46	Juan Landeo
pg. 47	Juan Landeo
pg. 65	Luis Salazar
pg. 77	Jesús Alcázar
pg. 94	Helen Beaufort-Murphy
pg. 95	Helen Beaufort-Murphy
pg. 96	Juan Landeo (both photos)
pg. 109	Raymundo Medina
pg. 115	Gigi Chang

France

Mexico

Switzerlan

el

China

Finland

Italy

Denmark

meroon

Dominican Re

Yemen

Ecuador

Argentina

ada

Ghana

Netherlands

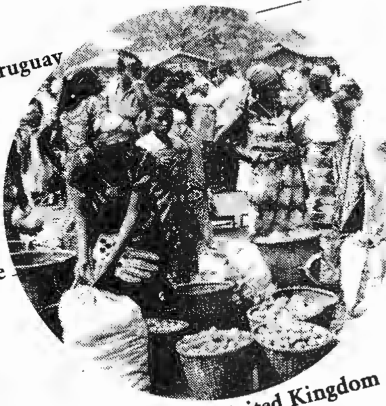
Japan

Burundi

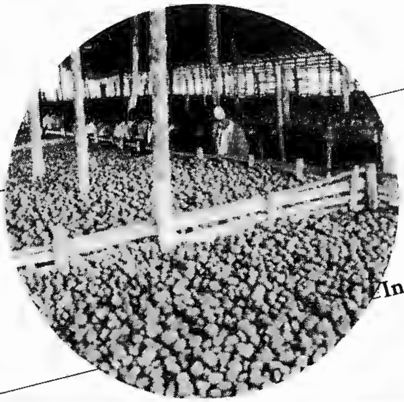
Belgium

Nicaragua

Uruguay



Peru



many

Chile

India

United Kingdom

INTERNATIONAL POTATO CENTER (CIP)